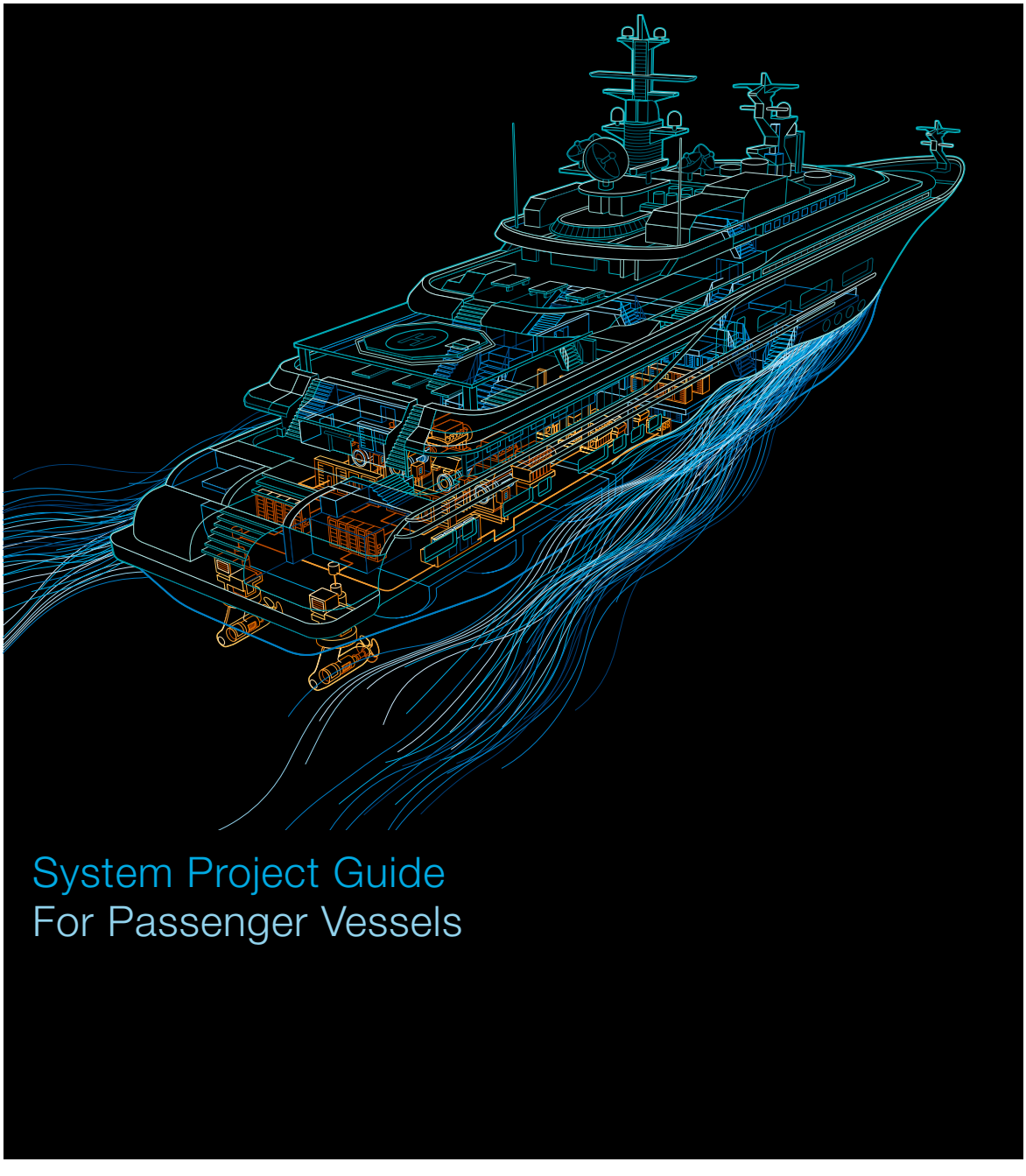

# System Project Guide
# For Passenger Vessels

Power and productivity
for a better world™

ABB

# Preface

This project guide provides system data and information for preliminary project evaluation of an electrical propulsion system in accordance of power plant benefits resulting from the selection. More detailed information is available in our platform-specific “Product Introduction” publications. Furthermore, our project and sales departments are available to advise on more specific questions concerning our products and regarding the installation of the system components.

Our power plant and propulsion system offering is constantly reviewed and refined according to the technology development and the needs of our customers. Therefore, we reserve the right to make changes to any data and information herein without notice.

All information provided in this publication is meant to be informative only. All project-specific issues shall be agreed separately and therefore any information given in this publication shall not be used as part of agreement or contract.

Helsinki, February 2011

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# 1 Foreword

**Dear reader,**
The System Project Guide for Passenger Vessels that you are now holding is made to function as a tool. Its purpose is to help ship designers to take advantage of the latest ideas in improving energy efficiency. Therefore we hope that this handbook would end up on the desks of as many designers as possible.You can maintain your competitive edge only by being prepared for the future.

It is difficult to foresee how the world will change, but in ship design there is one thing that is certain. The competition between ship owners will get harder and the energy consumed by ships will constitute a larger part of the total operating costs. The environmental regulations for ships will get even stricter. A ship that is built today must be competitive in terms of operating costs and environmental standards in decades from now. Vessels powered by electric propulsion provide flexibility to changes, which enables ship owners and designers to adapt to emerging challenges.

**New perspective to ship design**
You are holding a unique piece of work: the whole structure of this handbook and its contents were created from the perspective of energy efficiency. ABB compiled this book because energy efficiency is our core competence and we want to advocate the efficient use of energy in all contexts.

The book is logically structured. Chapter 3 brings forth some of the reasons why so many ship owners are shifting

to electric propulsion. In Chapter 4 we explain the different factors that make up the total energy efficiency of a vessel. Chapter 5 compares and contrasts the energy efficiencies of different propulsion solutions with different vessel types that have varying operational profiles. We believe that especially Chapters 4 and 5 help in the everyday design work, provide ready-made solutions, and give a chance to compare the differences between options. The examples will show that for every vessel type it is possible to design an optimal solution in terms of energy efficiency and life-cycle costs. Towards the end of the book, we discuss ABB project management and training services. Furthermore, we introduce Marine products and provide the necessary product information tables.

We hope you enjoy reading this book. It was an expedition cruise also for ourselves to put all this information in one package. We learned many things while putting together the contents of this book. We hope that you will be as amazed as we are – amazed of all the things that ABB has discovered.

Marcus Högblom
Vice President Sales

For further information, please visit **www.abb.com/marine**. Please send your feedback and any suggestions for corrections and improvements to **marine.spg@fi.abb.com**.

# 2 ABB Marine – a global technology partner to the marine industry

ABB Marine and Cranes is the leading manufacturer of electric power and propulsion systems, with a worldwide maritime organisation that provides efficient solutions and qualified services throughout the lifecycle of our customers' ships.

Through innovative solutions, high competence and global capability, ABB Marine contributes to reliable, safe, more profitable and environmentally friendly operation of high-performance vessels. Our roots go back to the early days of electrifying the society. ABB Marine has supplied electric power and propulsion systems to ships for nearly a century already, and the number of vessel types and customers preferring electric propulsion is continuously increasing. We have the longest experience and the largest number of installed electric propulsion systems worldwide.

**ABB Marine's business environment**

Today, hundreds of cruise ships, passenger vessels, icebreakers, tankers and special vessels are equipped with environmentally friendly diesel-electric propulsion systems. Recent ship

types with this type of propulsion system include LNG carriers and vessels for offshore service and construction work.

From 1990 to the end of 2010, more than 200 Azipod propulsion units have been built with more than 6 million accumulated operating hours. This serves as a solid basis for new business and developments.

ABB Marine and Cranes is part of ABB Group, the global leader in power and automation technologies. ABB Marine is the market leader in five core vessel segments: cruise ships, ice breakers, offshore supply vessels, LNG carriers and drilling vessels.

To meet the varying requirements of our customers, ABB offers a wide range of products ranging from pumps, fans, compressors and other onboard process applications through to machinery and marine applications. Special emphasis has also been put on the total energy consumption management by introducing completely new approaches into the ways that energy can be saved.

**Worldwide operation with strong local presence**

ABB Marine´s operations are organised and coordinated by two centers of excellence, CoE Cruise & Ferries and CoE Oil & Gas. The main sales locations are in Finland, Norway, China and Singapore.

All in all, ABB Marine employs some 1000 people. After-sales services, support and training are integral parts of ABB Marine's total delivery. ABB has service operations in more than 100 countries with Marine Service Centers located in the world's main shipping and shipbuilding areas.

**ABB milestones during the past century**

The next pages present some of the milestones in our history and highlight the technologies that are the result of consistent development work and the experience we have gained.

**Strömberg – a pioneer in electricity utilization**

In 1889, Gottfrid Strömberg established an electrical hardware store in Helsinki to sell dynamos and motors he had developed, as well as lighting equipment for houses. The equipment was manufactured in a small workshop by four employees. This was the beginning of Oy Strömberg Ab.

The company made its first exports as early as in 1894 when it sold dynamos to the newly built premises of the Russian Government and the Russian Admiralty.

**Strömberg – a pioneer in electricity utilization**

First diesel-electric icebreaker

The production extended to industrial transformers and electrical works for municipalities and industries, and in a few decades, the company was among the biggest in Finland.

**First diesel-electric icebreaker**
In the 1930s, the company moved its production to Pitäjänmäki where the manufacture of electrical generators and DC motors for vehicles and vessels started.

The first Finnish-built diesel-electric icebreaker Sisu was completed in 1939. The diesel engine powered generators produced electricity for three motors driving the propellers. The ship had two propellers in the stern and one in the bow.The icebreaker Sisu utilized the Ward-Leonard system, in which each diesel driven DC generator supplied electric power directly to its DC propulsion motor.

**New factories – more power**
The electrification of Finland progressed in the 1940s. Strömberg expanded its operations. A new factory was established in Vaasa in 1944. In 1954, the icebreaker Voima was built. It had nearly three times the power of what Sisu had – 10,500 shp, two stern propellers, two bow propellers and six diesel generators. The ship was renovated in 1979, but the original propeller motors were kept.

Electronics production began in Pitäjänmäki in the 1960s, as did the development work with power electronics.

The Pitäjänmäki facilities in the 1970s.

**Rapid technological development**
Many icebreakers were built in Finland for Baltic and Arctic operations. The technology developed quickly. The polar icebreaker Moskva, boasting 22,000 shp, was completed in 1960. Electrical equipment for the world's four most powerful diesel-electric icebreakers, the Jermak class polar icebreakers with 36,000 shp each, was delivered during 1974–1976.

Initially, both the generators and propeller motors were heavy DC equipment. With the development of power electronics, AC generators and thyristor-controlled DC motors were introduced, and all of a ship's electricity consumption could be supplied from the same network (the power plant principle). The first vessel to utilize this concept was the icebreaker Kapitan Izmaylov (1976).

**First cycloconverters in maritime use**
Frequency converters for regulating the speed of AC motors were developed in the 1970s.
In 1983, the research vessel Aranda was completed. It was the first vessel in which cycloconverter technology was used. The propeller was driven by a synchronous motor. Otso, the world's first icebreaker utilizing similar AC-AC technology, was completed in 1986.

**New ship technology breakthrough – ABB was founded**
PWM (Pulse Width Modulation) inverter technology was first applied to maritime use on the pipe-laying vessel Lorelay (1986).

AC motors allowed power to be increased. This also meant that electric propulsion could be fitted into in passenger vessels. The first cruise ship application was ordered in 1987 for Carnival Cruise Lines' Fantasy cruise ship series (propulsion power 2x14 MW). During the same year Asea acquired Strömberg and ABB was created in 1988 through the merger of Asea and AG Brown Boveri. The first Azipod® patent applications were filed in 1987.

### First applications of the Azipod® propulsion units

The development of Azipod propulsion started in 1989 as a partnership between Masa-Yards and ABB, and the first unit was delivered in 1990 for the waterway service vessel Seili of the Finnish Maritime Administration.

The first high-power Azipod unit (11.4 MW) was retrofitted into the tanker ship m/t Uikku in 1993, and to her sistership m/t Lunni in 1995. Uikku was the first western cargo ship to sail through the entire North-East Passage, unassisted, in 1997.

### First cruise ships fitted with Azipod® propulsion

The good experiences from the first installations demonstrated to the major cruise lines that Azipod was the right solution for their ships. The first passenger vessels that were fitted with Azipod propulsion units were the two last ships in the Fantasy series of Carnival Cruise Lines, m/s Elation and m/s Paradise. The propulsion units (2x14 MW) for these ships were ordered in 1995. The ships were completed at Kvaerner Masa-Yards' Helsinki shipyard in 1998.

### ABB Azipod Oy was established

As ABB received several new orders for Azipod units, a separate company was established around the successful product. The number of partners increased, too.

**First cycloconverters in maritime use**

**New ship technology breakthrough – ABB was founded**

**Otso, the world's first icebreaker utilizing similar AC-AC technology**

**Tanker ship m/t Uikku**

ABB Azipod Oy was established in 1997, with ABB, Kvaerner Masa-Yards and another major builder of cruise ships, the Italian Fincantieri, as its shareholders. The company's operations at Vuosaari, in Helsinki, were focused on the sales, design and manufacture of the new product.

**First high voltage delivery**
The first high voltage power plant (11 kV) was delivered to the then world's largest cruise ship m/s Voyager of the Seas in 1999. The ship was fitted with two azimuthing and one fixed Azipod unit (3x14 MW).

At the beginning of 2000, ABB acquired all the shares in ABB Azipod Oy, and its operations were integrated with ABB's other marine-related operations. During the same year, the Compact Azipod® family, intended particularly for applications below five megawatts, was introduced.

**First Double-Acting tanker**
Thanks to Azipod propulsion, completely new ship concepts could be developed and introduced. Azipod propulsion made it possible to construct m/t Tempera, the world's first tanker newbuilding designed to break ice with the stern first (2002) Double Acting Ship (DAS) technology developed by Aker Arctic Technology.

The first Compact Azipod unit was delivered for the Norwegian exploration ship Normand Rover a year earlier. By the beginning of 2002, more than 70 Azipod propulsion units had been delivered for nearly 40 different vessels, 11 of which were ice-going.

**Contra Rotating Propulsion (CRP)**
The first two ships fitted with CRP Azipod propulsion, the Japanese passenger ferries m/s Akashia and m/s Hamanasu, were completed in 2004. They also received the first 3,000V AC-S6000SD type frequency converters.

In 2005, ABB Marine had a breakthrough when it delivered the electric propulsion for the first large-size diesel-electric liquefied natural gas carriers, owned by Gaz de France and NYK Line.

**First cruise ships fitted with Azipod® propulsion**

The world-wide maintenance network was strengthened, and customer training and preventive maintenance products were developed.

**ABB Marine's new Azipod® production plant and office**

At the new Marine House in Vuosaari, established in 2007, ABB assembles and tests every Azipod unit before it is shipped to the client's shipyards. The casts, propellers, assembly blocks, steering gear, bearings and other various parts and systems are produced by a well integrated international supplier network. The electric systems, such as the rotors and stators for the Azipod units, as well as generators, switchboards, transformers and frequency converters, are produced at other ABB units located in Finland and in other countries.

**Azipod® propulsion for icebreaking vessels**

A fixed pitch propeller powered by an electric motor is an unmatched combination for an icebreaking vessel. An electric drive can produce full torque from zero propeller speed up to full power. This is an important feature when the propellers are surrounded by ice blocks.

Over the years the electric icebreaker transmission developed from DC generators and DC propulsion motors (DC-DC) to AC-DC and eventually to the most efficient and compact AC-AC propulsion.

Azipod propulsion was first developed for icebreakers to improve their manoeuvrability. It resulted in the development of entirely new types of icebreaking ships such as the Double Acting Ship, which efficiently breaks ice by going with the stern first, and the Oblique Icebreaker, which breaks a wide channel by going sideways.*
(*developed by Aker Arctic Technology where ABB is shareholder)

**Azipod® propulsion for cruise ships and superyachts**

A modern cruise ship is a floating city that needs power for both the hotel and her technical operation. The varying demand for power is ideally suited for the electric power plant concept. The number of main engines connected to the network equals the power demand at any given point in time. They run at a high load and constant speed, which improves fuel efficiency and reduces maintenance costs and emissions.

Azipod propulsion brings many further benefits and significant savings in fuel consumption. Every week, Elation, the first cruise ship with Azipod, consumes some 40 tonnes less fuel than her sisterships with traditional propeller shafts. Improved manoeuvrability increases safety. Good ship control is important in narrow passages and ports. Azipod propulsion allows for bigger cruise ships to be built. Its silent operation and low vibration levels result in unmatched pas-

**The most advanced electrical propulsion systems in the world are designed in ABB factories in Finland and China. The new premises in Vuosaari, Helsinki, and Shanghai were completed in 2007 and 2010, respectively.**

senger comfort. All these features are also well appreciated by an increasing number of owners of superyachts, such as the 90 meters long M/Y Ice.

**CRP Azipod® Propulsion – major benefits for fast ferries and cargo vessels**
Contra-rotating (CRP) Azipod propulsion is designed for high-speed, high-power vessels such as large container ships and fast ferries. The Azipod unit is placed behind a conventional shaft-driven propeller.

A main benefit of CRP is its increased propulsion efficiency.

The first applications of CRP were two high-speed RoPax vessels, Akashia and Hamanasu delivered by Mitsubishi Heavy Industries in 2004 to Japanese Shin Nihonkai Ferry. With a gross tonnage of 34,100, length of 224.5 meters and service speed of 30.5 knots, these two RoPax ferries are the largest and fastest in Japan. The total propulsion power is 42.8 MW with 25.2 MW on the CP propeller and 17.6 MW on the Azipod. Compared to the previous vessels on the route, a 20 percent reduction in fuel consumption is achieved.

## ABB MARINE TODAY: NEW IDEAS, NEW TARGETS

**Onboard DC electrical system will increase the energy efficiency of ships by up to 20 percent**
ABB has introduced a new DC (direct current) electrical system for marine applications. The new system is part of a revival of power solutions using DC electricity, and it will provide highly efficient power distribution and electric propulsion for a wide range of vessels. It is designed for ships with low voltage onboard power systems, such as offshore support vessels, tug boats, ferries and yachts, and can reduce fuel consumption and emissions by up to 20 percent.

In traditional electrical propulsion vessels, multiple DC connections are made from the AC circuit to thrusters and propulsion drives, which account for more than 80 percent of the electrical power consumption. ABB's onboard DC system represents a step forward in optimized propulsion by connecting all DC links and distributing the power through one main DC circuit.

This approach is making DC the technology of choice for many power transmission solutions, battery storage and other energy supply applications. It can vary the generator speed to optimize fuel consumption and improve a ship's operational efficiency by up to 20 percent compared with traditional AC powered systems.

**First Double-Acting tanker**

**Contra Rotating Propulsion (CRP)**

ABB's onboard DC system incorporates proven products already operating on today's ships, such as AC generators, inverter modules, AC motors, etc., but eliminates the main AC switchgear and transformers.

Furthermore, ABB's onboard DC system enables supplementary DC energy sources such as solar panels, fuel cells, or batteries to be plugged directly into the ship's DC electrical system, for further fuel savings. The new onboard DC technology can be applied to ships already now.

**ABB delivers comprehensive electricity production and distribution systems to new cruisers for Norwegian Cruise Line.**

**New orders: Two huge cruisers and the world´s first passenger ferry powered by LNG-electric propulsion**

ABB has received an order to deliver the electricity and propulsion systems for two huge cruisers for Norwegian Cruise Line. The cruisers will be built by Meyer Werft in Papenburg, Germany, and they are scheduled to be delivered in the springs of 2013 and 2014. The delivery includes the electricity production and distribution systems, bow thruster motors, and two 17.5 MW propulsion systems.

Viking Line has ordered a new passenger ship. The 240-million-euro ferry will be built by STX in Turku, Finland. The ferry will be 210 meters long with a capacity of 2,800 passengers. It will be the most environmentally friendly vessel in its size category and it will be fuelled by liquefied natural gas. It is scheduled to start operating between Turku and Stockholm in 2013.

**The most environmentally friendly ferry in the world is scheduled for delivery in 2013.**

# 3 The future lies in diesel-electric propulsion

There is a clear shift in the shipbuilding industry from diesel-mechanical propulsion to diesel-electric propulsion.

**The main trends are:**

- stricter environmental regulations and safety criteria
- increasing competition
- rising oil price
- emerging alternative energy sources
- changing transfer routes and itineraries
- diesel-electric propulsion is becoming a commodity

The mutual importance and order of these trends are in constant change, but they all reinforce each other and the movement towards diesel-electric propulsion. The shift is inevitable, and opting for diesel-electric propulsion becomes a wise and safe decision in the long run.

**Environmental regulations and safety criteria**
At present, international shipping is excluded from international environmental agreements, such as the Kyoto Protocol. However, sooner or later discussion in climate change conferences will turn to emissions produced by shipping.

The International Maritime Organization (IMO) ship pollution rules are known as MARPOL 73/78 and commonly referred as the Tier I, II and III standards.

NOX emission control technologies are needed to meet these standards; this means that the prevailing engine design is going to be outdated soon. MARPOL defines two limits on the sulfur content of fuel oil that apply to two different areas: global areas and Emission Control Areas (ECA). Heavy fuel oil is allowed provided it meets the acceptable sulfur limit. These limits on the emissions and contents of the fuel oil mean that the design of the engines onboard will be a center of attention in the future.

Safe Return to Port (SRTP) is a new set of regulations for passenger vessels built since 2010. Cruise vessels meet these regulations quite easily. Ropax vessels, however, aim to maximize the amount of cargo space and they do not have many duplicate and redundant systems. Because of the lack of this redundancy, they might have difficulties in meeting the requirements.

The requirements for propulsion are clear: “Propulsion machinery and auxiliary machinery essential for the propulsion of the ship should remain operable.” Because flooding or fire can lead to the loss of one engine room, it is required that there is another engine room that can provide enough propulsion power for returning from the sea.

Redundancy is one the benefits of a diesel-electric propulsion system. The engine rooms are already segregated in prevailing designs and adequate propulsion power is available in case of emergency. Propulsion is not the only critical issue in case of emergency; there must be enough electrical power available to maintain normal and safe travel conditions for the passengers. Electrical power is needed to maintain the prevailing

conditions and prevent panic onboard. What could be a better solution for providing electric power and safe propulsion than a diesel-electric propulsion system?

Energy Efficient Design Index (EEDI) is a new indicator that can be used to compare different types of vessels. EEDI inherently favors diesel-electric propulsion which enables fuel-efficient designs. The question of whether EEDI is the right index to compare various vessels types has been heavily debated, because it would mainly lead to power limitations for new ships. In any case, a vessel with a diesel-electric propulsion system can benefit from limited service speeds without compromising fuel economy.

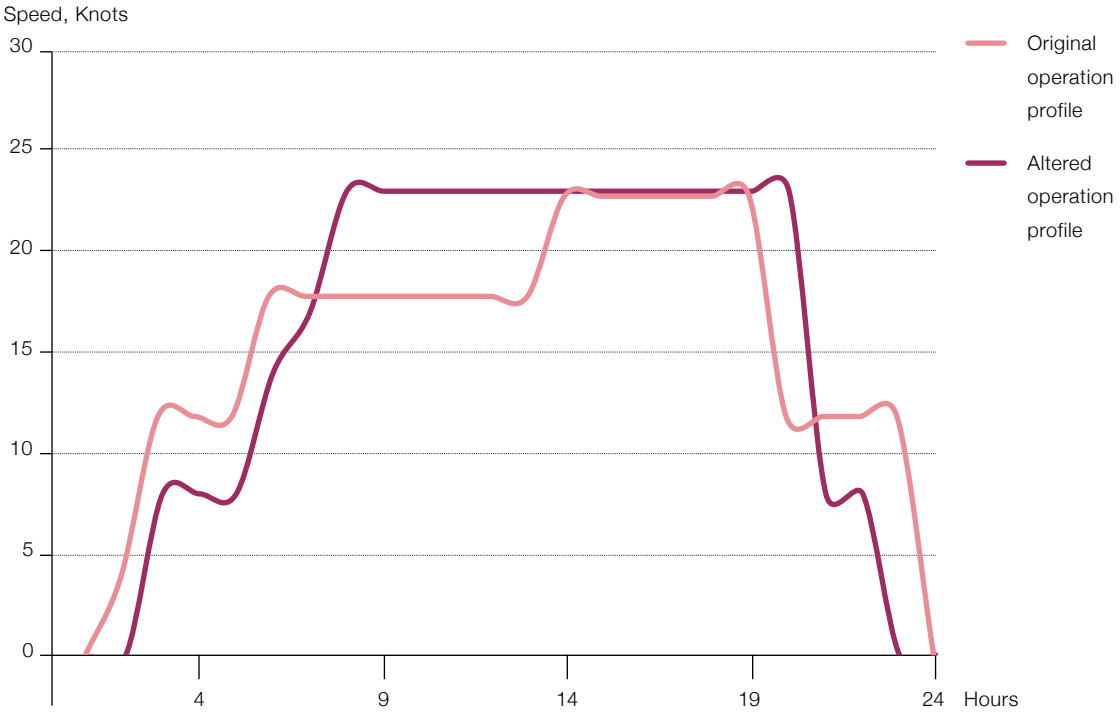
**Increasing competition**

A company must be able to see the big picture, be innovative and people-centric, coordinate with outsiders, use the right technology and have a deep domain of expertise to survive in the competition. Should shipyards and ship owners turn to diesel-electric propulsion to rise above their competitors? Perhaps – at least diesel-electric propulsion provides the foundation for maintaining your competitive edge in the future.

**Rising oil price**

With climbing oil price, savings resulting from better fuel efficiency become more significant and the payback times for investments will shorten. Diesel-electric propulsion is a tempting concept and could provide better efficiency and thereby offset higher investment costs.

**Original and altered operation profile.**




**There are several reasons why operational profiles must be adjusted. The environmental regulations may demand speed limits in archipelago to reduce wave formation. Harbor access can take more time and the change of fuel type may be necessary. All in all, regional legislation can be a source of surprises with very short notice.**

### Alternative energy sources

Rising oil price will make room for alternative combustion materials, such as liquefied natural gas (LNG), or totally different energy technologies, such as batteries, fuel cells or solar power. Electric propulsion can easily adapt to changes in the source of the primary energy. Gas turbines, for example, can be used instead of diesel engines without making dramatic changes to the design. Whether it will be gas turbines, diesel engines, or something else, the change is evident and oil price will continue to play a major role in the process. The only question is about the pace of this change.

### Changes of routes and itineraries

Ships are typically designed for a specific route or with a specific transportation task in mind. However, if we consider the changes that can occur during the life span of 30 years of a ship, it is difficult to forecast whether a certain route remains profitable or a single transportation task the same. Diesel-electric propulsion is the optimal solution when there is uncertainty with the route or operational area. It works as an insurance against changing tasks, itineraries, and routes.

**Diesel-electric propulsion is becoming a commodity**

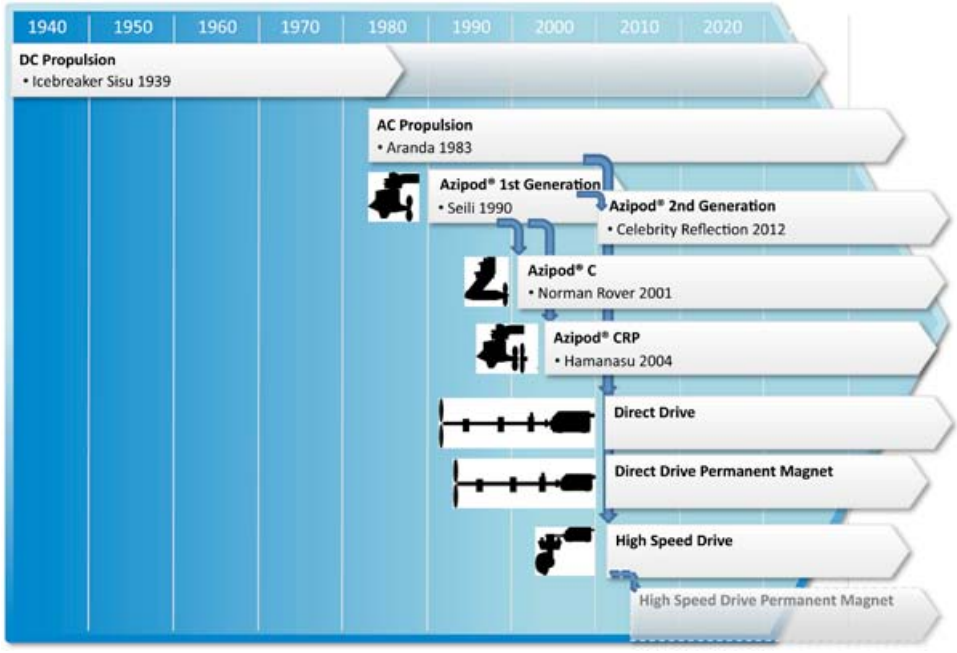
Diesel-electric propulsion has evolved from DC systems to AC systems and spread to various vessel types. As the number of more experienced players in the industry has grown, the buying and selling has become more professional. Popularity has lowered the barriers of entry for new competitors. Commoditization means that offers are alike and differentiation is difficult to achieve. Experience is needed to find those significant differences which profit the ship owner. Any company that brings something new and beneficial into the shipbuilding industry creates a growing demand for its products. Furthermore, commoditization means that diesel-electric propulsion is becoming simpler to operate and maintain. A growing fleet of ships will ultimately result in more competent workforce and accumulating experience.

All this culminates to the state-of-the-art propulsion system – Azipod. It represents the future of electric propulsion because it does not depend on a specific type of energy production. At present, Azipod propulsion is the foundation for ultimate energy-efficiency; the next revolutionary generation might again be able to improve its efficiency. Perhaps ABB's Energy Monitoring and Management system (EMMA) will take us towards this next generation.

## SUMMARY

Diesel-electric propulsion is a safe choice against uncertainty, future modifications and tightening regulations. Furthermore, diesel-electric propulsion provides more freedom in spatial arrangement, better tolerance for malfunctions and better fuel efficiency.

**Evolution of ABB Electric Propulsion**



# 4 Energy efficiency of the passenger vessel

## Knowledge is power in the battle against wasted energy. In the end, it all comes down to the quantity and efficiency of the energy production.

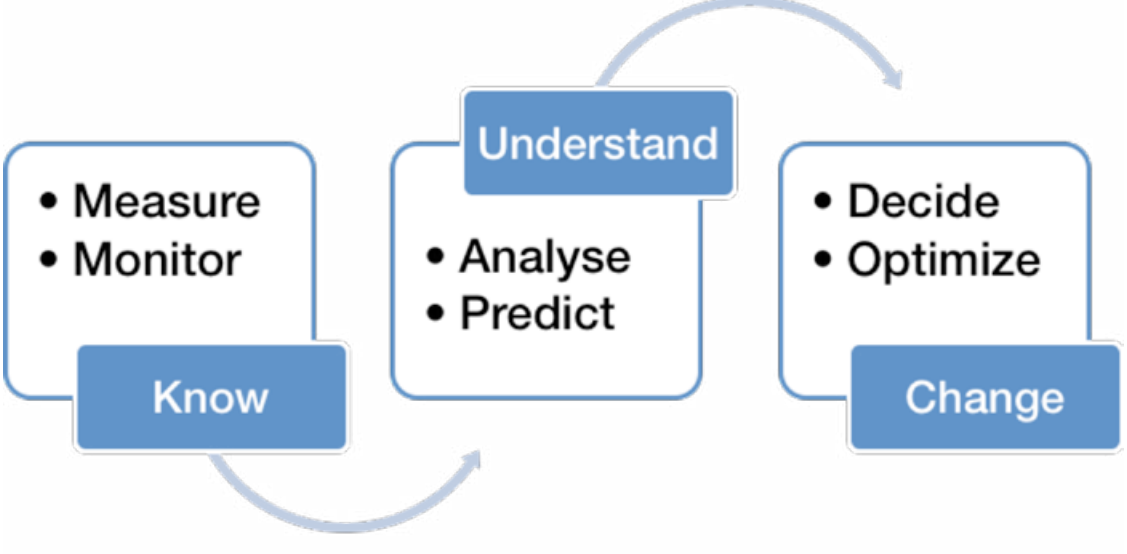
The challenge in improving the energy efficiency is in achieving the reductions as easily as possible. There are several ways to improve the current situation and it has become a standard in the marine industry to make use of new technologies and practices. Today's operators work under heavy time pressures, and hence the projects should be designed efficiently and the results copied into the existing fleet if possible. ABB has introduced tools that help in using all the gained information from new projects to improve the energy efficiency of the existing fleet, and vice versa.

**To know**

The approach that ABB has adopted leads into significant improvements in energy efficiency. Our approach is to consider the reductions in the energy use on the whole ship level and compare these changes to other ships in the fleet. This approach is based on measuring and understanding the energy consumption and energy flow within the system, which are issues that need to be addressed first. Once a good understanding of the consumption is reached – regardless of whether we are dealing with a single consumer, onboard process or the total energy production – potential targets for savings might be discovered.

**To understand**

You can start analyzing the energy consumption once you can measure it. You should be able to monitor it on the level in which alterations in the consumer level are noticed and the changes can be seen from other indicators as well (pressure and temperature readings, for example). Once this level is reached, you can evaluate whether:



- The selected components are efficient.
- Processes work as designed.
- Processes are efficient.
- Processes are used efficiently (if operations can be affected by human factors, as is the case with the propulsion system).
- Process consumption occurs within the frame that supports the energy efficiency of the vessel (load management).
- All energy forms are considered in the energy monitoring and analysis.

Experience has shown that targeting energy efficiency requires a sufficient period of time to measure and monitor the system. It might take months to a year before an analysis can be conducted on the basis of the results. Especially in passenger vessels, this results from the fact that the number of onboard processes is large, simultaneous consumption varies, and the existing monitoring systems are poor because other design criteria were thought of as more important.

When the technical specification of a new vessel is written, the criteria that will define the performance of a single consumer are of vital importance. In this stage the game is easily lost.

**To change**

The power consumption of a single consumer can be reduced in many ways. Good choices in writing the technical specification result in full-scale success later on:

- Each consumer should be controllable and use only the minimum amount of energy. The technical specification should define the motor and frequency converter so that they are suitable for the vessel. When there are hundreds of onboard consumers, it becomes important to simplify the ways in which they are controlled. This can be done with a standard control interface that can be used regardless of the process in which the consumer is located.
- Each consumer should be monitored. When there are hundreds of onboard consumers, it is important to simplify the manner in which they are monitored. A standard control interface can monitor the consumers regardless of the process in which they are used.
- In addition to optimizing the performance of single components, the technology should be selected so that the whole process is optimized according to future operational needs. This should be emphasized when the propulsion system is being selected. However, even then the performance is often poorly defined for the whole vessel, but well documented for individual components.
- All possible processes should have an interface with and be controllable from the energy management system. Choke valves should be replaced with frequency converters that provide drastically better efficiency.
- The information and data that have been obtained and measured from existing vessels should be taken into account when devising the specification for the new vessel. Accurate information helps shipyards to get rid of oversized systems, for example.
- The internal efficiency of the consumers should be on a good level.
- The components used in the consumers should be efficient.

The ship owner seldom has a chance to concentrate on the equipment-internal components and therefore a more realistic approach is to concentrate on issues from the equipment-level up. The technical specification should provide a more detailed view of the design.

If you hesitate, ABB is happy to guide you in writing the technical features into your specification. We have the experience and we have the know-how.

How to write efficiency into the technical specification of a ship? The main challenge in bringing the efficiency philosophy into the specification is to be able to describe the efficiency requirements in such a way that leaves room for the competition of different technologies and does not name any particular manufacturer or technology. The technical specification should be about the performance requirements, not about the technology.

**The importance of a correct operational profile**
In what area will your ship operate? Ideally, the exact itinerary of your vessel is known for the coming years. If it is not known, the second best option is to estimate it as closely as possible. The prognosis should cover the typical operation, the time at harbor and particular operational cases.

Any technical evaluation made in designing the vessel should be based on the detailed operational profile. When passenger vessels are considered, the operational profile of ferries is typically the easiest to estimate, but the operational profiles of cruise ships and yachts are often less clear.

It is of the greatest importance to note the operational states in which the ship owner and operator need to improve the energy efficiency. Efficiency requirements should be specified for those states. Some proposals for writing the efficiency into ship design:

- Define the energy use in harbor.
- Define the operational efficiency.
- Define the minimum efficiency requirement for the propulsion system.
- Define the minimum efficiency requirement for the power plant.
- Define the auxiliary load efficiency.
- Define the efficiency booster solutions, such as batteries.

**SHIPOWNER TIP:**

The energy efficiency onboard is and should be a target of continuous improvement. In case you know the ways in which consumption can be reduced, the longer you wait, the more you waste. It is therefore crucial for the improvement of energy-saving attitude among the crew that these improvements are encouraged. The monitoring of energy consumption should lead into a positive work atmosphere, not into punishments and control from the main office, as it is easily interpreted onboard. ABB offers a variety of Energy Efficiency Services, through which we can act as a supporting partner and a link between the office and the vessel. Services like Energy Coaching can lead to useful conversations, they distribute best practices between all parties, and can lead to new inventions.

## Three significant factors in energy efficiency

### Production
The first factor in energy efficiency is, quite naturally, the efficient production of energy. In a ship, the diesel engine is a good producer of electricity, but the power plant that is constructed around the diesel engine is a deciding factor on how efficiently the power and energy produced by the engines can be utilized.

### Consumption
With different ships and with different operational profiles some propulsion solutions are more energy efficient than others. One has to know how to choose the right system.

### Operation
Operation includes the energy needed to other things in addition to moving the vessel. In a cruise ship, for example, this part of the energy consumption is remarkably large. A good energy management system can bring significant savings by timing some necessary operations.

+ + +

### ABB power plant
The number of engines or other power sources connected to the network can be varied and the engine load can be adjusted to be at the optimal level by matching the running power source configuration with the power need.

### ABB electric propulsion systems
Electric propulsion offers a full range of systems – from variable speed electric machinery for shaftline propulsion and mechanical thusters to a unique family of podded propulsion systems.

### EMMA
EMMA is a powerful solution for energy efficiency improvement and fuel cost reduction. For the ship owner, EMMA represents a key element of an energy management program. It improves the profitability and reduces the overall environmental footprint of a company.

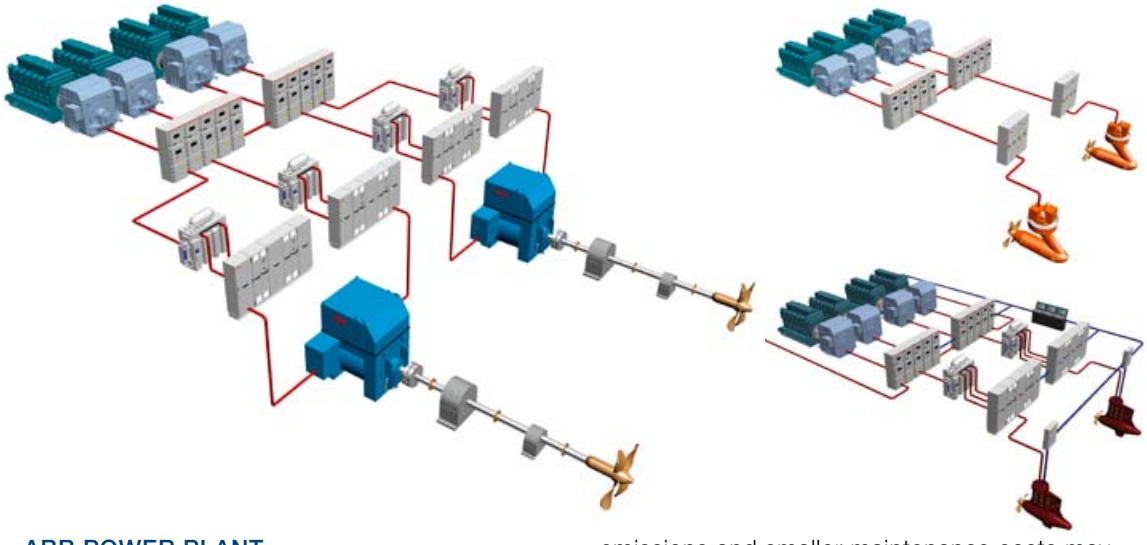
+ + +

### Energy efficiency
When any of the three sections above are thought of from the point of view of energy efficiency, reductions in the energy consumption as compared to the reference level can be achieved. When two or more sections are combined at the same time, the results will be even more striking.

+ + +

### Operational changes and a positive attitude towards continuous improvement
All technology is affected by the human factor. Therefore the operators are in a key role to adopt the right attitude to change things.

Various configuration examples



## ABB POWER PLANT

### Better overall performance

The high demands on the performance, overall reliability and safety of vessels have resulted in the increased focus on the total concept of the vessel and the interaction of the installed equipment and systems. A solution that encompasses the whole power plant, the propulsion system, and the control systems has several advantages.

Typical operation profiles have large variations in their power demand, which makes an electric power plant concept especially suitable for them. The number of engines or other power sources that are connected to the network can vary, and the engine load can be adjusted to the optimal level by matching the number of the engines that are running with the electricity need. A major benefit that the electrical power plant concept has is that the main engines run at a constant speed. While writing this book, however, ABB is introducing the possibility of improving the good and proven principle. The load and speed parameters can be varied to always find the optimal load level or speed for the main engine. The present power plant principle of running the engine with good fuel efficiency, reduced exhaust emissions and smaller maintenance costs may be facing some changes in the very near future. More about new concepts can be found in the chapter dedicated to the onboard DC grid.

A variable-speed electric propulsion drive system consists of an electric motor, which is located in the engine room or encapsulated in an Azipod® unit, a frequency converter and, in most cases, a supply transformer. The required propulsion torque is controlled by the frequency converter, which varies the motor frequency and voltage. To achieve the optimum diesel engine load, the number of the generator sets connected to the electric distribution network is automatically selected to match the total electricity consumption at a given point in time.

## ABB ELECTRIC PROPULSION SYSTEMS

The combination of the power plant concept and an AC electric propulsion system has a number of economical and technical advantages: good level of fuel efficiency, reduced exhaust emissions, low noise and vibration levels, improved maneuverability, flexibility to different machinery layouts, reliability and availability. The benefits were further enhanced when ABB's Azipod sys-

tem, the first podded propulsion system in the world, was introduced.

### Electric propulsion

ABB is the leading manufacturer of electric propulsion systems in the world. Our products are the preferred choice for an increasing number of vessel types and we offer a full range of different systems – from variable speed electric machinery for shaftline propulsion and mechanical thrusters to the unique family of podded propulsion systems. Through our worldwide operations, we obtain first-hand knowledge of the requirements that our users have, and our systems represent the accumulated experience that we have gained from more than 60 years of close cooperation with shipbuilders, operators and designers.

The use of electric propulsion is well established in many ship types and is emerging in several new ones. The ever-increasing demands on safety, reliability, operational economy and environmental performance are the driving force behind the growing number of ship owners that investigate and select the advantages of electric propulsion for different vessel types.

### The main advantages of electric propulsion

- Safety and reliability with improved maneuverability.
- High level of redundancy.
- Standardized, proven technology.
- Increased payload through efficient modularization and flexibility to different machinery layouts.
- Environmental benefits from lower fuel consumption and emissions resulting from the constant-speed engine operation with optimized load and high efficiency.
- High performance in rough conditions due to the maximum torque at zero speed.
- Better comfort level for the crew and passengers due to reduced vibration and noise.
- Flexible general arrangement and easy installation compared to diesel-mechanical systems.
- Reduced lifecycle costs that result from the improved operational economy, reduced fuel consumption and lower maintenance costs.

## EMMA

### EMMA ship energy manager

ABB's Energy Monitoring and Management system (EMMA) predicts, monitors and manages the onboard energy use. EMMA is a powerful tool for improving the energy efficiency and reducing fuel costs. For the ship owner, EMMA is a key element in the energy management program, improving the profitability and reducing the overall environmental footprint of the company. The energy manager can be used to optimize the performance of a single ship, several ships or the full fleet. EMMA provides an advanced and comprehensive toolset for managing and optimizing the energy operations throughout a vessel. EMMA includes planning tools that are used to predict the energy consumption and calculate the corresponding energy supply schedule. Combined with real-time monitoring of the operational and process data, EMMA can control and manage the energy balance onboard a vessel.

To optimize the energy use and supply, the prediction of future energy demand is done for the whole voyage. Both vessel-internal processes and external forces to the hull are analyzed. Based on this analysis, the ship energy manager finds the best configuration to minimize the fuel consumption and to use the diesel generators efficiently.

EMMA ship energy manager is a modular system that allows the customer to start with basic energy monitoring and reporting, and later expand to other functionalities, such as the optimization of energy use and supply for the whole ship or the entire fleet.

# 5 Vessel type examples

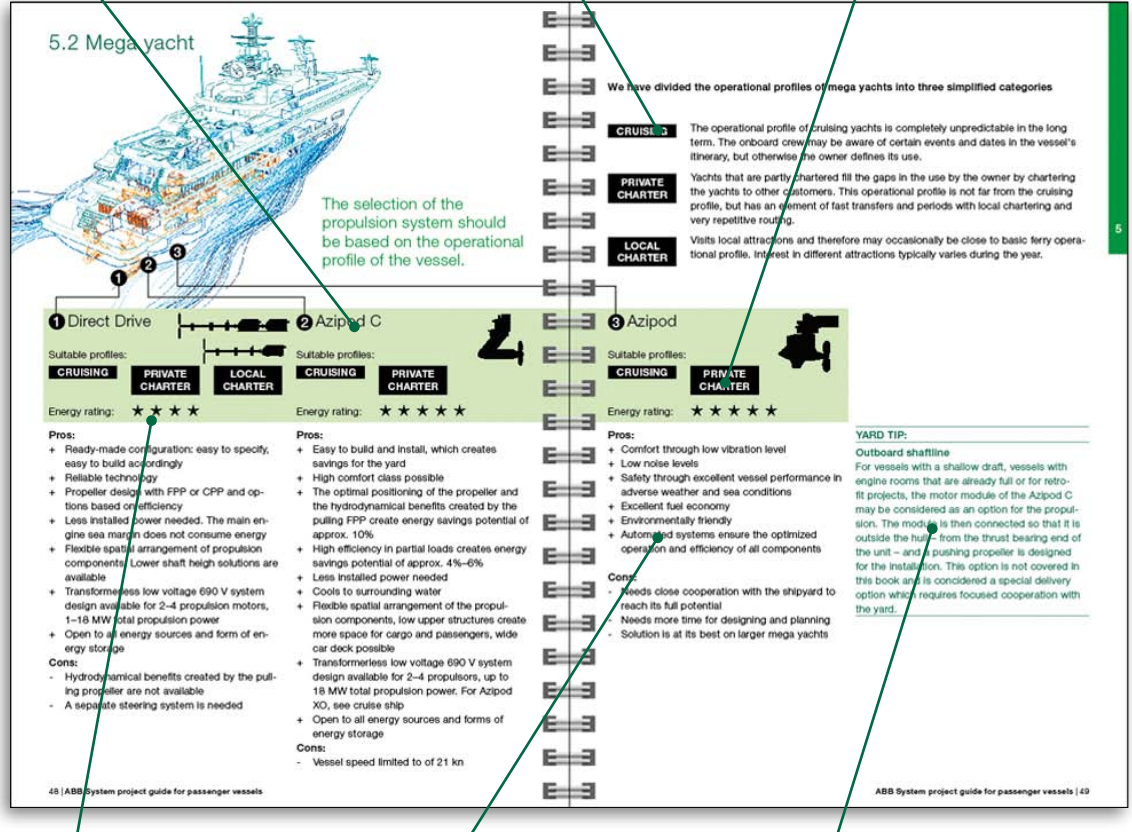
## How to choose the most cost-effective propulsion system?

**This is how you read the summary spreads (pages 30-31, 48-49, 64-65).**

1. Select the operational profile that best fits to the needs of the ship owners (with ferry, we are limited by space and cannot present all the possible varieties of vessels.)

2. On this line you find the different propulsion solutions that are suitable for a certain vessel type.

3. Here you find the proper operational profile for the chosen propulsion selection.




4. The energy rating tells you how energy efficient the chosen solution is compared to other possibilities.

5. Pros and cons of the solution.

6. In some cases you find some additional information or useful hints for the designer or shipyard here.

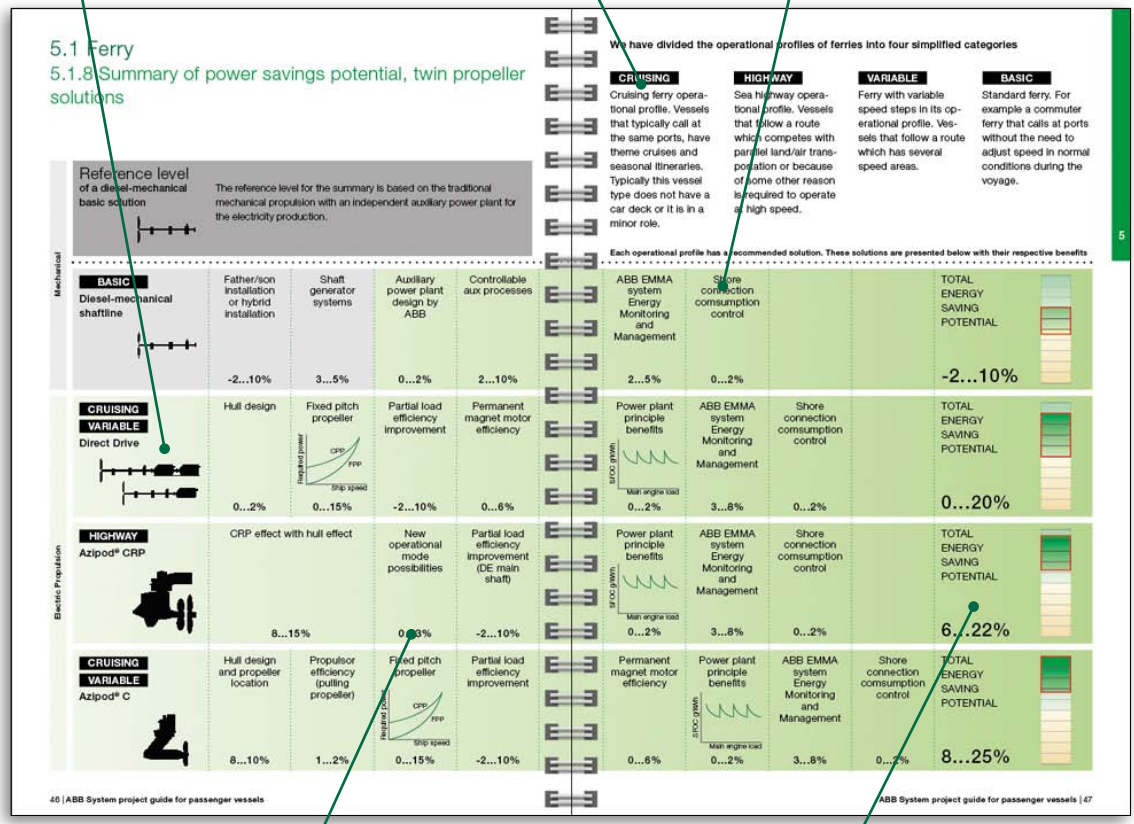
# How to save as much energy as possible?

**How to read power savings potential summary spreads (pages 46-47, 62-63, 74-75).**

1. Propulsion solution with most suitable operational profiles.

2. Examples of typical operational profiles. Choose the one that is closest to your and your clients' needs.

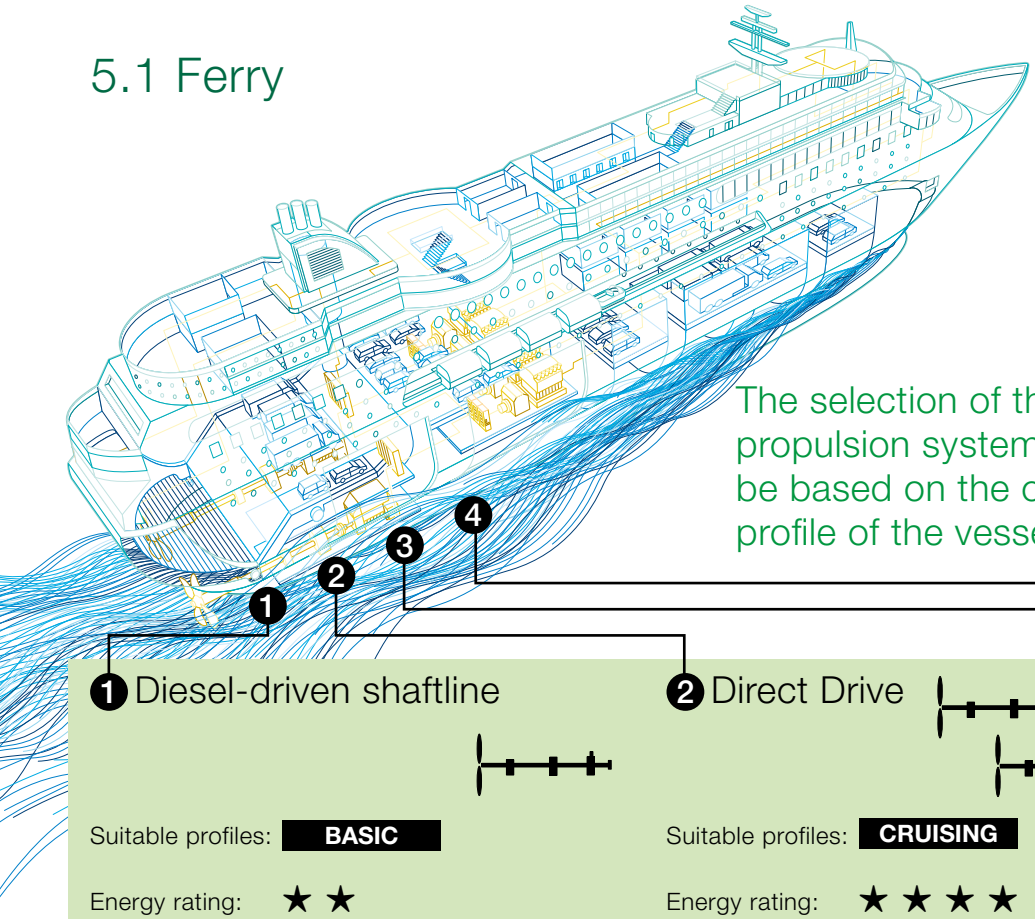
3. Examples of available power saving elements.




5. Guidance of the quantity of the energy saving potential [%].

6. Guidance of the quantity of the total energy saving potential [%].

# 5.1 Ferry




The selection of the propulsion system should be based on the operational profile of the vessel.

## 1 Diesel-driven shaftline



Suitable profiles: **BASIC**

Energy rating: ★ ★

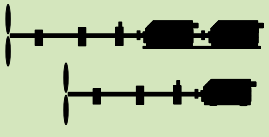
**Pros:**

+ Reliable technology
+ Simple solution
+ Efficient engine performance at the nominal speed range
+ Solutions available from many manufacturers, keen competition
+ Auxiliary plant is open to all energy sources and forms of energy storage at small scale

**Cons:**

- Hydrodynamical benefits created by the pulling propeller are not available
- The main engine sea margin rotates all the time
- High vibration level
- Engine defines the form of the hull
- A separate steering system is needed
- Low motor performance at variable speed
- Even simple, the shafting solution is often long with challenging bearing and long shafts
- New energy sources can not be utilised in propulsion

## 2 Direct Drive



Suitable profiles: **CRUISING** **VARIABLE**

Energy rating: ★ ★ ★ ★

**Pros:**

+ Ready-made configuration: easy to specify, easy to build accordingly
+ Reliable technology
+ Propeller design with FPP or CPP and options based on efficiency
+ Less installed power needed. The main engine sea margin does not consume energy.
+ Flexible spatial arrangement of the propulsion components. Lower shaft heigh solutions are available.
+ Transformerless low voltage 690 V system design available for 2–4 propulsion motors, 1–18 MW total propulsion power.
+ Open to all energy sources and forms of energy storage

**Cons:**

- Hydrodynamical benefits created by the pulling propeller are not available
- A separate steering system is needed

**We have divided the operational profiles of ferries into four simplified categories**

**CRUISING** Cruising ferry operational profile. Vessels that typically call at the same ports, have theme cruises and seasonal itineraries. Typically this vessel type does not have a car deck or it is in a minor role.

**HIGHWAY** Sea highway operational profile. Vessels that follow a route which competes with parallel land/air transportation or because of some other reason is required to operate at high speed.

**VARIABLE** Ferry with variable speed steps in its operation profile. Vessels that follow a route which has several speed areas.

**BASIC** Standard ferry. For example a commuter ferry that calls at ports without the need to adjust speed in normal conditions during the voyage.



## 3 Azipod CRP

Suitable profiles: **HIGHWAY**

Energy rating: ★★★★★

**Pros:**

+ High energy savings in high speed operations because of the CRP effect.
+ High efficiency in partial loads. Operation by only an electrical motor is possible.
+ More operational options to design the speed profile for the route.
+ Less installed power needed.
+ Concept open to all energy sources and forms of energy storage.
+ The main shaft can be either mechanical or diesel-electrical, which provides power plant benefits.
+ Steady and low vibration levels when sailing at high speeds

**Cons:**

- Vessel speed is crucial for the CRP effect, which will not stand out at slower speeds
- Where rudder redundancy is required, separate small rudders may be required

## 4 Azipod C

Suitable profiles: **CRUISING** **VARIABLE**

Energy rating: ★★★★★

**Pros:**

+ Easy to build and install which creates savings for the yard
+ High comfort class possible
+ The optimal positioning of the propeller and the hydrodynamical benefits created by the pulling FPP create energy savings potential of approx. 10%
+ Highest efficiency due to PM motor in partial loads creates energy savings potential of approx. 4%–6%
+ Less installed power needed.
+ Cools to surrounding water
+ Flexible spatial arrangement of the propulsion components, low upper structures create more space for cargo and passengers, wide car deck possible
+ Transformerless low voltage 690 V system design available for 2–4 propulsors, up to 18 MW total propulsion power. For Azipod XO, see cruise ship.
+ Open to all energy sources and forms of energy storage.

**Cons:**

- Vessel speed limited to of 21 kn

# 5.1 Ferry

## 5.1.1 Diesel-driven shaftline – system delivery

**BASIC**

❶ The power plant design – with a modern approach – combined with a consumer control design and the total energy efficiency approach from the start creates energy savings potential in the power production chain. It has an influence on the generator design and also enables the option of a shore-to-ship power supply connection.

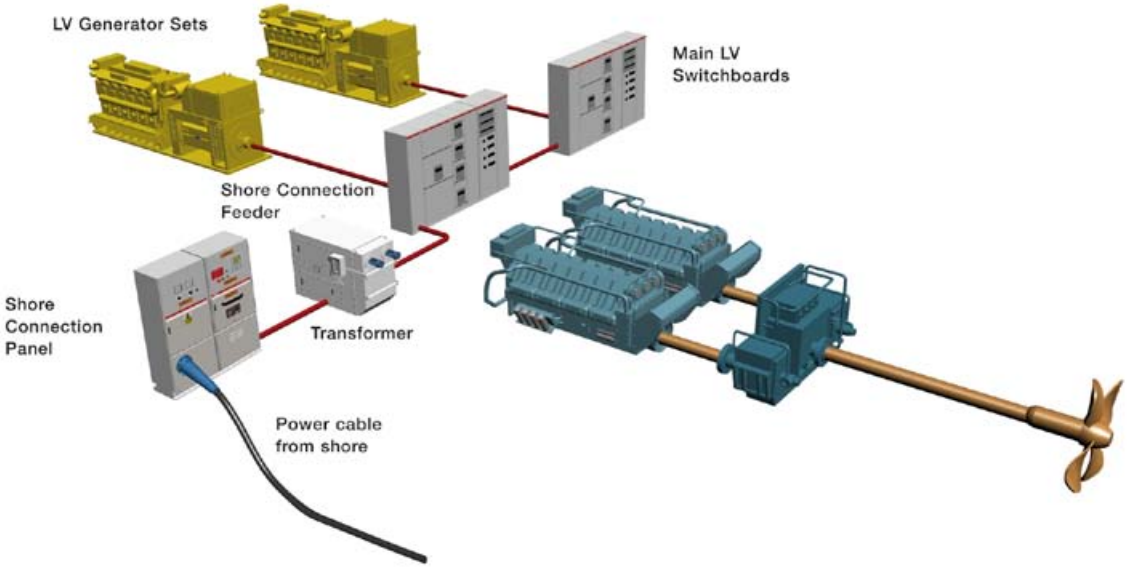
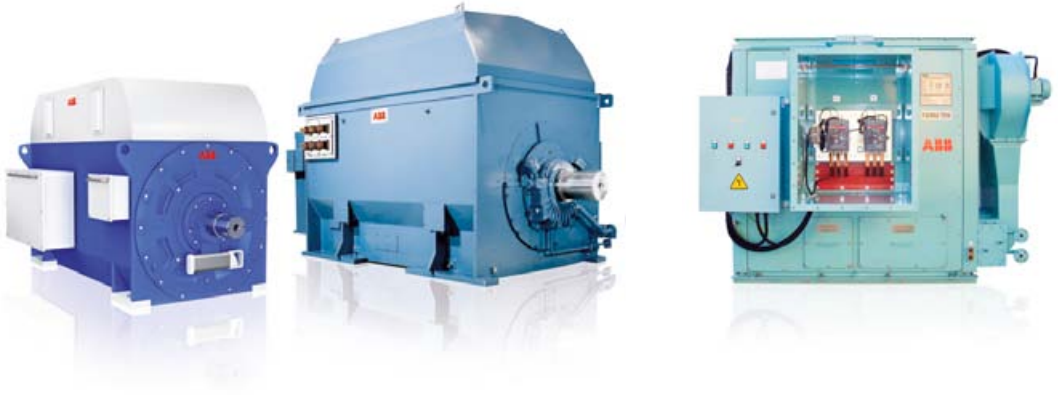



ABB has a unique position in the market and we understand the shipowners' point of view from the shore side deliveries (harbor side equipment, crane systems etc.) to the smallest consumers onboard and to the control and management systems for all of these.

**Below: ABB low voltage generators and a marine cast coil transformer.**



## For vessels with mechanical propulsion, ABB focuses on the auxiliary power plant and on the total energy balance of the vessel.

In cases where mechanical propulsion is selected, energy efficiency improvement potential outside the main propulsion should be recognized. Modern solutions, like controllable consumer supplies, can be integrated seamlessly into the design:

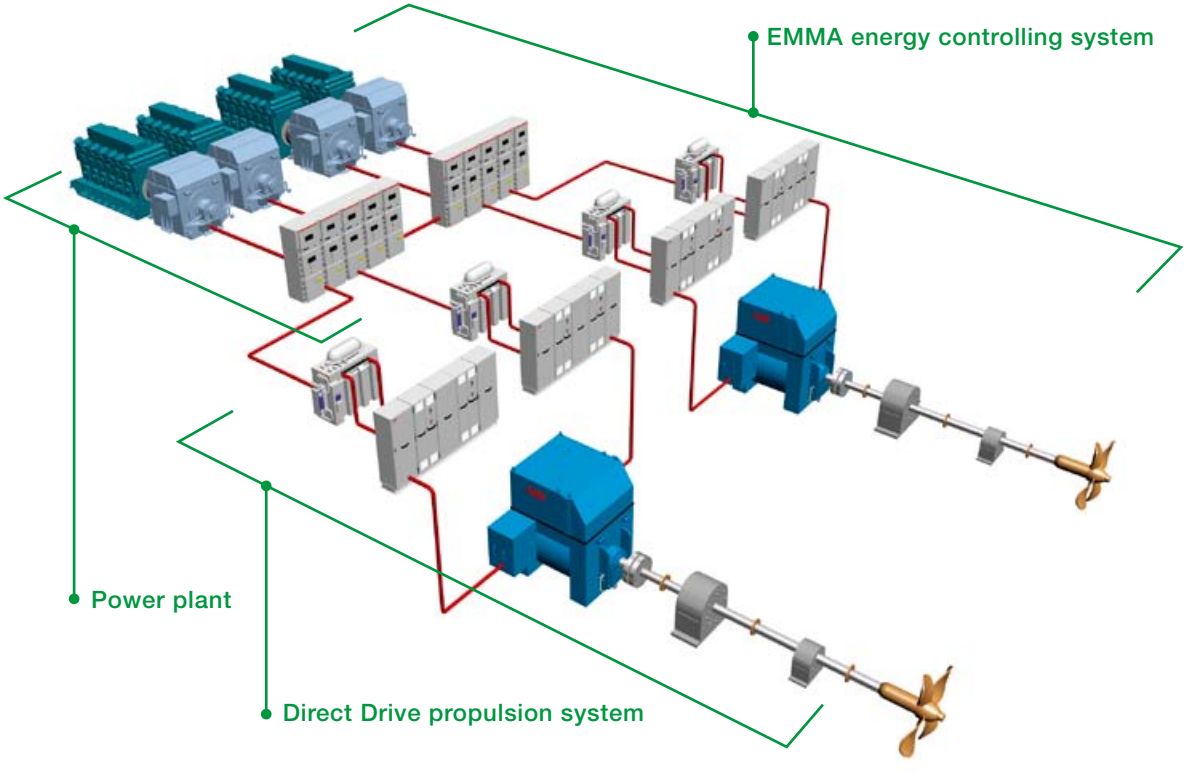
ACS800 frequency converters integrated into the MNS low voltage switchboard are used to supply consumers.

ABB cast iron-frame-motors together with aluminum-frame motors, controlled by the frequency converter through the power range from the smallest to the biggest, create a perfect platform for the energy monitoring and management system ABB EMMA to improve the results of the energy consumption reductions.

# 5.1 Ferry
## 5.1.2 Direct Drive propulsion system – system delivery

**CRUISING** **VARIABLE**

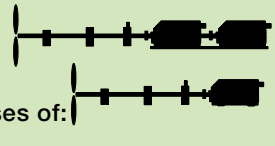
❷ Direct Drive is the optimal solution for conventional propulsion. A wide selection range, proven products and simple design satisfy the needs of even the most demanding customers. Redundancy levels provide an extensive selection for operational and passenger safety.




### ❷ Direct Drive

SIZE 0,5 – 20 MW / UNIT

**CRUISING** **VARIABLE**



**Shaftline propulsion system comprises of:**
Propulsion motor
Propulsion frequency converter
Propulsion control
Propulsion transformer (if applicable)

| Available solutions | Benefits |
| --- | --- |
| **Direct Drive propulsion system**<br>Sort according to performance, efficiency, footprint, weight or redundancy – whichever you value the most – and find your solution. The combination of a propulsion motor, frequency converter and control system will guarantee a successful voyage. | ▶ **Effect on energy efficiency**<br>Minimize the consumption by selecting the maximum performance. |
| + | |
| **Power plant**<br>Optimize your power plant according to the consumers. Set the number of generators. | ▶ **Effect on energy efficiency**<br>Boosts your efficiency with different main engine ratings. |
| + | |
| **EMMA energy controlling system**<br>Specify and design the energy production and consumption so that they can be easily monitored and managed. | ▶ **Effect on energy efficiency**<br>Savings produced by energy management are possible and unnecessary consumption is avoided. |
| = | |

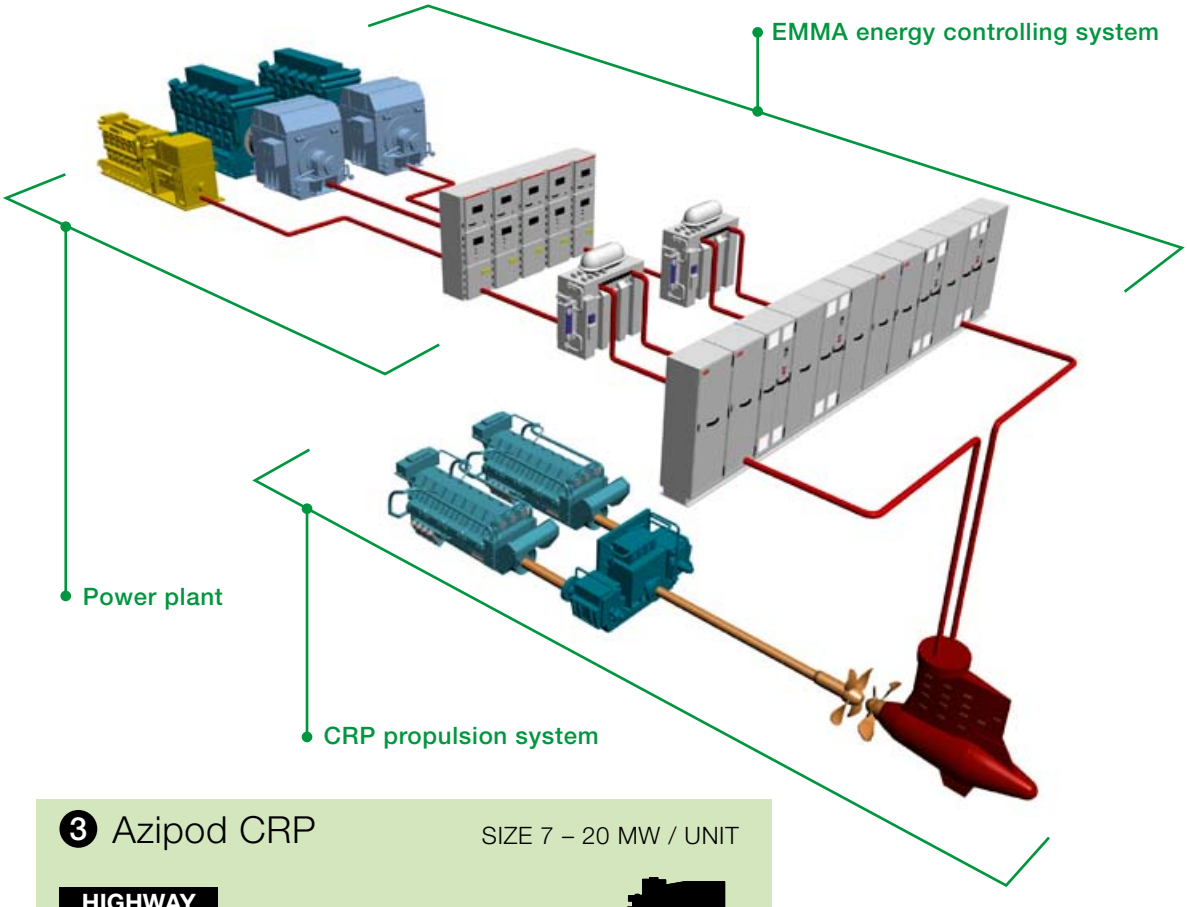
## Combined advantages

Energy design and efficient total design, including the selected equipment, have a major impact on the operational costs. Often the most efficient solution also lowers the investment costs. The results of the energy efficiency design are in use immediatelly, not after a period of wasted energy.

# 5.1 Ferry
## 5.1.3 Azipod CRP – system delivery

**HIGHWAY**

❸ Azipod CRP (Contra-Rotating Propulsion) propulsion is a proven solution, which is a perfect match for ferry operations with high speeds. When the vessel speed exceeds 25 kn, the hydrodynamical benefits of the propeller pair that rotates towards each other – strenghtening the combined performance – become obvious.




### ❸ Azipod CRP

SIZE 7 – 20 MW / UNIT

**HIGHWAY**

**Shaftline propulsion system comprises of:**
Azipod CRP propulsor
Propulsion frequency converter
Propulsion transformers (when applicable)
Propulsion control

| Available solutions | Benefits |
| --- | --- |
| **CRP propulsion system**<br>The propellers are designed together to guarantee performance at the highest level. The main shaft may be direct mechanical or electrical direct drive depending on the operational profile. | ▶ **Effect on energy efficiency**<br>Gains from the CRP effect and additional operational modes with less running cylinders on the line. |
| + | |
| **Power plant**<br>Optimize your power plant to match the needs defined by the profile. Define when to run with the main shaft – and when only with Azipod. | ▶ **Effect on energy efficiency**<br>Design an efficient configuration to support operation only with Azipod. |
| + | |
| **EMMA energy controlling system**<br>Specify and design the energy production and consumption in a manner which allows the monitoring and management of energy production and the use of all energy forms. | ▶ **Effect on energy efficiency**<br>Savings produced by energy management are possible and unnecessary consumption is avoided. |
| = | |

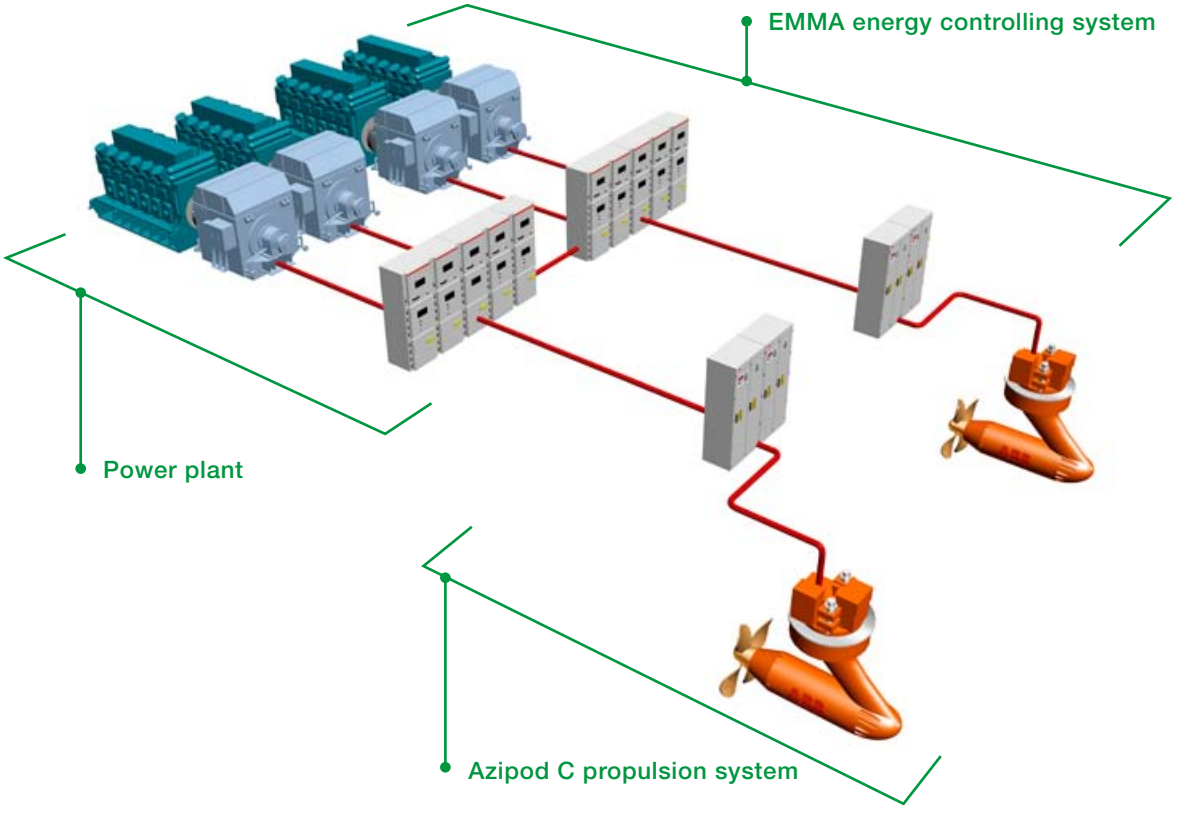
## Combined advantages

Energy consumption reductions provided by the CRP vessel are the main design parameter to select this propulsion system in the first hand. The total level of burnt fuel is lower and reductions in consumption can be supported by the total energy efficiency design and the selected equipment.

# 5.1 Ferry
## 5.1.4 Azipod C – system delivery

**CRUISING** **VARIABLE**

❹ ABB Azipod C propulsion system is widely used in varius solutions. Because of its high performance capability, high comfort class rating and small amount of components inside the hull, it is the perfect solution for passenger vessels with a propeller power up to 4.5 MW.




### ❹ Azipod C

SIZE 1 – 4,5 MW / UNIT

**CRUISING** **VARIABLE**

**Shaftline propulsion system comprises of:**
Azipod C propulsor and steering unit
Propulsion frequency converter
Propulsion transformers (when applicable)
Propulsion control

| Available solutions | Benefits |
| --- | --- |
| **Azipod C propulsion system**<br>The Azipod C propulsion system allows the propeller to be located optimally according to the hull lines. Simple transformerless power chain combined with hydrodynamical benefits provide high class performance with comfort. | ▶ **Effect on energy efficiency**<br>Gains from the pulling propeller and excellent partial load performance of the permanent magnet synchronous motor. |
| + | |
| **Power plant**<br>Optimize your power plant configuration to be efficient at all operational points of the propulsion power. | ▶ **Effect on energy efficiency**<br>The main engine load is always in the optimal area. |
| + | |
| **EMMA energy controlling system**<br>Specify and design the energy production and consumption in a manner which allows the monitoring and management of energy production and the use of all energy forms. | ▶ **Effect on energy efficiency**<br>Savings produced by energy management are possible and unnecessary consumption is avoided. |
| = | |
| **Combined advantages**<br>The propulsion system may be driven as the main consumer of the power plant, loading the main engines optimally and controlling the consumption and propulsion simultaneously to reach the destination with minimum fuel consumption. | |

# 5.1 Ferry
## 5.1.5 Direct Drive propulsion system – system components

**CRUISING** **VARIABLE**

Direct Drive is a new concept in which the best shaftline solutions are used for maximum reliability and performance.

## ABB portfolio for the low voltage system:

For smaller vessels and for the onboard processes, ABB offers the smartest drive with internal redundancy and propulsion motors with efficiency options.

**From top to bottom: LV main generator, main switchboard MNS, propulsion drive ACS800 and propulsion motor. Ready-made Direct Drive solutions are available at the motor shaft heights from 560 mm to 1000 mm.**

**DESIGNER TIP:**

Use ready-made ABB Direct Drive designs (see chapters 13–15)

## ABB portfolio for the medium voltage system:

For larger cruise vessels ABB offers the best and most reliable products in the market.

**From top to bottom; MV main generator, main switchboard Unigear, transformer, propulsion drive ACS6000 and propulsion motor. Ready-made Direct Drive solutions are available at the motor shaft heights from 1120 mm to 2000 mm.**

**DESIGNER TIP:**

Use ready-made ABB Direct Drive designs (see chapters 13–15)

# 5.1 Ferry
## 5.1.6 Azipod CRP – system components

**HIGHWAY**

The propellers are designed for the project as a pair.

**Below ABB basic components for power production: the medium voltage marine generator and marine main switchboard ABB SACE Unigear.**

## ABB scope in the CRP deliveries includes the propulsion system and the power plant.



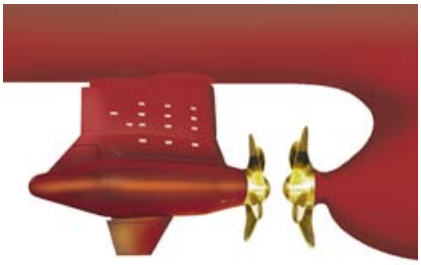
In cases where direct mechanical propulsion is selected for the main shaft, the main propeller has in recent deliveries been a Controllable Pitch Propeller (CPP) and the Azipod CRP propeller has been a Fixed Pitch Propeller (FPP), as is always the case with Azipod. ABB has been involved in the design processes of both propellers.

The delivery uses the medium voltage level, which means that the propulsion frequency converter is a voltage source inverter ACS6000, which is designed for high-efficiency synchronous motors. The performance of the synchronous motor in partial loads has led us to this motor technology selection.

Between the network and the propulsion drive ABB can select from three different transformer technologies. The selection is made according to the dimension requirements and installed power.

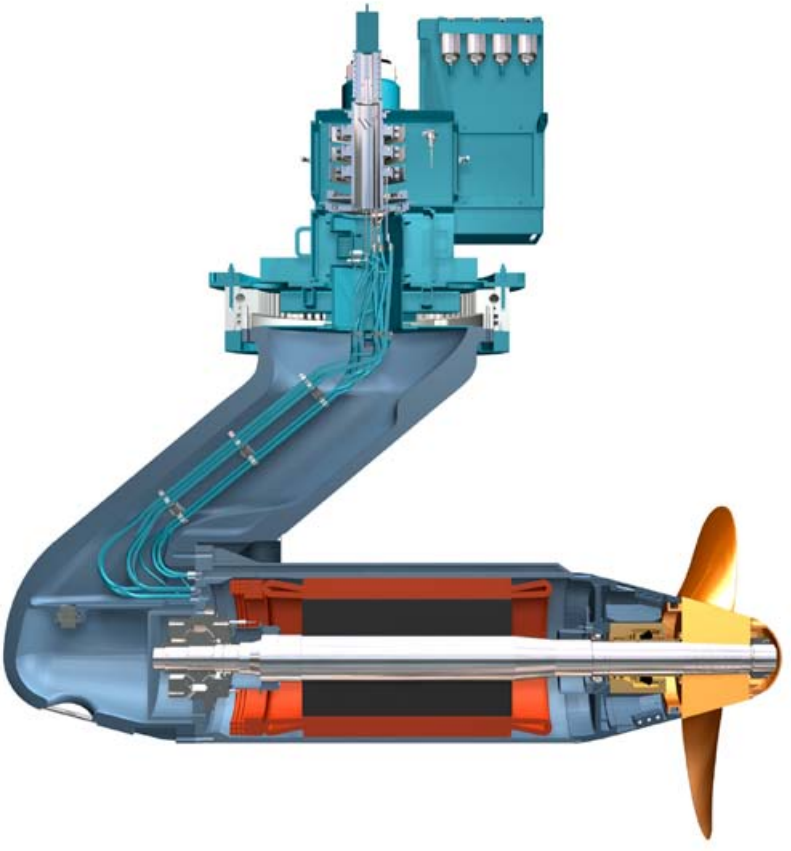
The power generated by the medium voltage generators is distributed via an ABB main switchboard, which can be designed with low short circuit current ratings (design towards the lower values is a safety issue which reduces forces in case of a short circuit). The main reasons for this design are the high and constant power factor of a modern frequency converter as well as the low disturbances in the network voltage, which allows design without oversizing the generators.

**Below propulsion chain components: transformer, drive and Azipod CRP.**



# 5.1 Ferry
## 5.1.7 Azipod C – system components

**VARIABLE** **CRUISING**



The insides of Azipod® C are very simple. The shaft with a small amount of components is located in the motor module, which is attached to the strut. The strut is bolt-connected to the steering module, which is ready-made and tested.

**Below ABB basic components for power production: the low voltage marine generator and marine main switchboard ABB MNS.**

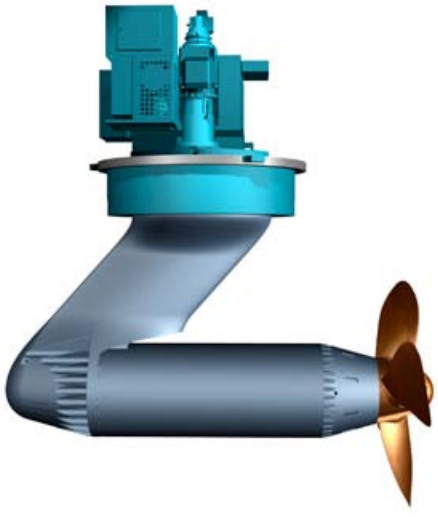
## ABB Azipod® C propulsion system is always targeted to be a transformerless design.

With the Azipod C propulsion, the delivery normally uses the low voltage level of 690 VAC. This means that the propulsion frequency converter is a voltage source inverter, ABB ACS800, designed for high-efficiency permanent magnet synchronous motors.

ABB ACS800 propulsion drive offers additional internal redundancy by supplying the motor with parallel modules. This brings operational availability in addition to the redundancy concept and often leads to system simplifications.

The power generated by the low voltage generators is distributed via an ABB main switchboard, which can be designed with low short circuit current ratings (design towards the lower values is a safety issue which reduces forces in case of a short circuit). The main reasons for this design are the high and constant power factor of a modern frequency converter as well as the low disturbances in the network voltage, which allows design without oversizing the generators.

**Below propulsion chain components: the revolutionary ACS800 drive and Azipod C propulsion unit with direct cooling into the sea and is utilizing the permanent magnet motor, with highest performance.**

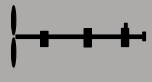


# 5.1 Ferry

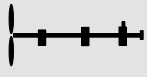
## 5.1.8 Summary of power savings potential, twin propeller solutions

Mechanical

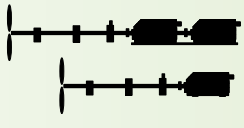
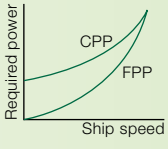
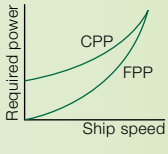
**Reference level**
**of a diesel-mechanical basic solution**



The reference level for the summary is based on the traditional mechanical propulsion with an independent auxiliary power plant for the electricity production.

| | | | | | |
|---|---|---|---|---|---|
| **BASIC**<br>**Diesel-mechanical shaftline**<br>  | Father/son installation or hybrid installation<br>**-2...10%** | Shaft generator systems<br>**3...5%** | Auxiliary power plant design by ABB<br>**0...2%** | Controllable aux processes<br>**2...10%** | |

Electric Propulsion

| | | | | | |
|---|---|---|---|---|---|
| **CRUISING**<br>**VARIABLE**<br>**Direct Drive**<br>  | Hull design<br>**0...2%** | Fixed pitch propeller<br>  <br>**0...15%** | Partial load efficiency improvement<br>**-2...10%** | Permanent magnet motor efficiency<br>**0...6%** | |
| **HIGHWAY**<br>**Azipod® CRP**<br> | CRP effect with hull effect<br>**8...15%** | | New operational mode possibilities<br>**0...3%** | Partial load efficiency improvement (DE main shaft)<br>**-2...10%** | |
| **CRUISING**<br>**VARIABLE**<br>**Azipod® C**<br> | Hull design and propeller location<br>**8...10%** | Propulsor efficiency (pulling propeller)<br>**1...2%** | Fixed pitch propeller<br>  <br>**0...15%** | Partial load efficiency improvement<br>**-2...10%** | |

**We have divided the operational profiles of ferries into four simplified categories**

**CRUISING**

Cruising ferry operational profile. Vessels that typically call at the same ports, have theme cruises and seasonal itineraries. Typically this vessel type does not have a car deck or it is in a minor role.

**HIGHWAY**

Sea highway operational profile. Vessels that follow a route which competes with parallel land/air transportation or because of some other reason is required to operate at high speed.

**VARIABLE**

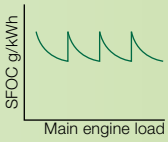
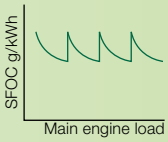
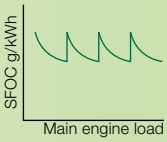
Ferry with variable speed steps in its operational profile. Vessels that follow a route which has several speed areas.

**BASIC**

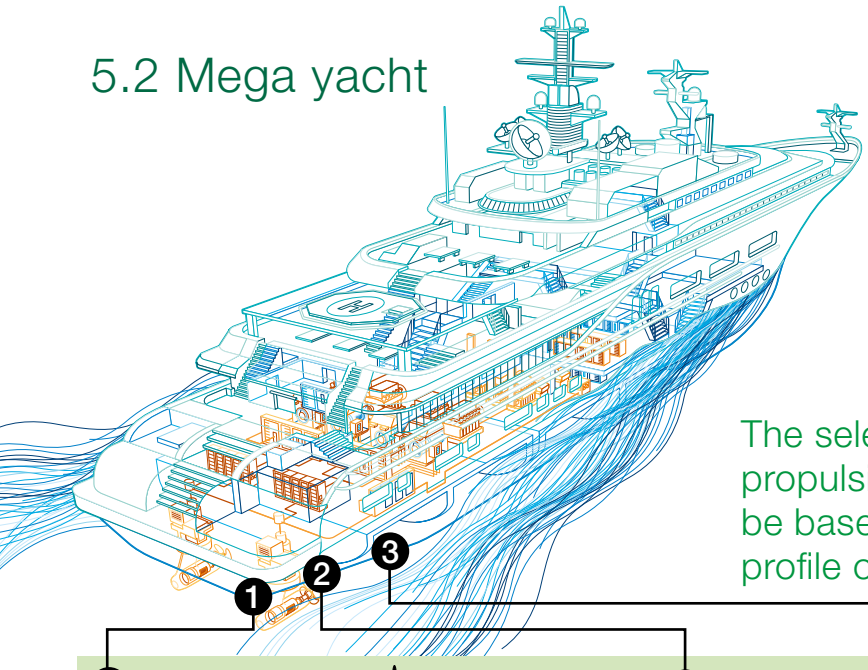
Standard ferry. For example a commuter ferry that calls at ports without the need to adjust speed in normal conditions during the voyage.



**Each operational profile has a recommended solution. These solutions are presented below with their respective benefits**

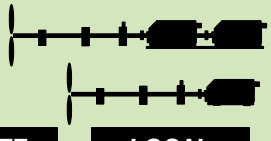
| | | | | |
|---|---|---|---|---|
| ABB EMMA system Energy Monitoring and Management<br>**2…5%** | Shore connection comsumption control<br>**0…2%** | | | TOTAL ENERGY SAVING POTENTIAL<br>**-2…10%** |
| Power plant principle benefits<br>  <br>**0…2%** | ABB EMMA system Energy Monitoring and Management<br>**3…8%** | Shore connection comsumption control<br>**0…2%** | | TOTAL ENERGY SAVING POTENTIAL<br>**0…20%** |
| Power plant principle benefits<br>  <br>**0…2%** | ABB EMMA system Energy Monitoring and Management<br>**3…8%** | Shore connection comsumption control<br>**0…2%** | | TOTAL ENERGY SAVING POTENTIAL<br>**6…22%** |
| Permanent magnet motor efficiency<br>**0…6%** | Power plant principle benefits<br>  <br>**0…2%** | ABB EMMA system Energy Monitoring and Management<br>**3…8%** | Shore connection comsumption control<br>**0…2%** | TOTAL ENERGY SAVING POTENTIAL<br>**8…25%** |

# 5.2 Mega yacht




The selection of the propulsion system should be based on the operational profile of the vessel.

## 1 Direct Drive



Suitable profiles:

**CRUISING** **PRIVATE CHARTER** **LOCAL CHARTER**

Energy rating: ★ ★ ★ ★

**Pros:**

+ Ready-made configuration: easy to specify, easy to build accordingly
+ Reliable technology
+ Propeller design with FPP or CPP and options based on efficiency
+ Less installed power needed. The main engine sea margin does not consume energy
+ Flexible spatial arrangement of propulsion components. Lower shaft heigh solutions are available
+ Transformerless low voltage 690 V system design available for 2–4 propulsion motors, 1–18 MW total propulsion power
+ Open to all energy sources and form of energy storage

**Cons:**

- Hydrodynamical benefits created by the pulling propeller are not available
- A separate steering system is needed

## 2 Azipod C

Suitable profiles:

**CRUISING** **PRIVATE CHARTER**

Energy rating: ★ ★ ★ ★ ★

**Pros:**

+ Easy to build and install, which creates savings for the yard
+ High comfort class possible
+ The optimal positioning of the propeller and the hydrodynamical benefits created by the pulling FPP create energy savings potential of approx. 10%
+ Highest efficiency due to PM motor in partial loads creates energy savings potential of approx. 4%–6%
+ Less installed power needed
+ Cools to surrounding water
+ Flexible spatial arrangement of the propulsion components, low upper structures create more space for cargo and passengers, wide car deck possible
+ Transformerless low voltage 690 V system design available for 2–4 propulsors, up to 18 MW total propulsion power. For Azipod XO, see cruise ship
+ Open to all energy sources and forms of energy storage

**Cons:**

- Vessel speed limited to of 21 kn

**We have divided the operational profiles of mega yachts into three simplified categories**

**CRUISING** The operational profile of cruising yachts is completely unpredictable in the long term. The onboard crew may be aware of certain events and dates in the vessel's itinerary, but otherwise the owner defines its use.

**PRIVATE CHARTER** Yachts that are partly chartered fill the gaps in the use by the owner by chartering the yachts to other customers. This operational profile is not far from the cruising profile, but has an element of fast transfers and periods with local chartering and very repetitive routing.

**LOCAL CHARTER** Visits local attractions and therefore may occasionally be close to basic ferry operational profile. Interest in different attractions typically varies during the year.



## 3 Azipod

Suitable profiles:

**CRUISING** **PRIVATE CHARTER**

Energy rating: ★ ★ ★ ★ ★

**Pros:**

+ Comfort through low vibration level
+ Low noise levels
+ Safety through excellent vessel performance in adverse weather and sea conditions
+ Excellent fuel economy
+ Environmentally friendly
+ Automated systems ensure the optimized operation and efficiency of all components

**Cons:**

- Needs close cooperation with the shipyard to reach its full potential
- Needs more time for designing and planning
- Solution is at its best on larger mega yachts

**YARD TIP:**

**Outboard shaftline**

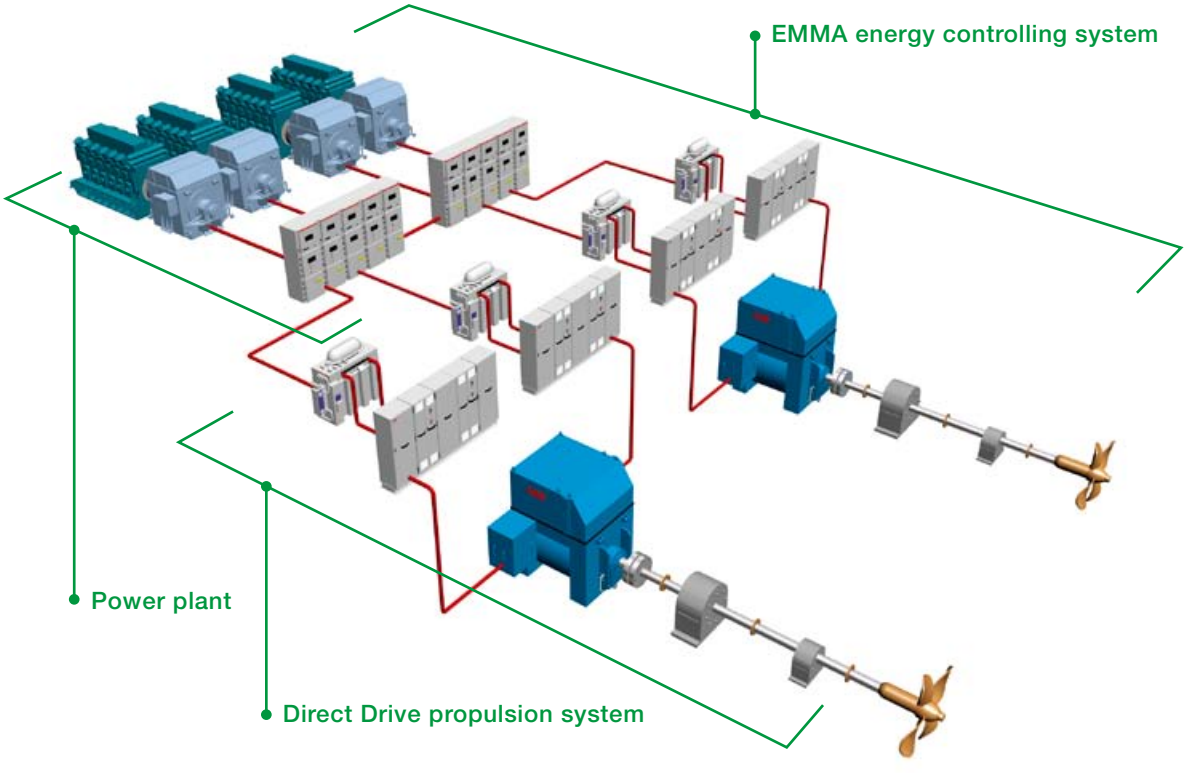
For vessels with a shallow draft, vessels with engine rooms that are already full or for retrofit projects, the motor module of the Azipod C may be considered as an option for the propulsion. The module is then connected so that it is outside the hull – from the thrust bearing end of the unit – and a pushing propeller is designed for the installation. This option is not covered in this book and is concidered a special delivery option which requires focused cooperation with the yard.

# 5.2 Mega yacht

## 5.2.1 Direct Drive propulsion system – system delivery

**CRUISING** **PRIVATE CHARTER** **LOCAL CHARTER**

❶ Direct Drive is the optimal solution for conventional propulsion. A wide selection range, proven products and simple design satisfy the needs of even the most demanding customers. Redundancy levels provide an extensive selection for operational and passenger safety.

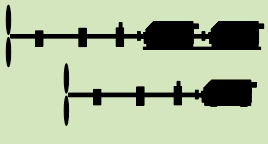



### ❶ Direct Drive

SIZE 0,5 – 20 MW / UNIT

**CRUISING** **PRIVATE CHARTER** **LOCAL CHARTER**

**Shaftline propulsion system comprises of:**
Propulsion motor
Propulsion frequency converter
Propulsion control
Propulsion transformer (if applicable)



| Available solutions | Benefits |
| --- | --- |
| **Direct Drive propulsion system**<br>Sort according to performance, efficiency footprint, weight or redundancy – whichever you value the most – and find your solution. The combination of a propulsion motor, frequency converter and control system will guarantee a succesful voyage. | ▶ **Effect on energy efficiency**<br>Minimize the consumption by selecting the maximum performance. |
| + | |
| **Power plant**<br>Optimize your power plant according to the consumers. Set the number of generators. | ▶ **Effect on energy efficiency**<br>Boosts your efficiency with different main engine ratings. |
| + | |
| **EMMA energy controlling system**<br>Specify and design the energy production and consumption so that they can be easily monitored and managed. | ▶ **Effect on energy efficiency**<br>Savings produced by energy management are possible and unnecessary consumption is avoided. |
| = | |

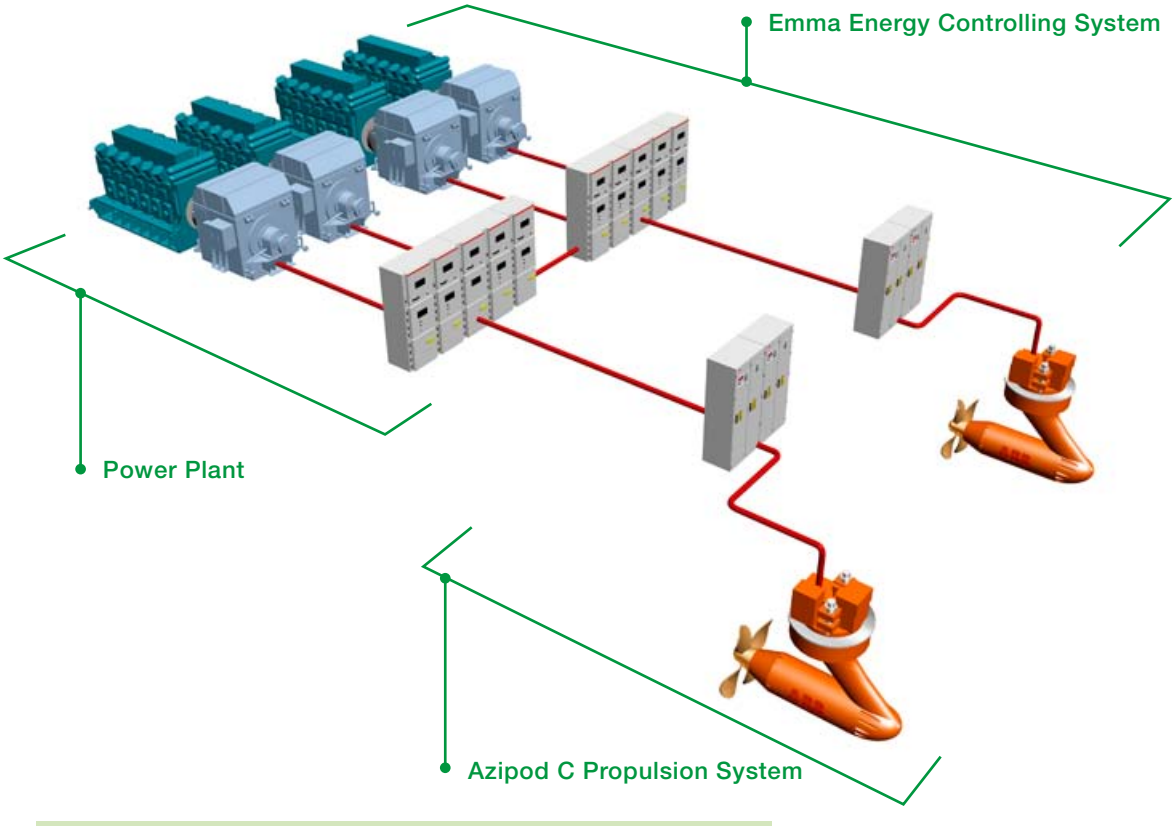
## Combined advantages

Energy design and efficient total design, including the selected equipment, have a major impact on the operational costs. Often the most efficient solution also lowers the investment costs. The results of the energy efficiency design are in use immediatelly, not after a period of wasted energy.

# 5.2 Mega yacht
## 5.2.2 Azipod C – system delivery

**CRUISING** **PRIVATE CHARTER**

❷ ABB Azipod C propulsion system is widely used in varius solutions. Because of its high performance capability, high comfort class rating and small amount of components inside the hull, it is the perfect solution for passenger vessels with a propeller power of up to 4.5 MW.




### ❷ Azipod C

SIZE 1–4.5 MW / UNIT

**CRUISING** **PRIVATE CHARTER**

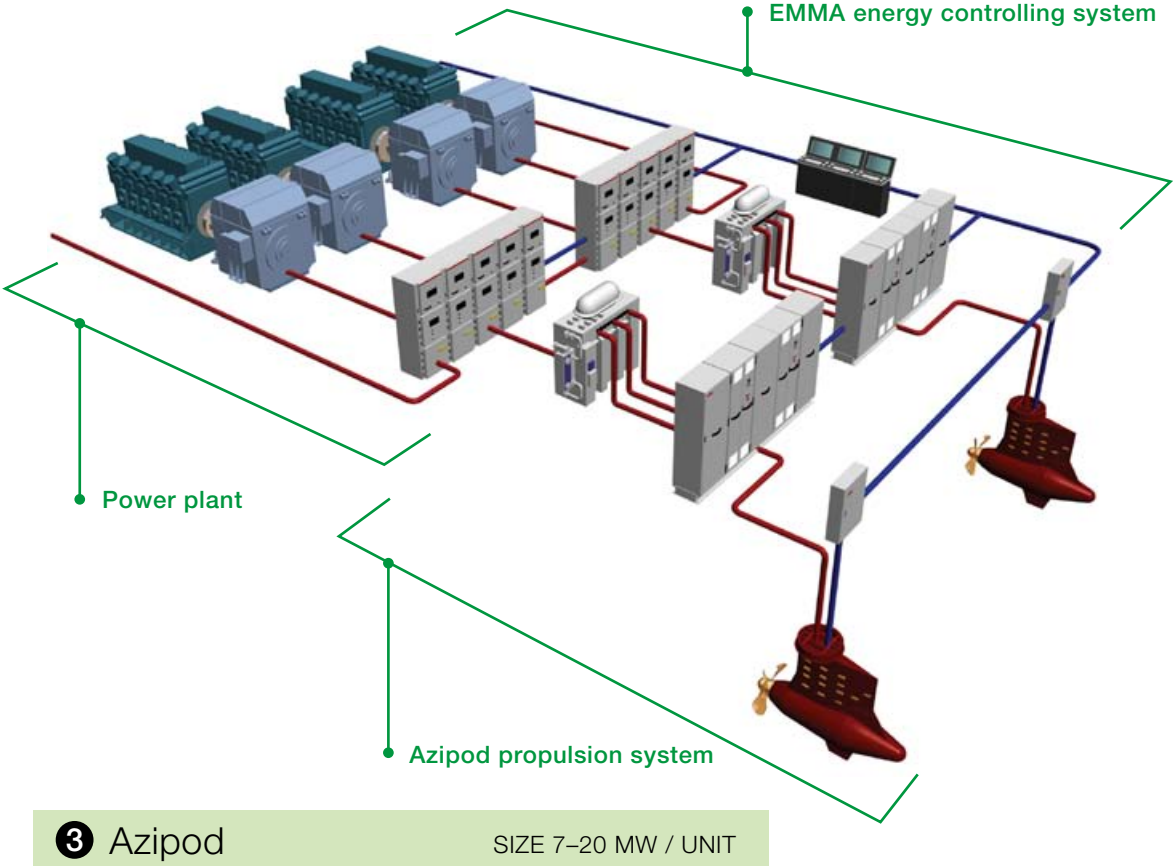
**Azipod C propulsion system comprises of:**
Azipod C propulsor and steering unit
Propulsion frequency converter
Propulsion transformer (if applicable)
Propulsion control

| Available solutions | Benefits |
| --- | --- |
| **Azipod C propulsion system**<br>The Azipod C propulsion system allows the propeller to be optimally located according to the hull lines. Simple transformerless power chain combined with hydrodynamical benefits provide high class performance with comfort. | ▶ **Effect on energy efficiency**<br>Gains from the pulling propeller and excellent partial load performance of the permanent magnet synchronous motor. |
| + | |
| **Power plant**<br>Optimize your power plant configuration to be efficient at all operational points of the propulsion power. | ▶ **Effect on energy efficiency**<br>The main engine load is always in the optimal area. |
| + | |
| **EMMA energy controlling system**<br>Specify and design the energy consumption in a manner which allows the monitoring and management of the energy production and the use of all energy forms. | ▶ **Effect on energy efficiency**<br>Savings produced by energy management are possible and unnecessary consumption is avoided. |
| = | |
| **Combined advantages**<br>The propulsion system may be driven as the main consumer of the power plant, loading the main engines optimally and controlling the consumption and propulsion simultaneously to reach the destination with minimum fuel consumption. | |

# 5.2 Mega yacht
## 5.2.3 Azipod – system delivery

**CRUISING** **PRIVATE CHARTER**

❸ ABB Azipod propulsion system is widely used in various passenger ships. Because of its high performance capability, high comfort class rating and small amount of components inside the hull, it is a perfect solution for passenger vessels on the power level of 10–20 MW per unit.




### ❸ Azipod

SIZE 7–20 MW / UNIT

**CRUISING** **PRIVATE CHARTER**

**Azipod propulsion system comprises of:**
Azipod propulsor and steering unit + aux. equipment
Propulsion frequency converter
Propulsion transformer (if applicable)
Propulsion control

**Available solutions** | **Benefits**

## Azipod propulsion system

The Azipod propulsion system allows the propeller to be optimally located according to the hull lines. Efficient performance throughout the power range combined with hydrodynamical benefits provide high class performance with comfort.

### ▶Effect on energy efficiency

Gains from the pulling propeller and excellent partial load performance of the permanent magnet synchronous motor.

+

## Power plant

Optimize your power plant configuration to be efficient at all operational points of the propulsion power.

### ▶Effect on energy efficiency

The main engine load is always in the optimal area.

+

## EMMA energy controlling system

Specify and design the energy consumption in a manner which allows the monitoring and management of the energy production and the use of all energy forms.

### ▶Effect on energy efficiency

Savings produced by energy management are possible and unnecessary consumption is avoided.

=

## Combined advantages

The propulsion system may be driven as the main consumer of the power plant, loading the main engines optimally and controlling the consumption and propulsion simultaneously to reach the destination with minimum fuel consumption.

# 5.2 Mega yacht

## 5.2.4 Direct Drive propulsion system – system components

**CRUISING** **PRIVATE CHARTER** **LOCAL CHARTER**

Direct Drive is a new concept in which the best shaft line solutions are used for maximum reliability and performance.

## ABB portfolio for the low voltage system:

For smaller vessels and for the onboard processes, ABB offers the smartest drive with internal redundancy and propulsion motors with efficiency options.

**From top to bottom: LV main generator, main switchboard MNS, propulsion drive ACS800 and propulsion motor. Ready-made Direct Drive solutions are available at the motor shaft heights from 560 mm to 1000 mm.**

**DESIGNER TIP:**

Use ready-made ABB Direct Drive designs (see chapters 13–15)

## ABB portfolio for the medium voltage system:

For large cruise vessels ABB offers the best and most reliable products in the market.

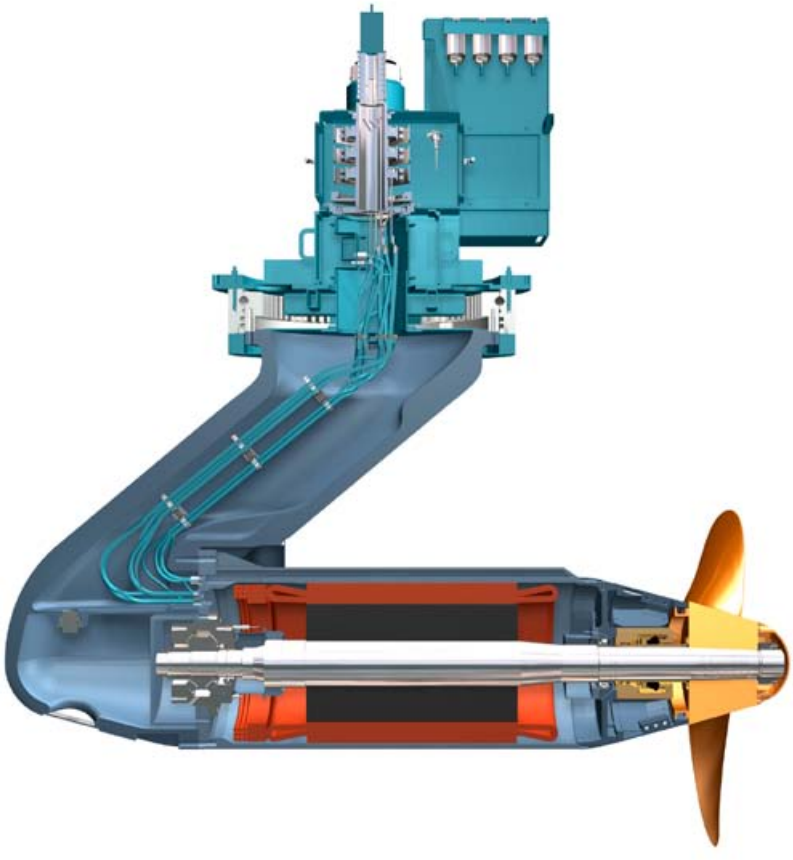
**From top to bottom: MV main generator, main switchboard Unigear, transformer, propulsion drive ACS6000 and propulsion motor. Ready-made Direct Drive solutions are available at the motor shaft heights from 1120 mm to 2000 mm.**

**DESIGNER TIP:**

Use ready-made ABB Direct Drive designs (see chapters 13–15)

# 5.2 Mega yacht
## 5.2.5 Azipod C – system components

**CRUISING** **PRIVATE CHARTER**



The insides of Azipod® C are very simple. The shaft with a small amount of components is located in the motor module, which is attached to the strut. The strut is bolt-connected to the steering module, which is ready-made and tested.

**Below ABB basic components for power production: low voltage marine generator and marine main switchboard ABB MNS.**

## ABB Azipod® C propulsion system is always targeted to be a transformerless design.

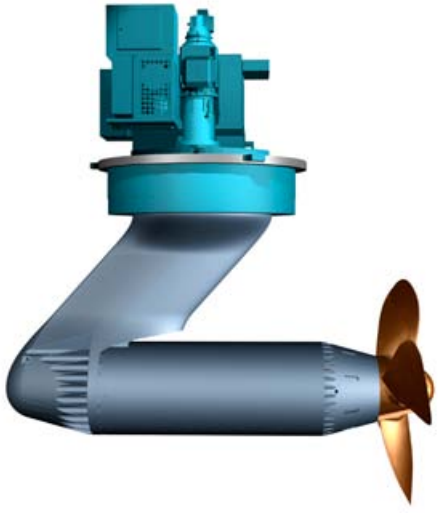


With the Azipod C propulsion, the delivery normally uses the low voltage level of 690 VAC. This means that the propulsion frequency converter is a voltage source inverter, ABB ACS800, designed for high-efficiency permanent magnet synchronous motors.

ABB ACS800 propulsion drive offers additional internal redundancy by supplying the motor with parallel modules. This brings operational availability in addition to the redundancy concept and often leads to system simplifications.

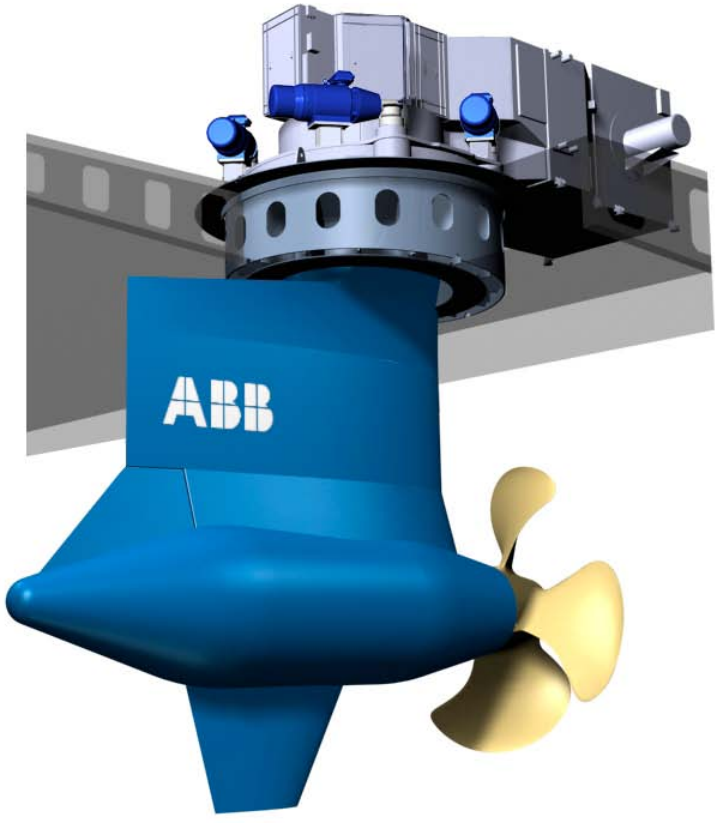
The power generated by low voltage generators is distributed via an ABB main switchboard, which can be designed with low short circuit current ratings (design towards the lower values is a safety issue which reduces forces in case of a short circuit). The main reasons for this design are the high and constant power factor of a modern frequency converter as well as the low disturbances in the network voltage, which allows design without oversizing the generators.

**Below propulsion chain components: the revolutionary ACS800 drive and Azipod C propulsion unit with direct cooling into the sea.**



# 5.2 Mega yacht
## 5.2.6 Azipod – system components

**CRUISING** **PRIVATE CHARTER**




The Azipod® delivery is very simple. Instead of the alignment work involved in long shaftlines, the Azipod® unit is modular and combined from pre-tested units.

**Below ABB basic components for power production: medium voltage marine generator and marine main switchboard ABB Unigear.**

## ABB Azipod® propulsion system is targeted to maximum passenger comfort in large mega yachts – and it does its job efficiently.

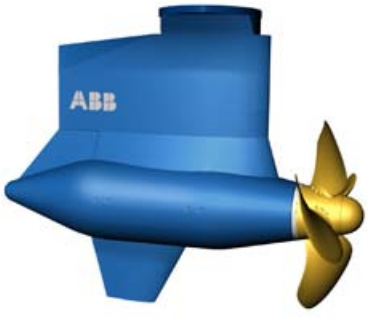


With the Azipod propulsion, the delivery normally uses the medium voltage level in the network. This means that the propulsion frequency converter is a voltage source inverter, ABB ACS6000, designed for high-efficiency synchronous motors.

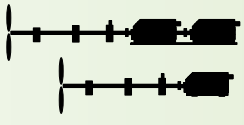
ABB ACS6000 propulsion drive offers additional design benefits which make the overall system design very favourable for energy efficiency optimization as well. This can bring down the operational costs while at the same time providing the highest level of comfort onboard.

The power generated by the medium voltage generators is distributed via an ABB main switchboard, which can be designed with low short circuit current ratings (design towards the lower values is a safety issue which reduces forces in case of a short circuit). The main reasons for this design are the high and constant power factor of a modern frequency converter as well as the low disturbances in the network voltage, which allows design without oversizing the generators.

**Below propulsion chain components: propulsion transformer, modern ACS6000 drive and Azipod propulsion unit.**



# 5.2 Mega yacht
## 5.2.7 Selection summary

| | Profile recommendation | Comfort [1] | Space flexibility |
|---|---|---|---|
| Direct Drive  | CRUISING<br>PRIVATE CHARTER<br>LOCAL CHARTER | 80…90% | 70…80% |
| Azipod C | CRUISING<br>PRIVATE CHARTER | 90…100% | 90…100% |
| Azipod® | CRUISING<br>PRIVATE CHARTER | 90…100% | 90…100% |

[1] Less vibration and noise inside. More accurate manoeuvrability and easier harbor access. The best comfort and luxury money can buy. State-of-the-art.

**We have divided the operational profiles of mega yachts into three simplified categories**

**CRUISING**

The operational profile of cruising yachts is completely unpredictable in the long term. The onboard crew may be aware of certain events and dates in the vessel's itinerary, but otherwise the owner defines its use.

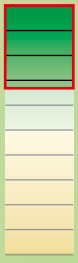
**PRIVATE CHARTER**

Yachts that are partly chartered fill the gaps in the use by the owner by chartering the yachts to other customers. This operational profile is not far from the cruising profile, but has an element of fast transfers and periods with local chartering and very repetitive routing.

**LOCAL CHARTER**

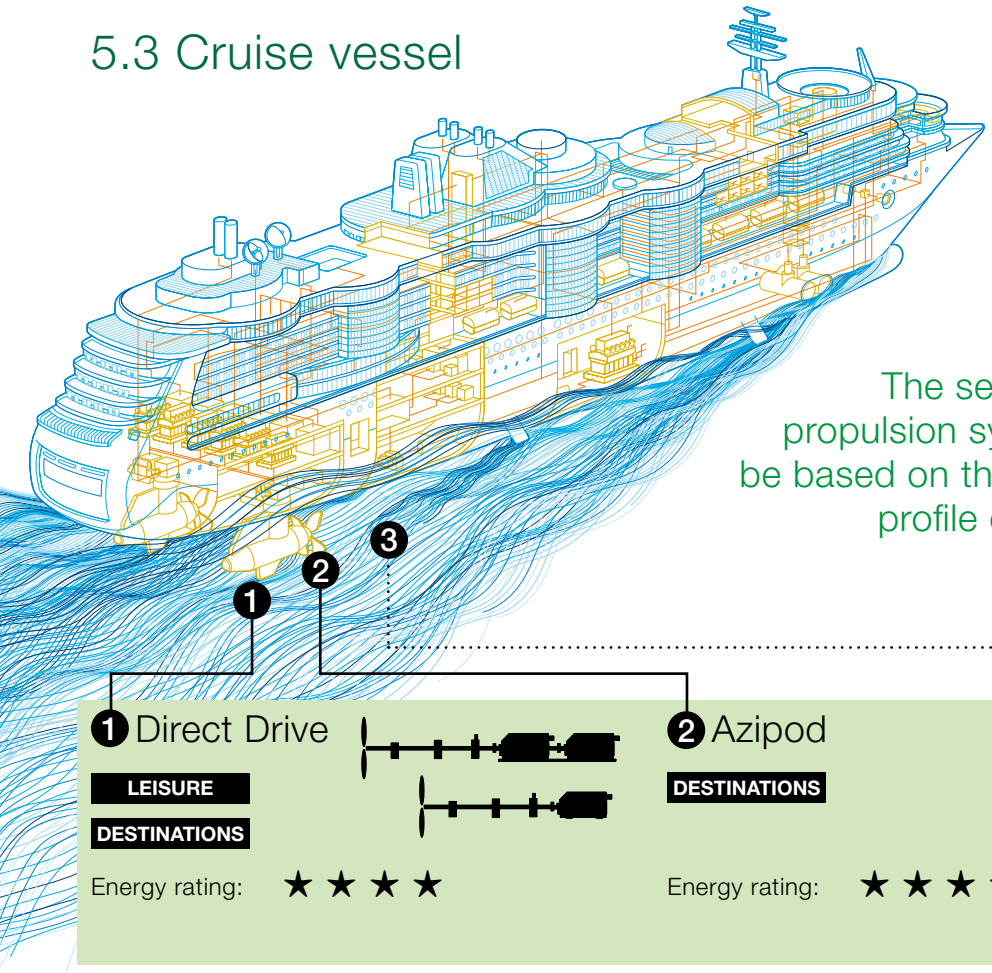
Visits local attractions and therefore may occasionally be close to ferry-like operational profile. Interest in different attractions typically varies during the year.



| Service support | Station keeping | Freedom to select construction dock [2] | Energy saving potential | Compatibility |
|---|---|---|---|---|
| Local = 50 %<br>Global = 50 % | | | See cruise vessels | |
| 100% | 70...80% | 100% | 0...20% | ★★★ |
| 100% | 100% | 100% | 8...25%  | ★★★★★ |
| 100% | 100% | 80% | 8...25% | ★★★★★ |

[2] Requires lifting capacity

# 5.3 Cruise vessel




The selection of the propulsion system should be based on the operational profile of the vessel.

## 1 Direct Drive



**LEISURE**

**DESTINATIONS**

Energy rating: ★ ★ ★ ★

**Pros:**

+ Ready-made configuration: easy to specify, easy to build accordingly
+ Reliable technology
+ Propeller design with FPP or CPP and options based on efficiency
+ Less installed power needed. The main engine sea margin does not consume energy.
+ Flexible spatial arrangement of the propulsion components. Lower shaft heigh solutions are available.
+ Transformerless low voltage 690 V system design available for 2–4 propulsion motors, 1–18 MW total propulsion power.
+ Open to all energy sources and forms of energy storage

**Cons:**

- Hydrodymanical benefits created by the pulling propeller are not available
- A separate steering system is needed

## 2 Azipod

**DESTINATIONS**

Energy rating: ★ ★ ★ ★ ★

**Pros:**

+ Comfort through low vibration level
+ Low noise levels
+ Safety through excellent vessel performance in adverse weather and sea conditions
+ Excellent fuel economy
+ Environmentally friendly
+ Automated systems ensure the optimized operation and efficiency of all components

**Cons:**

- Needs close cooperation with the shipyard to reach its full potential

**We have divided the operational profiles of cruise vessels into two simplified categories**

**LEISURE**

Cruise vessel operational profile with more focus on passenger comfort than on the covered distance and destinations. The vessels sail more in the low speed range than at high speeds. Onboard activities have a key role.

**DESTINATIONS**

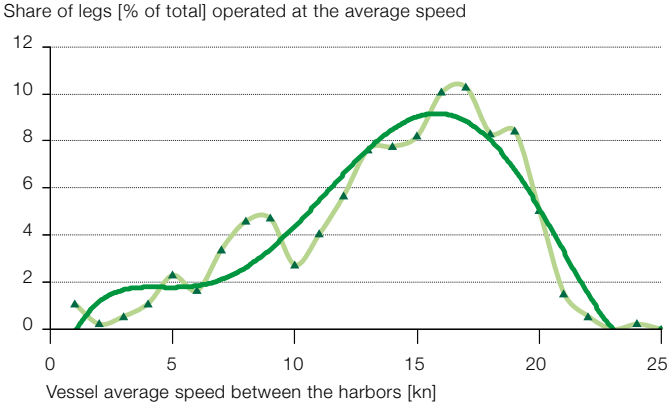
It is more important to see new places and locations. Onshore activities have a key role.



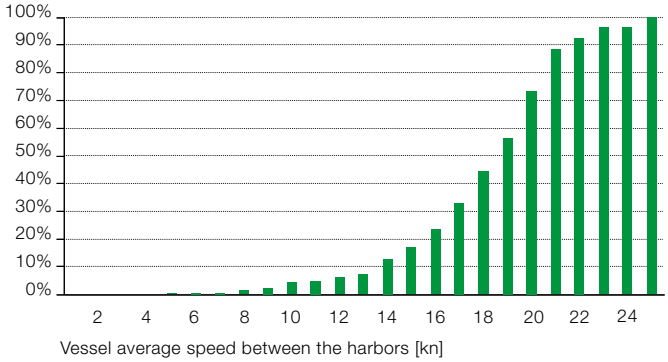
## 3 Azipod C

### YARD TIP:

In some projects when the vessel speed is below 21 kn, it may be reasonable to consider a fully low voltage solution with three Azipod C units. This solution is suitable for high comfort classes when the total propulsion power is within the product range. See the mega yacht section for details.




**Cruise vessels operate according to the itinerary requirements, which are based on the season and area of operation. To determine a standard and comparable itinerary, cruises in the season 2009–2010 were analyzed. Based on approximatelly 1,000 legs from 150 cruises, ABB Marine established a cruise ship standard.**



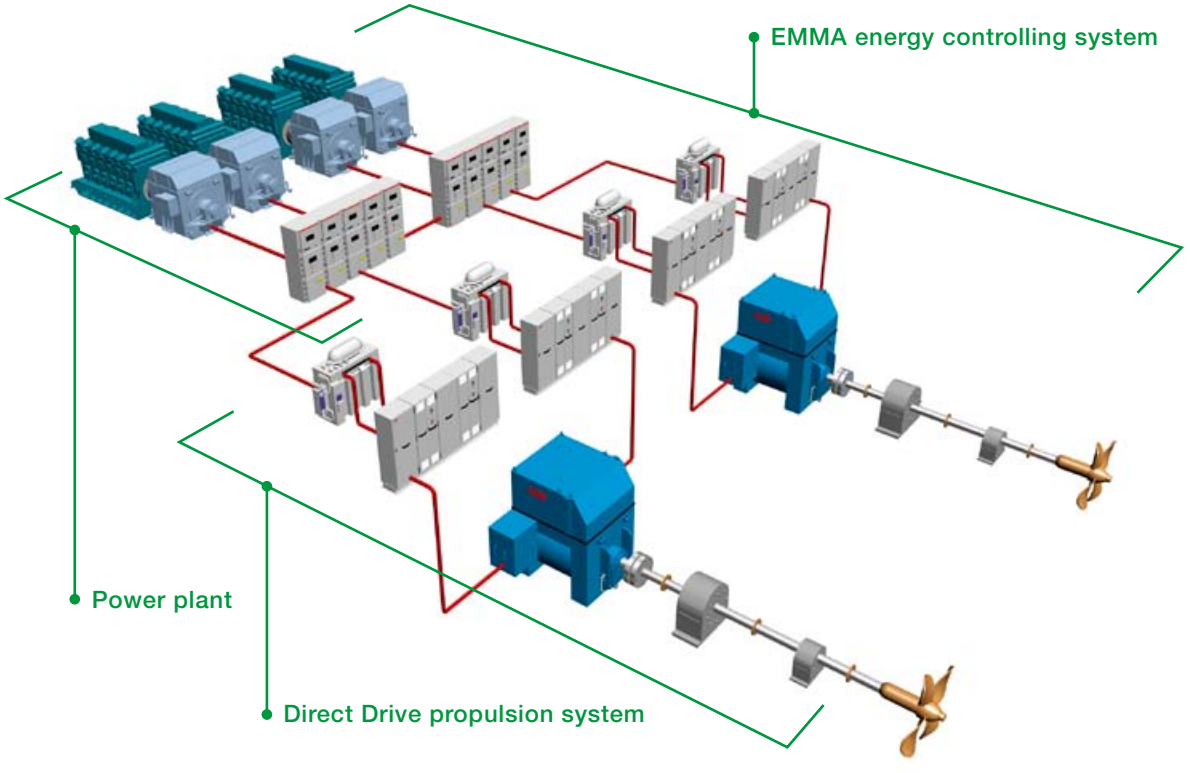

**Share of cumulative energy consumption (% of the total consumption) of the 'Cruise vessel standard'. Calculations made for shaftline vessels in the customer project evaluation phase.**

# 5.3 Cruise vessel

## 5.3.1 Direct Drive – system delivery

**LEISURE** **DESTINATIONS**

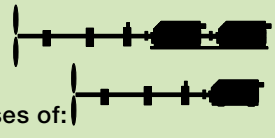
❶ Direct Drive is the optimal solution for conventional propulsion. A wide selection range, proven products and simple design satisfy the needs of even the most demanding customers. Redundancy levels provide an extensive selection for operational and passenger safety.




### ❶ Direct Drive

SIZE 0,5 – 20 MW / UNIT

**LEISURE** **DESTINATIONS**



**Shaftline propulsion system comprises of:**

Propulsion motor
Propulsion frequency converter
Propulsion control
Propulsion transformer (if applicable)

| Available solutions | Benefits |
| --- | --- |
| **Direct Drive propulsion system**<br>Sort according to performance, efficiency footprint, weight or redundancy – whichever you value the most – and find your solution. The combination of a propulsion motor, frequency converter and control system will guarantee a succesful voyage. | ▶ **Effect on energy efficiency**<br>Minimize the consumption by selecting the maximum performance. |
| + | |
| **Power plant**<br>Optimize your power plant according to the consumers. Set the number of generators. | ▶ **Effect on energy efficiency**<br>Boosts your efficiency with different main engine ratings. |
| + | |
| **EMMA energy controlling system**<br>Specify and design the energy production and consumption so that they can be easily monitored and managed. | ▶ **Effect on energy efficiency**<br>Savings produced by energy management are possible and unnecessary consumption is avoided. |
| = | |

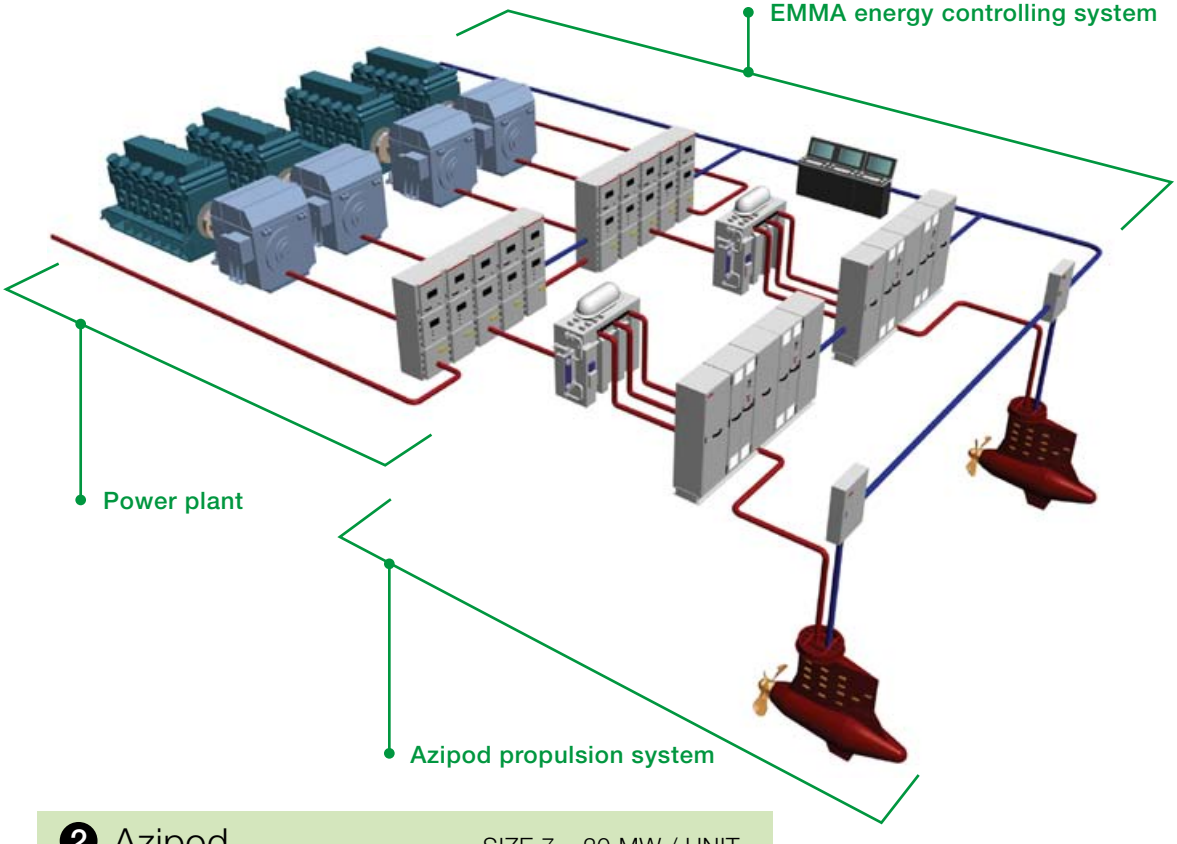
## Combined advantages

Energy design and efficient total design, including the selected equipment, have a major impact on the operational costs. Often the most efficient solution also lowers the investment costs. The results of the energy efficiency design are in use immediatelly, not after a period of wasted energy.

# 5.3 Cruise vessel
## 5.3.2 Azipod – system delivery

**DESTINATIONS**

❷ ABB Azipod propulsion system is widely used in varius passenger ships. Because of its high performance capability, high comfort class rating and small amount of components inside the hull, it is a perfect solution for passenger vessels on the power level of 10–20 MW per unit.




### ❷ Azipod

SIZE 7 – 20 MW / UNIT

**DESTINATIONS**

**Azipod propulsion system comprises of:**
Azipod propulsor and steering unit + aux. equipment
Propulsion frequency converter
Propulsion transformer (if applicable)
Propulsion control

| Available solutions | Benefits |
| --- | --- |
| **Azipod propulsion system**<br>The Azipod propulsion system allows the propeller to be located optimally according to the hull lines. Efficient performance throughout the power range combined with hydrodynamical benefits provide high class performance with comfort. | ▶ **Effect on energy efficiency**<br>Gains from the pulling propeller and excellent partial load performance of the permanent magnet synchronous motor. |
| + | |
| **Power plant**<br>Optimize your power plant configuration to be efficient at all operational points of the propulsion power. | ▶ **Effect on energy efficiency**<br>The main engine load is always in the optimal area. |
| + | |
| **EMMA energy controlling system**<br>Specify and design the energy consumption in a manner which allows the monitoring and management of the energy production and the use of all energy forms. | ▶ **Effect on energy efficiency**<br>Savings produced by energy management are possible and unnecessary consumption is avoided. |
| = | |
| **Combined advantages of total**<br>The propulsion system may be driven as the main consumer of the power plant, loading the main engines optimally and controlling the consumption and propulsion simultaneously to reach the destination with minimum fuel consumption. | |

# 5.3 Cruise vessel
## 5.3.3 Direct Drive – system components

**LEISURE** **DESTINATIONS**

Direct Drive is a new concept in which the best shaftline solutions are used for maximum reliability and performance.

## ABB portfolio for the low voltage system:

For smaller vessel and for the onboard processes, ABB offers the smartest drive with internal redundancy and propulsion motors with efficiency options.

**From top to bottom: LV main generator, main switchboard MNS, propulsion drive ACS800 and propulsion motor. Ready-made Direct Drive solutions are available at the motor shaft heights from 560 mm to 1000 mm.**

**DESIGNER TIP:**

Use ready-made ABB Direct Drive designs (see chapters 13–15)

## ABB portfolio for the medium voltage system:

For large cruise vessels ABB offers the best and most reliable products in the market.

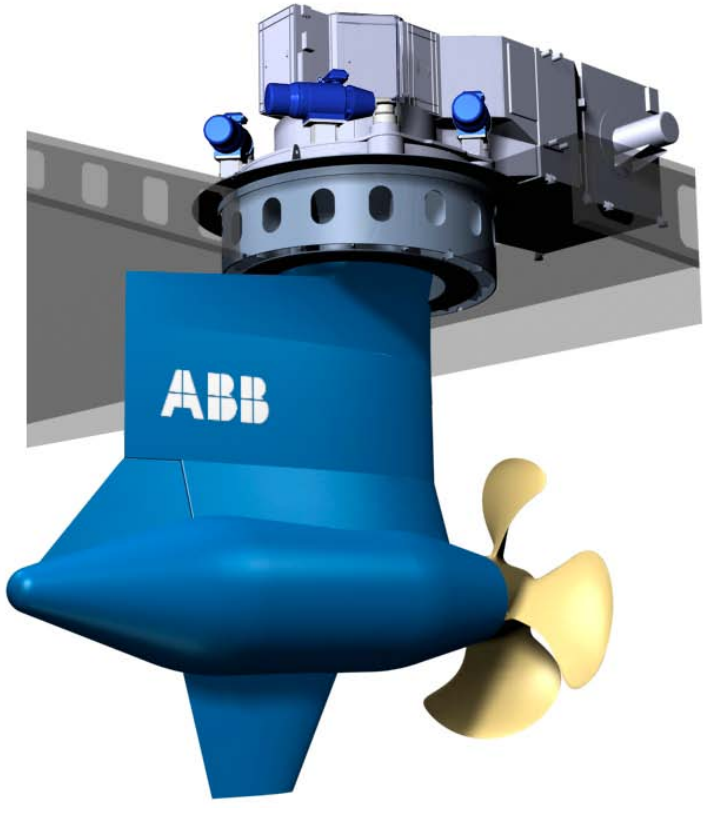
**From top to bottom: MV main generator, main switchboard Unigear, transformer, propulsion drive ACS6000 and propulsion motor. Ready-made Direct Drive solutions are available at the motor shaft heights from 1120 mm to 2000 mm.**

**DESIGNER TIP:**

Use ready-made ABB Direct Drive designs (see chapters 13–15)

# 5.3 Cruise vessel
## 5.3.4 Azipod – system components

**DESTINATIONS**




The Azipod® delivery is very simple. Instead of the alignment work involved long shaftlines, the Azipod® unit is modular and combined from pre-tested units.

**Below ABB basic components for power production: medium voltage marine generator and marine main switchboard ABB Unigear.**

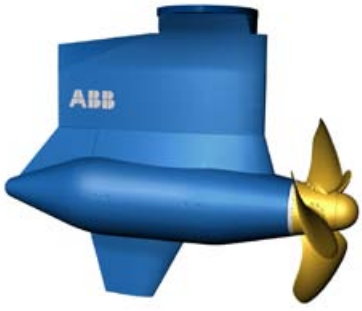
## ABB Azipod® propulsion system is the proven and ever-improving cruise vessel standard that is the best solution when the vessel size, passenger comfort and manoeuvrability requirements are important.

With the Azipod propulsion, the delivery normally uses the medium voltage level in the network. This means that the propulsion frequency converter is a voltage source inverter, ABB ACS6000, designed for high-efficiency synchronous motors.

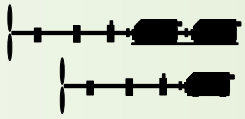
ABB ACS6000 propulsion drive offers additional design benefits which make the overall system design very favourable for energy efficiency optimization as well. This can bring down the operational costs while at the same time providing the highest level of comfort onboard.

The power generated by the medium voltage generators is distributed via an ABB main switchboard, which can be designed with low short circuit current ratings (design towards the lower values is a safety issue which reduces forces in case of a short circuit). The main reasons for this design are the high and constant power factor of a modern frequency converter as well as the low disturbances in the network voltage, which allows design without oversizing the generators.

**Below propulsion chain components: propulsion transformer, modern ACS6000 drive and Azipod propulsion unit.**



# 5.3 Cruise vessel
## 5.3.5 Summary of power savings potential

| | Propeller selection | Hull design (current preferences) | Power plant | Harbor access ability |
|---|---|---|---|---|
| Direct Drive  LEISURE | CPP -15…0%<br>FPP 0% | 0…3% | -5…3% | -1…0% |
| Azipod® LEISURE DESTINATIONS | FPP 0% | 8…10% | -5…3% | 0…1% |
| | Azipod has always FPP | Electric propulsion gives new possibilities for hull design which in turn enables power savings. | The selected power plant has a significant effect on energy consumption | Poor harbor access ability increases harbor time and in some cases the time must be won back with a higher cruise speed. |

**We have divided the operational profiles of cruise vessels into two simplified categories**

**LEISURE**

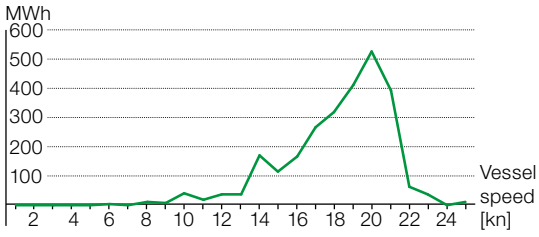
Cruise vessel operational profile with more focus on passenger comfort than on the covered distance and destinations. The vessels sail more in the low speed range than at high speeds. Onboard activities have a key role.

**DESTINATIONS**

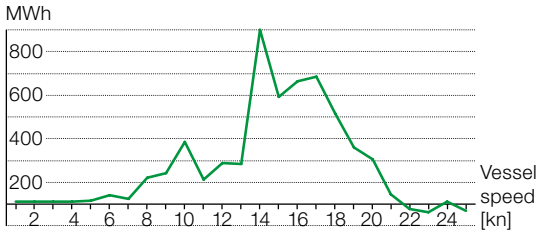
It is more important to see new places and locations. Onshore activities have a key role.

| Propulsion drive (ref. 98%) | Propulsion motor (ref. 97%) | ABB EMMA | Shore connection | TOTAL ENERGY SAVING POTENTIAL |
|---|---|---|---|---|
| -1…1% | -1…1% | 3…8% | 0…1% | **-5…12%** |
| 0…1% | -1…1% | 3…8% | 0…1% | **5…20%** |

**Savings within the 10,000 running hours when the voltage source inverter is selected instead of the traditional LCI-type (cruise ship standard as presented on page 65).**




**Savings within the 10,000 running hours when a synchronous motor is selected instead of an asynchronous motor. (cruise ship standard as presented on page 65).**



# 5.4 ABB propulsion solutions
## 5.4.1 Redundancy

When selecting the propulsion system for passenger vessels, the minimum required level of redundancy is clearly described in all classification rules. The rules give the propulsion redundancies a class mark, which describes the agreed level of redundancy.

The things that are not described in the classification rules easily become a ground for competition for the yards and manufacturers who seek for the solution with the lowest cost that fills the class requirements. One item which is typically not covered in these rules is the equipment-internal redundancy.

When it comes to the redundancy of the power plant, marine installations rarely provide redundancy in other aspects than in the number of generators and engine rooms. From the point of view of ship design, this is understandable; the ship is a vibrating and moving environment, and the installation of double bus bar switchboards or double breakers is more problematic than in land-based industries. However, multiple internal redundancy options are often available in the propulsion system configuration:

**1. Propulsion transformers**

a. Redundancy is achieved by having several transformers that supply the propulsion drive. Transformer-internal redundancy is not available in the market and redundancy is easier to achieve by having two parallel transformers.

**NOTE:** The purpose of two secondary windings in the transformer is to limit the number of harmonic disturbances in the network, not to increase redundancy.

**2. Propulsion drive**

a. In low voltage systems, one motor is supplied by one frequency converter. In the frequency converters, ACS800 drives, there can be a maximum of 11 three-phase modules in parallel both in the network side and in the motor side. This brings additional redundancy to the possibility to continue after removal of the defective module.
b. In medium voltage systems, one motor can be supplied by one or two frequency converters. Each frequency converter (input 3 kV–2 x 1.75 kV) can have one or two units in the network side. In each motor output, one or two individual, or two or three parallel units are available.

**3. Propulsion motors**

a. The induction motor, also known as the asynchronous motor, is a motor with a single winding system. The redundancy in the induction motor may be increased by connecting two motors in tandem or by connecting two motors in parallel in the gearbox (in this case the gearbox does not have redundancy).
b. The permanent magnet synchronous motor, as in the Azipod CO or Direct Drive permanent magnet, is a motor with a single winding system. The redundancy of an onboard motor may be increased by connecting two motors in tandem or by connecting two motors in parallel in the gearbox (in this case the gearbox does not have redundancy). The redundancy for Azipod C can be achieved by increasing the number of units.
c. Synchronous motors can be wound into the YY0 configuration, which places two winding systems under the same control and into the

same physical slots in the motor structure. When wound into the YY30 configuration, the motor is also a two winding system motor, in which the galvanic separation between winding systems provides additional redundancy against an electrical failure in the winding. In both synchronous motor configurations, YY0 and YY30, the excitation machine is a single common component. Both solutions are available for shaftlines and for Azipod XO.

Increasing the redundancy improves the availability of the propulsion system, but decreases the time between failures, due to the increased number of components that can get broken. Furthermore, the maintenance costs of operation increase. It is good to note that the larger number of auxiliary devices typically increases the losses in the system and therefore reduces the overall efficiency.

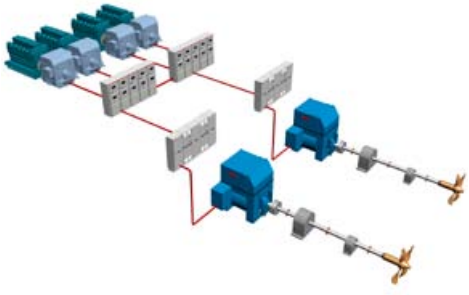


| | | Single engine / Single winding | | Two geared engines / Double windings | | Tandem motors | |
|---|---|---|---|---|---|---|---|
| | | Low voltage solutions | Medium voltage solutions | Low voltage solutions | Medium voltage solutions | Low voltage solutions | Medium voltage solutions |
| Ferry | Mechanical | 1 | 1 | 2 | 2 | | |
| | Direct Drive | 1 | 1 | | 1 | 2 | |
| | Azipod CRP | | 1 | | 1 | | |
| | Azipod C | 1 | | | | | |
| Cruise vessel | Direct Drive | 1 | 1 | | 1 | 2 | |
| | Azipod V/X | 1 | 1 | | 1 | | |
| MegaYacht | Mechanical | 1 | 1 | 2 | 2 | | |
| | Direct Drive | 1 | 1 | | 1 | 2 | |
| | Azipod V/X | | 1 | | 1 | | |
| | Azipod C | 1 | | | | | |

1 2 **Number of engines/motors per propeller**

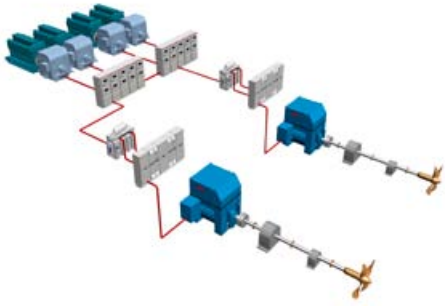
# 5.4 ABB propulsion solutions
## 5.4.2 Redundancy options

### Type 1 Single Drive and Single Drive (AFE)



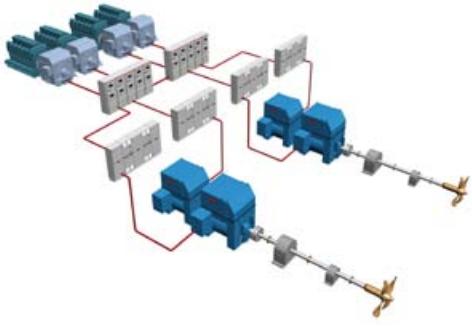
Single Drive comprises one frequency converter and one motor

### Type 2 Single Drive (with Transformer)



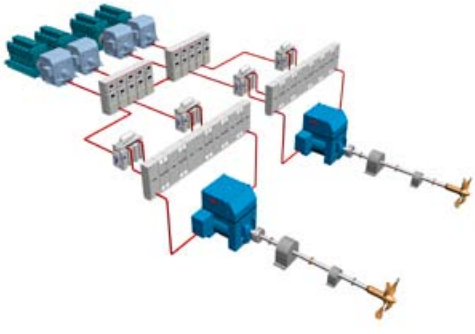
Single Drive (with Transformer) comprises one transformer, one frequency converter and one motor

### Type 3 Tandem Drive



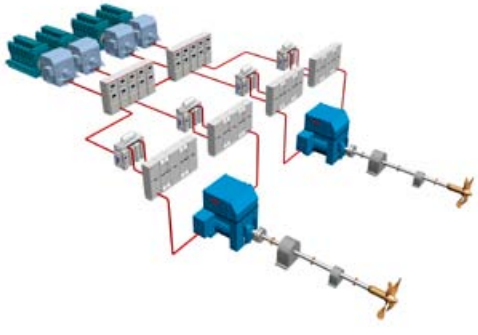
Tandem Drive comprises two frequency converters and two motors in tandem configuration

### Type 4 Single Drive (twin in/out)



Single Drive (twin in/out) comprises two tranformers, one frequency converter and one motor with two stator systems

### Type 5 Full Redundant Drive



Full Redundant Drive comprises two transformers, two frequency converters and one motor with two stator systems

**DESIGNER TIP:**

These principles (except Tandem Drive) apply to Azipod propulsion too.

The redundancy selection for a propulsion system (presented here with the Direct Drive family) offers redundancy options that allow the customer to select the desired level of reliability. The customer decides between the best availability (type 1), redundancy (type 3), maximum reliability (type 5) or something in between.

**Redundancy**

Ships are designed for different types of operation and voyages. When the level of redundancy is increased, the number of components that can get broken becomes larger, but the total availability of the system increases. When balancing between different levels of redundancy, one must remember that in a twin-screw vessel, the other screw will always remain operational according to the single failure principle. **Types 3, 4 and 5** provide adequate redundancy also for vessels operating with a single shaftline. In a case of a failure, half-drive operation is possible and automatic with **types 3 and 5**. In **type 4,** half-drive operation needs the intervention of an operator. Half-drive operation is not possible with **types 1 and 2**.

There are three types of faults that can lead to the loss of half of the drive; supply failure, converter failure or winding failure. In **types 1 and 2** these faults lead to the loss of the whole drive. Redundancy is a cure for electrical problems, but if a propeller damage or shaftline bearing problems occur, then it is likely that the whole shaftline must be taken out of operation.

Redundancy also means balancing between spatial needs and the payload. Sometimes passenger comfort is the defining design criterion, sometimes the spatial need for payload wins.

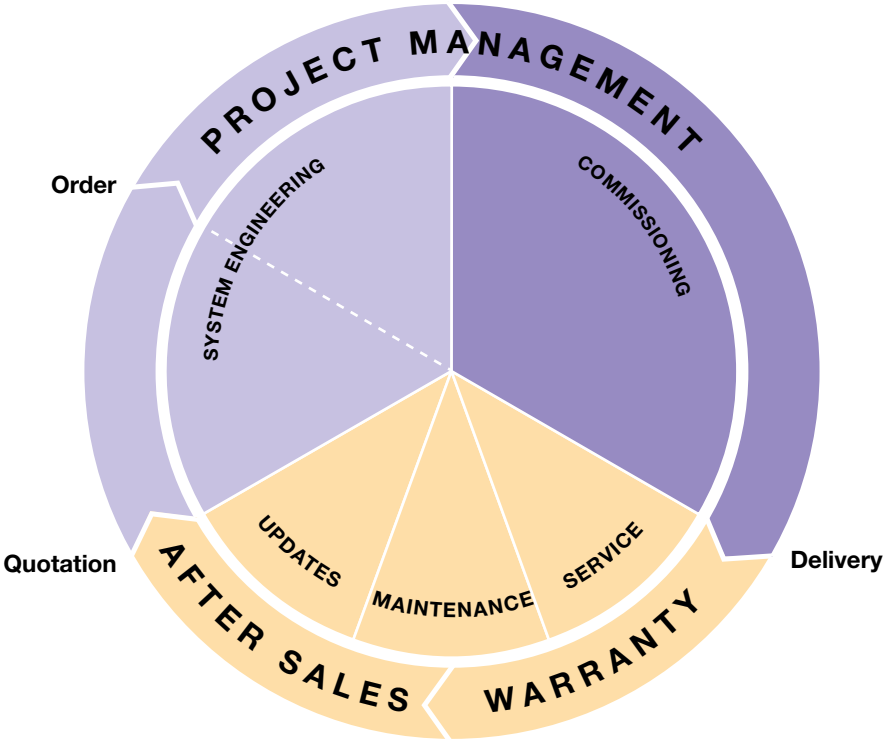
Again, redundancy means balancing between operational safety and investment costs. When the number of components gets larger, the complexity of the system increases along with the costs. In some cases, simple can be reliable and attractive cost-wise.

Increased redundancy is reflected all the way up to the navigating officers; the man in the watch will see the amount of available propulsion power, the engine rooms will house more primary and auxiliary systems and the shipyard needs to integrate more items to reach compatibility. But in case of an emergency, returning to port is effortless.

Due to the characteristics of different motors and frequency converters, there are certain power range limitations with different redundancy types.

# 6 ABB Project Management

## ABB Circle of Excellence in planning, delivery and operation

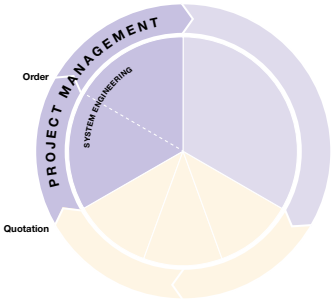



**Project management**

ABB Project Management ensures that you get exactly what you need. Our strength is in managing the big picture. We have the skills to execute the project with precision according to your needs and schedule. We can accurately estimate the scope of the project and provide a team of the right size and with the needed skills. Because of our extensive experience and know-how, we can devise a reliable timetable for your project, and foresee and avoid any potential risks in the delivery.

As a guarantee of our expertise, we can present you with a certified training program and an extensive and satisfied body of clients.

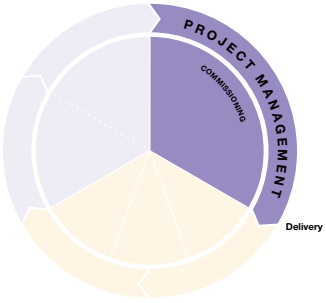
ABB Project Management ensures that your project proceeds swiftly and cost efficiently. This leaves you free to focus on tasks that are more central to your business.




### Quotation and System Engineering

In the Quotation stage the customer's needs and demands are translated into concrete solutions and devices. Furthermore, the costs of different options are charted.

In the System Engineering stage the solutions, devices and applications that have been chosen for your project are modified into one technically coherent solution. The different phases of the project implementation are agreed on, and the technical details of the power plant and the propulsion system are decided. Furthermore, our project team and the customer decide the extent to which standard module solutions and tailored project-specific solutions are used. In the System Engineering stage ABB Marine's extensive expertise translates into overall customer value and different parts of the project become more than the sum of its parts – a ship that meets the expectations of the customer.




### Commissioning

Because of ABB's standing and long experience it is easy for designers, shipyards and subcontractors to collaborate with ABB. We have plenty of experience in and knowledge of managing the subcontractor network, which enables us to divide and interlace the different project phases cost efficiently. Our on-site project management is in charge of organizing the work and making sure that the project proceeds as planned. This minimizes the risks that the shipyards and our customers may face. The whole process aims at ensuring that the agreed quality, performance level, and timetable targets are met.

### Warranty, Maintenance & After Sales

ABB remains active and responsible after the ship has been delivered. Every ship project is assigned a single source of contact, who acts as an active middleman between the ship owner, shipyard and ABB. During the actual use of the ship, our After Sales and Maintenance services ensure its undisturbed use. These services include spare parts, device and software updates, extensive modernization packages, and 24-hour support. Through our extensive network, we can offer these services on a local level throughout the globe.

# 7 ABB life cycle services

## Improving the productivity of processes and applications

The goal of ABB Services is clear and explicit: to keep all processes and equipment running in the most secure, energy efficient, and cost efficient way.

Some of the demands that ship owners and operators face at sea include:

- Increasing demands for higher reliability
- Increasing operational and capital costs associated with running a plant, process, system or installation
- Rising energy prices
- Pressures to improve productivity
- Stricter environmental and safety regulations

**ABB can help**

One of ABB's key objectives is to minimize the off-hire times of the ship by ensuring the reliable operation and optimum lifetime for all ABB products in a predictable, safe and cost efficient manner.

ABB Services cover the entire lifespan of a vessel, from the moment the customer makes the first inquiry to the disposal and recycling of the ship.

Among the benefits of using ABB Services are higher reliability, lower operational costs, improved productivity, reduced environmental impact and enhanced safety.

**Maximizing the return on investment**
At the heart of ABB's services is our drive life cycle management model. All services that are available for ABB low voltage drives are planned according to this model. For customers it is easy to see which services are available at which phase.

Drive-specific maintenance schedules are also based on this four-phase model. The customer knows the precise timing of the part replacements and all other maintenance-related action. The model also helps the customer when making decisions about upgrades, retrofits and replacements.

The professional management of the drive's life cycle maximizes the return on investment in ABB low voltage drives.



## ABB drive life cycle management model

| Active | Classic | Limited | Obsolete |
|---|---|---|---|
| The drive, with complete life cycle services, is available for purchase. | The drive, with complete life cycle services, is available for plant extensions. | Spare part, maintenance and repair services are available as long as materials can be obtained at a reasonable cost. | ABB cannot guarantee the availability of life cycle services for technical reasons or at a reasonable cost. |

**Complete life cycle services**
To ensure the availability of complete life cycle services, a drive must be in the Active or Classic phase. A drive can be kept in the Active or Classic phase by upgrading, retrofitting or replacing.

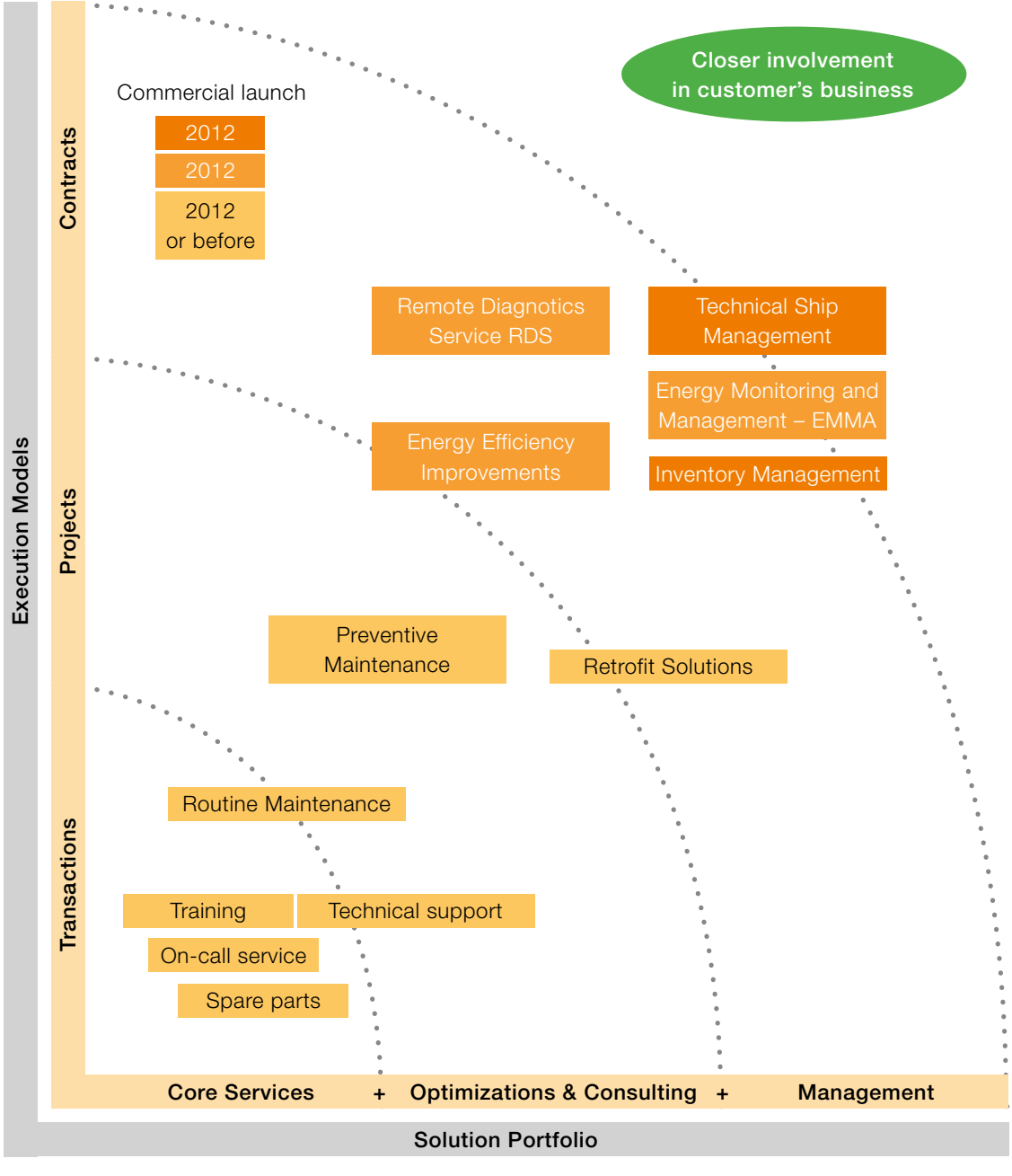
**Limited life cycle services**
Note that a drive entering the Limited or Obsolete phase has limited repair options. This may result in unpredictable process downtime. To avoid this, the drive should be kept in the Active or Classic phase.

**ABB follows a four-phase model for managing the life cycles of drives. The model has the benefits of enhanced customer support and improved efficiency.**

**Examples of life cycle services are: selecting and dimensioning the system, installation and commissioning, preventive and corrective maintenance, remote services, spare part services, training and learning, technical support, upgrading and retrofitting, replacement and recycling.**

## Marine Services Strategy

ABB is an efficient partner for ship owners and shipyards in optimizing their assets.



## The solutions portfolio for Marine Services Strategy is divided into three parts:

**Core Services**
Core Services include routine maintenance, technical support and personnel training. Solutions that aim at ensuring these are our on-call and spare parts services. ABB has spare part service stations in throughtout the world. The training centers for onboard personnel are located in Helsinki and Singapore.

**Optimization & Consulting**
Optimization & Consulting includes preventive maintenance and retrofit solutions, which are organized into projects. Energy efficiency improvements belong to this part in some cases.

**Management**
Tasks that are related to improvement and management are based on contracts between the customer and ABB. We familiarize ourselves with our customer's business and use our experience and database to find the most suitable solution for the customer. The solutions can include energy efficiency improvements, Energy Monitoring and Management systems (EMMA), Remote Diagnostics Service (RDS), technical ship management and inventory management.

# 8 ABB Marine Academy

## ABB Marine Academy is designed to provide you with the necessary technical understanding and working skills to guarantee the full functionality of your ABB installation. Competence is a key factor in smooth and safe sailing.

ABB Marine Academy develops and produces training designed for the ship's technical crew. In 2010 we led 150 different courses. There are two main locations which handle and coordinate the training for different types of ships together with a worldwide network of partners.

**Helsinki:** Cruise & Ferries, Ice-going ships
**Singapore:** Oil & Gas related ships, FPSO

**Training centre at Singapore**

## Take a new course!

**General**
The general courses introduce the ABB onboard system as a whole. The contents of the course are tailored according to the actual customer installation.

- ABB propulsion system courses

**Advanced**
The advanced courses deepen the customer's knowledge by focusing on one sub-system at a time. In addition to the advanced technical courses, we provide safety courses for marine high voltage systems and Azipod confined spaces. The objective in the safety courses is to provide the customer with the knowledge and skills to manage risks and to adopt safe working methods in high voltage environments and confined spaces. The contents of the safety courses are in accordance with generally accepted standards, rules and regulations.

- Azipod-courses
- Marine drive courses
- Drilling drive courses
- Safety courses
- Power distribution courses
- Electronic governor system courses
- Azipod-C courses
- Automation courses

**Onboard training**
Most of our standard training courses are designed to be delivered in ABB training centers. In onboard training the approach is cooperative and the emphasis is on learning together. The training is delivered by experts who are familiar with the actual ABB installation.

The training objectives for the onboard sessions are agreed on together with the ship's crew. To ensure that we deliver onboard training that meets our educational standards, we have introduced an internal training program. In the program a selected group of senior field engineers are trained in a wide range of pedagogical skills. This "train the trainers" program has been developed together with carefully selected global partners from the field of educational science. In onboard training we can use eMST® – electronic Maintenance Support Tool. eMST® is a novel concept that enables just-in-time access to high-quality e-learning material.

- eMST® – electronic Maintenance Support Tool

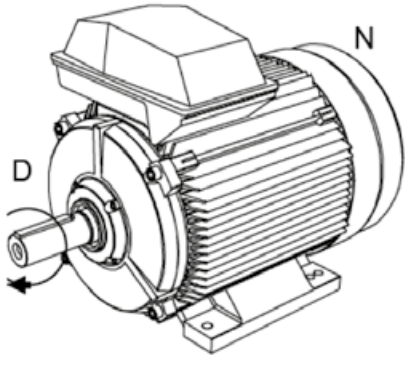
# 9 ABB products
# 9.1 Main generator information

ABB offers a full range of power plant electrical products, covering the low and medium voltage generators, low and medium voltage switchboards including switching and protection devices, as well as a wide range of electrical components utilized for all kinds of electrical distribution needs.

The selected generators and their design are the most important factors on the short circuit rating of other components and therefore they have a direct economical impact as well. The propulsion selection and the starting requirements of the largest electrical consumers dictate the generator design.

**Operating principle of rotating machines**
The ends of an electric machine are defined by the letters D (Drive end) and N (Non-drive end), as shown in the figure below. The shaft rotates either clockwise or counter-clockwise, as seen from the D end. This viewpoint may differ between the ship design engineers. Therefore the rotation direction must be verified in the design phase when connecting the generator to the rotating machine.

The internal winding in three-phase AC generators results in the following operation: When the shaft rotates clockwise, the connectors U, V and W produce network phases L1, L2 and L3. This operation principle is valid also when the structure of the generator allows it to rotate only counter-clockwise.



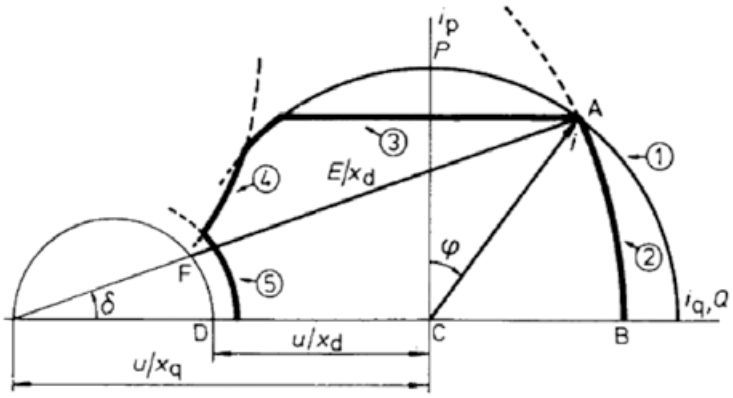

**SHIPYARD TIP.**

The rotating direction of the phases can be verified already at the first start of the diesel engine when the cabling work is safe enough for a remanence voltage checking. The fire protection insulation of the cable MCT frame can be left open before the main voltage is connected. Thus the rotation direction of the network can be tested when cabling corrections are still possible. The rotation direction must be verified by a qualified professional. It should be noted that the residual voltage of a medium voltage generator can be remarkably high, hundreds of volts.

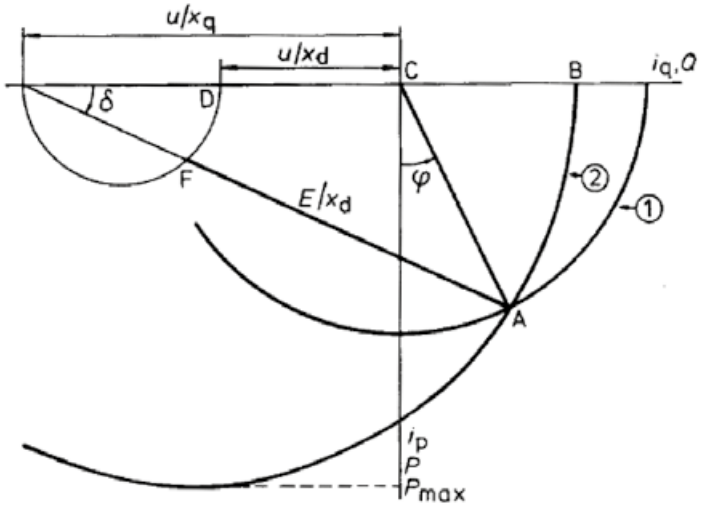
Synchronous machines rotate at synchronous speed ( f / p; f = frequency, p = number of pole pairs).

Synchronous machines are excited with direct current. The machine can function as either a generator or motor, depending on the direction of the external axial torque. Each motor torque/load curve value has a respective excitation current value. The terminal voltage of a stand-alone generator is adjusted by the excitation current. In parallel operation, the network often determines the terminal voltage of the synchronous machine and the excitation current controls the direction and amount of the machine's reactive power.

Vector diagram of synchronous machine (generator quadrants)




Vector diagram of synchronous machine (motor quadrants)




| | | | |
|---|---|---|---|
| A | nominal/rated operating point | 4 | static stability limit |
| B | no-load operation point with nominal excitation | 5 | minimum excitation current limit |
| C | no-load operation point with no-load excitation | u | stator voltage |
| D | no-load operation point without excitation | P | active power |
| CA | stator current (= i) | Q | reactive power |
| FA | nominal excitation current | I | stator current ($i_p$ = active current, $i_q$ = reactive current) |
| DC | no-load excitation current | E | no-load voltage with nominal excitation |
| 1 | nominal stator current, stator temperature rise limit | $x_d$ | direct axis synchronous reactance |
| 2 | nominal rotor current, rotor temperature rise limit | $x_q$ | quadrature axis synchronous reactance |
| 3 | prime mover limit (max power of prime mover) | δ | load angle (pole angle) |
| | | Φ | power angle (cos φ = power factor) |
| | | $P_{max}$ | maximum power with nominal excitation |

Powers, currents, voltages and reactances are per unit values.

The definitions in the previous vector diagram apply also for a synchronous motor.

The maximum torque of a synchronous machine depends on the dimensions of the machine, network voltage (U) and excitation (E).

$T\ max \approx k \cdot U \cdot E \approx (1.5...2.5)\ T\ N$ ,
k = constant
N = nominal torque

T max in the above equation represents the maximum steady state torque of the synchronous machine. In transient conditions, the torque can temporarily reach a 30–50% higher value.

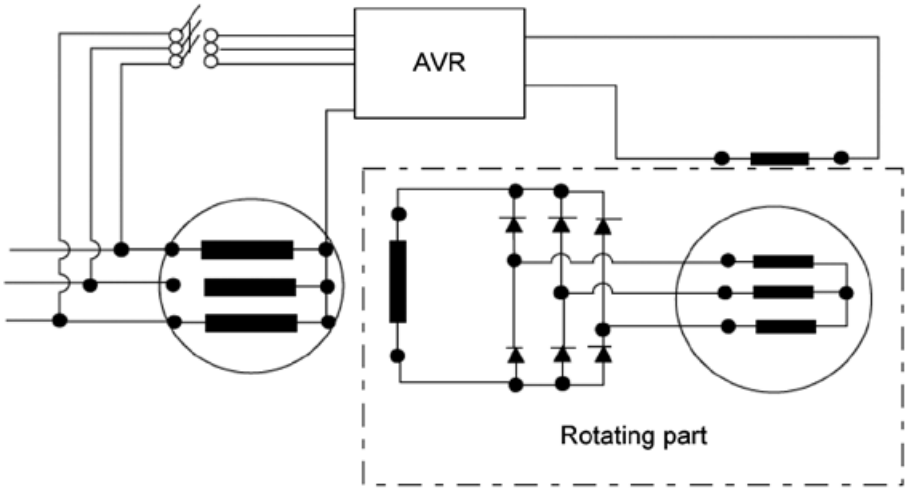
If the load of the machine increases too much, or if the torque of the machine is reduced because of reduced voltage or reduced excitation current, the machine will drop out of the synchronous speed/frequency.

The prime mover (a turbine or diesel engine, for example) accelerates the generator close to the synchronous speed (f / p). Then the generator is excited and synchronized to the network. In modern power plants the start-up is usually carried out automatically by a power management system.

Synchronous machines need direct current in the rotor for excitation. Direct current can be supplied to the rotor from an external excitation device via slip rings. However, this type of excitation distribution is rarely used in vessels today, because of the increased need of maintenance.

The excitation can also be brushless. There is a small AC generator in the rotor, which produces alternating current which is rectified by a diode bridge before feeding the current to the rotor winding. The poles in this auxiliary machine are fixed (in the stator), which allows it to be fed directly from outside and the required excitation power is low. Nowadays, the generators in marine applications are almost always brushless excited.

Principle drawing of brushless excited synchronous generator.




Generators are always equipped with an excitation controller, an automatic voltage regulator (AVR). The regulator keeps the generator voltage in the set value, according to the selected accuracy, regardless of the changes in load, temperature and frequency. In parallel run with other generators, the regulator regulates the reactive power depending on the network voltage or set values. Synchronous motors can also be equipped with a voltage regulator which keeps the motor's reactive power or power factor stable.

The currently used digital voltage regulator is usually selected from the ABB Unitrol 1000 product family, but classical analogical voltage regulators are installed frequently as well.

In the network configurations, which are operated with the bus tie open, no separate master governors are needed in digital solutions. This is due to the capability of modern technology to communicate via a data bus and keep the individual sections at the same voltage conditions. Load-dependant droop may be corrected on both of the sections allowing the same voltage level on both sides of the bus tie.

# 9.2 ABB generators – low voltage products

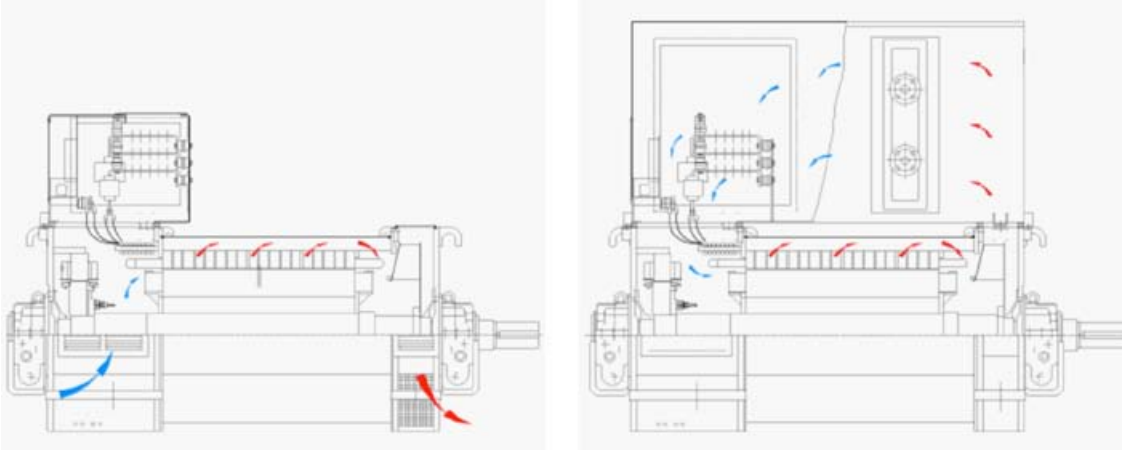
## ABB offers a wide range of marine LV generators from 500 kVA to 5000 kVA.

Frame sizes 400, 500, 560 and 630 cover the designs of 4, 6, 8 and 10 pole solutions at 50 Hz / 60 Hz. The insulation class of the generators is H and the temperature rise class F or H. (The frame size number stands for the rough indication of the shaft height.)

Selection can be made between IC0A1 / IP23 or IC8A1W7 / IP44 designs.

Both air- and water-cooled generators may be selected with roller or sleeve bearings. ABB design is based on the two-bearing solution, where external loads are not considered on the bearing dimensioning in the standard solutions as presented here. In case product tailoring is needed, please contact our sales department for verifying the possibilities to deliver the required features.

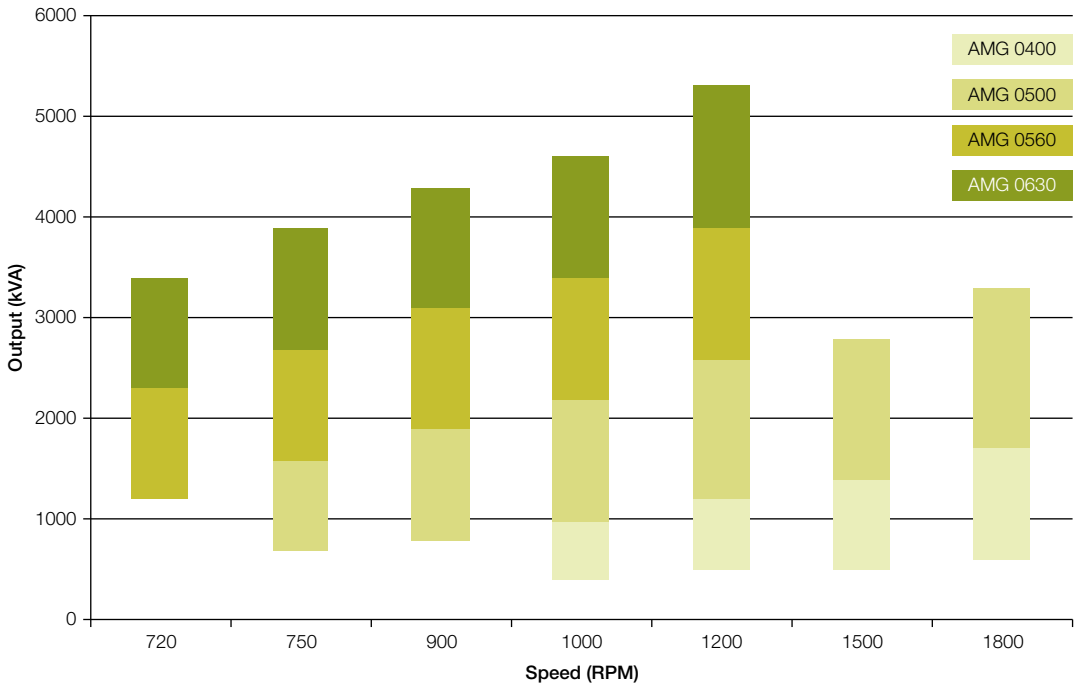
Standard designs are available for the mounting classes IM1101, IM1305, IM2401. If different mounting classes are required, these may be specified by the customer.



The picture on the left presents an open air-cooled generator (IC0A1) with drip proof protection (IP23). The picture on the right presents a fully enclosed generator (IP44) that uses an air-to-water heat exchanger (IC8A1W7)



The table below specifies the output values of ABB marine low voltage generators at different speeds:



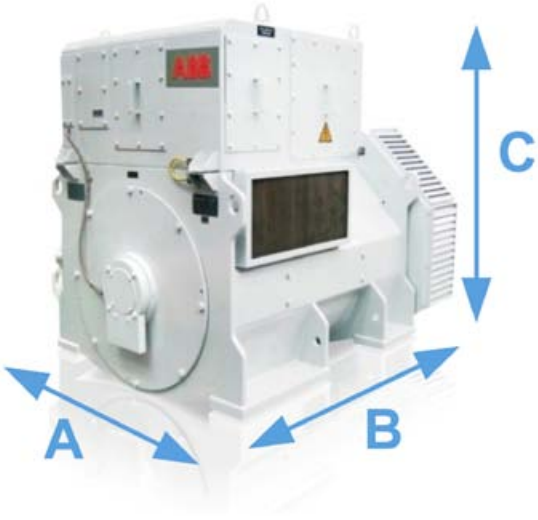



**ABB Marine LV Generator selection table: The dimensioning is based on the 690 VAC voltage level. Each frame size splits into subcategories S, M and L, depending on the length of active parts (IP23, IC0A1).**

| Product | A [mm] | B [mm] | C [mm] | Weight [tn] |
|---|---|---|---|---|
| AMG 400S | 1250 | 1877 | 1510 | 3,5 - 5,0 |
| AMG 400M | 1250 | 2027 | 1510 | 3,5 - 5,0 |
| AMG 400L | 1250 | 2227 | 1510 | 3,5 - 5,0 |
| AMG 500S | 1280 | 2063 | 1680 | 5,5 - 7,5 |
| AMG 500M | 1280 | 2263 | 1680 | 5,5 - 7,5 |
| AMG 500L | 1280 | 2463 | 1680 | 5,5 - 7,5 |
| AMG 560S | 1600 | 2300 | 1905 | 7,5 - 10 |
| AMG 560M | 1600 | 2500 | 1905 | 7,5 - 10 |
| AMG 560L | 1600 | 2700 | 1905 | 7,5 - 10 |
| AMG 630S | 1700 | 2602 | 1938 | 10 – 13,5 |
| AMG 630M | 1700 | 2802 | 1938 | 10 – 13,5 |
| AMG 630L | 1700 | 3002 | 1938 | 10 – 13,5 |

**Generator outer dimension table, IP 44, heat exchanger air-to-water IC8A1W7:**

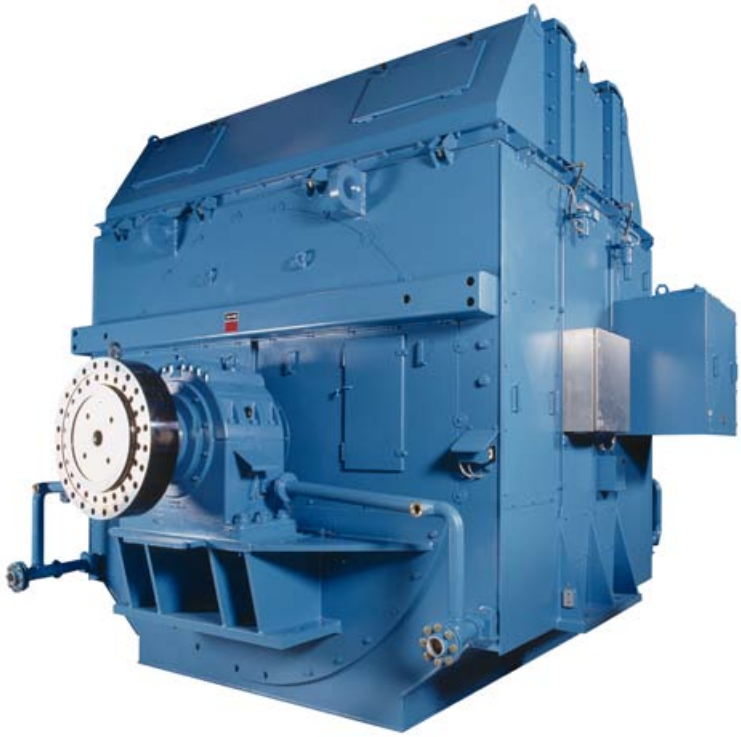
| Product | A [mm] | B [mm] | C [mm] | Weight [tn] |
|---|---|---|---|---|
| AMG 500S | 1500 | 2063 | 2080 | 5,5 - 7,5 |
| AMG 500M | 1500 | 2263 | 2080 | 5,5 - 7,5 |
| AMG 500L | 1500 | 2463 | 2080 | 5,5 - 7,5 |
| AMG 560S | 1600 | 2617 | 2365 | 7,5 - 10 |
| AMG 560M | 1600 | 2817 | 2365 | 7,5 - 10 |
| AMG 560L | 1600 | 3017 | 2365 | 7,5 - 10 |
| AMG 630S | 1800 | 2923 | 2498 | 10 – 13,5 |
| AMG 630M | 1800 | 3123 | 2498 | 10 – 13,5 |
| AMG 630L | 1800 | 3323 | 2498 | 10 – 13,5 |

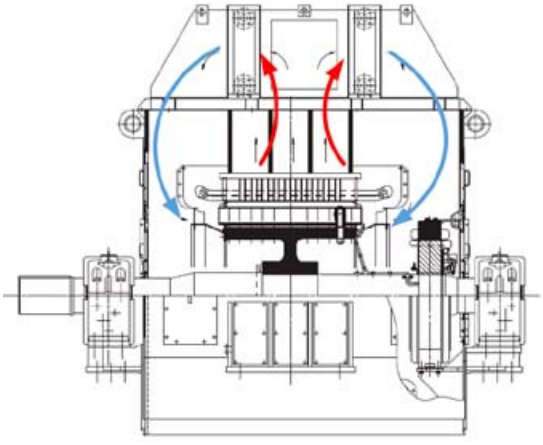
# 9.3 ABB generators – medium voltage products

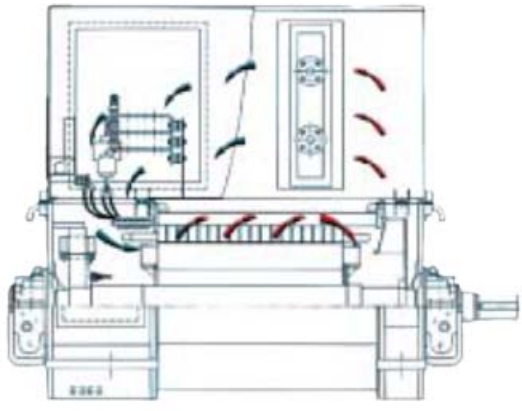
## ABB offers a wide range of marine MV generators up to 50 MVA.

Frame sizes 710, 900, 1120, 1250, 1600, (2000 and 2500) cover all the needed designs at 50 Hz / 60 Hz. The insulation class of the generators is F and the temperature rise class F. (The frame size number stands for the rough indication of the shaft height.)

Medium voltage generators are normally designed with an air-to-water closed circuit cooling type. This solution is ideal for marine applications, since the main engine cooling water can normally also be used for the generator cooling purposes.

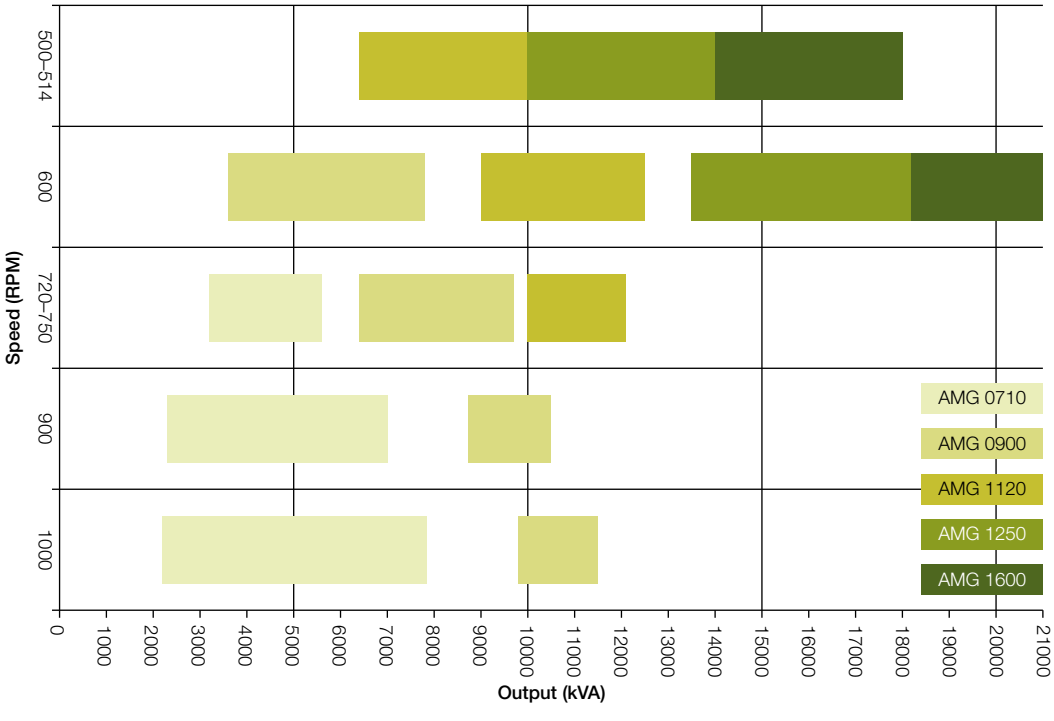


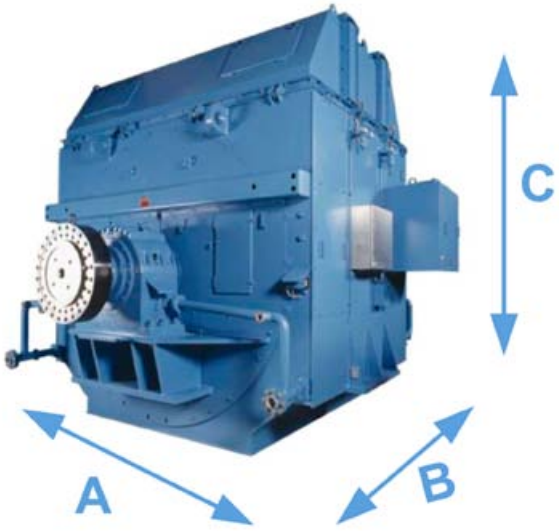




The closed cooling air circulation is either symmetrical with two heat exchangers (as on the left above) or asymmetrical with a single heat exchanger (as on the right above), depending on the generator frame size. Both solutions conform to IP44 and IC8A1W7.

**The table below specifies the output values of ABB marine medium voltage generators at different speeds:**






Standard designs are available for the mounting classes IM1101 or IM7315. If different mounting classes are required, these may be specified by the customer.



**ABB Marine MV Generator selection table: The dimensioning is based on the 6.6 kVAC voltage level, which needs to be converted to the design voltage. Each frame size has multiple possibilities to select the electrical active parts length from.**

| Product | A [mm] | B [mm] | C [mm] | Weight [tn] |
|---|---|---|---|---|
| AMG 710S | 2030 | 3210 | 2670 | 10 – 12,5 |
| AMG 710M | 2030 | 3410 | 2670 | 13,6 - 14,2 |
| AMG 710L | 2030 | 3610 | 2670 | 14,9 – 15,9 |
| AMG 900S | 2100 | 3390 | 3010 | 16,4 – 18,9 |
| AMG 900M | 2100 | 3590 | 3010 | 20,1 – 21,7 |
| AMG 900L | 2100 | 3790 | 3010 | 22,7 – 24,3 |
| AMG 900X | 2100 | 3990 | 3010 | 24, 9 - 25,5 |
| AMG 1120S | 2530 | 3560 | 3440 | 27,0 – 28,5 |
| AMG 1120M | 2530 | 3760 | 3440 | 29,4 – 31,4 |
| AMG 1120L | 2530 | 3960 | 3440 | 33,3 – 35,3 |
| AMG 1120X | 2530 | 4160 | 3440 | 36 – 37,5 |
| AMG 1250S | 3140 | 3900 | 3872 | 42,5 – 44 |
| AMG 1250U | 3140 | 4100 | 3872 | 45,5 - 47 |
| AMG 1600Q | 3840 | 3900 | 4092 | 49,5 - 51 |
| AMG 1600S | 3840 | 4100 | 4092 | 53– 56 |

# 9.4 Main switchboard information

An often ignored fact is that the operational profile of the vessel should be considered in the basic electrical design of the main switchboard as well. Some passenger vessels need multiple breaker switches per day (shuttle ferries), while others operate the breaker closed all the time, which means that the switching interval has basically no input to the design.

Several safety aspects have been recently introduced that need to be taken into account in the electrical design of the main switchboard. In the medium voltage solutions these safety aspects include the choice between a vacuum type breaker (always used in low voltage solutions) or an SF6 type breaker in the switching chamber, as well as the need to reduce short-circuit currents in the system.

**Possibilities offered by the centralized system are numerous:**

# 9.4.1 ABB low voltage switchboard MNS

ABB is the global leader in the production of low voltage switchboards with over 1.2 million MNS cubicles delivered worldwide since the system was introduced in 1973. ABB's history in the production of switchboards can be tracked even further, back to the 1890s, when we manufactured switchboard systems in Sweden.

With these credentials, it is no surprise that the MNS system is the benchmark for operational safety, reliability and quality.

In the low voltage solutions the design is guided by the selected propulsion system: If the chosen propulsion drive is of the Active Front End (AFE) type, we recommend that the network layout is designed so that the electrical consumers are galvanically isolated from the main bus bar by means of a screened transformer. If there is a diode bridge in the propulsion drive, the main switchboard is often designed as one centralized combination of the main switchboard and the motor control center (MCC).

**DESIGNER TIP:**

In this respect it is important not to forget the overall target of improving the energy efficiency by making the correct technical choices; one good solution is to consider frequency converter driven consumers and integrate drives directly into the switchboard.

**Main switchboard MNS performance table:**

| | | | |
|---|---|---|---|
| Electrical data | Rated voltages | Rated insulation voltage $U_i$ | 1000 V 3~, 1500 V- ** |
| | | Rated operating voltage $U_e$ | 690 V 3~, 750 V- ** |
| | | Rated impulse withstand voltage Uimp | 6 / 8 / 12 kV ** |
| | | Overvoltage category | II / III / IV ** |
| | | Degree of pollution | 3 |
| | | Rated frequency | up to 60 Hz |
| | Rated current | Copper Bushbars: | |
| | | Rated current Ie | up to 6300 A |
| | | Rated peak withstand current Ipk | up to 250 kA |
| | | Rated short-time withstand current Icw | up to 100 kA |
| | | Copper distribution bars: | |
| | | Rated current Ie | up to 2000 A |
| | | Rated peak withstand current Ipk | up to 176 kA |
| | | Rated short-time withstand current Icw | up to 100 kA |
| | Arc Fault Containment | Rated operational voltage | 690 V |
| | | Prospective short-circuit current | 100 kA |
| | | Duration | 300 ms |
| | | Criteria | 1 to 5 |
| | Forms of separation | | Up to Form 4 |

**Standard main dimension of ABB MNS-switchboard. Marine installations are often deeper.**

If a parallel supply is requested or two parallel consumers are installed, an often selected solution is to have one consumer driven by a converter and the other – the stand-by unit – as DOL-started from the distribution switchboard.

MNS cabinets are available in the classes IP22, IP41, IP43 and IP54, of which the standard design is IP22.

**The main features of ABB MNS switchboards as owner benefits:**
Module replacement in one minute: MNS modules are operated with the multifunction operating handle. This handle also activates the electrical and mechanical interlocking of the module and the module door. As no other tools or unlocking devices are necessary in withdrawing a module, replacing a module takes less than a minute. The replacement and retrofitting of modules can be performed while the vessel is in operation.

ACB withdrawable operation: In a withdrawable solution the ACB assembly consists of two components, the fixed part (cassette) and the moving part (ACB). This enables the ACB to be located in three positions:

**CONNECTED:** The moving part is fully inserted into the fixed part with both the power terminals and the auxiliary contacts connected. The circuit breaker is operational and the mechanical indicator shows ‘CONNECTED’.

**TEST/ISOLATED:** The moving part is inserted into the fixed part with the power terminals not connected, but with the auxiliary terminals connected. The circuit breaker can be operated for offline tests. The mechanical indicator shows ‘TEST ISOLATED’.

**DISCONNECTED:** The moving part is inserted into the fixed part with both the power and auxiliary terminals not connected. In this position all electric operation of the ACB is prevented. The mechanical indicator shows ‘DISCONNECTED’. The switchboard compartment door can remain closed, therefore not compromising the IP rating of the switchgear. The ACB cassette (fixed part) has shutters which close during the racking-out process to prevent the possibility of a contact with other parts.

# 9.4.2 ABB medium voltage switchboard UNIGEAR

In medium voltage solutions the design is guided by the selected propulsion system: if the chosen propulsion drive is of the modern voltage source inverter type, the selected switchboard can be designed either with reduced short-circuit current or as a heavy structure, which was the marine industry standard earlier. Due to low harmonics of the modern drive technology, the generator dimensioning is no longer defined by the THD-U level in the network and a lower short-circuit current level is reached.

The ABB UniGear switchboard as per IEC62271-200 is constructed by placing standardized panels side by side. The cubicles house vacuum or SF6 circuit breakers of the withdrawable type for the main consumers. For other consumers, contactors can be used as well.

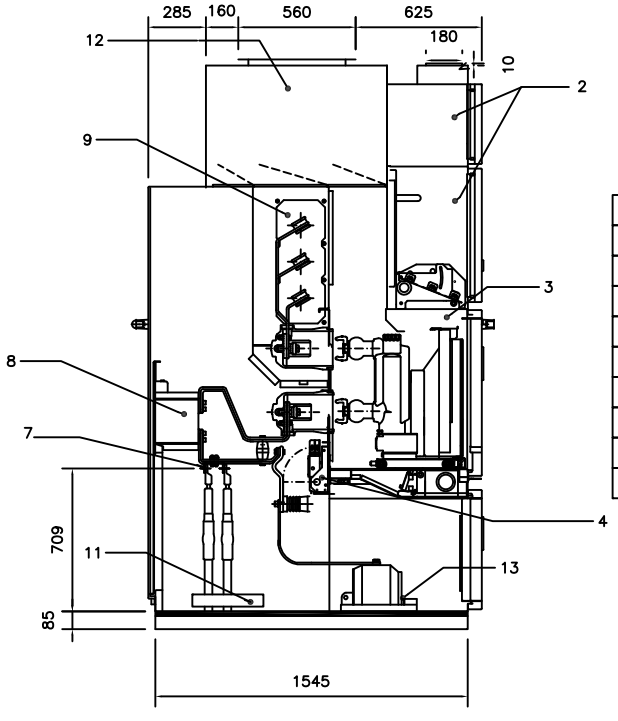
Every cubicle is divided into various compartments for power equipment (bus bar, feeder, circuit breaker, VT compartments) and for auxiliaries (instrument compartment, wiring ducts for interconnections) separated by metal partitions.

All auxiliary relays, measurement transformers, transducers and other needed components are installed according to the needs of the design. The main switchboard is equipped with cubicle-internal space heaters.

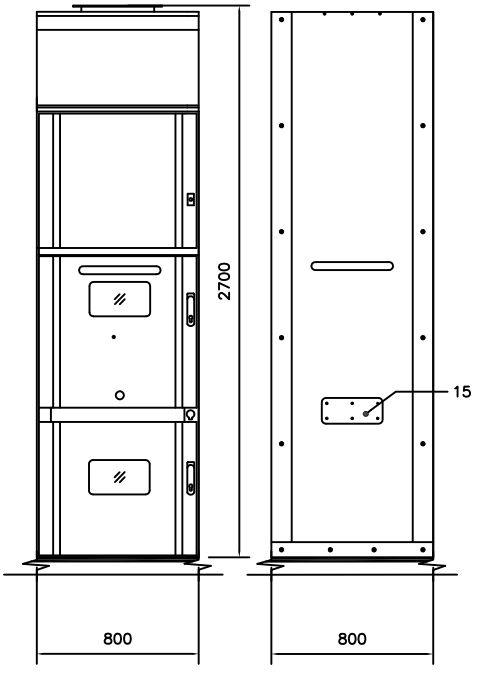
Inadvertent operation is prevented by special locks, which together with mechanical position indicators and inspection windows for the cable compartment create safe operating conditions for the personnel.

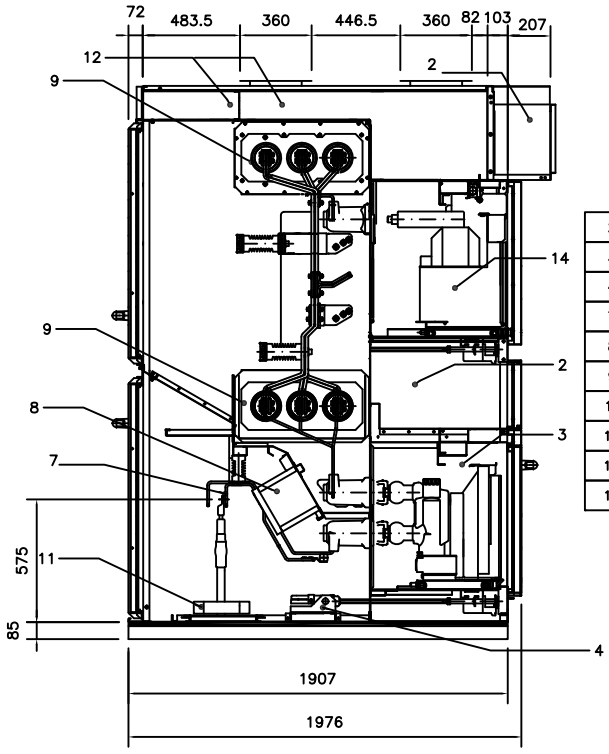
All ABB Unigear busbar edges are round-off filed for preventing sparking and hot spots. Each part is serial numbered.

Most common ABB Unigear medium voltage switchboard cubicles, according the number of consumers (single / double).

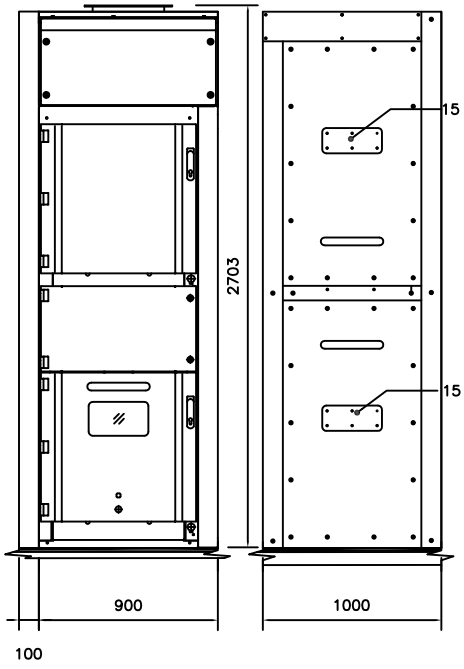



| | |
|---|---|
| 2 | L.V. COMPARTMENT |
| 3 | CIRCUIT BREAKER COMPARTMENT |
| 4 | EARTHING SWITCH |
| 7 | MEDIUM VOLTAGE CABLES CONNECTIONS |
| 8 | CURRENT TRASFORMERS |
| 9 | MAIN BUSBARS COMPARTMENT |
| 11 | RING CURRENT TRANSFORMER |
| 12 | GAS DUCT |
| 13 | VOLTAGE SENSORS |
| 15 | REMOVABLE PLATE FOR THERMOGRAPHIC INSPECTION |






| | |
|---|---|
| 2 | L.V. COMPARTMENT |
| 3 | CIRCUIT BREAKER COMPARTMENT |
| 4 | EARTHING SWITCH |
| 7 | MEDIUM VOLTAGE CABLES CONNECTIONS |
| 8 | CURRENT TRASFORMERS |
| 9 | MAIN BUSBARS COMPARTMENT |
| 11 | RING CURRENT TRANSFORMER |
| 12 | GAS DUCT |
| 14 | V.T'S MOUNTED ON WITHDRAWABLE TRUCK |
| 15 | REMOVABLE PLATE FOR THERMOGRAPHIC INSPECTION |

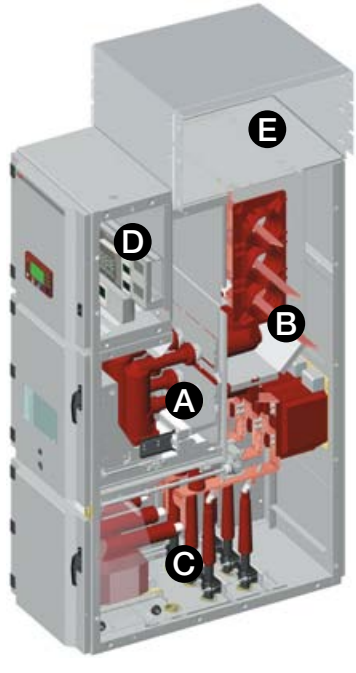


| Dimensions | Definition | mm |
|---|---|---|
| Height | Bottom frame | 65 – 160 |
| | Anti-vibration rubber | 0 – 4 |
| | Height of the basic structure (705 mm control section) | 2200 |
| | Height of the basic structure (1100 mm control section) | 2595 |
| | Height of the double level basic structure | 2698 |
| | + top arrangement for gas ducting | 5 – 300 |
| Width | Feeder panels up to 1250 A (31.5 kA 550-series only) | 550 |
| | Feeder panels up to 1250 A (up to 31.5 kA SF6-breaker) | 650 |
| | Feeder panels up to 1250 A (up to 50 kA vacuum breaker) | 650 |
| | Feeder panels up to 1250 A (above 31.5 kA SF6) | 800 |
| | Feeder panels up to 1600 A-2000 A | 800 |
| | Feeder panels up to above 2000 A | 1000 |
| Depth | Single level unit (up to 40 kA) | 1340 |
| | Single level unit (50 kA) | 1390 |
| | Single level unit – deeper model / deep model | 1650 / 1865 |
| | Double level unit | 1976 |

The basic unit, the single level cabinet structure is presented on the right. The breaker section A, bus bar section B and cabling compartment C are typical standard structures, but other compartments often vary according to project needs.

The height of the instrument section D is project-dependent. The structure of the upper exhaust gas duct E is selected from the standard design options. A skid of 65–160 mm is to be added under the cabinets, depending on the selected delivery lengths and available space above the switchboard.

In addition to the standard single-level cabinet, a deeper double-level cubicle is also available. It can be connected to the single-unit cubicles with a connecting unit, which requires no additional space and hence no additional cubicles are needed.



**DESIGNER TIP:**

From the point of view of dimensions, the proper point to select the double-level cubicles is when more than six smaller consumers are distributed from the main bus bar.

**SHIPYARD TIP:**

The stronger the bottom frame is, the longer installations can be delivered in one piece and a major part of the commissioning work can be done already in the factory. With the 160 mm bottom frame, the transfer length of the switchboard is dictated by the length of the truck, which is typically 10–10.5 meters. With a lower skid, the switchboard bends, and the length of the unit that can be delivered in one piece becomes shorter.

The main switchboard is equipped with ABB breaking devices. The switching devices for the main consumers are VD4 vacuum-insulated circuit breaker (on the left below) and HD4 SF6-insulated circuit breaker (middle). The switching device that is used for other consumers is V-contact vacuum contactor with fuses (right). V-contact can be supplied with surge arrestors if needed (for consumers that are not vacuum-proof).

The REM/REF/RET protection relay family (above REF543, other types are visually similar) is typically used for the power plant protection. Type REF is used in the transfer, bus riser and transformer feeder cubicles, while REM is used for DOL motor feeder and generator protection. RET is used for the propulsion transformer feeder cubicle if differential protection is needed.

Protection relays collect the needed input measurements and digital signals locally within the cabinet. They communicate with the automation system of the ship through hard-wired relays or data bus communication.

The protection principles for ABB medium voltage solutions for passenger vessels:

| Cubicle name: | Performed protection functions * |
|---|---|
| Generator incomer cubicle | Reverse power protection (32)<br>Excitation fault protection (40)<br>Negative-phase sequence (46)<br>Over load protection (49)<br>Short circuit protection (transfer) (50)<br>Over current protection (generator) (51)<br>Over voltage (59)<br>Residual over voltage (59N)<br>Directional earth fault protection (67N)<br>Differential protection (87)<br>Circuit breaker under voltage coil trip (27)<br>Synchronization DEIF (25) |
| Shore incomer cubicle | Under voltage protection (27)<br>Reverse power protection (32)<br>Negative-phase sequence (46)<br>Over load protection (49)<br>Short circuit protection (transfer) (50)<br>Over current protection (shore income) (51)<br>Over voltage (59)<br>Residual over voltage (59N)<br>Directional earth fault protection (67N)<br>Differential protection (87)<br>Circuit breaker under voltage coil trip (27)<br>Synchronization DEIF (25) |
| Bus measurement cubicle | Under voltage (27)<br>Residual over voltage protection (59N) |
| Transfer cubicle | Synchronization (25)<br>Under voltage (27)<br>Non directional earth fault (51N)<br>Directional over current protection (67) |
| Motor feeder cubicle | Under voltage protection (27)<br>Negative-phase sequence (46)<br>Three phase start-up supervision (48)<br>Over load protection (49)<br>Short circuit protection (50)<br>Non directional earth fault protection (51N) |
| Transformer feeder cubicle | Under voltage protection (27)<br>Over load protection (49)<br>Short circuit protection (50)<br>Non directional earth fault protection (51N) |
| Propulsion transformer feeder cubicle | Under voltage protection (27)<br>Over load protection (49)<br>Short circuit protection (50)<br>Non directional earth fault protection (51N)<br>DC ground detector protection (51N) - optional<br>Differential protection (87) – optional |
| Joint cubicle with bus tie breaker | Under voltage protection (27)<br>Residual over voltage protection(59N) |
| Bus riser measurement cubicle | Bus tie breaker synchronization (25)<br>Under voltage (27)<br>Residual over voltage protection (59N) |

* ) The protection functions for protection relays have been standardized by ANSI (American National Standards Institute) and this protection code is widely used in the marine industry. Each protection function is individually indicated by a specific code number, such as 49 for overload protection and this number should be – according to good engineering manners – shown when the protection functions are drawn in the diagrams or listed in the specifications etc.

ANSI codes for protection relay functions:

1 – Master Element
2 – Time Delay Starting or Closing Relay
3 – Checking or Interlocking Relay
4 – Master Contactor
5 – Stopping Device
6 – Starting Circuit Breaker
7 – Anode Circuit Breaker
8 – Control Power Disconnecting Device
9 – Reversing Device
10 – Unit Sequence Switch
11 – Reserved for future application
12 – Over speed Device
13 – Synchronous-speed Device
14 – Under speed Device
15 – Speed – or Frequency, Matching Device
16 – Reserved for future application
17 – Shunting or Discharge Switch
18 – Accelerating or Decelerating Device
19 – Starting to Running Transition Contactor
20 – Electrically Operated Valve
21 – Distance Relay
22 – Equalizer Circuit Breaker
23 – Temperature Control Device
24 – Over-Excitation Relay (V/Hz)
25 – Synchronizing or Synchronism-Check Device
26 – Apparatus Thermal Device
27 – Under voltage Relay
28 – Flame Detector
29 – Isolating Contactor
30 – Annunciator Relay
31 – Separate Excitation Device
32 – Directional Power Relay
33 – Position Switch
34 – Master Sequence Device
35 – Brush-Operating or Slip-Ring Short-Circuiting, Device
36 – Polarity or Polarizing Voltage Devices
37 – Under current or Under power Relay
38 – Bearing Protective Device
39 – Mechanical Conduction Monitor
40 – Field Relay
41 – Field Circuit Breaker
42 – Running Circuit Breaker
43 – Manual Transfer or Selector Device
44 – Unit Sequence Starting Relay
45 – Atmospheric Condition Monitor
46 – Reverse-phase or Phase-Balance Current Relay
47 – Phase-Sequence Voltage Relay
48 – Incomplete Sequence Relay
49 – Machine or Transformer, Thermal Relay
50 – Instantaneous Over current or Rate of Rise, Relay
51 – AC Time Over current Relay
52 – AC Circuit Breaker
53 – Exciter or DC Generator Relay
54 – High-Speed DC Circuit Breaker
55 – Power Factor Relay
56 – Field Application Relay
57 – Short-Circuiting or Grounding (Earthing) Device
58 – Rectification Failure Relay
59 – Overvoltage Relay
60 – Voltage or Current Balance Relay
61 – Machine Split Phase Current Balance
62 – Time-Delay Stopping or Opening Relay
63 – Pressure Switch
64 – Ground (Earth) Detector Relay
65 – Governor
66 – Notching or Jogging Device
67 – AC Directional Over current Relay
68 – Blocking Relay
69 – Permissive Control Device
70 – Rheostat
71 – Level Switch
72 – DC Circuit Breaker
73 – Load-Resistor Contactor
74 – Alarm Relay
75 – Position Changing Mechanism
76 – DC Over current Relay
77 – Pulse Transmitter
78 – Phase-Angle Measuring or Out-of-Step Protective Relay
79 – AC Reclosing Relay
80 – Flow Switch
81 – Frequency Relay
82 – DC Reclosing Relay
83 – Automatic Selective Control or Transfer Relay
84 – Operating Mechanism
85 – Carrier or Pilot-Wire Receiver Relay
86 – Lockout Relay
87 – Differential Protective Relay
88 – Auxiliary Motor or Motor Generator
89 – Line Switch
90 – Regulating Device
91 – Voltage Directional Relay
92 – Voltage and Power Directional Relay
93 – Field Changing Contactor
94 – Tripping or Trip-Free Relay
95 – Reluctance Torque synchro-check
96 – Auto-loading Relay

Sometimes a letter that gives additional information about the protection is added to these codes. Code 51G, for instance, may indicate an over current ground relay, and 87T that a differential relay is used for the transformer protection.

Traditionally ANSI codes have been used for protection definition, while the specifications often refer to the IEC coding. See the reference table for IEC codes attached to chapter 16.5.

# 9.4.3 Integrated $I_s$-limiter expands design windows

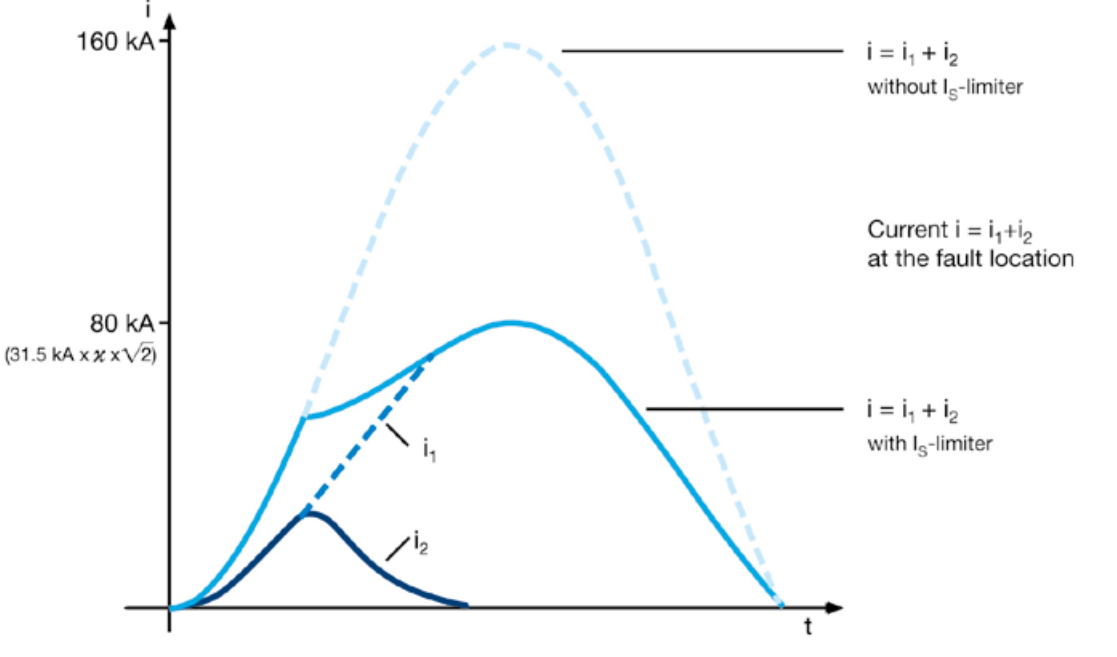
$I_s$-limiter, the world's fastest switching device, is used in the ship concepts if the following features benefit the system design:

- Solves short-circuit problems in new substations and substation extensions
- Is an optimum solution for the interconnection of switchboards and substations
- In most cases the only technical solution
- Direct investment costs are reduced when unnecessary transformer installations are avoided
- Main consumer losses (often the propulsion main circuit) are reduced
- In case a certain consumer does not withstand enough short-circuit current, it can be protected with the $I_s$-limiter segregation from the network.

The $I_s$-limiter has been a reliable and function-proofed solution in thousands of installations since 1960. It is in service worldwide and is also used by ABB Marine.

The use of $I_s$-limiters reduces the short-circuit current in new systems, thus saving costs. Circuit-breakers cannot provide any protection against unduly high peak short-circuit currents, because they are too slow. Only the $I_s$-limiter is capable of detecting and limiting a short-circuit current at the moment of the first rise, i.e. in less than 1 ms. The maximum instantaneous current occurring with the $I_s$-limiter remains well below the level of the peak short-circuit current without the $I_s$-limiter.

The $I_s$-limiter is in every regard the ideal switching device to solve the short-circuit problems for switchgears in ship applications where the low-voltage level could not otherwise be achieved. The best benefits in the power plant are typically achieved in the solutions in which the propulsion power is in the range of 5–9 MW per shaft and a low voltage solution is appreciated. The short circuit tolerance is enhanced also in cases in which the network voltage is ≥ 3.3 kV.

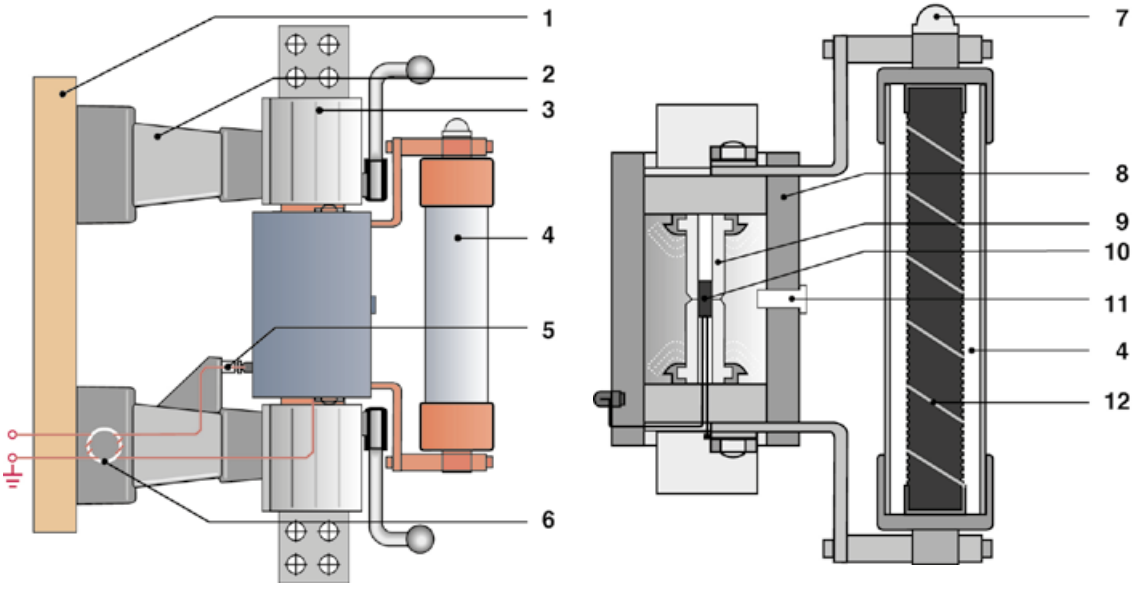


A quick example of how the $I_s$-limiter functions: A short-circuit downstream from an outgoing feeder breaker is assumed. The oscillogram shown on the previous page indicates the course of the short-circuit currents in the first half wave. A short-circuit current of 31.5 kA can flow to the fault location through each transformer. This would result in a total short-circuit current of 63 kA, which is twice as much as the switchgear capability. The course of the current through the $I_s$-limiter in such an event is shown below as current i2. The $I_s$-limiter operates so rapidly that there is no contribution via the transformer T2 to the total peak short-circuit current ($i_1 + i_2$). Therefore, a switchgear with a rating of 31.5 kA is suitable for this application.

$I_s$-limiters consist of $I_s$-limiter holders, $I_s$-limiter inserts, and a measuring and tripping device.

**$I_s$-limiter insert holder with insert for 12 kV, 3000 A (left) and $I_s$-limiter insert (right)**

**1 Base plate**
**2 Insulator**
**3 Pole head with clamping device**
**4 Fuse**
**5 Telescopic contact**
**6 Insulator with pulse transformer**
**7 Fuse indicator**
**8 Insulating tube**
**9 Bursting bridge**
**10 Charge**
**11 Main conductor indicator**
**12 Fuse element**



The measuring and tripping device is located in the low voltage compartment of the $I_s$-limiter panel. The functional groups within the control cabinet or low voltage compartment are combined so that they form replaceable units and are partly mounted on hinged frames.

**DESIGNER TIP:**

In the scope of delivery provided by ABB Marine, the $I_s$-limiter is always certified as a part of the switchboard. For low voltage deliveries, the $I_s$-limiter may be delivered as a separate component (certified by GL) and for the medium voltage solutions as a separate truck installation (certified by DNV).

In the project short circuit calculation, the calculated network may be considered as the network limited by the $I_s$-limiters. However, the network beyond the limiters needs to be considered in the calculation according to the limitation setting.

**$I_s$-limiter control cabinet.**

**Truck mounted $I_s$-limiter in a switchgear panel. Fixed mounting is also available.**

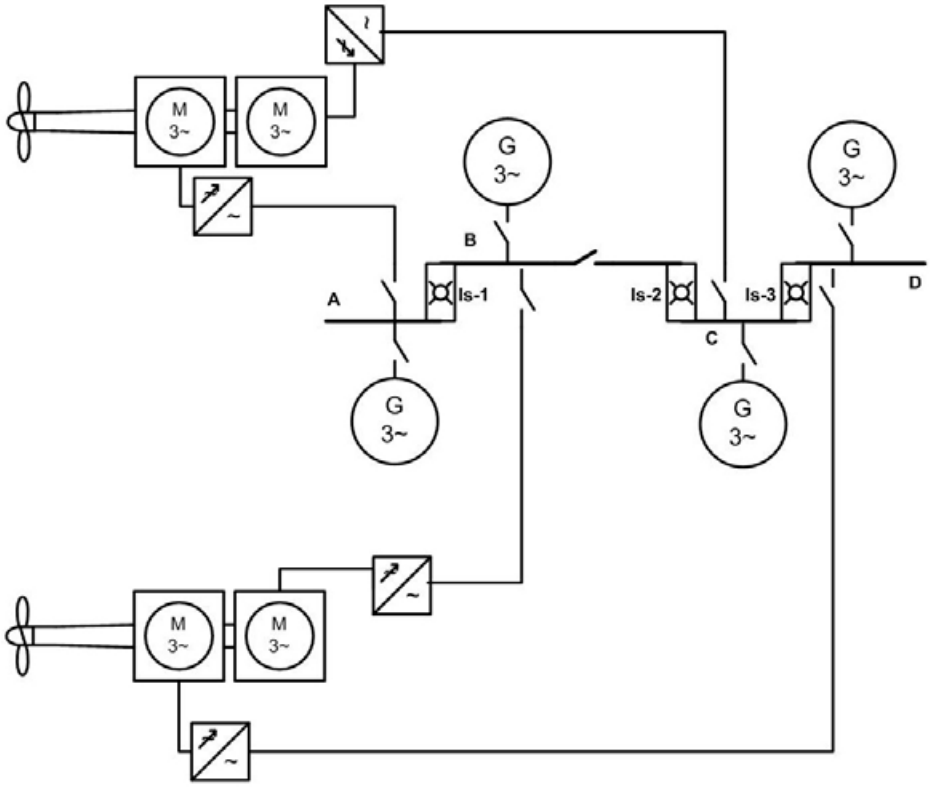
**Technical data for a truck-mounted $I_s$-limiter in a medium voltage Unigear switchboard:**

| Rated voltage [kV] | Rated current [A] | Rated power-frequency withstand voltage [kV] | Rated lighting impulse withstand voltage [kV] | Dimensions [mm] | | | Weight including $I_s$-limiter truck [kg] |
|---|---|---|---|---|---|---|---|
| | | | | Height | Width | Height | |
| 12 | 2500<br>3000<br>4000 | 28 | 75 | 2200 | 1000 | 1300<br>1350<br>1350 | Approx. 1200 |
| 17,5 | 3000<br>4000 | 38 | 95 | 2200 | 1000 | 1300<br>1350<br>1350 | Approx. 1200 |

**$I_s$-limiter as a separate component. The option on the left is for the 690 VAC and on the right for 12 kV.**

**Technical data for a $I_s$-limiter insert and holder as separate components:**

| Rated voltage [V] | Rated current [A] | Interrupting current [$kA_{RMS}$] | Rated power-frequency withstand voltage [kV] | Rated lighting impulse withstand voltage [kV] | Dimensions [mm] | | | Weight insert hold / insert [kg] |
|---|---|---|---|---|---|---|---|---|
| | | | | | Height | Width | Height | |
| | | | | | Height is insert holder height, depth with insert. | | | |
| 690 | 1250<br>2000<br>3000<br>4000<br>5000 | Up to 140 | 3 | - | 554 | 148 | 384 | 10.5 /<br>17 |
| 12000 | 2500<br>3000<br>4000 | Up to 210 | 28 | 75 | 951 | 180 | 509 | 65 /<br>15.5 |




**Example of extending 2 x 9 MW propulsion power to a fully low voltage 690 VAC installation without transformers in the Direct Drive configuration (this solution was originally offered for navy purposes).**

### Use of more than one $I_s$-limiter with selectivity

In order to achieve selectivity with more than one $I_s$-limiter installed, additional tripping criteria needs to be introduced. These criteria are the sum or difference of the currents, and possibly an additional comparison of the current directions. If there are two $I_s$-limiters installed in a switchboard and selective tripping is required, a measurement of the total current is necessary.

### The $I_s$-limiter trips as follows in a multi-unit installation:

Short circuit in section A: only $I_s$-limiter no. 1 trips.
Short circuit in section B: $I_s$-limiters no. 1 and no. 2 trip.
Short circuit in section C: $I_s$-limiters no. 2 and no. 3 trip.
Short circuit in section D: Only $I_s$-limiter no. 3 trips.

# 9.5 Transformer information

Marine variable speed drive (VSD) transformers provide the voltage transformation as well as the electric isolation that are often requested for motor drive applications in marine medium voltage networks. Converter transformers are normally fed by 6–11 kV networks and the converter supply to motor usually ranges from 635 V to 3 kV.

Marine distribution transformers are used to minimize the fire hazard in seagoing vessels, but they also make the cabling work easier, especially when the cable route goes through multiple fire zones.

The main electrical design parameters for transformers are:

1. The power rating of transformers (According to IEC rules)
2. The connection group of the transformer (pulse formation requirement)
3. Short circuit impedance
   a. Primary and secondary voltages at a no-load situation
   b. Primary and secondary voltages at a full load situation
   c. The maximum allowed short circuit current in the secondary side
4. Switching device (vacuum breaker, vacuum contactor, SF6-breaker…)
5. Load characteristics (especially the drive type)
6. Selected cooling type
7. Voltage regulation requirement (tapping)
8. Need for pre-magnetization

ABB Marine utilizes three in-house transformer technologies in the deliveries to passenger vessels.

- Vacuum cast dry-type transformers
- Resin encapsulated, glass fiber strengthened dry-type transformer, ABB Resibloc®
- Midel-filled liquid transformer

In passenger vessels, the transformer technology often faces further requirements in addition to the performance and compatibility issues. The defining requirements are:

- In passenger vessels the deck height is typically the most important defining criterion. Unless located in the engine room, the maximum transformer height is normally restricted to 3–3.5 m, though sometimes it can be even less than 2 m.
- The competence level of the crew often varies, which increases the interest to make the vessel technically as safe as possible. Vacuum circuit breakers in the transformer supply, for example, are one technical option that increases the safety onboard. Transformer technology needs to be reasonably well tested to tolerate different electrical phenomena.
- The noise that is carried from the transformer to the hull needs to be minimized.
- An earthed screen is required between the primary and secondary sides.

**Vacuum cast transformer (below left), resin encapsulated glass fiber strengthened transformer (in the middle) and Midel-filled liquid transformer (right).**

**Typical comparison criteria for ABB transformers:**

| | **Cast resin dry-type transformer** | **Resin encapsulated, glass fiber strengthened transformer** | **Liquid filled (Midel) transformer** |
|---|---|---|---|
| Main benefits | • Low investment costs<br>• Reliability<br>• Proven solution | • 'No-crack' guarantee<br>• Very strong structure<br>• Partial discharge free<br>• Linear voltage distribution through the winding<br>• Tested for vacuum breaker supply<br>• High impulse withstand ability<br>• High short circuit withstand ability<br>• Proven solution | • Small footprint<br>• Insulation between primary and secondary changes continuously (no spot marking)<br>• High impulse withstand ability<br>• Proven solution |
| Winding material | Al or Cu | Al or Cu | Al or Cu |
| Typical area of use | • Distribution <5 MVA<br>• LV propulsion | • Distribution >2 MVA<br>• MV propulsion | • MV propulsion |
| Typical cooling arrangement | • AN<br>• AFWF | • AFWF | • KFWF |
| Typical protection class (IP class) | • IP00<br>• IP23<br>• IP44 | • IP44 | • IP44 |
| Investment cost | LOW | LOW/MEDIUM | MEDIUM |
| Dimensions | Ready-made designs with some latitude. | Tailored. The volume remains unchanged, but dimensions can be modified quite freely. | Tailored. Small footprint, but liquid tank defines the overall height and form. |

**80% of the transformers in the world are delivered with aluminum windings.**
In the cast resin and oil-immersed technologies the winding material strength is directly related to the tensile strength of the material and insulation material combination itself. In ABB Resibloc® the winding material is covered in epoxy with 80% content of fiber class, which forms a structure that has the tensile strength of steel.

**DESIGNER TIP:**

Select the transformer winding structure that is strengthened with fiber class to locations where the mechanical or climatic stress-level is high. Such places may be the bow peak or installations below the open deck.

**Technical characteristics of conductors:**
Copper electrical conductivity
($\sigma_{cu}$) = 57 m /ohms mm$^2$
Aluminum electrical conductivity
($\sigma_{Al}$) = 36 m /ohms mm$^2$

Copper density ($\rho_{cu}$) = 8,9 kg/dm$^3$
Aluminum density ($\rho_{Al}$) = 2,7 kg/dm$^3$

Copper specific heat ($c_{cu}$) = 0,092 cal/(gºC)
Aluminum specific heat ($c_{Al}$) = 0,220 cal/(gºC)

Aluminum winding weight = 0,488 x Cu winding weight ($W_{Al}$ = 0,488 x $W_{cu}$)

For two identical transformers (same winding resistance and length = amps/turns), the conductor section is in inverse relation to the electrical conductivity.

**The section is**
$R_{Cu} = L_{Cu}/S_{Cu} \times R_{Cu}R_{Al}$
$= L_{Al}/S_{Al} \times R_{Al}\ S_{Al}/S_{Cu}$
$= R_{Cu}/R_{Al}$
$= 57/36$
$= 1,61$
$\Rightarrow S_{Al} = 1,61\ S_{Cu}$

**The mass is**
$M_{Al} = L_{Al} \times S_{Al} \times d_{Al}\ M_{Cu}$
$= L_{Cu} \times S_{Cu} \times d_{Cu} M_{Al} / M_{Cu}$
$= L_{Al}/L_{Cu} \times S_{Al}/S_{Cu} \times d_{Al}/d_{Cu}$
$= 1x\ 1,61 \times 2,7/8,9 = 0,488$

**The calorific capacity is the product of the weight and the specific heat:**
Calorific capacity Al = $W_{Al} \times c_{Al}$
Calorific capacity Cu = $W_{Cu} \times c_{Cu}$
Calorific capacity Al / Calorific capacity Cu
$= W_{Al}/W_{Cu} \times c_{Al}/ c_{Cu}$
$= 0,488 \times 0,220/0,092$
$= 1,167$ calorific capacity aluminum
= 17% higher than calorific capacity copper

**Properties of different materials:**

| Material | Coefficient of thermal expansion | Tensile strength |
|---|---|---|
| Aluminum | 23.8 | 70 |
| Copper | 16.2 | 230 |
| Epoxy | 65 | 60-80 |
| Fiber glass | 5 | 1500 |
| Epoxy with 66% quartz-powder | 38 | 75-90 |
| Epoxy with 80% fiber glass | 25 | 600-750 |
| Steel | 11.5 | 370-850 |

**Better thermal behavior in case of a short-circuit**

In case of a short circuit, the temperature rise is inversely proportional to the calorific capacity. Therefore the final short circuit temperature for aluminum windings is lower than for copper windings. Consequently, the stress on the insulation is lower and its lifetime longer.

The technical specification of a ship often calls for ‘oil-filled’ or ‘dry-type’ transformers. However, the specified and requested matter should be the performance, not the technology.

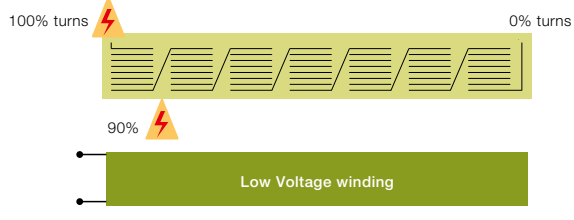
After the selection between the oil-filled and dry-type transformers has been made, the second decision is normally to decide the technology that will be used. Among the oil-filled transformers there is only one solution for marine purposes: windings installed into a tank. If the dry-type transformers are chosen, there are two options: Resibloc and Vacuum Cast Coil.

The glass fiber strengthened winding in Resibloc was developed to distribute voltage linearly through the winding, reducing spot stresses in the winding end. This structure also reduces the

**Coil setup is different between these technologies:**

**Resin encapsulated coil with air ducts**

**Cast LV Coil with air ducts**

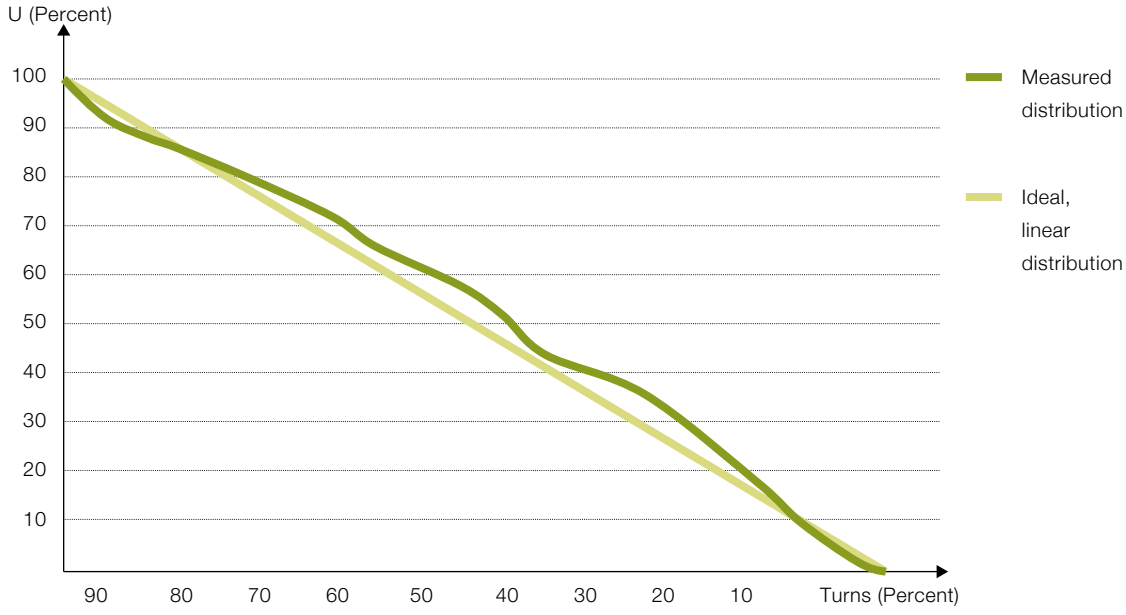


low voltage stresses in the event of a voltage peak. The result is an equal stress of insulation through the whole winding, measured impulse voltage distribution to ground (impulse wave 1.2/50). Resibloc is a premium-class transformer and available only from ABB.

ABB is the technology leader in vacuum cast coil transformers. We have the broadest application range and extensive experience. Vacuum cast coil transformers are long-life transformers because of their low level of thermal and dielectric aging. The epoxy resin casted in a vacuum protects against the entry of moisture. Fiberglass reinforcement provides superior mechanical strength. The transformers are safe because of the non-flammable and self-extinguishing design. They provide high resistance to short circuits, high capacity to withstand overload and capability to withstand even the most severe vibration conditions.



**Linear distribution of impulse voltages in ABB Resibloc® transformer.**



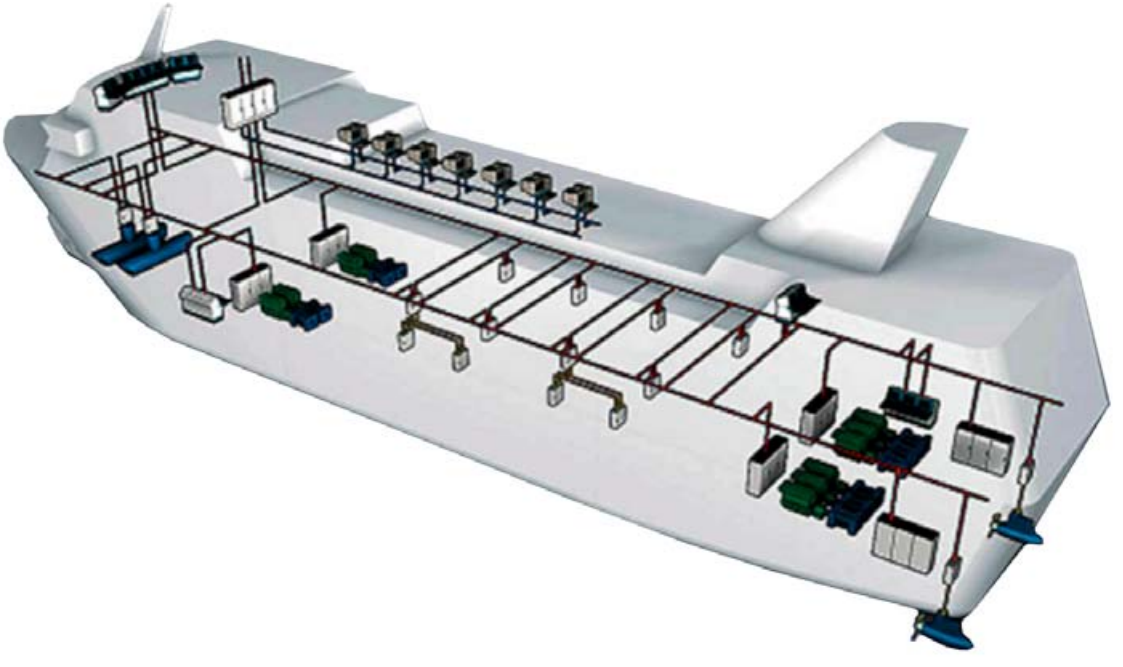
# 9.6 Frequency converter information

Frequency converters are used all around the vessel. In large cruise vessels, the total number of frequency converters that are used simultaneously can nowadays be in the hundreds. The frequency converter that tends to get the most attention in a diesel-electric vessel is, without a doubt, the propulsion drive.

The propulsion drive defines the overall network design and renders the performance of the vessel as energy efficient – or not so energy efficient.

Without concentrating on the selection of the propulsion system here, it can be said that ABB primarily selects a voltage source inverter (VSI) to act as the propulsion drive. This propulsion drive type is beneficial to the overall network design because of the following features:

VSI has a constant and high power factor (0.95) towards the network. This means that that the propulsion – as the load increases – does not deteriorate the network total power factor to a large extent. This helps in keeping the power production losses small. The benefit that VSI brings as compared to other technologies is on the level of one percent of energy efficiency in power production – resulting only from the type of drive that is used.



VSI harmonics disturbance is well known and the system is easier to design. The harmonics level can be decreased by several percents compared to some other drive types. The level of heating of the installed electrical equipment is smaller, which improves the lifetime expectation of the equipment.

Main generators can be designed with higher longitudinal reactance values, which helps the generator design itself and is also beneficial to the dimensioning of the main switchboard. In earlier designs a constant problem was to find components rated for the 50 kA level of short circuit withstand ability, while in modern designs the level has decreased to below 25–31.5 kA limits.

The VSI type Variable Speed Drive (VSD) is rather simple. Basically it consists of three main parts (low voltage direct drive), which are:

- **The line-side module** forms the drive-internal (intermediate) DC-link voltage. This voltage level is defined in the design phase by the power need in the propulsion. The only task that line-side modules have is to guarantee that this voltage is available.
- **The inverter module** takes energy from the DC-link and rotates the electrical field in the motor according to the captain's reference.
- **The propulsion motor** is designed so that it is able to rotate the propeller as designed.

**Above: this is what the modules look in real life. The diode unit of a line-side unit is being changed (on the left) and a motor-inverter unit is pulled out (on the right).**

When it comes to auxiliary drives, ABB has a wide offering of frequency converters from the smallest units to the biggest ones. This unique position means that ABB can offer solutions that comprise the whole vessel and emphasize the total energy management.

As was mentioned in the chapter about the main switchboard, frequency converters that are integrated into the switchboard are one option to consider when designing the total energy efficiency of the vessel. The multi-drive type, combined frequency converters that locally feed multiple motors is also a practical solution that can be used to design controllable consumers.

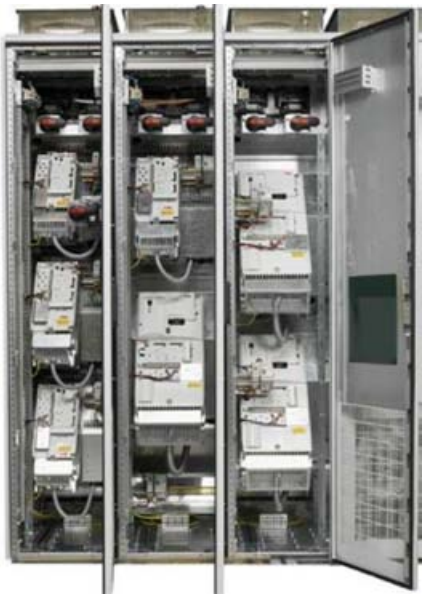


**ABB ACS800 Multidrive (air cooled)**

## A propulsion drive requires a propulsion control application.

A propulsion drive solution always needs a dedicated control application. This application protects the network from the drive and also the drive from the network. It can also be linked with the energy management system, which often offers great potential for power limitation functions.

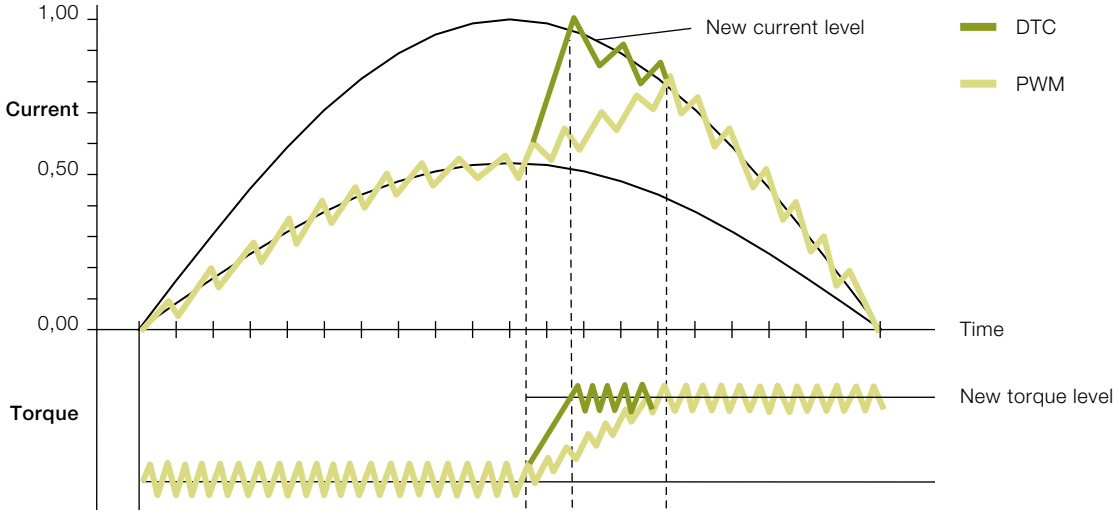
Propulsion control application functions are:

- Starting and stopping of the propulsion
- Alarm and fault handling, self-diagnose
- Blackout protection
- Overload protection
- Propulsion motor protection
- RPM handling or power reference handling
- Remote control indications in the control places / interface to Remote Control System (RCS)
- Interface to the machinery automation system, Dynamic Positioning (DP),
- Autopilot, joystick, Voyage Data Recorder (VDR) and Energy Management (EMMA)

Our recommendation is to specify these functionalities in the ship specification.

All ABB drives utilize a modern version of the traditional Pulse Width Modulation (PWM) in the drive internal control. Instead of using the constant fire pattern frequency for controlling the semiconductors, ABB's Direct Torque Control (DTC) uses a reference level correction control, which has various benefits:

- Accurate speed or torque control
  - excellent static and dynamic accuracy
  - outstanding torque step rise time
  - immediate response to load changes
  - full torque at zero speed
  - direct control of the torque – no nuisance trips from the torque ripple
- Power loss ride through; no unnecessary process interruptions
- Fast control leading to precise protection




**DTC performance compared to traditional PWM control.**

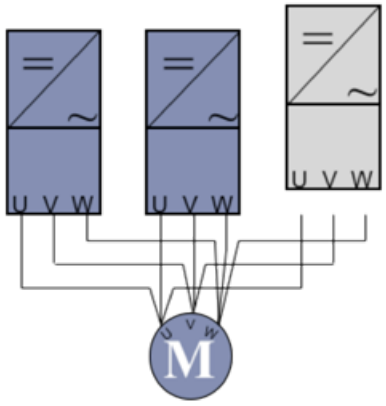
Since the application itself does not require a high switching frequency and the DTC control can form a good sinusoidal-like motor voltage and current at low frequencies, ABB can take the efficiency aspects into account when designing the combined motor and drive losses. It is important to remember that when evaluating component efficiencies, the evaluations need to be done in the same setting as in real life and preferably with partial loads, too. (Different drive-motor combinations for shaftlines can be seen in the chapter Propulsion solutions – Direct Drive.)

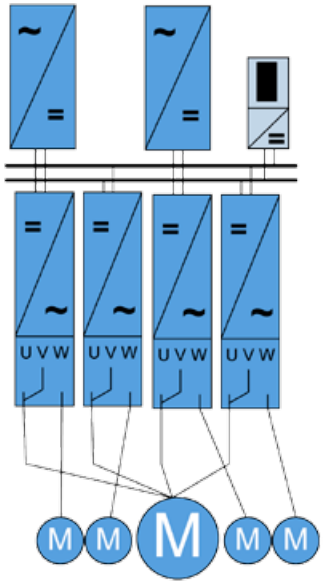
Exact and detailed information about the state of the drive before and after the fault can be read from the drive memory, and both local and remote access to the drive diagnostic programs are available. The same diagnostic software is used with all the different ABB drives.

**ABB low voltage propulsion drive**

In the low voltage propulsion systems, the standard ABB propulsion drive is a liquid cooled ACS800 Marine drive, which has the IGBT (Insulated-gate bipolar transistor) type main semiconductor. This drive has certain advantages that make it stand out from the competition:

- The structure with three-phase modules has changed the electrical design of the ship. Each module controls its three-phase current independently, which means that if there are parallel-connected modules and one of them has a fault, the rest can continue with a power limitation after the faulty module has been disconnected. ACS800 has in-built redundancy like never before.

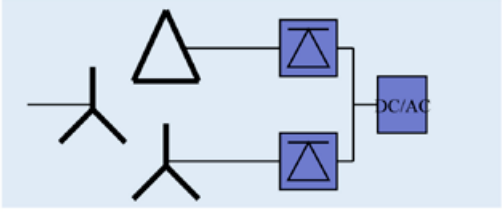



- The crew does not need to have high voltage certifications. If the drive is a low voltage drive, we always aim to design a low voltage system without transformers. ACS800 enables this thanks to its high withstand ability of up to 137 kA against short circuit peak currents. (If values higher than this are needed, see the information on the $I_s$-limiter.)
- Since the majority of the electrical components are inside the modules, the troubleshooting and maintenance require a lower level of competence. When the same hardware is used throughout the vessel, there are fewer different systems that need to be mastered.
- Because of the three-phase modules, each module can also have a multifunctional role. The drive can supply a propulsion motor with four modules at the sea, but at the harbor the same module can supply two luggage belt conveyor motors plus two car deck fan motors.

The simplified drawing above has two diode modules on the network side and a brake chopper feeding the regenerative energy from the propeller to the brake resistor. Because of the diode bridge, the drive generates six-pulse interference towards the network, which requires filtering. The solution with a diode supply unit is the most efficient one, because the filtering is not located in the main energy flow, as is the case with radio-frequency filtering, which is needed in the Active Front End (AFE) drives.

## Transformer solution with a 12-pulse rectifier.

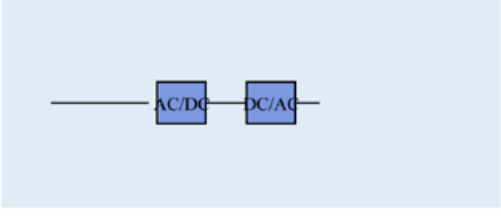



An additional transformer and additional cabling are more complicated. The drive line side is equipped with a diode bridge.

**THD solution**

$U_{thd}$ reaches the acceptable level by means of transformer connection group design.

## Transformerless solution with a 6-pulse rectifier.




A transformer is not needed and cabling is simpler.

**THD solution**

$U_{thd}$ reaches the acceptable level by means of the electrical design of the generator and EMC filtering (case AFE) or by means of harmonic filtering (case diode bridge).

With low voltage solutions the similar inverter module that is used on the motor side can also be used on the line side, which also enables the active control of the network side. This solution is called Active Front End (AFE). The harmonics that AFE generates are generally on a lower level and related to the engine configuration. If AFE is selected for the project, the THD evaluation should be made according to the network short circuit power. If the short circuit power in the network is five times (or more) the available propulsion power, the design is safely below the limits defined by classification societies.

**DESIGNER TIP:**

IEC 60533 defines the radio frequency interferences, zones and limits for each. These guidancies should always be concidered when designing the ships network with frequency converters. In the special power distribution zone (equals the propulsion network in the onboard installation), the IEC limits of radio frequency interference should be limited by means of galvanic separation from the other - surrounding - network and by the screen between primary and secondary of this point, but in any case before general distribution zone (equals the consumer distribution network onboard). This design procedure limits the highest radio interface disturbance into the limited network section.

**ABB medium voltage propulsion drive**
In the medium voltage range, a transformer, or at least a short circuit current limiting reactor, is introduced into the propulsion chain. In passenger vessels this is done in order to separate the propulsion systems and therefore rule out the possibility of two simultaneous faults creating a circulating and uncontrollable fault current via their common power distribution (in medium voltage systems the short circuit power is on a higher level than in low voltage systems).

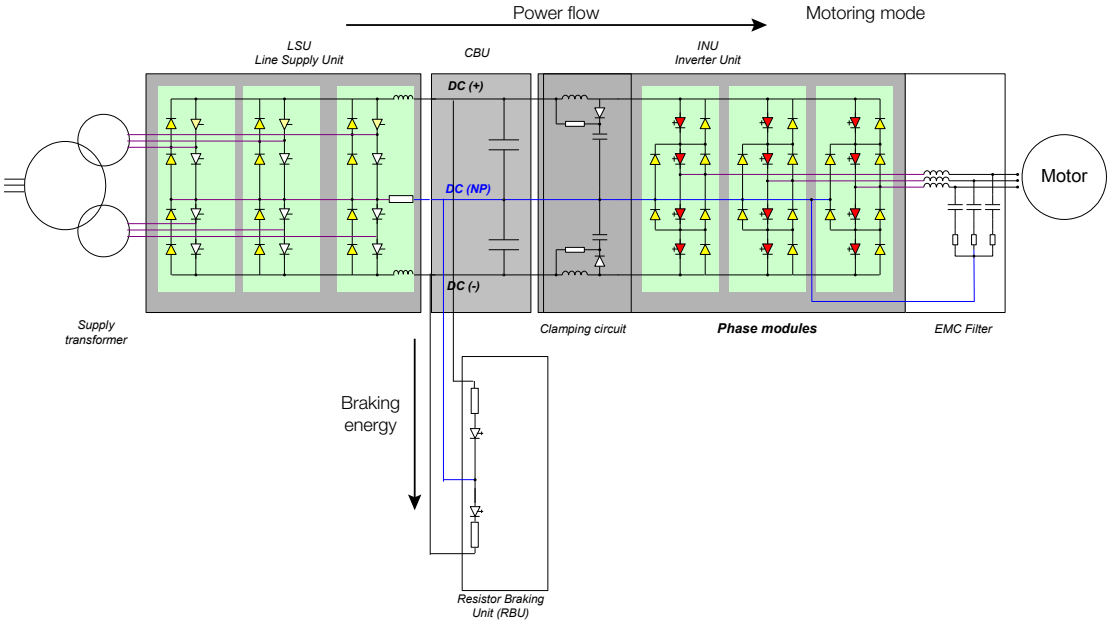
In the medium voltage range the selected drive is typically a voltage source inverter ACS 6000, though the traditional Load Commutated Inverter (LCI) is also occasionally required.

The semiconductor that ABB has selected for medium voltage drives is an IGCT (Integrated Gate Commutated Thyristors) type semiconductor.

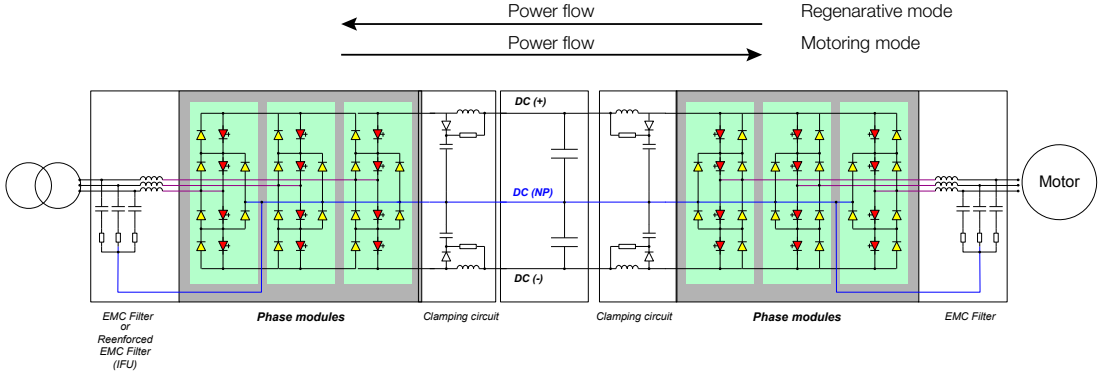
**Above: 9 MVA ACS6000.**

# Employed MV drive technologies (2Q drive is a marine option)

### 2Q drive




### 4Q drive with AFE and LCL-filtering



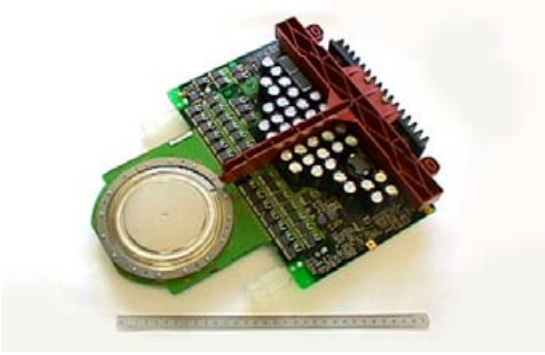
In marine solutions, the two-quadrant diode bridge is the only alternative that is used. This is done in order to keep the drive chain efficiency as good as possible and to avoid additional losses and the use of additional components in the network side. The major benefits of this configuration are listed in several places, but to summarize:

- A constant high power factor and low THD generation reduce costs and improve safety aspects.
- Because a diode bridge is selected, there are no LCL filtering losses
- Fewer installed components keep the solution simple

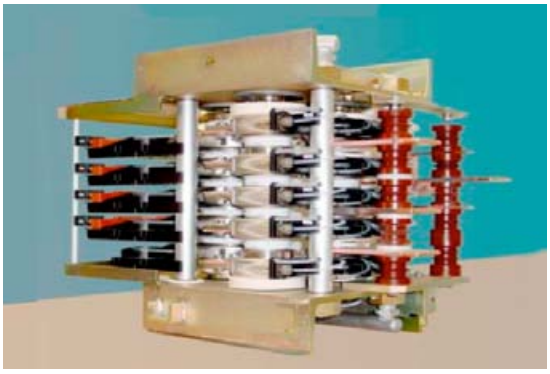
The downside of the diode bridge is the additional brake resistor that needs to be introduced into the system, while with AFE it is possible to distribute the energy generated by the braking back to the network.

With medium voltage drives ABB has put a lot of effort in simplifying the control electronics and maintainability of the drive. The inverter unit consists of three-phase modules without fuses, which can be dismounted without the need for high professional competence and all maintenance can be carried out from the front. As all electrical engineers understand, this is a great safety benefit and it reduces the possibility of a human error in the maintenance work.

Another difference to the low voltage drive is that the capacitors are not within the modules, but in a separate cubicle. These capacitors are dimensioned to supply voltage to the DC link, but also according to the application power needs. The brake resistor is typically dimensioned according to the level of about 20% of the nominal power in shaftlines, but it can be smaller in Azipod®, or it can even be discarded in mechanical thruster applications.



**The IGCT taken out from the phase module. The semiconductor itself is very robust and contains one current carrying surface that is trigged fully on with only one gate pulse.**



**ACS 6000 inverter module. One phase module weights approx. 80 kg and can be changed within a 15-minute working period.**

**Module control cards are located in the segregated top section of the inverter cubicle. The control hardware is designed to be very simple. It also takes into account the Application Motor Controller card (not visible in the picture above).**

# 9.7 Motors

ABB delivers motors from the smallest one-kilogram-size up to the largest 300-ton propulsion motors. ABB has 10 motor factories located around the world and all the main technology options are manufactured in them.

**Auxiliary motors**

The efficiency of the auxiliary motors for onboard processes has become more and more targeted. Furthermore, the demand for control processes has an impact on the motor design as well. The motor needs to match the requirements of the supplying frequency converter; these requirements need to be fulfilled in the technical specification of the ship.

The induction-machine-type motor – also known as the asynchronous motor – has been the obvious choice for the onboard auxiliary motors for decades. This motor type is a robust choice and the technology is standardized.

**Some of the international guidelines have been updated lately to meet the increasing interest in the efficiency comparison of the motors, such as the new efficiency class IE4:**

| | | |
|---|---|---|
| Super premium efficiency * | IE4 | Super premium efficiency |
| Premium efficiency | IE3 | Premium |
| High efficiency | IE2 | Comparable to EFF1 |
| Standard efficiency | IE1 | Comparable to EFF2 |

*) IE4 level for asynchronous and synchronous motors defined by IEC 60034-31: 2010

The efficiency class coverage of the ABB motor offering for the process motors, according to the frame sizes (corresponds approximately to the shaft height in mm):

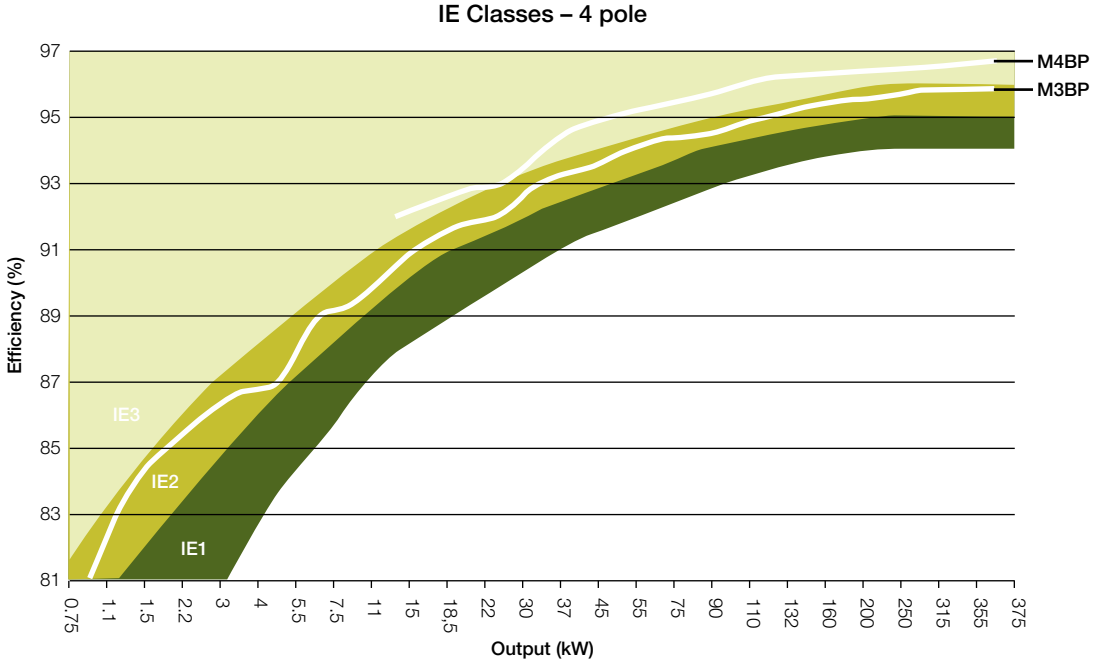
- High-efficiency motors are stock motors with IE2 class, type M3BP ranging from 0.25 kW to 1 MW. The motors have a cast iron frame (sizes 71 to 450).
- Premium-efficiency motors are stock motors with IE3 class, type M4BP ranging from 11 kW to 375 kW. The motors have a cast iron frame (sizes 160 to 355).
- Super-premium-efficiency motors are stock motors with IE4 class, type M5BP ranging from 75 kW to 375 kW. The motors have a cast iron frame (sizes 280 to 355).

**EFFICIENCY TIP:**

In other industries, the tendency has been for the last ten years to replace induction machines with permanent magnet synchronous motors, which are far more efficient at partial loads. These motors have higher investment costs, but the payback time has been experienced to be reasonable. Contact your local ABB representative for this option if the motor size is above 200 mm in shaft height.

**Insulation classes of motors**

| | B | F | H |
|---|---|---|---|
| Allowed ”hot spot” temperature °C | 130 | 155 | 180 |
| Allowed winding temperature (by means of a resistive measurement) °C | 120 | 145 | 165 |
| Allowed short term winding temperature above the ambient temperature +40°C | 80 | 105 | 125 |




**Example curves for the IE classes of the four-pole motor through the power range, where classes IE1-IE3 are available. NOTE: The evaluation is made at the nominal speed. The partial load efficiencies are not visible in this form of presentation, but the overall level of the efficiency curve can be specified according to the nominal speed efficiency classes.**

Physical changes are needed in the motor when it is supplied with a frequency converter.

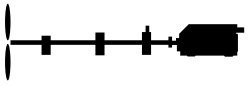
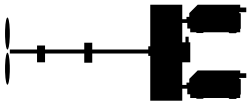
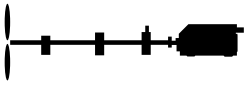
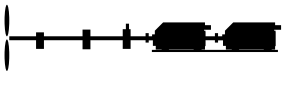
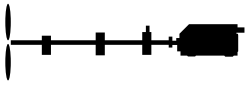
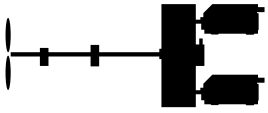
- Separate cooling is usually used in the VSD to improve the cooling at low speeds. The most common solution is to have the fan and fan motor mounted axially at the N-end (see the picture below). In applications in which the total length of the motor is limited, the cooling fan can also be mounted above or at any of the sides of the main motor. Separate cooling can also be combined with encoder or brake solutions.
- The terminal box of the motor needs to be designed according to the ΔU/Δt requirements of the supplying frequency converter.
- The design must take into account the circulating bearing currents, and in many cases the bearing insulation faces changes when a converter is added.
- Non-sinusoidal heat losses need to be considered when selecting the correct motor size. When the power is close to the limit of what the frame size of the motor can provide, and a frequency converter is added to the configuration, it might be necessary to select the next motor size.

**Additional cooling fan installed at the end of the induction motor.**

**Propulsion motors**

The propulsion motor of a passenger vessel is used mainly in partial loads and the amount of energy that is consumed in partial loads is large; this means that the differences in partial-load efficiency should be emphasized. The operational profile of the vessel defines the propulsion motor technology selection.

**In practice there are three different motor technologies to select the propulsion motor from (the DC solution is normally not considered with passenger vessels, though it is available and used in research vessels):**

| | Asynchronous = Induction motor | Permanent magnet synchronous motor | Synchronous motor |
|---|---|---|---|
| Typical motor use |  Below 6MW, <350rpm  2 x 0–13MW, <1500 rpm Z- or L- drive thrusters |  3-4.5MW, < 250 rpm  5 – 9 MW, < 250 rpm Azipod® C 0980-1400 sizes |  5 – 25 MW, < 200 rpm  2 x 5-25MW, < 675 rpm Azipod® XO, Azipod®VO, Azipod® VI |
| Solution voltage level | Low Voltage, Medium Voltage | Low Voltage | Medium Voltage |
| Main benefit of technology | • Simplicity<br>• Encoder-less control<br>• Good efficiency at upper half of the speed range<br>• Low investment costs | • Simplicity<br>• Encoder-less control<br>• Good efficiency also at partial loads<br>• High torque capability<br>• High power factor | • Good efficiency also at partial loads<br>• 2-stator configuration<br>• Reliable solution for high powers<br>• High torque capability<br>• Power factor 1.00<br>• Long track record |
| Efficiency “class” for propulsion utility * | A | AB (shaftline)<br>ABB (Azipod® C) | AB (shaftline)<br>ABB (Azipod®) |

*) The efficiency class A is an ABB internal rating for the best optimization of the drive and the motor. The efficiency class AB improves the efficiency at a partial load situation. Efficiency classes A and AB are available in the Direct Drive family. The efficiency class ABB stands for tailored podded propulsion, which has gains additional benefits created by the pulling propeller and the propeller positioning.

The main selection criteria for passenger vessel propulsion motors are typically the maximum RPM of the propeller – defined by the diameter (the propeller tip speed should be below 42 m/s to avoid cavitations, but the diameter should be as wide as possible) – and the vessel speed with that propeller. Furthermore, the operational profile of the vessel is increasing in importance, especially when the partial load efficiency is an important factor.

A rough dimensioning of the propulsion motor follows the arithmetic below:

$$Max\ RPM = \frac{42\ \frac{m}{s}}{\frac{Draft}{125} * 100\pi} * 60s$$

Max RPM when the 25% tip clearance between the propeller and the hull is taken into account. This clearance is needed to achieve the low level of pressure pulses that is required in comfort classes:

Example:
7.0 meters draft at the propeller position:

$$Max\ RPM = \frac{42\ \frac{m}{s}}{\frac{7{,}0\ m}{125} * 100\pi} * 60s = 143\ rpm$$

In the example below, the design RPM value is calculated with a 35% tip clearance and 41 m/s tip speed.

$$Max\ RPM = \frac{41\ \frac{m}{s}}{\frac{7{,}0\ m}{135} * 100\pi} * 60s = 151\ rpm$$

RESULT: In the passenger vessel with 7.0 meters of draft, the propulsion motor supplies the nominal power at the preliminary speed range of 143–151 rpm depending on the hydrodynamic design. The preliminary selection of the motor can be made according to the 143 rpm propeller speed.

**DESIGNER TIP:**

In case there is unused reserve within the same motor frame size, it is recommended that this reserve is used by decreasing the motor RPM, which allows the propeller design to be optimized according to the propeller load or the comfort class of the vessel. In good design processes the electrical engineers and hydrodynamics engineers work together with a good understanding of the manufacturer's portfolio.

In the low voltage propulsion systems there are two options to select the propulsion motor from:

- Induction (Asynchronous) motor
- Permanent magnet synchronous motor

The induction machine rotor is excited via an air gap between the rotor and stator, and the rotor then follows the rotating electrical field in the stator with a minor delay, which is called the slippage. This slippage makes the motor power factor lower than in a synchronous motor. A typical power factor for an induction machine is 0.85–0.89.

The permanent magnet rotor looks a little different from inside. The magnets are embedded into a V-shape, and they provide the needed excitation. There is no slippage like in the induction motor and the motor has better partial-load efficiency. The efficiency of the permanent magnet motor is very good, typically 0.97–0.98.

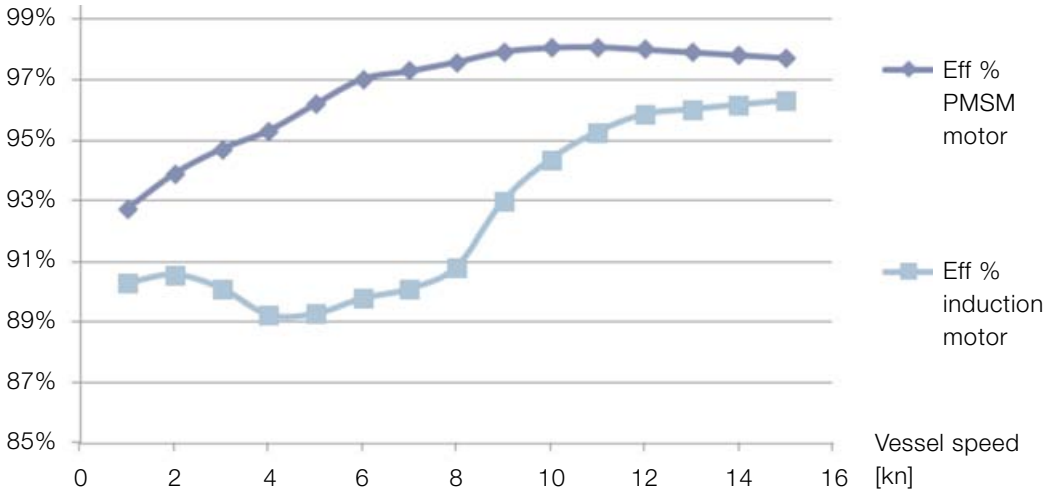
On the medium voltage level, possible options for the efficiency comparison are:

- Asynchronous motor
- Synchronous motor
- (Permanent magnet synchronous motor)

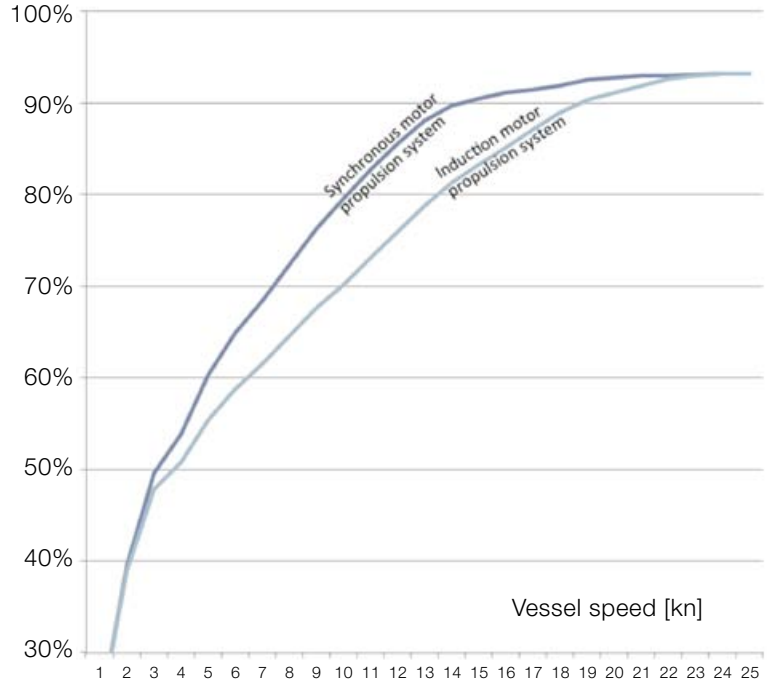
The rotor in the synchronous motor has salient poles. The excitation is brought to the rotor via a rotating transformer – the excitation machine – and then the diodes in the rotor rectify it to DC.

The ratio between no-load losses and load losses defines how the profile of the curve decreases towards the zero in zero speed. The no-load losses are always bigger in the asynchronous motor than in the synchronous motor. This is due to the fact that in the asynchronous motor the excitation is delivered to the rotor via an air gap. What makes the comparison difficult in real-life, however, is the fact that IEC requests synchronous motor manufacturers to measure

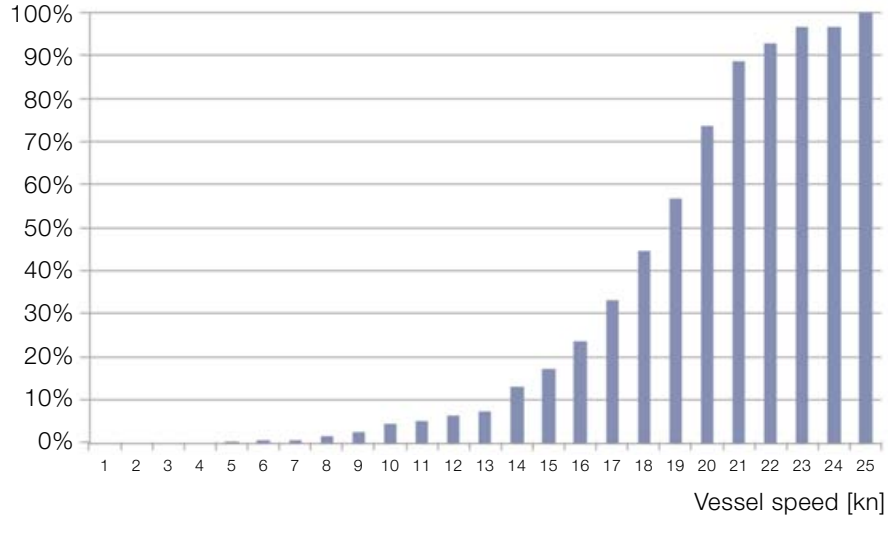
**Efficiency curves comparison between a slow speed permanent magnet motor and a high speed induction motor (the induction motor at its best performance level):**



**Comparison of the efficiency curves between the propulsion drives of a slow speed induction motor and a slow speed synchronous motor (direct and indirect losses of transformers, drives and motors):**




**Cumulative energy consumption of the average cruise ship: nearly 90% of propulsion energy consumption takes place below the typical service speed of 21 kn**



the additional losses of the motor in the factory acceptance test (FAT), whereas with asynchronous motors the measurement is not possible, and a mathematical method is allowed for 0–0.5 percentage units of additional losses. The effect of this tolerance is remarkable, and the comparison of partial load losses is made difficult for the customers to control. If the vessel uses variable speeds, as a cruise ship does, the evaluation of the speeds in which the energy is consumed becomes really important:

Cumulative energy consumption of an average cruise ship: nearly 90% of the propulsion energy is consumed in speeds below 21 kn of service speed.

While selecting the Direct Drive equipment for the shaftline vessels, ABB Marine has taken into account the typical operational requirements that affect the technology selection between different propulsion motors. All efficiency levels are available as readymade concepts, which makes comparison easier and the technical content of each option more transparent throughout the ship building process. When the ABB Direct Drive is selected and specified, the content is clear to all parties. See the chapter dedicated to ABB Direct Drive in this handbook.

# 9.7 Machinery Automation System

From the background of hundreds of vessels and from the strong, long lasting position of being the technological leader in many fields of land-based automation systems, ABB Marine and its partners have wide experience and an impressive portfolio of successful installations that are the foundation for providing the complete solutions for passenger vessels. ABB automation products cover solutions from the smallest ferries to the widest installations.

Differentiating from our competitors, ABB has a full portfolio of products which are needed for the total energy efficiency approach and for providing standard automation systems. ABB is in the position to offer additional outstanding benefits to all parties.

ABB and its partners use the open communication principle and allow freedom in the user interface design. Furthermore, the level of integration between different systems to form one uniform automation system is high.

**The ABB 800M Series controller connected to the S800 I/O-remote station, a solution widely utilized in the industry. It is also suitable for the automation systems of passenger vessels. This same controller is also used by ABB Marine as a propulsion system controller in large propulsion systems.**

**SHIPBUILDER TIP:**

You may benefit from the investment in the integrated automation system if you have purchased all the frequency converters from one source with tailored, but simplified interfaces. ABB data communication bus-lines between the drives can be designed to collect frequency converter information from multiple consumers (which need to be grouped according to the rules) and deliver it all into the automation system through a single point. The technological differences between these single points should be minimized to reach savings in the hardware and engineering work. By centralizing the frequency converter and motor purchases, you will also reduce the costs of the whole electrical package.

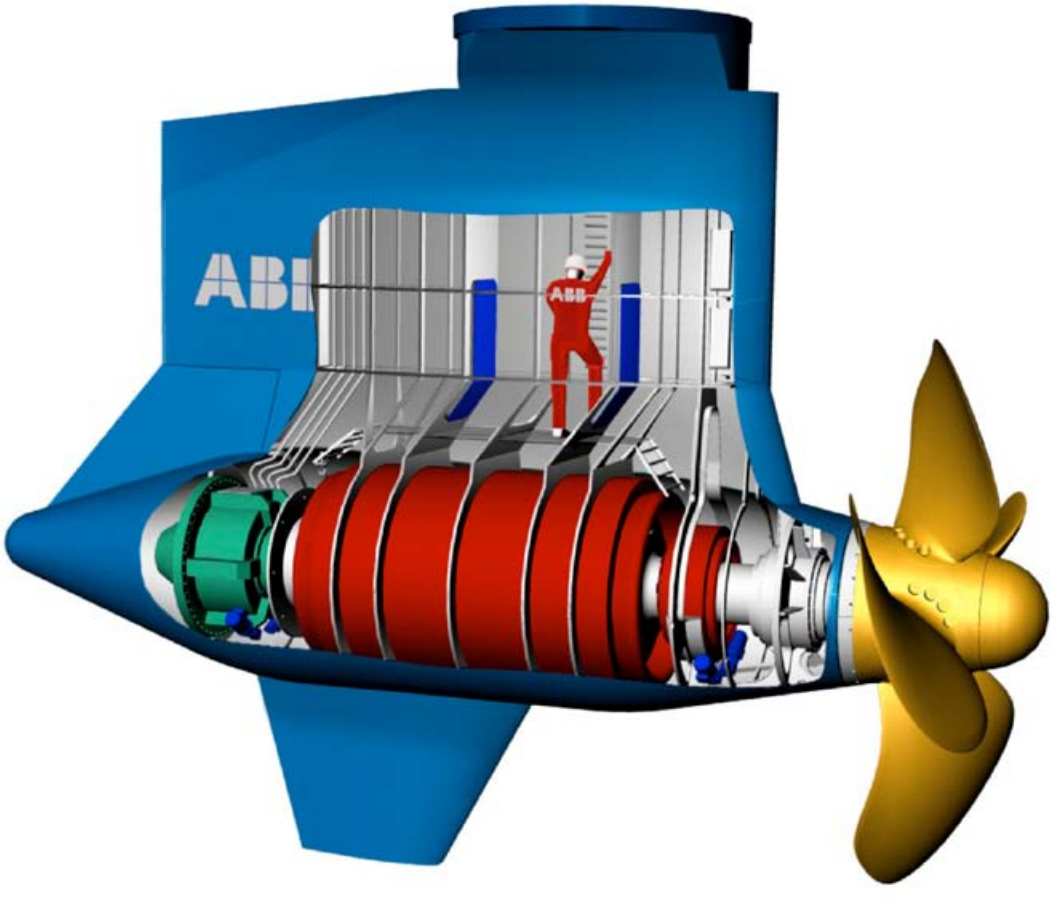
**OWNER TIP:**

You may benefit from the simplification of the equipment, i.e. spare parts stock reduction and lower competence / training requirements for the crew. You have a full platform ready for the energy monitoring and management solutions if you define the frequency converter and motor packages before the automation system. This type of installation also provides full information of each consumer to be available for other systems.

# 10 ABB propulsion solutions
## 10.1 Azipod® XO

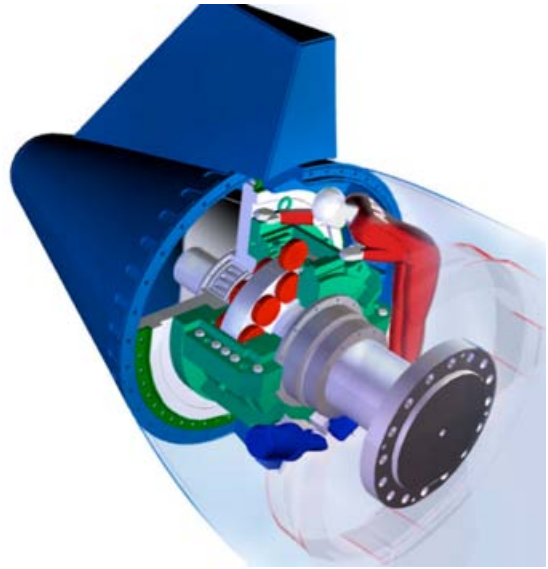
Currently, there are more than 60 passenger vessels equipped with Azipod® units in operation. Cumulative running hours for the total fleet is above 6 million.

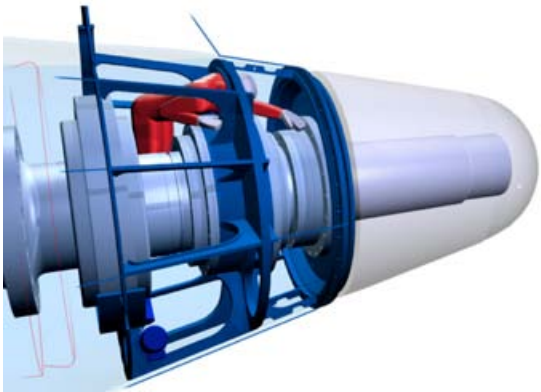
Our premium propulsion solution for the medium voltage propulsion system – the Azipod® propulsion – has been improved. The old open water VO generation has faced improvements in the total efficiency, maintainability of the unit and safety of the operation and work inside.

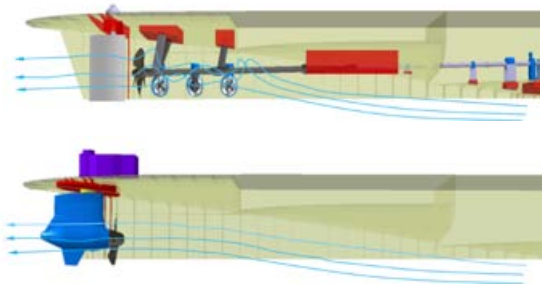


Special attention in the new-generation Azipod® has been paid on the reliability and efficiency, which have already been in a class of their own. The target has been to extend the docking interval and increase the maintainability from inside. The thrust pad and propeller seals can be changed from inside in models XO 2100 and above.

**Patent is pending for both items**







The unique efficiency of Azipod® units is based on the following characteristics:

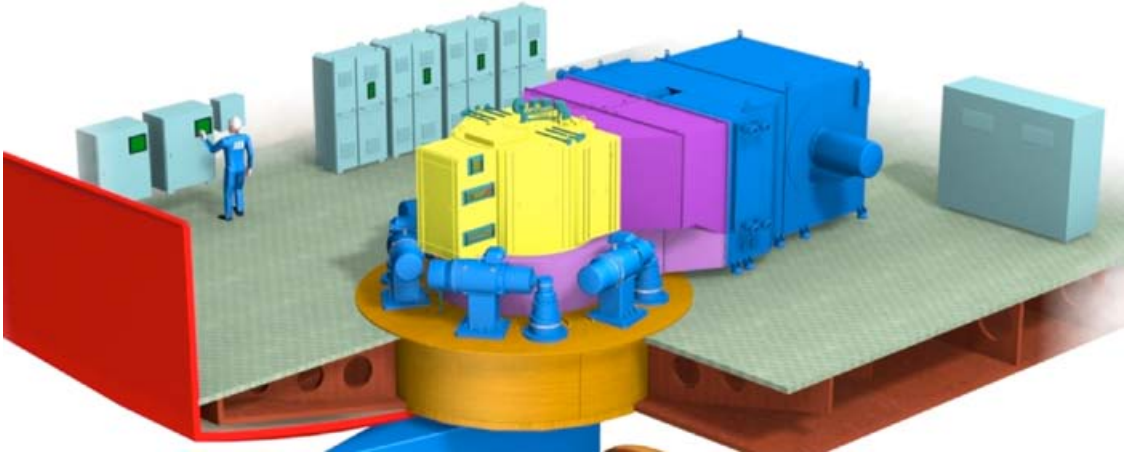
1. The pulling propeller eats from the homogenous field of water. The propeller is therefore loaded equally and there are no disturbing and resisting components in front of the propeller. Also the wake field behind the propeller is close to optimal.

2. The propeller positioning is optimized to the hull shape. In this aspect, the hull form of an Azipod® vessel differs from the shaftline hull, since this optimal positioning of the propeller allows more hull optimization based on the hydrodynamic evaluation. The propeller positioning and the hull form are designed together with the shipyard or design offices. The Azipod® projects are always evaluated case-by-case for the best final result.

3. The propulsion motor is a synchronous motor which meets the requirements of the ship's propulsion motor in large passenger vessels.

4. The propulsion drive is a voltage source inverter, which brings in the unique level of efficiency on the system level and combines with the ship-level requirements of the total vessel energy management.

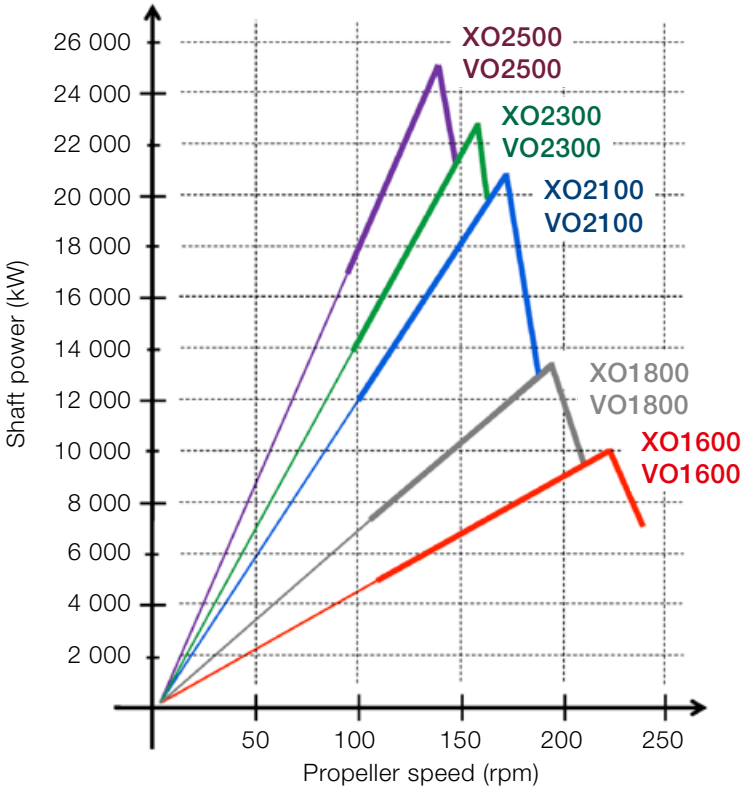
For a project with ABB Azipod®, contact us for the assistance and information or visit our website for more information.



The steering system in the new design is electrical. This eases the yard work by leaving out the piping and flushing, and increases the comfort onboard.

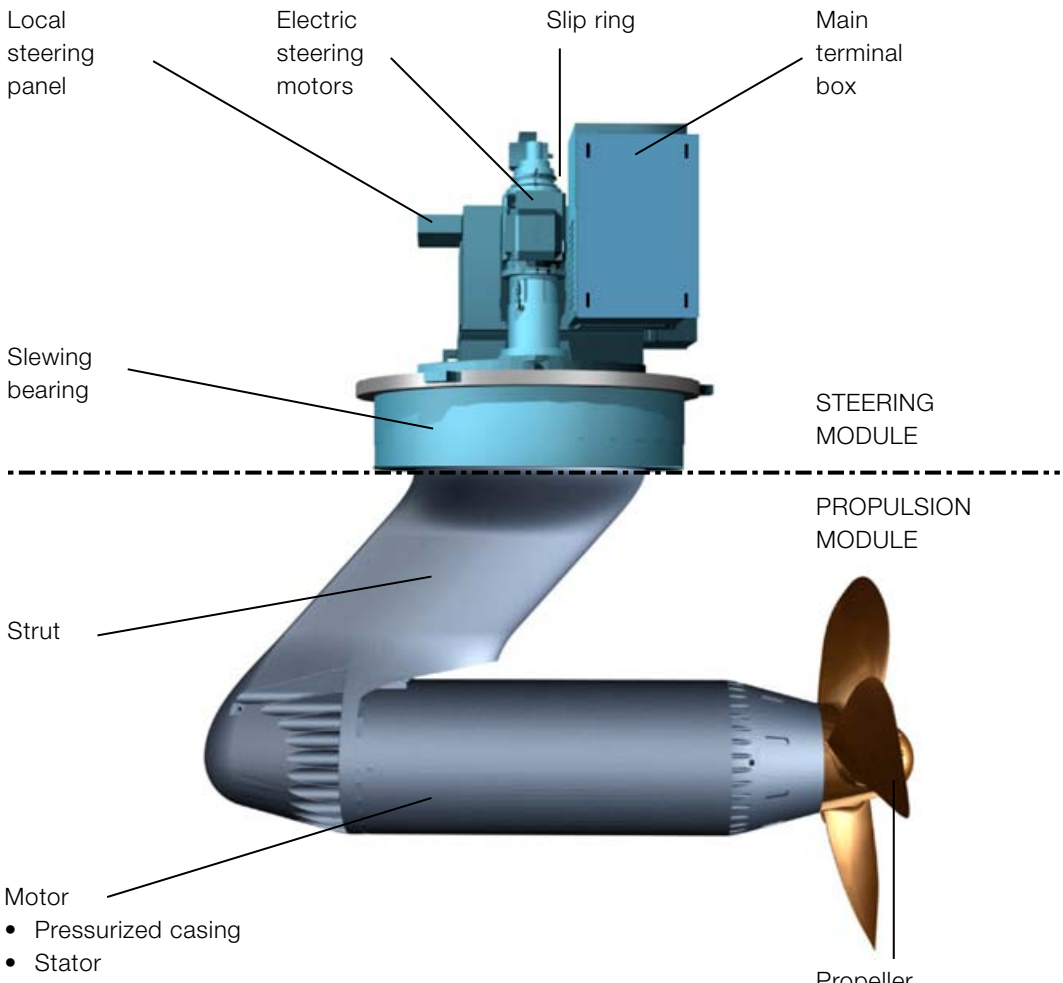
The efficiency of the Azipod® is on a unique level. Compared to a similar shaftline vessel, the ship's resistance is 10 percent lower in the design optimized for Azipod®. The unique hydrodynamic efficiency is finalized with the top-performance technical solutions inside the vessel and Azipod® unit – the synchronous motor controlled by modern drive technology.

**Azipod® XO family ranges with main rating.**



# 10.2 Azipod® CO

The efficient low voltage permanent magnet synchronous motor is cooled directly to the sea. Additional cooling arrangements are not needed. On the power range of 1300 – 4500 kW, the Azipod® CO is the easiest and most efficient propulsion selection for small and medium size passenger vessels that are operated below the speed of 21 knots.




- Pressurized casing
- Stator
- Rotor and shaft
- Thrust bearing
- Propeller bearing
- Shaft seals
- Maintenance brake

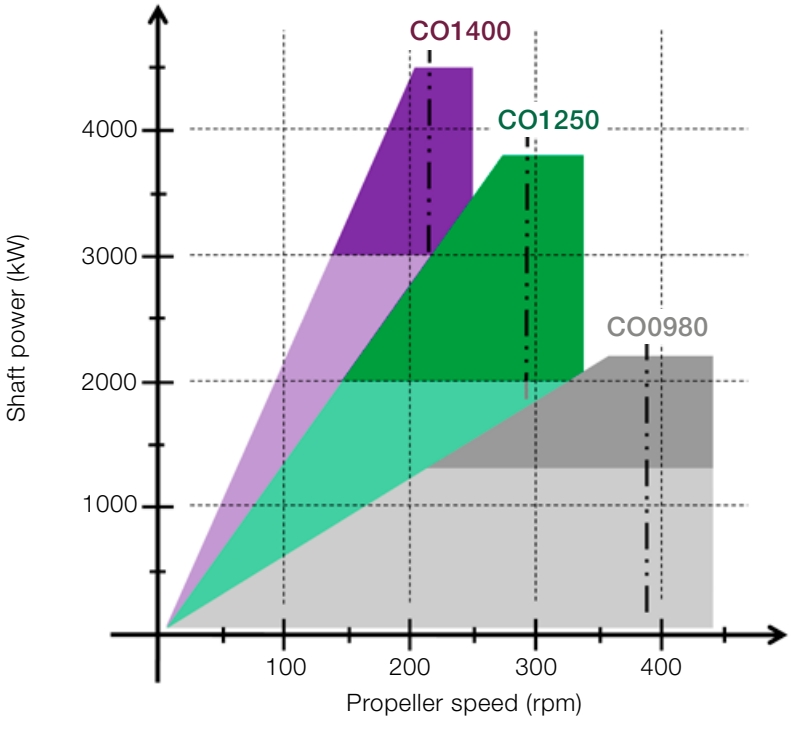
The standardized manner of production and simplicity of the installation allow the pulling propeller to be located optimally. This results in the best efficiency of the unit.

The installation work is easy and alignment work at the yard is not needed. Azipod® CO is delivered in two modules which are bolt-connected to the hull. The propeller is designed for each project individually to meet the hull form requirements.

For a project with ABB Azipod® CO, contact us for the assistance and information or visit our website for more information.

**SOLUTION TIP**

Since the low voltage power plant limitations are higher now than in the past years, it is possible to design a propulsion system with three or four Azipod® CO units without a medium voltage power plant and utilize the propulsion chain without a transformer. Consult ABB Marine for more information.



# 10.3 Azipod® XO as CRP

The Contra Rotating Propulsion (CRP) principle is a very efficient way to place an additional propeller behind the main propeller and gain hydrodynamic benefits from this arrangement. The main propeller is either diesel-mechanical or diesel-electrical.

In the ‘sea-highway’ type of operational profile, this arrangement has proven to bring energy savings in a scale which does not have a comparison.

The propellers are designed as a pair and therefore each project is always of individual design.

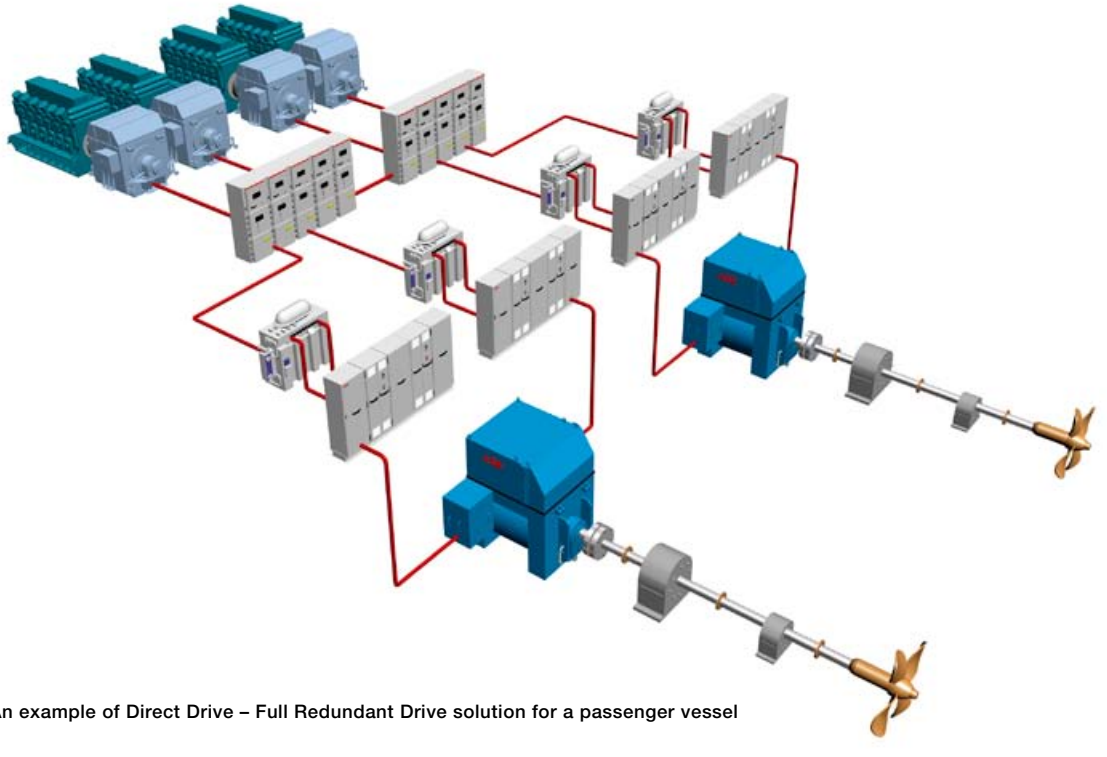
For a project with ABB Azipod® CRP, contact us for the assistance and information or visit our website for more information.

# 10.4 Direct Drive

## After introducing revolutionary improvements in the new Azipod® XO propulsion, ABB Marine has now revolutionized the industry standards in shaftline design.

We realized that there was too much useless and complex information about electric propulsion around. We decided to return back to basics and developed a propulsion family for traditional shaftlines. The Direct Drive family offers all the needed design information already presented in this guidebook. We wanted to keep it simple, and think that we succeeded.

**What is ABB Direct Drive?**
ABB Direct Drive means electric propulsion solutions in which an electric motor rotates the propeller shaft directly without any reduction gears. Since ABB is an expert on electric propulsion, we have integrated our core products under the umbrella of Direct Drive. Direct Drive solutions consist of motors, frequency converters, transformers and propulsion control. Instead of specifying each item separately, the only thing you need to know is the propeller point. We will guide you through the rest of the way.

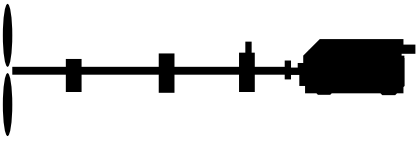


**An example of Direct Drive – Full Redundant Drive solution for a passenger vessel**

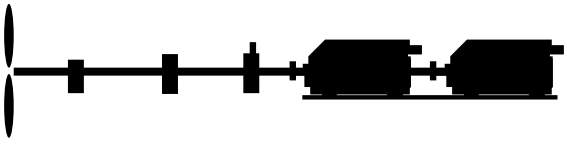
**Risk of wrong designs is minimized**
We realized that the best way to support our customers is to lower the level of complexity. Currently many iteration rounds are normally needed to find a best solution for a specific project. By providing ready-made solutions we minimize the risk of wrong designs involved in these iteration rounds. Direct Drive reduces the level of complexity by showing how changes are interconnected and what kind of outcomes can be expected.

Furthermore, several alternatives can be compared with each other to find the most suitable solution for each project. Until now such a comparison has been practically impossible to do, and endless changes and shifting preferences have made the suppliers to search for other business prospects.

Every ship owner, ship designer and shipyard needs continuity, predictability and reliability. Problems in their supply chains can cause them major problems and even put them out of business. Correct information is hence vital to keep the business on the right track.

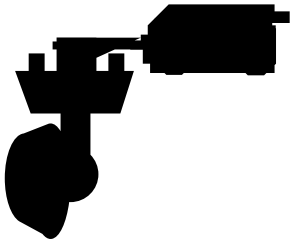


**Save your costs**
Fierce competition forces everyone to improve their processes in order to keep their customers loyal. One should also remember that several feasibility studies and confusion consumes time and resources. Every error is of course a lesson learned, but on the other hand, every error might give you a bad reputation. Imagine the savings potential that you could achieve with clear and transparent solutions! Gains in quality, safety and reliability are evident, and they enable you to push your costs down.



**Transparent solutions improve communication**
Exact information that is delivered early enough allows specification writing to be done in a transparent manner: the owner is familiar with the contents of the specification, the designer knows how to write the specification proposal and the shipyard, when receiving the specification, understands the expectations that the specification sets. All details are mutually understood throughout the ship building process.

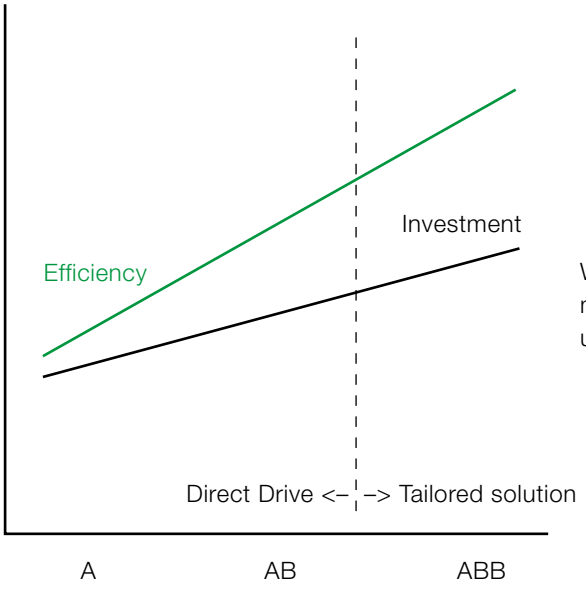
**Direct Drive promotes innovation and best practices**
Our innovation was not to invent something new. We studied our offering and customer requests and found out that we have good and proven products – why change? What we discovered was that we can be innovative with our existing products. As a result, we developed electric propulsion solutions that can be integrated into any vessel. In other words, the innovation is in changing the design process around; rather than waiting for customers to specify their propulsion systems, ABB will provide a catalog of ready-made solutions to choose from.



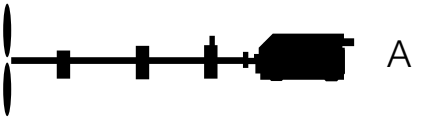
Two of the first principles were that our customers value different things and our solutions need to be customer-friendly. To meet these different needs, we designed three platforms. Within these three platforms there are different system alternatives, because one size does not fit all – neither does one system design. The rest we standardized with our expertise, and as a result set new standards for the industry.

**The dawn of your propulsion**

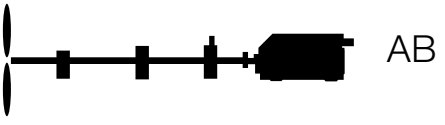
At a very early stage, an idea of a vessel has arisen. She is designed for a certain purpose. She will have a maximum service speed and draught. Then you need to start evaluating propulsion solutions. ABB is the leader in enabling customers to improve their performance while lowering the environmental impact. Three new categories were established for ABB solutions:



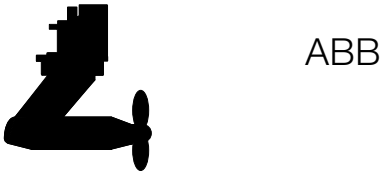

- **Category A** is a base level solution that comprises high quality products and good efficiency.




- **Category AB** provides superior efficiency achieved with a permanent magnet motor – especially with partial loads.




- **Category ABB** stands for Azipod®, which offers an outstanding efficiency level – there is nothing to compare it to.




We offer the widest portfolio of solutions in the market – something for every project. Contact us, and we will find the best solution for you.

### Benefits of Direct Drive

The Direct Drive family comprises three different product platforms that provide customer-friendly propulsion solutions. We have used our expertise to design the catalog of propulsion systems for shaftline vessels in a light and effective manner, but still leaving the door open for project-specific options as desired by the owner. The equipment – selected from proven products to minimize the technical risks – is pre-selected and 75% of the design is readymade at the stage of the offer:

- The propulsion drive and motor are pre-selected and designed, and the functionality of this pair is guaranteed.
- Equipment dimensions and weights are presented in this catalog, and dimensional drawings are available on the design CD.
- Technical specifications for the equipment are available at the stage of the offer.
- ABB Marine propulsion control system for passenger vessels is included in the design with all needed protection functions for the drive and the power plant.

### Propulsion selection

The most difficult decision comes early in the design process: what efficiency level and therefore technology selection is the most suitable one for the project? Is it better to rely on the industry standard and select an A-category solution (where available) or should you consider making an additional investment to improve the efficiency by selecting a permanent magnet motor or Azipod®? The more you invest, the more flexibility you get.

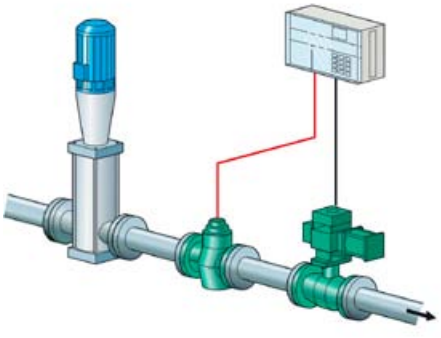
After this major decision things get simpler. If you have selected Direct Drive, you can find more information in chapters 12–15.

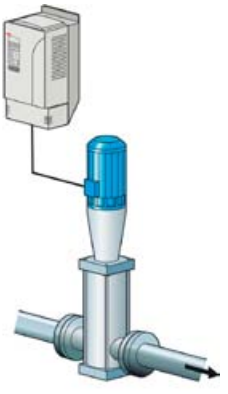
**SHIPYARD TIP:**

With ABB Direct Drive you will save in your design costs, lower the risks of wrong designs and minimize the technical risks involved in using new technologies. We have kept our design simple, which leaves you with more time to solve other demanding integration problems.

# 11 Energy saving solutions

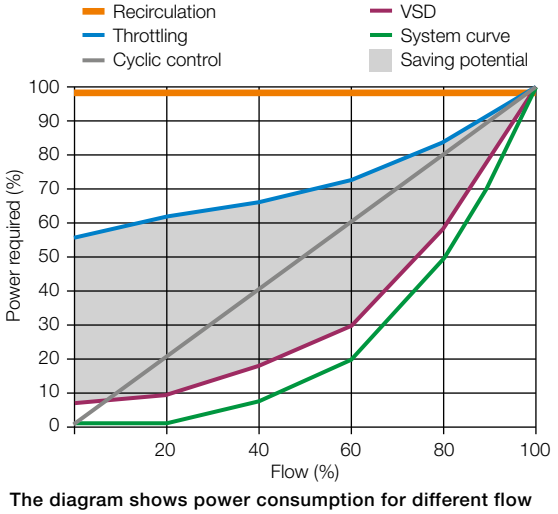
The simplest way to reach the controllability and high level of information monitoring is to use variable speed drives in the consumers' supply. This component replaces the starter or contactor unit in MCC (Motor Control Center) and provides the option to get rid of manual throttling.





The importance of such action becomes evident when it is recognized that 10% reduction in pump motor speed will reduce consumed power by 27%.

If we take as an example the sea water cooling pumping and evaluate it with a Voltage Source Drive (VSD, as utilized by ABB as a variable speed drive), the following results emerge:




**The diagram shows power consumption for different flow control methods. The grey area represents the energy savings generated by using a VSD instead of manual throttling.**

| **Application data** | |
|---|---|
| Seawater cooling pump | 90 kW |
| Electric motor power | 100 kW |

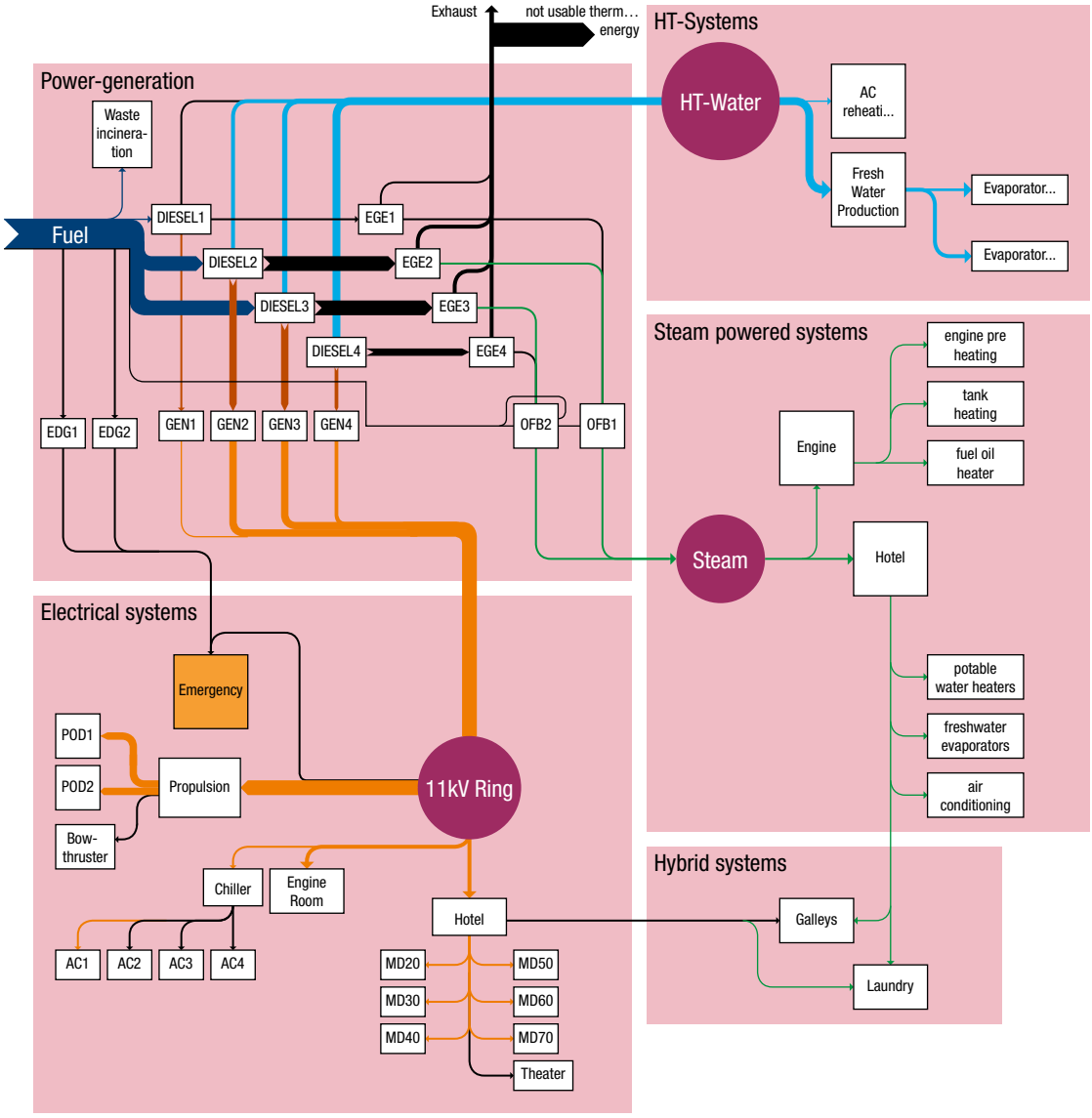
| **Operating profile** |
|---|
| 5300 hrs/year (40% of the time operating at 60–70% flow) |

| **Energy consumption** | |
|---|---|
| DOL with throttle | 426 MWh |
| VSD | 193 MWh |

| **Energy savings per year** |
|---|
| 233 MWh corresponding to ~29.000 USD |
| $CO_2$ reduction 117 ton |

Once the consumers are efficient and the process where they act is accordingly designed, further evaluation can be made if the energy efficiency battle may step on to the next level.

The next stage in the energy efficiency improvement work is to consider if there is room for energy management. When looking at the complex matrix of energy flows within a cruise vessel (presented below), most of the operators recognize the potential.



**The actions for energy management**

- Optimizing each onboard process in normal use. It is best to start from the easy ones and improve one at a time. Communicate the results to other vessels in the fleet and to the newbuilding team – and even the small saving multiplies.
- Creating possibilities for process-dedicated power limitations with certain time, interval and quantity. Power limitations may be used in case some other process will require temporarily more power than it normally does. In any case, if the possibility to run power limitations is in the system, the opportunity should be used to save energy. The main target is to save energy from the production but also to avoid the main engine from starting in every possible phase.
- Keep an eye on the different processes simultaneously and organize the consumption time-wise.
- If you have input data that assist you to make predictions, use it. If the prediction is not accurate, this result is also valuable and can lead into better understanding of the reliability of other predictions.
- Make the good operation manner an everyday practice. Educate and visualize the targets and benefits for the crew. When customer interface is simple, reaching target is easier.

**Now comes the time of self-evaluation.**

Did I write the technical specification properly? Am I now able to change the consumption according to my findings? Can I argument and present the required change in my organization? These are the issues that need to be understood while defining the system in the beginning. In the design phase there may be completely other drivers defining the targets of work.

The great feature of ABB's Energy Monitoring and Management system – ABB EMMA – is that it can be used also as a design verification tool at the shipyard's design office. When all three main parties in the shipbuilding process have a common interest, it makes the true improvement possible.

ABB EMMA is presented in the following chapter.

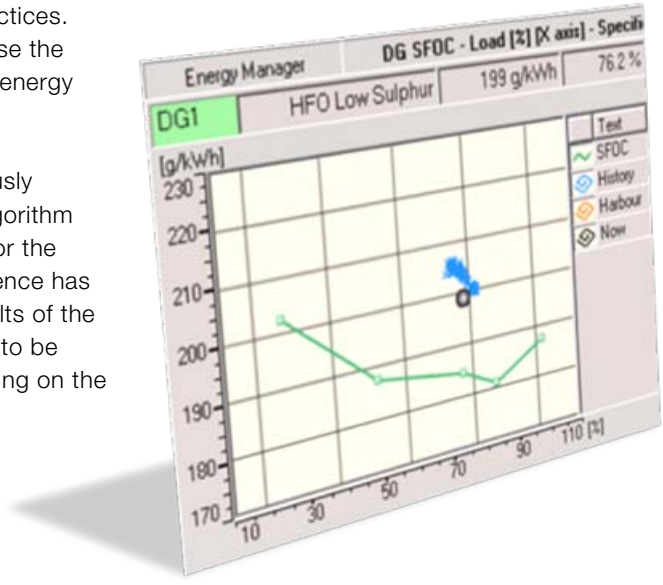
# 11.1 ABB EMMA®

After recognizing the complexity of energy production and consumption – often in many forms of energy – and the monitoring in the engine control room of a passenger vessel, the idea to build a suitable energy control interface was born. Understanding the huge potential offered by such an 'energy-playground' led the ABB Marine engineers to combine the onboard needs with an existing ABB product – the cpm Plus Energy Manager (program developed for land-based energy management needs). This resulted in the first full-scale Energy Monitoring and Management system, ABB EMMA®.

ABB EMMA® is an advisory system and solution platform for energy monitoring and management. It aims to reduce the fuel consumption to improve profitability and to cut the environmental footprint. By real-time monitoring of the operational and process data, EMMA guides in controlling and managing the energy balance onboard a vessel. By extensive reporting of the ship and fleet performance, it allows comparing, benchmarking and sharing the best practices. The ship's crew and management will use the tool with continuous support from ABB energy coaches.

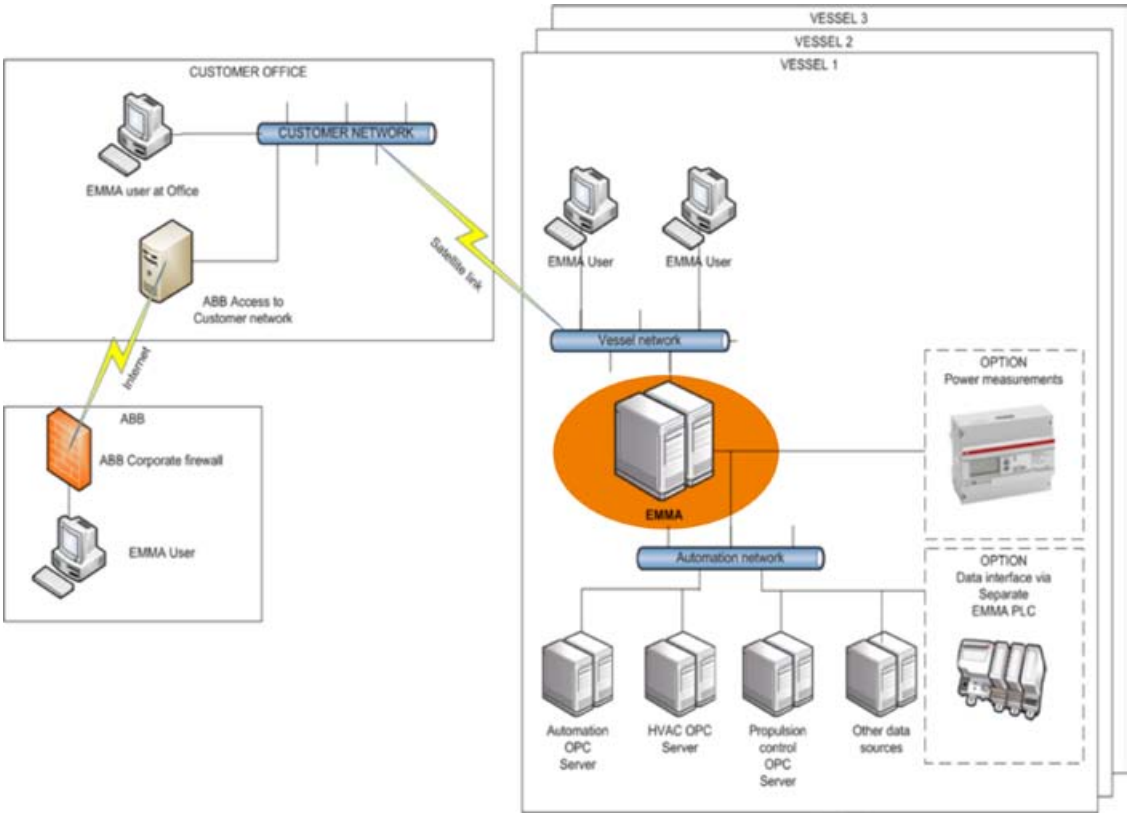
Being designed for multiple simultaneously optimizing calculations, the powerful algorithm in the ABB EMMA® computer is ready for the tasks required inside the vessel. Experience has shown that before the optimization results of the system are fully achievable, a lot needs to be done and agreed before actually switching on the optimizer.

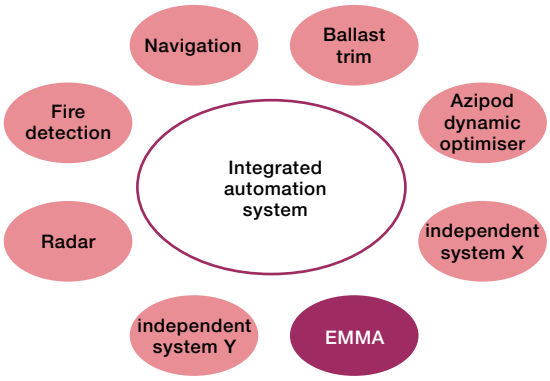
As a part of the vessel's information systems, ABB EMMA® can be placed within another system as an independent system, but it needs to be highlighted that functions – such as very powerful algorithm mathematics and data storage – require resources that may interfere the normal operation of the ship's automation system.



The installation of EMMA® includes practically a computer with optimization algorithm calculation, large data storage and simple interfaces, typically OPC connections, to the information source(s). Information can be collected not only from the ship's automation system, but also from the propulsion diagnostics system, power measurements devices, frequency converters, weather system or other sources of detailed information. In this respect, the more information – the better ground for analysis.

**Arrangement of the ABB EMMA® system with a remote interface in the office**



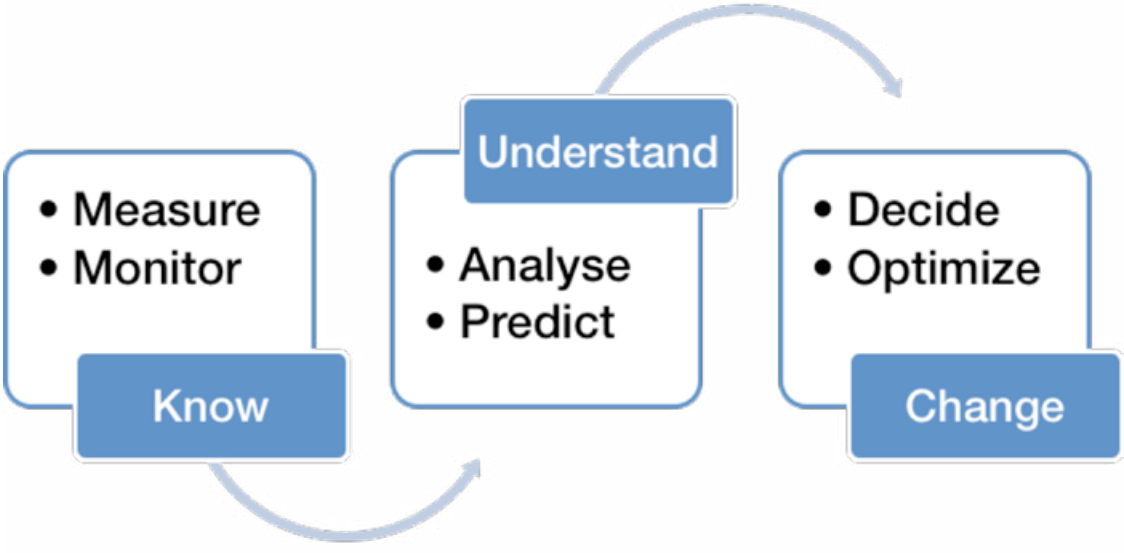



Regardless of whether the vessel is in operation or a new building project, the measurement and monitoring function needs to be organized first. In this sense, ABB EMMA® is quite practical. As soon as the system is connected to the information source, typically the integrated automation system and/or propulsion system diagnostics system, the information is available for the users. Data can be stored and used later on, but it is important to start collecting information as early as possible.

The collected information and measurement data lead to immediate results, such as:

- Recognition of energy consumption flows
- Recognition of obvious parameters that affect the energy flows
- Recognition of the sufficiency of the measurement points
- Simultaneousness of the consumer loads and possibility to manage loads time-wise to reduce the simultaneousness
- Verification of the operation manners and possible operational improvements
- Key performance indicators for each level of profession can be employed
- Consumers that are “energy-gluttons”, consuming more than expected, can be detected and modifications targeted precisely

**The learning path for energy efficiency should patiently follow the principle as presented below:**



- The recording and analysis of simultaneous phenomena can be used for further studies
- The results of completed optimization work can be measured
- Energy reporting can be established
- Design verification process can be started and immediately found design mistakes can be corrected. The sooner the improvements can be made, the longer the time period when savings can be made.

### TIP FOR SHIP BUILDING

The yard can benefit from the ABB EMMA® system by installing it in the beginning of the commissioning period. The system can be monitored remotely from the office. The commissioning development can be recorded, start-up processes recorded (for example commissioning phase energy consumption) and improved, the design selections can be verified. In the end, the vessel energy efficiency can be benchmarked. ABB EMMA® system may be included in the contract between the yard and the owner and the system remains in the vessel after the handover. In case any section of the energy map is poorly monitored, it can be improved during the commissioning phase.

### TIP FOR THE SHIP MANAGEMENT COMPANY

Once the vessel is equipped with ABB EMMA® system, the ship management contract may include re-compensation clauses for the measured energy savings and a recording period for the delivered vessel. Vessel performance – as it is at the moment of delivery – sets the reference level. The recorded savings are contractually defined and beneficial to both parties.

Once the measurement period is long enough for understanding the onboard processes on a level where the process control or tuning actions can be started and results from the made actions are readable, the short term benefits start to build up:

- Onboard process optimization – one process at a time – by means of setting iteration brings savings to each process
- Hidden simultaneous loadings can be organized
- PMS and automation settings can be retuned for better energy efficiency (to be in line with the operational needs)
- Optimization simulations and evaluations may be started
- In case the vessel is running the voyage optimization program, the prediction verification can be made
- Key performance indicators (KPI's) can be modified, improved and changed. New KPI's can be established according to the gained information. KPI's should be rewarding and built in the manner which leads to development in the energy savings, not to a controlling punishment.

Finally, on the stage of understanding the on-board processes and the use of the imported data, the optimization work aiming for the whole lifetime of the vessel can be started.

- On top of the single-process optimization, the short term power limitation for each controllable consumer can be sought and energy savings from these limitations can be gained. Each consumer with a possibility to power limit with sequence and length can be combined with other users and their individual limitation profiles, and power buffer – with online profile – can be formed. This power buffer can be use as a power saving directly or in the long term and used as a part of the optimization inputs for the optimized loading of main engines.
- Voyage planning optimization together with the propulsion system losses model can be inserted as input information of prediction for the optimization algorithm. Active online optimization can be established.
- Different forms of energy – such as steam production – can be introduced to the energy consumption optimization as input parameters.

In the optimization phase, the energy efficiency improvement process faces practical questions: How to control the consumers? How to manage the energy consumption?

As described, the controllability of the load is the key. Practical controlling is most easily performed via the automation system. For this purpose, ABB recommends a common signal interface to be used between the consumer drives and automation system, which allows an external control for the consumer rpm or at least a temporary power limitation. Optionally the EMMA® system may control the selected consumers directly.

## Easy energy management results? Certainly.

# 11.2 High voltage shore connection

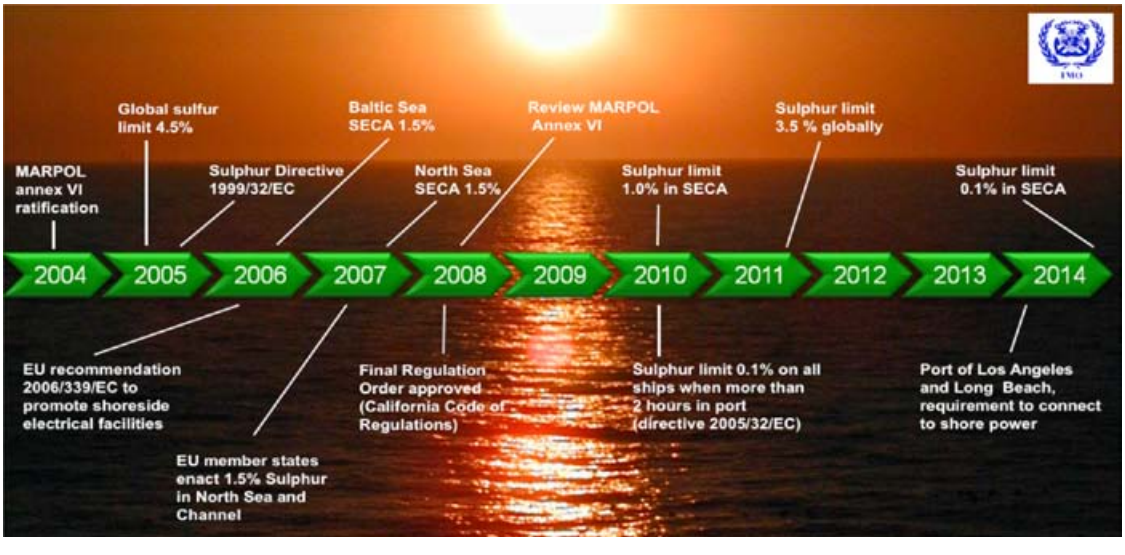
The interest on the shore connection systems has increased by a focus shift into the local air quality in the ports and port areas, as well as environmental regulations. Because the electricity providers and vessel operators have had challenges to find commercial opportunities to use the shore connection, the regulatory enforcement will continue to take place in many harbors around the world, which will create practises and price levels for the industry to follow.

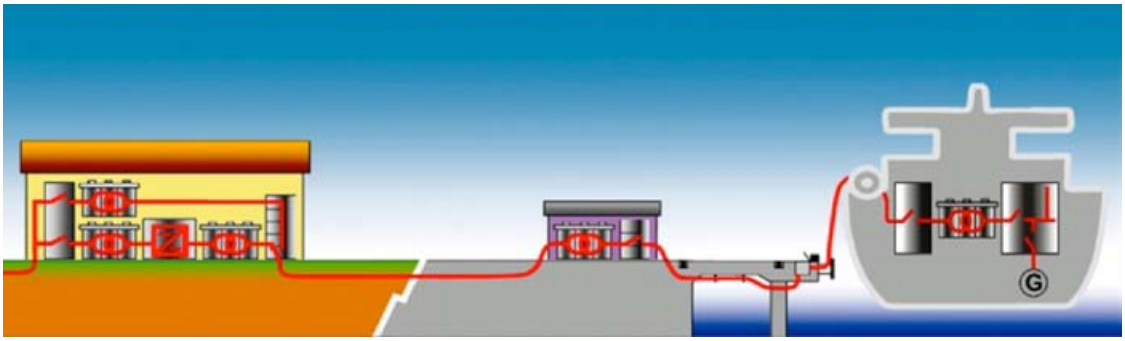
The auxiliary engines of ships that run in ports, produce $SO_X$, $NO_X$, $CO_2$ and particle discharge as well as noise and vibration. These pollutants have negative health and environmental impact on the surrounding communities.

**The existing environmental regulations include the following limitations for vessels:**

- MARPOL 73/78 Annex VI places limits on sulfur oxide and nitrogen oxide emissions from ship exhaust and prohibits deliberate emissions of ozone-depleting substances
- EU Directive 2005/33/EC limits the amount of sulfur to 0.1% in all marine fuel used while at berth for more than two hours in European ports
- Increasing local guidance needs to be noted (very dependent on the port)

ABB has developed a High Voltage Shore Connection which complies with the international standards





After years of participation in the IEC committee and effective technical guidance work within the work group, ABB is one of first companies in the market to supply a high voltage shore connection which complies with the international rules. This is very important due to the nature of shipping industry, in which the other party of the connection is in constant move.

**International regulation requirements for the system are:**

- High Voltage Shore Connection (HVSC) by IEC, ISO and IEEE
- IEC 60092-510 edition1 IEC/ISO PAS (release 2009, pre-standard), the final standard expected during 2011.

**What is the shore-to-ship power supply?**

- Ships can shut down their engines while berthed and plug in to an onshore power source.
- The ship's power load is transferred to the shore side power supply without disruption to the onboard services.
- Emissions to the local surroundings are eliminated.

Shore Connection is also known as Cold Ironing, On Shore Power Supply, Alternative Maritime Power supply (AMP), etc.

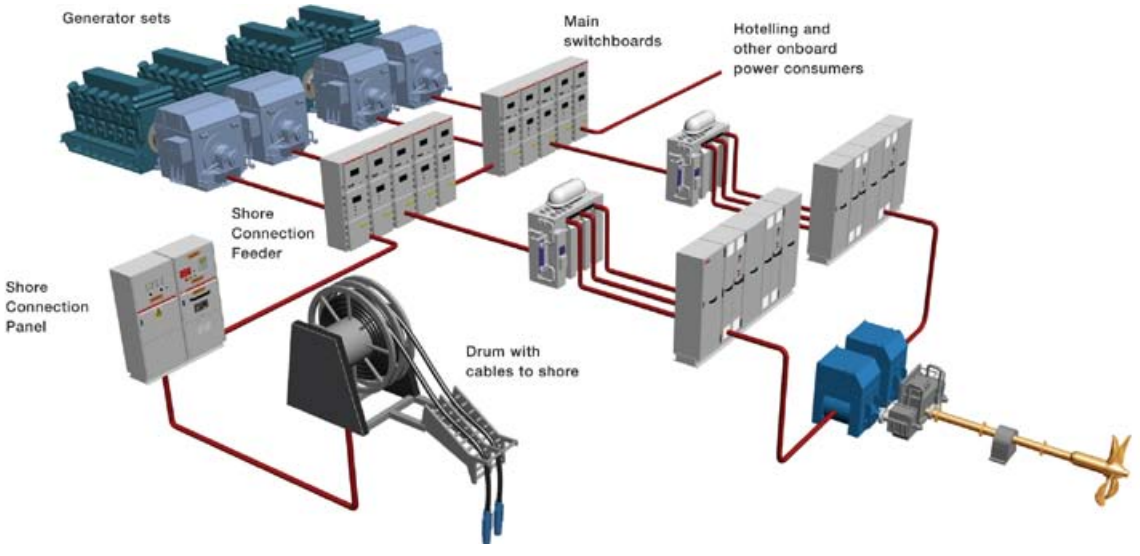
**DESIGNER TIP:**

The challenge of understanding the various technical solutions and comparing them makes – without a doubt – the ship owners' life complicated. Therefore it is highly recommended to compare only systems that can be fully integrated into one coherent solution. This way, the functionality of the installation can be verified and guaranteed. The challenging part for the manufacturer is to provide synchronization between the vessel and shore side so that they function without negative reflections on either networks.

**The complete onboard system solution from ABB includes:**

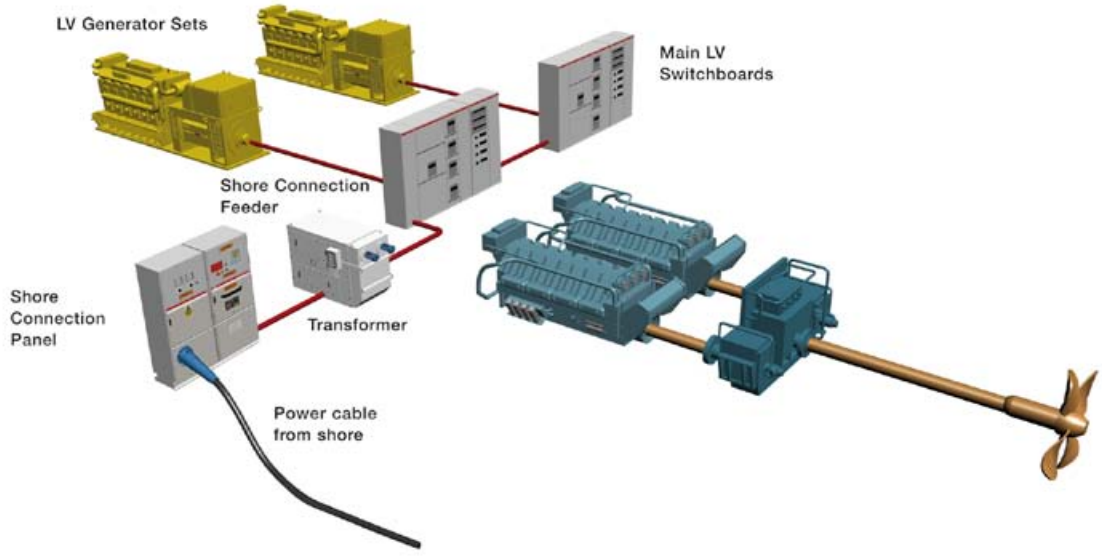
- All power equipment necessary to connect the ship to a shore side power point, including the cable management system
- All control equipment necessary to secure the seamless automated power transfer of the ship load from the onboard power plant to the shore side source and back
- Turn-key delivery including project management, engineering, installation, commissioning, testing and training

**Installation example 1: Ship with diesel-electric propulsion**




The Shore Connection system is configured with the Shore Connection Panel located outside the main switchboard room. An onboard cable drum lowers the cable down to the quay for onshore termination.

**Installation example 2: Ship with diesel machinery and a low voltage electric system.**




The Shore Connection Panel is located outside the main switchboard room with cable connectors mounted on the front. An onboard transformer steps down the power from high to low voltage.

The main onboard equipment is the Shore Connection Panel, which is a finished cabinet solution with a both power module and control module. This unit handles the synchronization and load transfer to the shore power. It may be supplied with cable connectors located in the front or with openings for cable entry through the cabinet floor. It provides the fully automated power transfer synchronization of the two power sources. The load transfer functions are controlled in the Shore Connection control system inside the control section of the unit.

The main functions required from the shore connection system are:

- Smooth, seamless load transfer
- Interface to the vessel's PMS and to the shore
- Two operation modes:
  - Remote auto mode: The Shore Connection breaker is controlled by IAS/PMS
  - Local auto mode: The Shore Connection breaker is controlled from the front of the Shore Connection Panel

Depending on the design of the vessel, ABB Marine Services can install and commission a complete Shore Connection system as a turn-key project during the operation of the vessel with minimal interruption to services.

**OWNER'S CHECKLIST:**

- Get enough information about the port side arrangement
- Agree on the responsibilities between the port and the vessel
- Reserve enough space for the shore connection equipment or make a cabinet available in the main switchboard of the vessel
- Determine and confirm the interface to the vessel's PMS
- Define the personnel safety requirements for the company and the installation
- Map the energy consumption reduction possibilities while connected to the external supply

# 11.3 Onboard DC grid

ABB delivers motors and drives from the smallest to the largest ones in propulsion systems. The logical next step is to simplify and improve the power plant of the vessel. This solution is designed for all types of vessels with a low voltage power plant.

The most advanced solution so far was introduced by ABB Marine in May 2011. This evolutionary phase of the power plant and distribution platform is based on the principles of the Onboard DC Grid. On the first stage, the platform is available for power plants of < 20 MW of total installed power.

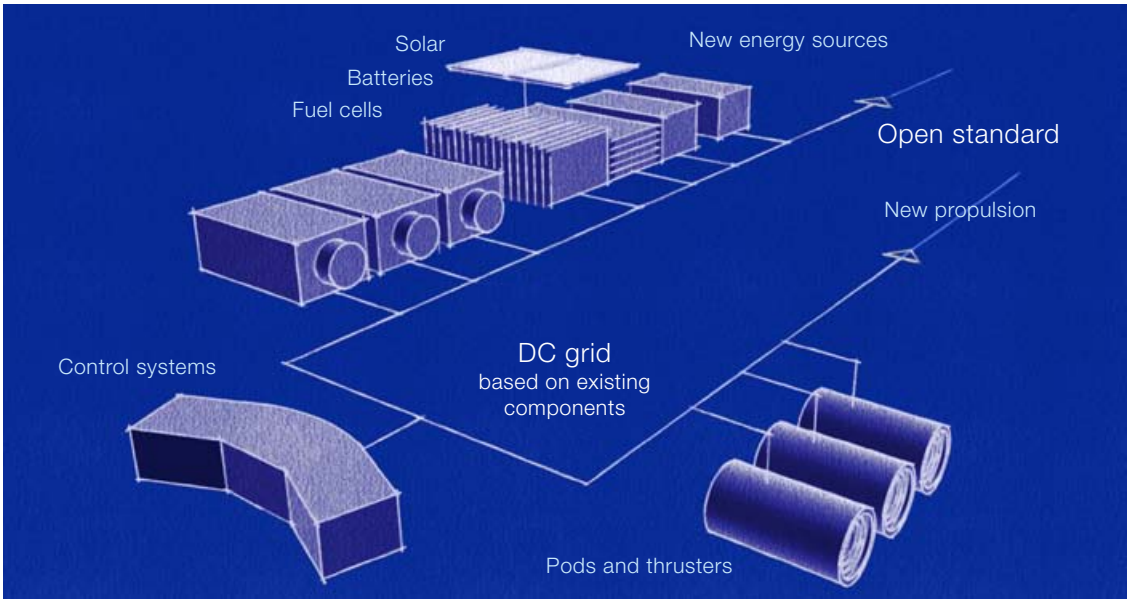
In the Onboard DC Grid, each power source – typically a diesel-driven generator – is connected to the DC distribution network via semiconductor bridges. This network principle allows the power source to be driven at any design speed with a very high power factor. Another benefit, that can be gained from this system is that when

**Simplified one-line presentation of the Onboard DC Grid. The main switchboards are removed from the configuration. Cabling is replaced by DC-bus.**

not following constant speed and frequency, the influence of load variation on the engine-specific fuel oil consumption (SFOC) can be optimized by adjusting speed as the function of the load. The gained efficiency improvement is dependent on the main engine, but in most cases it is many percentages.

The DC Grid solution is a response to the requests of using alternative power sources onboard. The system can also take in other forms of energy sources and connect then in parallel to the traditional sources in the network. The system-level energy storage is also a possible component in the DC Grid design. The platform itself is ready for the future.

When each power source supplies the network independently, the need for the main switchboard disappears. The needed hotel/auxiliary network is generated via an island-mode converter that is also connected to the DC Grid. The distribution system allows the segregated spread of the equipment and makes the 'local supply for local need' principle possible in the electricity network. The gained reduction in the footprint and additional flexibility in the equipment layout are remarkably better than in the traditional electrical installation.


Solar
Batteries
Fuel cells
New energy sources
Open standard
New propulsion
Control systems
DC grid
based on existing
components
Pods and thrusters

# 12 Direct Drive family

## ABB Direct Drive stands for ready-made solutions that drive a propeller with a variable speed drive.

The Direct Drive family is designed to meet the latest IEC standards and it is in compliance with the main classification societies. It covers a wide speed and power range and comprises inbuilt system options.

The fundamental idea behind the Direct Drive family is to introduce integrated propulsion solutions that can be fitted into various vessel types without any compatibility restrictions. The best designs have been worked out based on ABB's experience and know-how in order to standardize design and eliminate unnecessary complexity. As a result, ABB promotes best practices and sets new standards. We have recognized that our customers need continuity, predictability and reliability. The biggest risks in the shipbuilding industry are in missing deadlines – either a shipbuilder missing a launch or a ship owner missing a port call. With the Direct Drive family ABB minimizes the costs caused by wrong designs and provides essential information faster and earlier. This enables gains in quality, safety and reliability. By utilizing the existing technology, technical risks are minimized.

However, we realize that no two customer projects or implementations are exactly the same, and therefore each project will have unique components, sensors and signals that are likewise handled by the ABB project execution.

**Direct Drive family – a guide to choosing your system**

The Direct Drive family was created as a transparent basis of comparison that provides necessary information for anyone who is involved in the ship design or comparing different concepts.

The Direct Drive type code consists of four identifiers. These are:

- Platform
- System
- Size
- Drive Steps

**SHIP OWNER TIP:**

It has been noted that the design of an optimal electric motor and an optimal propeller are in contradiction; an optimal electric motor calls for high speed resulting in smaller torque, while an optimal propeller would be a low-speed propeller with a large diameter resulting in a high level of torque. ABB's wide speed and power range enables the whole propulsion chain to be optimized to produce the best possible performance. The transparency of ABB solutions improves the continuity, predictability and reliability of your business.

# 12.1 Platforms

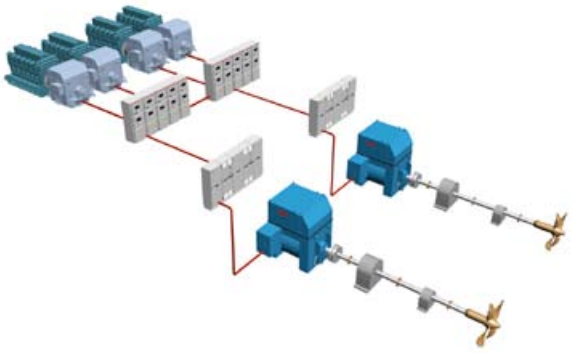
## The platforms in the Direct Drive family are:

- Direct Drive
- Direct Drive Permanent Magnet
- High Speed Drive

**Direct Drive** is the main platform of the Direct Drive family. Direct Drive comprises the widest power range with compact or redundant shaftline propulsion solutions. Base level solutions offer high quality products and provide good efficiency. The performance and efficiency are aligned with other manufacturers.

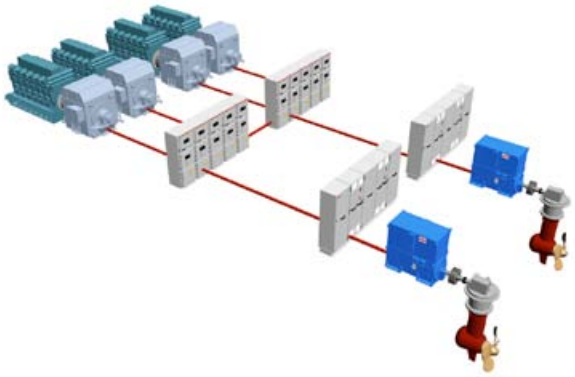
**Direct Drive Permanent Magnet** is an enhancement to the base level solution. The permanent magnet motor provides superior efficiency – especially with partial loads – and keeps the life cycle costs low.

**Direct Drive and Direct Drive Permanent Magnet**



**High Speed Drive** is a platform with mechanical thrusters. While the ship operator achieves better maneuverability, ABB can apply a shaftline approach and keep the same proven design and robust functionality as in the two other platforms.

**High Speed Drive**



# 12.2 Systems

The system selection comprises a set of alternatives to meet versatile needs. Throughout the whole power range, a simple system and a more sophisticated system are available. A simple system is always more cost-efficient, while a more sophisticated system has other advantages.

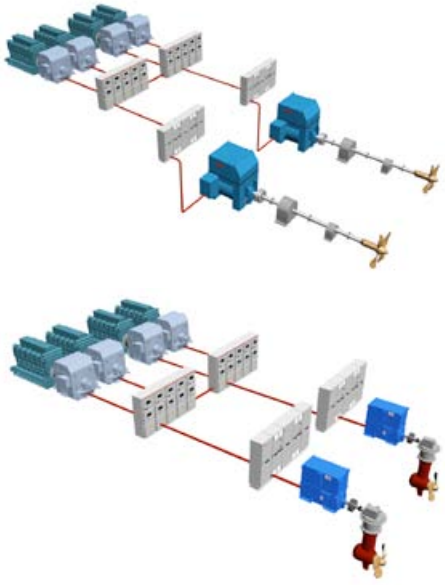
There are six systems available. The fundamental idea was to recognize the versatile needs of various projects and offer distinctive systems that satisfy those needs. Within these six systems, we can offer ready-made solutions that can be ranked and compared according to performance, efficiency, footprint, volume, weight or price – whichever you value the most.

| | Single Drive | Single Drive (AFE) | Single Drive (with transformer) | Tandem Drive | Single Drive (twin in/out) | Full Redundant Drive |
|---|---|---|---|---|---|---|
| Direct Drive | X | X | X | X | X | X |
| Direct Drive Permanent Magnet | X | X | X | X | | |
| High Speed Drive | X | X | X | | | |

**Single Drive** is the simplest and most cost-efficient system. It comprises a motor, frequency converter, propulsion control and harmonic filter. Single Drives up to 5 MW are low voltage versions. Induction and synchronous motor types are used.

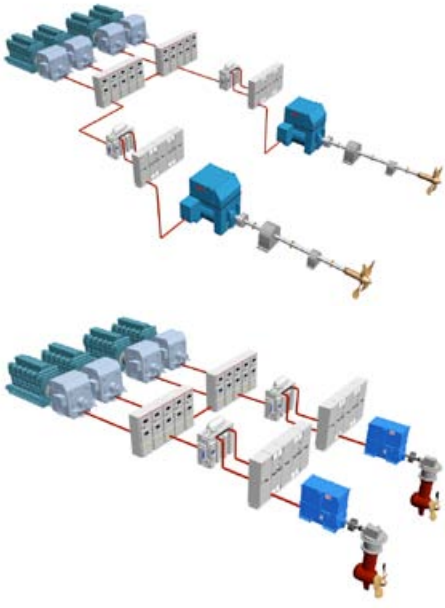
**Single Drive (AFE)** is equipped with active-front-end frequency converters that can regenerate into the network. Thanks to the regeneration, a separate braking resistor is not needed. Single Drive (AFE) is available for induction motors with up to 5 MW of shaft power. Other parts of the system are as in Single Drive.

**Single Drive and Single Drive (AFE) solutions**



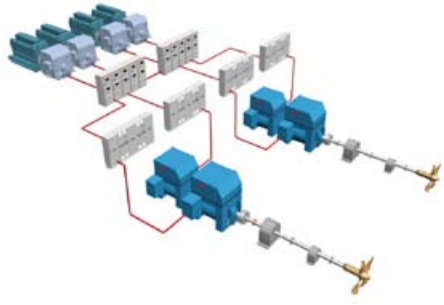
**Single Drive (with Transformer)** is the first one of systems that incorporate a transformer. Thanks to the transformer, this system has the widest coverage, from 0.8 MW up to 11.5 MW. The system can be integrated into various power plant voltages. Furthermore, the transformer eliminates the need for harmonic filters. Induction and synchronous motor types are used.

**Single Drive (with Transformer) solutions**



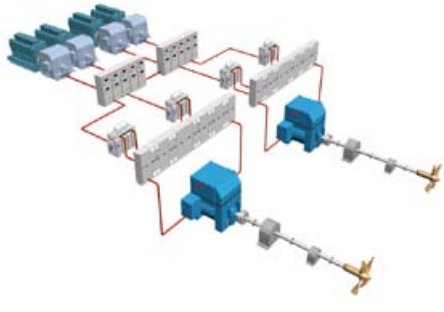
**Tandem Drive** is a retro design making its way back to the centre of attention. Tandem induction motors rotate a single shaft and provide essential redundancy for the most demanding operations. Two frequency converters will guarantee that a failure will not render the shaft inoperative. The tandem configuration allows the deck height to be lowered, which brings flexibility to projects with critical height restrictions. Tandem Drive is a low voltage solution and can be operated without a certified electrician onboard. Tandem Drives are available from 3.0 MW to 9.6 MW.

**Tandem Drive**



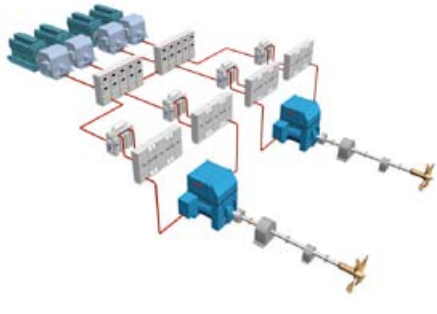
**Single Drive (twin in/out)** is a twin channel solution for high powers; the frequency converter has a twin supply and it is installed in one lineup. The synchronous motor has two stators. Each channel provides 50% of the propulsion energy. Single Drive (twin in/out) has two transformers that both deliver 50% of the power. Two transformers can be more easily accommodated onboard a vessel instead of one large transformer.

**Single Drive (twin in/out) solutions**



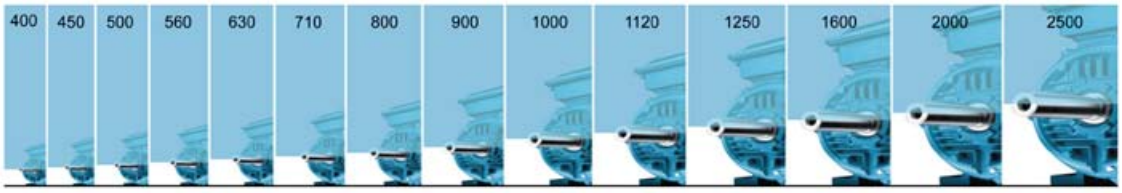
**Full Redundant Drive** is the most sophisticated system providing redundancy for high powers. Redundancy is an insurance against failures; there is enough redundancy to keep the propeller rotating even in the worst case scenario. The system has a synchronous motor with two stators, two frequency converters, two transformers and two excitation transformers. Shaft powers up to 20 MW can be achieved.

**Full Redundant solutions**

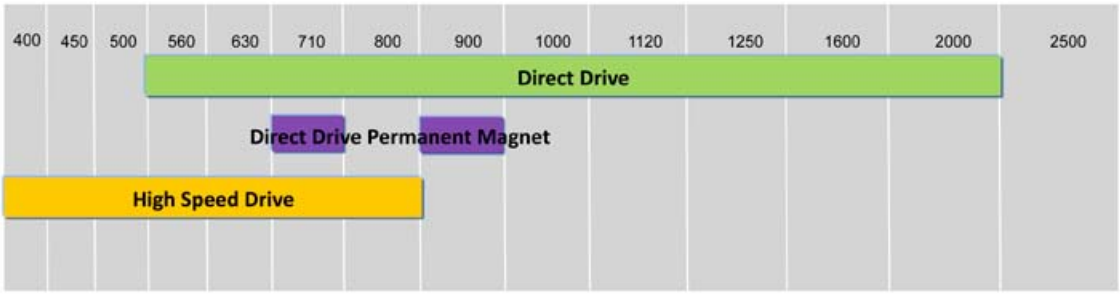


# 12.3 Sizes and drive steps

ABB propulsion motor frame sizes 400 – 2500 (approx. Equal to shaft height)




Availability of Direct Drive platforms




**Sizes**

The Direct Drive size refers to the shaft height of the motor, for example, 560 means 560 mm shaft height.

**Drive steps**

Within sizes, drive steps reflect changes in power that take place when the propeller speed increases. The different drive steps are:

- S
- M
- L
- X
- Y
- Z

# 12.4 Main components

All main components are designed to withstand extreme electrical and mechanical stress caused by marine operation. Compatibility is ensured by ABB engineering. The motor, frequency converter and propulsion control are always included in the scope of the delivery. The braking resistor, transformer, excitation transformer and harmonic filters are case dependent. The Remote Control System and Uninterrupted Power Supply are optional. The number of the main components depends on the selected system.

The motor meets the requirements specified in IEC 60034 and IEC 60092. The motor is fully enclosed and contains an air-to-water cooling unit. Sufficient cooling is ensured in all load and speed conditions.

The frequency converter utilizes a DTC (Direct Torque Control) method, which guarantees minimum torque ripple and results in the minimum wear of the machinery. The diode front end is a standard rectifier, but an active front end is also available as a system of its own.

The propulsion control is an integral part of the frequency converter and it ensures a safe voyage in all operation conditions. Drive Control Unit (DCU) is a coordinated control system with propulsion functionality and protection. Propulsion Control Unit (PCU) is more a sophisticated and independent control system that allows more customization.

The braking resistor is used to absorb regenerative power.

The transformer is needed to transform the main voltage to appropriate levels for the frequency converter. Transformers contain an air-to-water cooling unit due to high power ratings.

The excitation transformer is utilized with synchronous motors. Excitation transformers are air-cooled due to low power ratings.

Harmonic filters are sometimes needed to filter harmonic distortion in the network.

The Remote Control System (RCS) comprises a human-to-machine interface for controlling the propulsion from the bridge.

The Uninterrupted Power Supply (UPS) keeps the propulsion control systems running in case of interruptions in the mains connection.

# 12.5 Selection process

## With these four simple selections you will find out what is the most cost-effective propulsion solution for your needs.

The selection process is straightforward and consists of four steps after the **propeller speed** and **power** are either known or estimated:

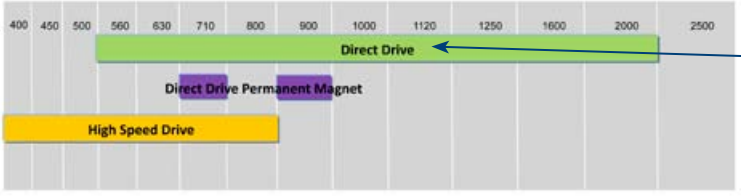
**1. Select platform** → **2. Select size** → **3. Select system** → **4. Select drive steps**

The list of the pre-calculated drive steps is not exhaustive and they can always be further optimized, but as the comparison of the drive steps shows, the changes that can be achieved are minor. In some cases, however, it might be reasonable to select the next Direct Drive size to achieve gains in efficiency.

**Example:**
Tank tests indicate that the power of 2000 kW at 220 rpm must be achieved for a shaft. The customer wants to have the most cost-efficient solution.

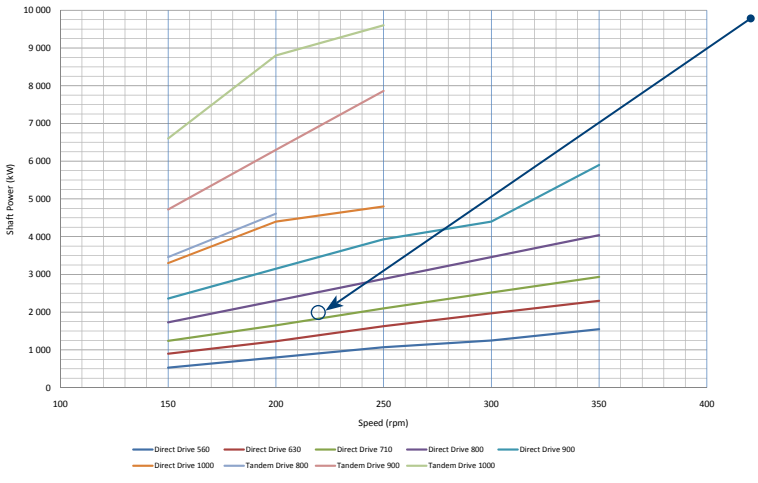
**1. Select platform:** The customer has compared different propulsion options and operational profiles and decided that the most appropriate and cost-efficient platform is Direct Drive.

Availability of Direct Drive systems




Direct Drive is the most cost-efficient platform over Direct Drive Permanent Magnet. High Speed Drive is not applicable.

**2. Select size:** The target is 2000 kW at 220 rpm. The performance limit curve indicates Direct Drive 800 for the speed of 220 rpm.




220 rpm requires Direct Drive 800

**3. Select system:**

Availability of Direct Drive systems

Single Drive is the most cost-efficient system for the example

**4. Select drive steps:**

Direct Drive 800 M can produce 2305 kW above 200 rpm (page 181), which makes it the proper drive step. The values for Direct Drive 800 M – Single Drive apply (page 181).

| Direct Drive 800 – Single Drive | | | | | |
|---|---|---|---|---|---|
| Drive Step | S | M | L | X | Y |
| Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| Maximum Power (kW) | 1730 | 2305 | 2880 | 3460 | 4040 |
| Maximum Torque (kNm) | 109,7 | 110,0 | 109,9 | 110,4 | 110,4 |
| Drive (kVA) | 2680 | 3330 | 3970 | 4630 | 5960 |
| Transformer (kVA) | - | - | - | - | - |
| Braking Capacity (MJ) | 21,6 | 21,6 | 21,6 | 21,6 | 21,6 |

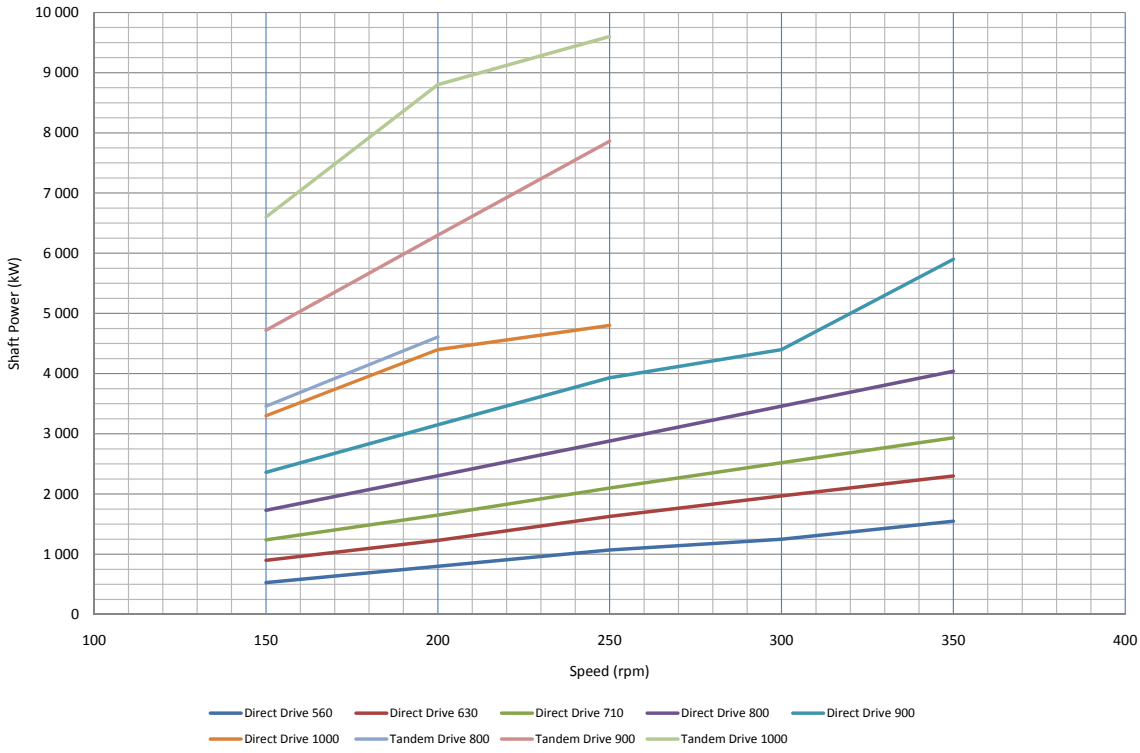
**DESIGNER TIP:**

Read more about the System selection (pages 166 – 168)

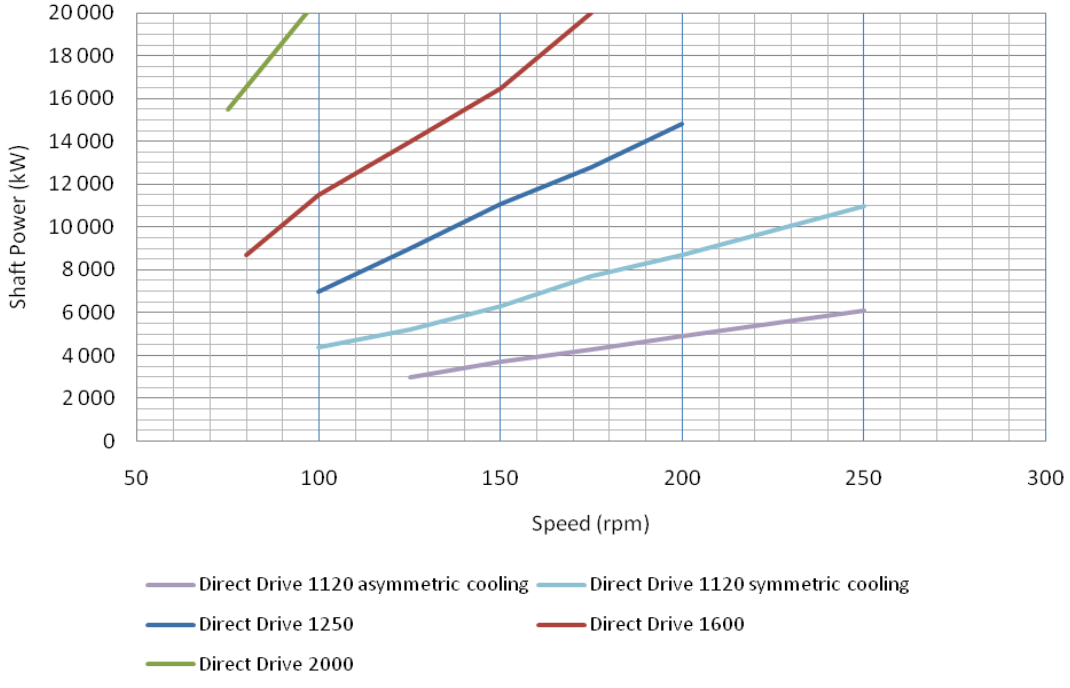
# 13 Technical specification for Direct Drive

The performance range for Direct Drive is divided into two graphs. The first graph charts the performance ranges for the sizes 560 to 1000. The second graph charts sizes 1120 to 2000. An appropriate drive size can be found in the graphs below.

Performance limits for Direct Drives 560 – 1000 (Figure 1)



Performance limits for Direct Drives 1120 – 2000. (Figure 2)




Power range (MW) for each system (check performance limits from figures 1 and 2)

| | Single Drive | Single Drive (AFE) | Single Drive (with Trans-former) | Tandem Drive | Single Drive (twin in/out) | Full Redundant Drive |
|---|---|---|---|---|---|---|
| Power Range | 0.5…6.3 | 0.5…5.1 | 0.8…11.5 | 3.4…9.6 | 12.8…20.0 | 11.1…20.0 |

Availability of Direct Drive systems

The table below summarizes the main components in each system.

| Number of main components – Direct Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Single Drive | Single Drive (AFE) | Single Drive (with Trans-former) | Tandem Drive | Single Drive (twin in/out) | Full Redundant Drive |
| Motor | 1 | 1 | 1 | 2 | 1 | 1 |
| Frequency converter | 1 | 1 | 1 | 2 | 1 | 2 |
| Braking resistor | 1 | 0 | 1 | 2 | 1 | 2 |
| Transformer | 0 | 0 | 1 | 0 | 2 | 2 |
| Excitation transformer | 0, 1) | 0 | 0, 1) | 0 | 1 | 2 |
| Harmonic filter | 1 | 0 | 0 | 1 | 0 | 0 |

1) One excitation transformer in case of a synchronous motor

| System features – Direct Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Single Drive | Single Drive (AFE) | Single Drive (with Trans-former) | Tandem Drive | Single Drive (twin in/out) | Full Redundant Drive |
| Motor | Induction up to size 1000, synchronous from size 1120 | Induction | Induction up to size 1000, synchronous from size 1120 | Induction | Synchronous | Synchronous |
| Stator system(s) in a motor | 1 | 1 | 1, 1) | 1 | 2 | 2 |
| Frequency converter | LV ≤ ~5 MW<br>MV ≥ ~5 MW | LV | LV ≤ ~5 MW<br>MV ≥ ~5 MW | LV | MV | MV |
| Pulse number | 6 | AFE | 12 | 6 | 24 | 24 |
| Propulsion control | Drive Control Unit (DCU),<br>Propulsion Control Unit (PCU) as an option | | | | | PCU |
| Remote Control System | Interface towards Remote Control System,<br>RCS as an option | | | | | |
| Uninterrupted Power Supply | UPS as an option | | | | | |

1) After 10 MW two stator systems

Technical data for the main components

| Technical data – Direct Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Motor | Frequency converter | Braking resistor | Transformer | Excitation transformer | Harmonic filter |
| Max. ambient temperature (°C) | 50 | 45 | 45 | 45 | 45 | 45 |
| Max. cooling water temperature (°C) | 36 | 36 | N/A | 36 | N/A | 36 |
| Method of cooling | IC86W | Direct Liquid Cooling | Air cooled | AFWF | AN | Air cooled |
| Installation | IM1001 / IM7315, [1] | One Lineup | Wall standing | Feet for welding | Feet for welding | Wall standing |
| Enclosure | IP44 | IP42 / IP32 [2] | IP23 | IP44 | IP23 | IP23 |
| Color | MUNSELL8B | RAL7035 | RAL7035 | RAL7035 | RAL7035 | RAL7035 |
| Insulation class [3] | F | N/A | N/A | F | F | N/A |
| Temperature rise class [3] | F | N/A | N/A | F | F | N/A |
| Cabling direction | Bottom | Bottom | Bottom | Bottom | Bottom | Bottom |
| Piping direction | Side | Side | N/A | Side | N/A | N/A |

[1] IM7315 for Direct Drives sizes 1250 and above

[2] Low voltage converter IP42, Medium voltage converter IP32

[3] According to DNV

**REMARK:**

Direct Drive is a pre-engineered solution and to guarantee a successful delivery, ABB's installation, cabling and operation instructions must be followed.

# 13.1 Technical data sheets – Direct Drive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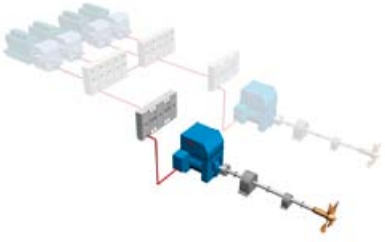
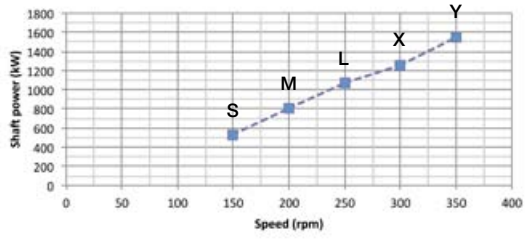
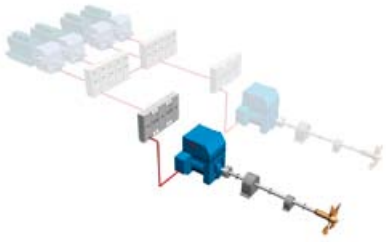
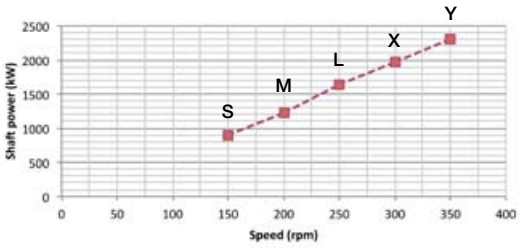


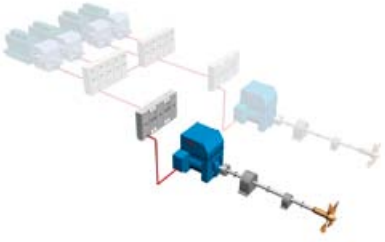


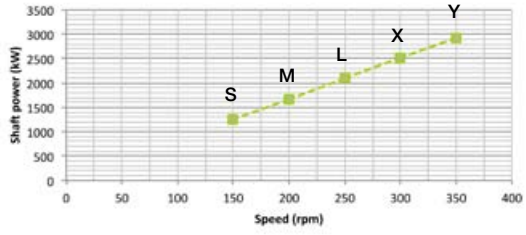

| Direct Drive 560 – Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 530 | 800 | 1070 | 1250 | 1550 |
| | Maximum Torque (kNm) | 33,7 | 38,1 | 40,9 | 39,7 | 42,2 |
| | Drive (kVA) | 940 | 1370 | 1590 | 2030 | 2680 |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | 10,8 | 10,8 | 10,8 | 10,8 | 21,6 |
| Drivetrain Efficiency (%) | Motor | 91,5 | 92,9 | 93,3 | 94 | 94,8 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 89,7 | 91,0 | 91,4 | 92,1 | 92,9 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 622 | 925 | 1232 | 1428 | 1756 |
| | Input Current (A) | 521 | 774 | 1031 | 1195 | 1469 |
| Footprint ($m^2$) | Motor | 8,1 | 8,1 | 8,1 | 8,1 | 8,1 |
| | Frequency Converter | 2,3 | 2,3 | 2,5 | 2,5 | 3,3 |
| | Braking Resistor | 0,6 | 0,6 | 0,6 | 0,6 | 1,2 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | 1,7 | 1,7 | 1,7 |
| | Total | 12,7 | 12,7 | 12,8 | 12,8 | 14,3 |
| Dimensions (L x W xH) | Motor | 3105 x 2605 x 2395 | 3105 x 2605 x 2395 | 3105 x 2605 x 2395 | 3105 x 2605 x 2395 | 3105 x 2605 x 2395 |
| | Frequency Converter | 3230 x 718 x 2088 | 3230 x 718 x 2088 | 3430 x 718 x 2088 | 3430 x 718 x 2088 | 4630 x 718 x 2088 |
| | Braking Resistor | 830 x 718 x 2088 | 830 x 718 x 2088 | 830 x 718 x 2088 | 830 x 718 x 2088 | 1630 x 718 x 2088 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 |
| Weight (kg) | Motor | 9670 | 9690 | 9960 | 9940 | 9940 |
| | Frequency Converter | 2170 | 2170 | 2320 | 2320 | 3310 |
| | Braking Resistor | 240 | 240 | 240 | 240 | 480 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1100 | 1100 | 1100 | 1100 |
| | Total | 13180 | 13200 | 13620 | 13600 | 14830 |
| LT-water flow ($m^3/h$) | Motor | 7,2 | 8,8 | 11,1 | 11,4 | 12,2 |
| | Frequency Converter | 2,7 | 2,7 | 3,5 | 3,5 | 5,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 45,5 | 55,9 | 70,6 | 72,6 | 76,9 |
| | Frequency Converter | 17 | 22 | 28 | 34 | 44 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 62,5 | 77,9 | 98,6 | 106,6 | 120,9 |
| Losses to ambient (kW) | Motor | 3,7 | 4,6 | 5,8 | 6,0 | 6,3 |
| | Frequency Converter | 1,1 | 1,6 | 2,1 | 2,5 | 3,1 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | 1,8 | 1,8 |
| | Total | 6,5 | 8,0 | 9,7 | 10,3 | 11,2 |



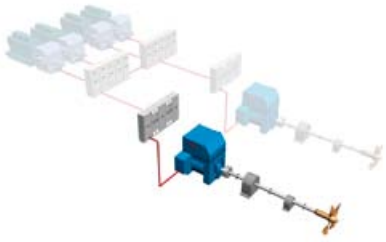


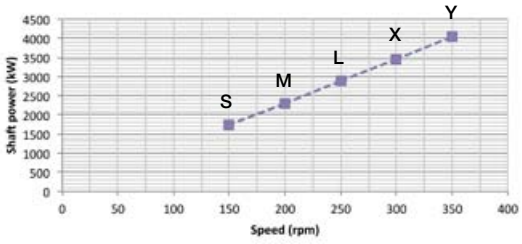

| Direct Drive 630 – Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 900 | 1230 | 1630 | 1970 | 2300 |
| | Maximum Torque (kNm) | 57,2 | 58,7 | 62,2 | 62,8 | 62,7 |
| | Drive (kVA) | 1370 | 2030 | 2680 | 3330 | 3330 |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | 10,8 | 10,8 | 21,6 | 21,6 | 21,6 |
| Drivetrain Efficiency (%) | Motor | 92,5 | 93,8 | 94,4 | 95,5 | 94,6 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 90,7 | 91,9 | 92,5 | 93,6 | 92,7 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 1045 | 1408 | 1855 | 2216 | 2611 |
| | Input Current (A) | 874 | 1179 | 1552 | 1854 | 2185 |
| Footprint ($m^2$) | Motor | 9,5 | 9,5 | 9,5 | 9,5 | 9,5 |
| | Frequency Converter | 2,3 | 2,5 | 3,3 | 3,6 | 3,6 |
| | Braking Resistor | 0,6 | 0,6 | 1,2 | 1,2 | 1,2 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | 1,7 | 1,7 | 1,7 |
| | Total | 14,1 | 14,2 | 15,7 | 15,9 | 15,9 |
| Dimensions (L x W xH) | Motor | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 |
| | Frequency Converter | 3230 x 718 x 2088 | 3430 x 718 x 2088 | 4630 x 718 x 2088 | 5030 x 718 x 2088 | 5030 x 718 x 2088 |
| | Braking Resistor | 830 x 718 x 2088 | 830 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 |
| Weight (kg) | Motor | 13460 | 13730 | 13570 | 13630 | 13730 |
| | Frequency Converter | 2070 | 2220 | 3210 | 3390 | 3390 |
| | Braking Resistor | 240 | 240 | 480 | 480 | 480 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1100 | 1100 | 1100 | 1100 |
| | Total | 16870 | 17290 | 18360 | 18600 | 18700 |
| LT-water flow ($m^3/h$) | Motor | 10,5 | 11,8 | 14 | 13,4 | 18,7 |
| | Frequency Converter | 2,7 | 3,5 | 5,4 | 6,2 | 6,2 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 67,6 | 74,9 | 89 | 85,2 | 119,3 |
| | Frequency Converter | 22 | 34 | 44 | 55 | 55 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 89,6 | 108,9 | 133,0 | 140,2 | 174,3 |
| Losses to ambient (kW) | Motor | 5,5 | 6,1 | 7,3 | 7,0 | 9,8 |
| | Frequency Converter | 1,8 | 2,5 | 3,3 | 3,9 | 4,6 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | 1,8 | 1,8 |
| | Total | 9,1 | 10,3 | 12,3 | 12,7 | 16,2 |



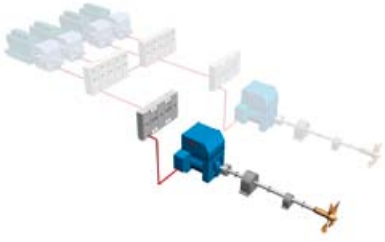


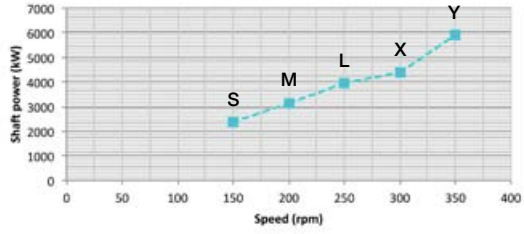

| Direct Drive 710 – Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 1240 | 1650 | 2100 | 2520 | 2935 |
| | Maximum Torque (kNm) | 78,5 | 78,5 | 80,0 | 80,0 | 80,0 |
| | Drive (kVA) | 2030 | 2680 | 3330 | 3970 | 3970 |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | 10,8 | 21,6 | 21,6 | 21,6 | 21,6 |
| Drivetrain Efficiency (%) | Motor | 93,5 | 94,3 | 95,4 | 95,7 | 95,9 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 91,6 | 92,4 | 93,5 | 93,8 | 94,0 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 1424 | 1879 | 2364 | 2828 | 3287 |
| | Input Current (A) | 1192 | 1573 | 1978 | 2367 | 2751 |
| Footprint ($m^2$) | Motor | 10,4 | 10,4 | 10,4 | 10,4 | 10,4 |
| | Frequency Converter | 2,5 | 3,3 | 3,6 | 3,8 | 3,8 |
| | Braking Resistor | 0,6 | 1,2 | 1,2 | 1,2 | 1,2 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | 1,7 | 1,7 | 1,7 |
| | Total | 15,2 | 16,6 | 16,9 | 17,0 | 17,0 |
| Dimensions (L x W xH) | Motor | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 |
| | Frequency Converter | 3430 x 718 x 2088 | 4630 x 718 x 2088 | 5030 x 718 x 2088 | 5230 x 718 x 2088 | 5230 x 718 x 2088 |
| | Braking Resistor | 830 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 |
| Weight (kg) | Motor | 19500 | 19500 | 20500 | 20500 | 20500 |
| | Frequency Converter | 2220 | 3210 | 3390 | 3540 | 3540 |
| | Braking Resistor | 240 | 480 | 480 | 480 | 480 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1100 | 1100 | 1100 | 1100 |
| | Total | 23060 | 24290 | 25470 | 25620 | 25620 |
| LT-water flow ($m^3/h$) | Motor | 23 | 23 | 23 | 23 | 23 |
| | Frequency Converter | 3,5 | 5,4 | 6,2 | 7,0 | 7,0 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 76 | 88 | 90 | 101 | 108 |
| | Frequency Converter | 34 | 44 | 55 | 66 | 66 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 110 | 132 | 145 | 167 | 174 |
| Losses to ambient (kW) | Motor | 10 | 11 | 11 | 12 | 13 |
| | Frequency Converter | 2,5 | 3,3 | 4,2 | 5,0 | 5,9 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | 1,8 | 1,8 |
| | Total | 14,2 | 16,1 | 17,0 | 18,8 | 20,6 |



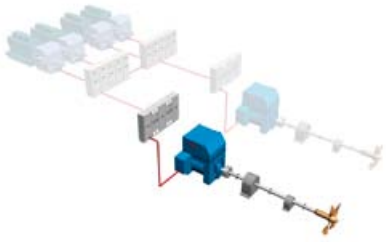


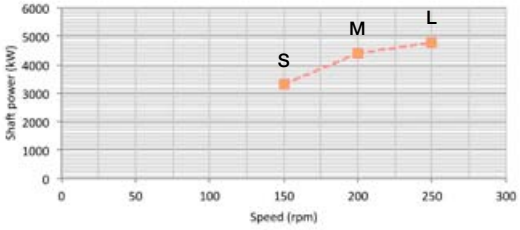

| Direct Drive 800 – Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 1730 | 2305 | 2880 | 3460 | 4040 |
| | Maximum Torque (kNm) | 109,7 | 110,0 | 109,9 | 110,4 | 110,4 |
| | Drive (kVA) | 2680 | 3330 | 3970 | 4630 | 5960 |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | 21,6 | 21,6 | 21,6 | 21,6 | 21,6 |
| Drivetrain Efficiency (%) | Motor | 93 | 94,6 | 95,3 | 95,6 | 96,4 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 91,1 | 92,7 | 93,4 | 93,7 | 94,5 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 1998 | 2617 | 3246 | 3887 | 4501 |
| | Input Current (A) | 1672 | 2190 | 2716 | 3253 | 3767 |
| Footprint ($m^2$) | Motor | 12,6 | 12,6 | 12,6 | 12,6 | 12,6 |
| | Frequency Converter | 3,3 | 3,6 | 3,8 | 4,4 | 4,7 |
| | Braking Resistor | 1,2 | 1,2 | 1,2 | 1,2 | 1,2 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | 1,7 | 1,7 | 1,7 |
| | Total | 18,8 | 19,1 | 19,2 | 19,9 | 20,2 |
| Dimensions (L x W xH) | Motor | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 |
| | Frequency Converter | 4630 x 718 x 2088 | 5030 x 718 x 2088 | 5230 x 718 x 2088 | 6130 x 718 x 2088 | 6530 x 718 x 2088 |
| | Braking Resistor | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 |
| Weight (kg) | Motor | 28500 | 28500 | 28500 | 28500 | 28500 |
| | Frequency Converter | 3210 | 3390 | 3540 | 4470 | 4860 |
| | Braking Resistor | 480 | 480 | 480 | 480 | 480 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1100 | 1100 | 1100 | 1100 |
| | Total | 33290 | 33470 | 33620 | 34550 | 34940 |
| LT-water flow ($m^3$/h) | Motor | 23 | 23 | 23 | 23 | 23 |
| | Frequency Converter | 5,4 | 6,2 | 7,0 | 8,9 | 10,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 106 | 116 | 120 | 142 | 134 |
| | Frequency Converter | 44 | 55 | 66 | 76 | 99 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 150 | 171 | 186 | 218 | 233 |
| Losses to ambient (kW) | Motor | 13 | 13 | 14 | 15 | 15 |
| | Frequency Converter | 3,5 | 4,6 | 5,8 | 6,9 | 8,1 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | 1,8 | 1,8 |
| | Total | 18,2 | 19,4 | 21,5 | 23,7 | 24,8 |



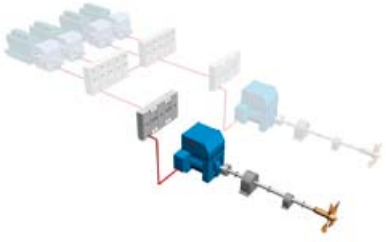


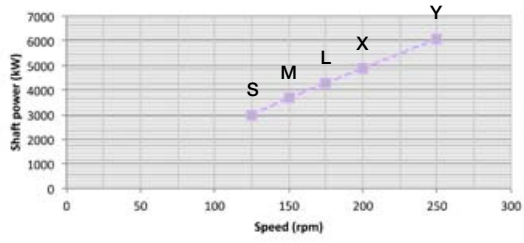

| Direct Drive 900 – Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 2360 | 3150 | 3930 | 4400 | 5900 |
| | Maximum Torque (kNm) | 150,3 | 150,2 | 149,9 | 140,2 | 161,0 |
| | Drive (kVA) | 3330 | 4630 | 5300 | 5960 | 9000 |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | 21,6 | 21,6 | 21,6 | 21,6 | 30 |
| Drivetrain Efficiency (%) | Motor | 94,1 | 95,4 | 95,9 | 96,2 | 96,7 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98,5 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 92,2 | 93,5 | 94,0 | 94,3 | 95,2 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 3300 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 2694 | 3547 | 4402 | 4913 | 6520 |
| | Input Current (A) | 2254 | 2968 | 3683 | 4111 | 1141 |
| Footprint ($m^2$) | Motor | 14,2 | 14,2 | 14,2 | 14,2 | 14,2 |
| | Frequency Converter | 3,6 | 4,4 | 4,5 | 4,7 | 8,6 |
| | Braking Resistor | 1,2 | 1,2 | 1,2 | 1,2 | 1,6 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | 1,7 | 1,7 | 2,6 |
| | Total | 20,7 | 21,5 | 21,6 | 21,8 | 27,1 |
| Dimensions (L x W xH) | Motor | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 |
| | Frequency Converter | 5030 x 718 x 2088 | 6130 x 718 x 2088 | 6330 x 718 x 2088 | 6530 x 718 x 2088 | 7330 x 1176 x 2475 |
| | Braking Resistor | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1800 x 900 x 1700 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 3440 x 760 x 2090 |
| Weight (kg) | Motor | 39500 | 39500 | 39500 | 36500 | 33110 |
| | Frequency Converter | 3390 | 4470 | 4620 | 4860 | 6800 |
| | Braking Resistor | 480 | 480 | 480 | 480 | 620 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1100 | 1100 | 1100 | 1700 |
| | Total | 44470 | 45550 | 45700 | 42940 | 42230 |
| LT-water flow ($m^3$/h) | Motor | 25 | 25 | 25 | 25 | 25 |
| | Frequency Converter | 6,2 | 8,9 | 9,7 | 10,4 | 10,1 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 130 | 135 | 150 | 156 | 181 |
| | Frequency Converter | 55 | 76 | 87 | 99 | 84 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 185 | 211 | 237 | 255 | 265 |
| Losses to ambient (kW) | Motor | 15 | 15 | 16 | 16 | 20 |
| | Frequency Converter | 4,7 | 6,3 | 7,9 | 8,8 | 7,1 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | 1,8 | 1,8 |
| | Total | 21,5 | 23,1 | 25,6 | 26,6 | 29,0 |



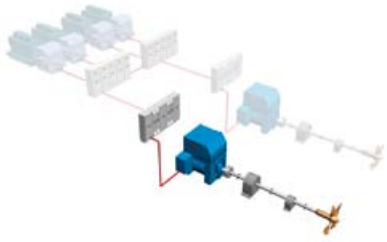


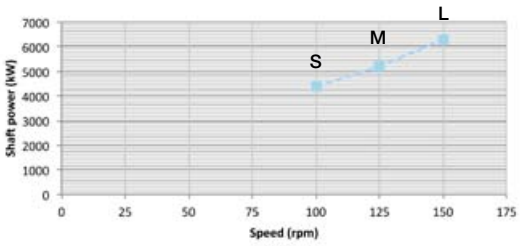

| Direct Drive 1000 – Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 3300 | 4400 | 4800 | - | - |
| | Maximum Torque (kNm) | 209,9 | 209,7 | 182,7 | - | - |
| | Drive (kVA) | 4630 | 5960 | 6620 | - | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | 21,6 | 21,6 | 21,6 | - | - |
| Drivetrain Efficiency (%) | Motor | 94,8 | 95,7 | 96,3 | - | - |
| | Frequency Converter | 98 | 98 | 98 | - | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 92,9 | 93,8 | 94,4 | - | - |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | - | - |
| | Power factor | 0,95 | 0,95 | 0,95 | - | - |
| | Input power (kVA) | 3739 | 4938 | 5354 | - | - |
| | Input Current (A) | 3129 | 4132 | 4480 | - | - |
| Footprint ($m^2$) | Motor | 15,1 | 15,1 | 15,1 | - | - |
| | Frequency Converter | 4,4 | 4,7 | 5,0 | - | - |
| | Braking Resistor | 1,2 | 1,2 | 1,2 | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | 1,7 | - | - |
| | Total | 22,4 | 22,7 | 23,0 | - | - |
| Dimensions (L x W xH) | Motor | 4980 x 3035 x 3285 | 4980 x 3035 x 3285 | 4980 x 3035 x 3285 | - | - |
| | Frequency Converter | 6130 x 718 x 2088 | 6530 x 718 x 2088 | 7030 x 718 x 2088 | - | - |
| | Braking Resistor | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | - | - |
| Weight (kg) | Motor | 55000 | 55000 | 48000 | - | - |
| | Frequency Converter | 4470 | 4860 | 5150 | - | - |
| | Braking Resistor | 480 | 480 | 480 | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1100 | 1100 | - | - |
| | Total | 61050 | 61440 | 54730 | - | - |
| LT-water flow ($m^3/h$) | Motor | 25 | 25 | 25 | - | - |
| | Frequency Converter | 8,9 | 10,4 | 6,7 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 160 | 180 | 166 | - | - |
| | Frequency Converter | 76 | 99 | 112 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 236 | 279 | 278 | - | - |
| Losses to ambient (kW) | Motor | 18 | 19 | 18 | - | - |
| | Frequency Converter | 6,6 | 8,8 | 9,6 | - | - |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | - | - |
| | Total | 26,4 | 29,6 | 29,4 | - | - |



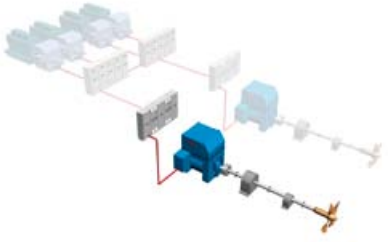


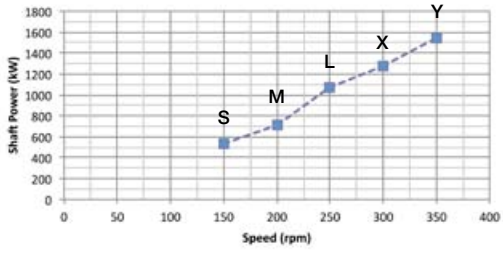

| Direct Drive 1120 asymmetric cooling – Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥125 | ≥150 | ≥175 | ≥200 | ≥250 |
| | Maximum Power (kW) | 3000 | 3700 | 4300 | 4900 | 6100 |
| | Maximum Torque (kNm) | 229,0 | 235,5 | 234,6 | 234,0 | 233,0 |
| | Drive (kVA) | 5000 | 5000 | 7000 | 7000 | 9000 |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | 30 | 30 | 30 | 30 | 30 |
| Drivetrain Efficiency (%) | Motor | 94,5 | 95,4 | 95,9 | 96,4 | 97,0 |
| | Frequency Converter | 98,5 | 98,5 | 98,5 | 98,5 | 98,5 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 93,1 | 94,0 | 94,4 | 95,0 | 95,6 |
| Main Connection | Input Voltage (VAC) | 3300 | 3300 | 3300 | 3300 | 3300 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 3391 | 4143 | 4793 | 5432 | 6718 |
| | Input Current (A) | 593 | 725 | 839 | 950 | 1175 |
| Footprint ($m^2$) | Motor | 17,1 | 17,1 | 17,1 | 17,1 | 17,1 |
| | Frequency Converter | 8,3 | 8,3 | 9,6 | 9,6 | 9,6 |
| | Braking Resistor | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | 0,8 | 0,8 | 0,8 | 0,8 | 0,8 |
| | Harmonic Filter | 2,6 | 2,6 | 2,6 | 2,6 | 2,6 |
| | Total | 30,4 | 30,4 | 31,7 | 31,7 | 31,7 |
| Dimensions (L x W xH) | Motor | 4820 x 3550 x 3345 | 4820 x 3550 x 3345 | 4820 x 3550 x 3345 | 4820 x 3550 x 3345 | 4820 x 3550 x 3345 |
| | Frequency Converter | 7030 x 1176 x 2475 | 7030 x 1176 x 2475 | 8130 x 1176 x 2475 | 8130 x 1176 x 2475 | 8130 x 1176 x 2475 |
| | Braking Resistor | 1800 x 900 x 1700 | 1800 x 900 x 1700 | 1800 x 900 x 1700 | 1800 x 900 x 1700 | 1800 x 900 x 1700 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1230 x 670 x 1355 |
| | Harmonic Filter | 3440 x 760 x 2090 | 3440 x 760 x 2090 | 3440 x 760 x 2090 | 3440 x 760 x 2090 | 3440 x 760 x 2090 |
| Weight (kg) | Motor | 38450 | 38500 | 38500 | 38550 | 38450 |
| | Frequency Converter | 6500 | 6500 | 7400 | 7400 | 7400 |
| | Braking Resistor | 620 | 620 | 620 | 620 | 620 |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | 1330 | 1330 | 1330 | 1330 | 1330 |
| | Harmonic Filter | 1700 | 1700 | 1700 | 1700 | 1700 |
| | Total | 47270 | 47320 | 48220 | 48270 | 48170 |
| LT-water flow ($m^3/h$) | Motor | 32 | 33 | 34 | 34 | 35 |
| | Frequency Converter | 6,5 | 6,5 | 7,9 | 7,9 | 9,7 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 164,9 | 167,9 | 175,5 | 176,0 | 177,4 |
| | Frequency Converter | 54,1 | 54,1 | 65,7 | 65,7 | 81 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 219,0 | 222,0 | 241,2 | 241,7 | 258,4 |
| Losses to ambient (kW) | Motor | 8,7 | 8,8 | 9,2 | 9,3 | 9,3 |
| | Frequency Converter | 8,8 | 8,8 | 9,6 | 9,6 | 10,8 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | 5,4 | 5,4 | 5,4 | 5,4 | 5,4 |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | 1,8 | 1,8 |
| | Total | 24,7 | 24,8 | 26,0 | 26,1 | 27,3 |



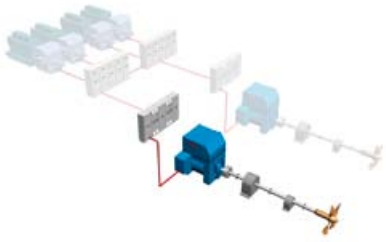


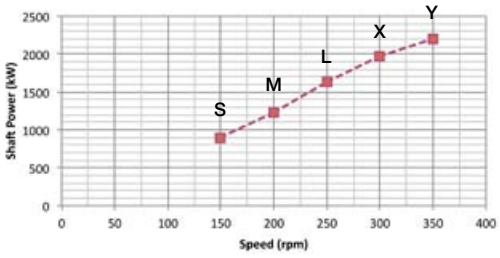

| Direct Drive 1120 symmetric cooling – Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥100 | ≥125 | ≥150 | - | - |
| | Maximum Power (kW) | 4400 | 5200 | 6300 | - | - |
| | Maximum Torque (kNm) | 420,0 | 397,0 | 401,0 | - | - |
| | Drive (kVA) | 7000 | 7000 | 9000 | - | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | 30 | 30 | 30 | - | - |
| Drivetrain Efficiency (%) | Motor | 94,4 | 95,0 | 95,7 | - | - |
| | Frequency Converter | 98,5 | 98,5 | 98,5 | - | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 93,0 | 93,5 | 94,3 | - | - |
| Main Connection | Input Voltage (VAC) | 3300 | 3300 | 3300 | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | - | - |
| | Power factor | 0,95 | 0,95 | 0,95 | - | - |
| | Input power (kVA) | 4982 | 5851 | 7036 | - | - |
| | Input Current (A) | 872 | 1024 | 1231 | - | - |
| Footprint ($m^2$) | Motor | 19,6 | 19,6 | 19,6 | - | - |
| | Frequency Converter | 9,6 | 9,6 | 9,6 | - | - |
| | Braking Resistor | 1,6 | 1,6 | 1,6 | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | 0,8 | 0,8 | 0,8 | - | - |
| | Harmonic Filter | 2,6 | 2,6 | 2,6 | - | - |
| | Total | 34,3 | 34,3 | 34,3 | - | - |
| Dimensions (L x W xH) | Motor | 5530 x 3550 x 3345 | 5530 x 3550 x 3345 | 5530 x 3550 x 3345 | - | - |
| | Frequency Converter | 8130 x 1176 x 2475 | 8130 x 1176 x 2475 | 8130 x 1176 x 2475 | - | - |
| | Braking Resistor | 1800 x 900 x 1700 | 1800 x 900 x 1700 | 1800 x 900 x 1700 | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1230 x 670 x 1355 | - | - |
| | Harmonic Filter | 3440 x 760 x 2090 | 3440 x 760 x 2090 | 3440 x 760 x 2090 | - | - |
| Weight (kg) | Motor | 52650 | 52050 | 52100 | - | - |
| | Frequency Converter | 7400 | 7400 | 7400 | - | - |
| | Braking Resistor | 620 | 620 | 620 | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | 1330 | 1330 | 1330 | - | - |
| | Harmonic Filter | 1700 | 1700 | 1700 | - | - |
| | Total | 62370 | 61770 | 61820 | - | - |
| LT-water flow ($m^3/h$) | Motor | 48 | 50 | 51 | - | - |
| | Frequency Converter | 7,9 | 7,9 | 9,7 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 248 | 262 | 270 | - | - |
| | Frequency Converter | 65,7 | 65,7 | 81 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 314 | 327 | 351 | - | - |
| Losses to ambient (kW) | Motor | 13 | 14 | 14 | - | - |
| | Frequency Converter | 9,6 | 9,6 | 10,8 | - | - |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | 5,4 | 5,4 | 5,4 | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | - | - |
| | Total | 29,9 | 30,6 | 32,2 | - | - |



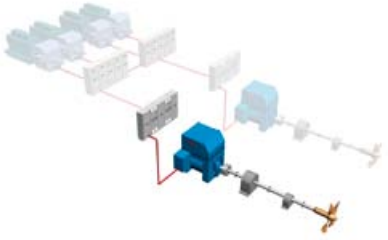


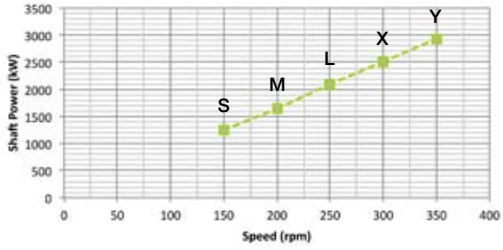

| Direct Drive 560 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 530 | 710 | 1070 | 1270 | 1550 |
| | Maximum Torque (kNm) | 33,6 | 33,8 | 41,1 | 40,5 | 42,2 |
| | Drive (kVA) | 950 | 950 | 1840 | 1840 | 2430 |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Yes | Yes | Yes | Yes | Yes |
| Drivetrain Efficiency (%) | Motor | 91,6 | 93,1 | 93,4 | 94,3 | 94,8 |
| | Frequency Converter | 97 | 97 | 97 | 97 | 97 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 88,9 | 90,3 | 90,6 | 91,5 | 92,0 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| | Input power (kVA) | 603 | 794 | 1193 | 1402 | 1703 |
| | Input Current (A) | 504 | 664 | 998 | 1173 | 1425 |
| Footprint ($m^2$) | Motor | 8,1 | 8,1 | 8,1 | 8,1 | 8,1 |
| | Frequency Converter | 2,7 | 2,7 | 3,1 | 3,1 | 3,8 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 10,8 | 10,8 | 11,2 | 11,2 | 11,8 |
| Dimensions (L x W xH) | Motor | 3105 x 2605 x 2395 | 3105 x 2605 x 2395 | 3105 x 2605 x 2395 | 3105 x 2605 x 2395 | 3105 x 2605 x 2395 |
| | Frequency Converter | 3830 x 718 x 2088 | 3830 x 718 x 2088 | 4330 x 718 x 2088 | 4330 x 718 x 2088 | 5230 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 9670 | 9690 | 9960 | 9940 | 9940 |
| | Frequency Converter | 2950 | 2950 | 3350 | 3350 | 4480 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 12620 | 12640 | 13310 | 13290 | 14420 |
| LT-water flow ($m^3/h$) | Motor | 7,1 | 7,6 | 9,9 | 10,9 | 12,2 |
| | Frequency Converter | 4,2 | 4,2 | 7,0 | 7,0 | 9,1 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 45,5 | 55,9 | 70,6 | 72,6 | 76,9 |
| | Frequency Converter | 34,8 | 34,8 | 56,2 | 56,2 | 77,9 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 80,3 | 90,7 | 126,8 | 128,8 | 154,8 |
| Losses to ambient (kW) | Motor | 3,7 | 4,6 | 5,8 | 6 | 6,3 |
| | Frequency Converter | 1,1 | 1,4 | 2,1 | 2,5 | 3,1 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 4,8 | 6,0 | 7,9 | 8,5 | 9,4 |



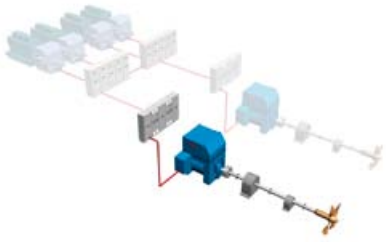


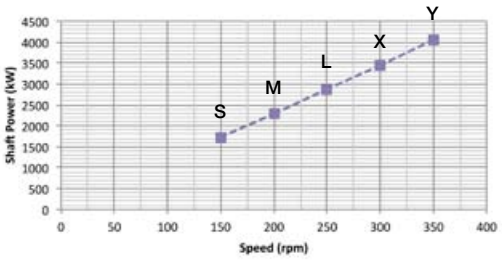

| Direct Drive 630 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 900 | 1230 | 1630 | 1970 | 2200 |
| | Maximum Torque (kNm) | 57,2 | 58,7 | 62,2 | 62,6 | 60,0 |
| | Drive (kVA) | 1240 | 1840 | 2430 | 3620 | 3620 |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Yes | Yes | Yes | Yes | Yes |
| Drivetrain Efficiency (%) | Motor | 92,3 | 93,9 | 94,4 | 95,4 | 95,5 |
| | Frequency Converter | 97 | 97 | 97 | 97 | 97 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 89,5 | 91,1 | 91,6 | 92,5 | 92,6 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| | Input power (kVA) | 1015 | 1364 | 1798 | 2150 | 2399 |
| | Input Current (A) | 850 | 1141 | 1505 | 1799 | 2007 |
| Footprint ($m^2$) | Motor | 9,5 | 9,5 | 9,5 | 9,5 | 9,5 |
| | Frequency Converter | 2,7 | 3,1 | 3,8 | 4,8 | 4,8 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 12,2 | 12,6 | 13,2 | 14,2 | 14,2 |
| Dimensions (L x W xH) | Motor | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 |
| | Frequency Converter | 3830 x 718 x 2088 | 4330 x 718 x 2088 | 5230 x 718 x 2088 | 6630 x 718 x 2088 | 6630 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 13460 | 13730 | 13570 | 13630 | 13730 |
| | Frequency Converter | 2950 | 3350 | 4480 | 5315 | 5315 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 16410 | 17080 | 18050 | 18945 | 19045 |
| LT-water flow ($m^3/h$) | Motor | 10,8 | 11,5 | 13,8 | 13,7 | 15 |
| | Frequency Converter | 4,7 | 7,0 | 9,1 | 13,4 | 13,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 67,6 | 74,9 | 89 | 85,2 | 119,3 |
| | Frequency Converter | 39,5 | 56,2 | 77,9 | 111 | 111 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 107,1 | 131,1 | 166,9 | 196,2 | 230,3 |
| Losses to ambient (kW) | Motor | 5,5 | 6,1 | 7,3 | 7 | 9,8 |
| | Frequency Converter | 1,8 | 2,5 | 3,3 | 3,9 | 4,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 7,3 | 8,6 | 10,6 | 10,9 | 14,2 |



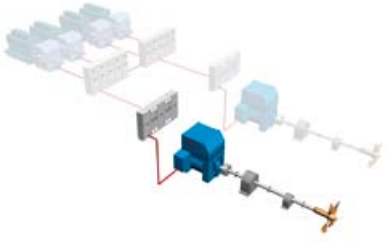


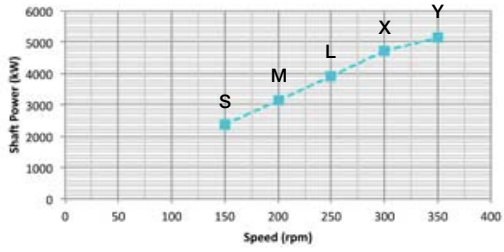

| Direct Drive 710 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 1240 | 1650 | 2100 | 2520 | 2935 |
| | Maximum Torque (kNm) | 78,9 | 78,8 | 80,2 | 80,2 | 80,1 |
| | Drive (kVA) | 1840 | 2430 | 3620 | 3620 | 3620 |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Yes | Yes | Yes | Yes | Yes |
| Drivetrain Efficiency (%) | Motor | 92,5 | 93,8 | 94,8 | 95,5 | 95,8 |
| | Frequency Converter | 97 | 97 | 97 | 97 | 97 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 89,7 | 91,0 | 92,0 | 92,6 | 92,9 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| | Input power (kVA) | 1396 | 1832 | 2307 | 2748 | 3190 |
| | Input Current (A) | 1168 | 1533 | 1930 | 2299 | 2669 |
| Footprint ($m^2$) | Motor | 10,4 | 10,4 | 10,4 | 10,4 | 10,4 |
| | Frequency Converter | 3,1 | 3,8 | 4,8 | 4,8 | 4,8 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 13,5 | 14,1 | 15,2 | 15,2 | 15,2 |
| Dimensions (L x W xH) | Motor | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 |
| | Frequency Converter | 4330 x 718 x 2088 | 5230 x 718 x 2088 | 6630 x 718 x 2088 | 6630 x 718 x 2088 | 6630 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 20000 | 20000 | 20500 | 20500 | 20500 |
| | Frequency Converter | 3350 | 4480 | 5315 | 5315 | 5315 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 23350 | 24480 | 25815 | 25815 | 25815 |
| LT-water flow ($m^3/h$) | Motor | 23 | 23 | 23 | 23 | 23 |
| | Frequency Converter | 7,0 | 9,1 | 13,4 | 13,4 | 13,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 90 | 98 | 103 | 104 | 114 |
| | Frequency Converter | 56,2 | 77,9 | 111 | 111 | 111 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 146,2 | 175,9 | 214 | 215 | 225 |
| Losses to ambient (kW) | Motor | 10 | 11 | 11 | 12 | 13 |
| | Frequency Converter | 2,5 | 3,3 | 4,2 | 5,0 | 5,9 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 12,5 | 14,3 | 15,2 | 17,0 | 18,9 |



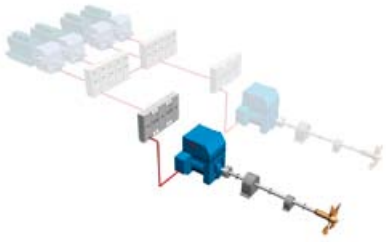


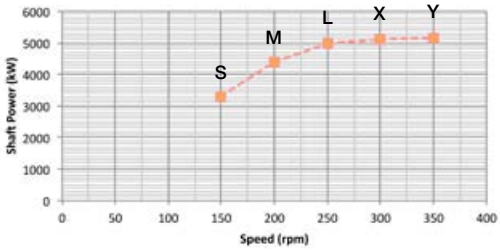

| Direct Drive 800 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 1730 | 2305 | 2880 | 3460 | 4040 |
| | Maximum Torque (kNm) | 110,1 | 110,1 | 110,0 | 110,1 | 110,2 |
| | Drive (kVA) | 2430 | 3620 | 3620 | 4630 | 5300 |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Yes | Yes | Yes | Yes | Yes |
| Drivetrain Efficiency (%) | Motor | 93 | 94,6 | 95,3 | 96 | 96,4 |
| | Frequency Converter | 97 | 97 | 97 | 97 | 97 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 90,2 | 91,8 | 92,4 | 93,1 | 93,5 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| | Input power (kVA) | 1937 | 2537 | 3147 | 3753 | 4364 |
| | Input Current (A) | 1621 | 2123 | 2633 | 3140 | 3652 |
| Footprint ($m^2$) | Motor | 12,6 | 12,6 | 12,6 | 12,6 | 12,6 |
| | Frequency Converter | 3,8 | 4,8 | 4,8 | 6,2 | 6,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 16,4 | 17,4 | 17,4 | 18,8 | 19,0 |
| Dimensions (L x W xH) | Motor | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 |
| | Frequency Converter | 5230 x 718 x 2088 | 6630 x 718 x 2088 | 6630 x 718 x 2088 | 8630 x 718 x 2088 | 8930 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 28500 | 28500 | 28500 | 28500 | 28500 |
| | Frequency Converter | 4480 | 5315 | 5315 | 7495 | 7295 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 32980 | 33815 | 33815 | 35995 | 35795 |
| LT-water flow ($m^3/h$) | Motor | 23 | 23 | 23 | 23 | 23 |
| | Frequency Converter | 9,1 | 13,4 | 13,4 | 17,5 | 19,7 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 116 | 117 | 126 | 128 | 134 |
| | Frequency Converter | 77,9 | 111 | 111 | 146,5 | 157,1 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 193,9 | 228 | 237 | 274,5 | 291,1 |
| Losses to ambient (kW) | Motor | 13 | 13 | 14 | 14 | 15 |
| | Frequency Converter | 3,5 | 4,6 | 5,8 | 6,9 | 8,1 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 16,5 | 17,6 | 19,8 | 20,9 | 23,1 |



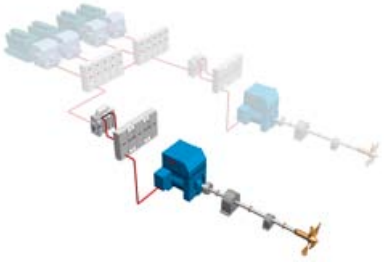


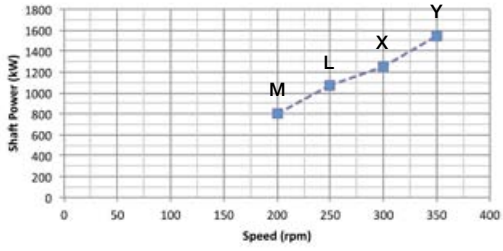

| Direct Drive 900 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 2360 | 3150 | 3930 | 4715 | 5130 |
| | Maximum Torque (kNm) | 150,3 | 150,4 | 150,1 | 150,1 | 140,0 |
| | Drive (kVA) | 3620 | 4630 | 5300 | 5960 | 6620 |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Yes | Yes | Yes | Yes | Yes |
| Drivetrain Efficiency (%) | Motor | 94,2 | 95,3 | 95,7 | 96,4 | 96,4 |
| | Frequency Converter | 97 | 97 | 97 | 97 | 97 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 91,4 | 92,4 | 92,8 | 93,5 | 93,5 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| | Input power (kVA) | 2609 | 3442 | 4276 | 5093 | 5542 |
| | Input Current (A) | 2183 | 2880 | 3578 | 4262 | 4637 |
| Footprint ($m^2$) | Motor | 14,2 | 14,2 | 14,2 | 14,2 | 14,2 |
| | Frequency Converter | 4,8 | 6,2 | 6,4 | 7,5 | 8,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 19,0 | 20,4 | 20,6 | 21,7 | 22,7 |
| Dimensions (L x W xH) | Motor | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 |
| | Frequency Converter | 6630 x 718 x 2088 | 8630 x 718 x 2088 | 8930 x 718 x 2088 | 10430 x 718 x 2088 | 11730 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 39500 | 39500 | 39500 | 39500 | 36500 |
| | Frequency Converter | 5315 | 7495 | 7295 | 9145 | 9885 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 44815 | 46995 | 46795 | 48645 | 46385 |
| LT-water flow ($m^3/h$) | Motor | 25 | 25 | 25 | 25 | 25 |
| | Frequency Converter | 13,4 | 17,5 | 19,7 | 21,8 | 24,7 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 129 | 139 | 157 | 155 | 170 |
| | Frequency Converter | 111 | 146,5 | 157,1 | 184 | 215 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 240 | 285,5 | 314,1 | 339 | 385 |
| Losses to ambient (kW) | Motor | 15 | 16 | 18 | 16 | 18 |
| | Frequency Converter | 4,7 | 6,3 | 7,9 | 9,4 | 10,3 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 19,7 | 22,3 | 25,9 | 25,4 | 28,3 |



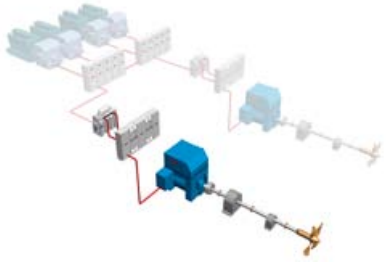


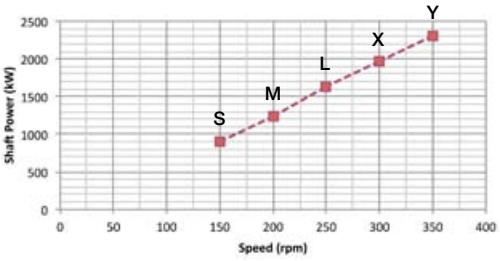

| Direct Drive 1000 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 3300 | 4400 | 5000 | 5100 | 5140 |
| | Maximum Torque (kNm) | 210,1 | 210,1 | 191,0 | 162,4 | 140,2 |
| | Drive (kVA) | 4630 | 5300 | 6620 | 6620 | 6620 |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Yes | Yes | Yes | Yes | Yes |
| Drivetrain Efficiency (%) | Motor | 94,8 | 95,4 | 95,8 | 96,5 | 96,4 |
| | Frequency Converter | 97 | 97 | 97 | 97 | 97 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 92,0 | 92,5 | 92,9 | 93,6 | 93,5 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| | Input power (kVA) | 3625 | 4803 | 5435 | 5503 | 5552 |
| | Input Current (A) | 3033 | 4019 | 4548 | 4605 | 4646 |
| Footprint ($m^2$) | Motor | 15,1 | 15,1 | 15,1 | 15,1 | 15,1 |
| | Frequency Converter | 6,2 | 6,4 | 8,4 | 8,4 | 8,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 21,3 | 21,5 | 23,5 | 23,5 | 23,5 |
| Dimensions (L x W xH) | Motor | 4980 x 3035 x 3285 | 4980 x 3035 x 3285 | 4980 x 3035 x 3285 | 4980 x 3035 x 3285 | 4980 x 3035 x 3285 |
| | Frequency Converter | 8630 x 718 x 2088 | 8930 x 718 x 2088 | 11730 x 718 x 2088 | 11730 x 718 x 2088 | 11730 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 55500 | 55500 | 50500 | 42500 | 36500 |
| | Frequency Converter | 7495 | 7295 | 9885 | 9885 | 9885 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 62995 | 62795 | 60385 | 52385 | 46385 |
| LT-water flow ($m^3/h$) | Motor | 25 | 25 | 25 | 25 | 25 |
| | Frequency Converter | 17,5 | 19,7 | 24,7 | 24,7 | 24,7 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 163 | 188 | 194 | 164 | 170 |
| | Frequency Converter | 146,5 | 157,1 | 215 | 215 | 215 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 309,5 | 345,1 | 409 | 379 | 385 |
| Losses to ambient (kW) | Motor | 18 | 19 | 21 | 19 | 19 |
| | Frequency Converter | 6,6 | 8,8 | 10,0 | 10,2 | 10,3 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 24,6 | 27,8 | 31,0 | 29,2 | 29,3 |



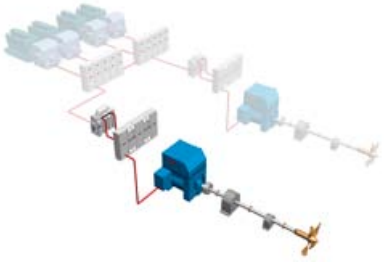


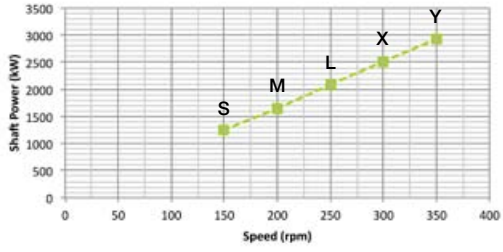

| Direct Drive 560 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | - | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | - | 800 | 1070 | 1250 | 1550 |
| | Maximum Torque (kNm) | - | 38,1 | 40,9 | 39,7 | 42,2 |
| | Drive (kVA) | - | 1370 | 1590 | 2030 | 2680 |
| | Transformer (kVA) | - | 1150 | 1450 | 1450 | 1850 |
| | Braking Capacity (MJ) | - | 10,8 | 10,8 | 10,8 | 21,6 |
| Drivetrain Efficiency (%) | Motor | - | 92,9 | 93,3 | 94 | 94,8 |
| | Frequency Converter | - | 98 | 98 | 98 | 98 |
| | Transformer | - | 99 | 99 | 99 | 99 |
| | Total Electrical Efficiency | - | 90,1 | 90,5 | 91,2 | 92,0 |
| Main Connection | Input Voltage (VAC) | - | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 |
| | Frequency (Hz) | - | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | - | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | - | 934 | 1244 | 1443 | 1774 |
| | Input Current (A) | - | 782 / 164 / 82 / 50 | 1042 / 218 / 109 / 66 | 1208 / 253 / 127 / 76 | 1485 / 311 / 156 / 94 |
| Footprint ($m^2$) | Motor | - | 8,1 | 8,1 | 8,1 | 8,1 |
| | Frequency Converter | - | 2,3 | 2,5 | 2,5 | 3,3 |
| | Braking Resistor | - | 0,5 | 0,5 | 0,5 | 1,2 |
| | Transformer | - | 5,9 | 6,5 | 6,5 | 6,9 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 16,8 | 17,5 | 17,5 | 19,5 |
| Dimensions (L x W xH) | Motor | - | 3105 x 2605 x 2395 | 3105 x 2605 x 2395 | 3105 x 2605 x 2395 | 3105 x 2605 x 2395 |
| | Frequency Converter | - | 3230 x 718 x 2088 | 3430 x 718 x 2088 | 3430 x 718 x 2088 | 4630 x 718 x 2088 |
| | Braking Resistor | - | 830 x 718 x 2088 | 830 x 718 x 2088 | 830 x 718 x 2088 | 1630 x 718 x 2088 |
| | Transformer | - | 2800 x 2100 x 1950 | 3000 x 2150 x 2100 | 3000 x 2150 x 2100 | 3150 x 2200 x 2250 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | - | 9690 | 9960 | 9940 | 9940 |
| | Frequency Converter | - | 2070 | 2220 | 2220 | 3210 |
| | Braking Resistor | - | 240 | 240 | 240 | 480 |
| | Transformer | - | 3650 | 4300 | 4300 | 4900 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 15650 | 16720 | 16700 | 18530 |
| LT-water flow ($m^3/h$) | Motor | - | 8,8 | 11,1 | 11,4 | 12,2 |
| | Frequency Converter | - | 2,7 | 3,5 | 3,5 | 5,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 5 | 6 | 6 | 7 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | - | 55,9 | 70,6 | 72,6 | 76,9 |
| | Frequency Converter | - | 22 | 28 | 34 | 44 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 26 | 35 | 35 | 40 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 77,9 | 98,6 | 106,6 | 120,9 |
| Losses to ambient (kW) | Motor | - | 4,6 | 5,8 | 6 | 6,3 |
| | Frequency Converter | - | 1,6 | 2,1 | 2,5 | 3,1 |
| | Braking Resistor | - | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | - | 4,5 | 5,1 | 5,1 | 5,6 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 10,7 | 13,0 | 13,6 | 15,0 |



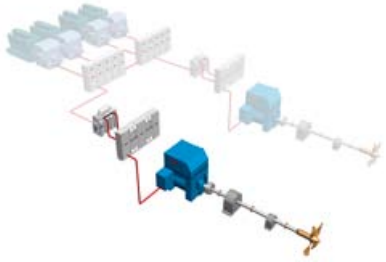


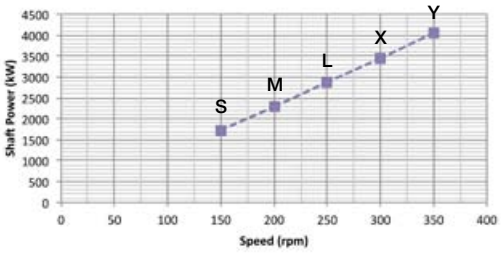

| Direct Drive 630 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 900 | 1230 | 1630 | 1970 | 2300 |
| | Maximum Torque (kNm) | 57,2 | 58,7 | 62,2 | 62,8 | 62,7 |
| | Drive (kVA) | 1370 | 2030 | 2680 | 3330 | 3330 |
| | Transformer (kVA) | 1150 | 1450 | 2300 | 2300 | 2900 |
| | Braking Capacity (MJ) | 10,8 | 10,8 | 21,6 | 21,6 | 21,6 |
| Drivetrain Efficiency (%) | Motor | 92,5 | 93,8 | 94,4 | 95,5 | 94,6 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98 |
| | Transformer | 99 | 99 | 99 | 99 | 99 |
| | Total Electrical Efficiency | 89,7 | 91,0 | 91,6 | 92,7 | 91,8 |
| Main Connection | Input Voltage (VAC) | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 1056 | 1423 | 1873 | 2238 | 2638 |
| | Input Current (A) | 884 / 185 / 93 / 56 | 1191 / 249 / 125 / 75 | 1568 / 328 / 164 / 99 | 1873 / 392 / 196 / 118 | 2208 / 462 / 231 / 139 |
| Footprint ($m^2$) | Motor | 9,5 | 9,5 | 9,5 | 9,5 | 9,5 |
| | Frequency Converter | 2,3 | 2,5 | 3,3 | 3,6 | 3,6 |
| | Braking Resistor | 0,5 | 0,5 | 1,2 | 1,2 | 1,2 |
| | Transformer | 5,9 | 6,5 | 7,3 | 7,3 | 8,0 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 18,2 | 18,9 | 21,3 | 21,5 | 22,2 |
| Dimensions (L x W xH) | Motor | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 | 3395 x 2785 x 2545 |
| | Frequency Converter | 3230 x 718 x 2088 | 3430 x 718 x 2088 | 4630 x 718 x 2088 | 5030 x 718 x 2088 | 5030 x 718 x 2088 |
| | Braking Resistor | 830 x 718 x 2088 | 830 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 |
| | Transformer | 2800 x 2100 x 1950 | 3000 x 2150 x 2100 | 3250 x 2250 x 2400 | 3250 x 2250 x 2400 | 3400 x 2350 x 2400 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 13460 | 13730 | 13570 | 13630 | 13730 |
| | Frequency Converter | 2070 | 2220 | 3210 | 3390 | 3390 |
| | Braking Resistor | 240 | 240 | 480 | 480 | 480 |
| | Transformer | 3650 | 4300 | 5600 | 5600 | 6000 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 19420 | 20490 | 22860 | 23100 | 23600 |
| LT-water flow ($m^3/h$) | Motor | 10,5 | 11,8 | 14 | 13,4 | 18,7 |
| | Frequency Converter | 2,7 | 3,5 | 5,4 | 6,2 | 6,2 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 5 | 6 | 7 | 7 | 5,5 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 67,6 | 74,9 | 89 | 85,2 | 119,3 |
| | Frequency Converter | 22 | 34 | 44 | 55 | 55 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 26 | 35 | 40 | 40 | 46 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 89,6 | 108,9 | 133 | 140,2 | 174,3 |
| Losses to ambient (kW) | Motor | 5,5 | 6,1 | 7,3 | 7 | 9,8 |
| | Frequency Converter | 1,8 | 2,5 | 3,3 | 3,9 | 4,6 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | 4,5 | 5,1 | 6,1 | 6,1 | 6,4 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 11,8 | 13,6 | 16,6 | 17,0 | 20,8 |



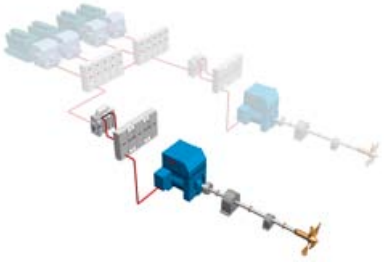


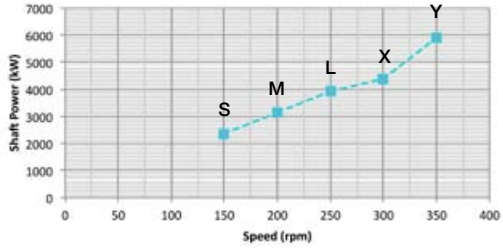

| Direct Drive 710 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 1240 | 1650 | 2100 | 2520 | 2935 |
| | Maximum Torque (kNm) | 78,5 | 78,5 | 80,0 | 80,0 | 80,0 |
| | Drive (kVA) | 2030 | 2680 | 3330 | 3970 | 3970 |
| | Transformer (kVA) | 1450 | 2300 | 2900 | 2900 | 3700 |
| | Braking Capacity (MJ) | 10,8 | 21,6 | 21,6 | 21,6 | 21,6 |
| Drivetrain Efficiency (%) | Motor | 93,5 | 94,3 | 95,4 | 95,7 | 95,9 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98 |
| | Transformer | 99 | 99 | 99 | 99 | 99 |
| | Total Electrical Efficiency | 90,7 | 91,5 | 92,6 | 92,8 | 93,0 |
| Main Connection | Input Voltage (VAC) | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 1439 | 1898 | 2388 | 2857 | 3321 |
| | Input Current (A) | 1204 / 252 / 126 / 76 | 1589 / 333 / 167 / 100 | 1999 / 418 / 209 / 126 | 2391 / 500 / 250 / 150 | 2779 / 581 / 291 / 175 |
| Footprint ($m^2$) | Motor | 10,4 | 10,4 | 10,4 | 10,4 | 10,4 |
| | Frequency Converter | 2,5 | 3,3 | 3,6 | 3,8 | 3,8 |
| | Braking Resistor | 0,5 | 1,2 | 1,2 | 1,2 | 1,2 |
| | Transformer | 6,5 | 7,3 | 8,0 | 8,0 | 8,1 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 19,8 | 22,2 | 23,2 | 23,3 | 23,4 |
| Dimensions (L x W xH) | Motor | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 | 3900 x 2665 x 2730 |
| | Frequency Converter | 3430 x 718 x 2088 | 4630 x 718 x 2088 | 5030 x 718 x 2088 | 5230 x 718 x 2088 | 5230 x 718 x 2088 |
| | Braking Resistor | 830 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 |
| | Transformer | 3000 x 2150 x 2100 | 3250 x 2250 x 2400 | 3400 x 2350 x 2400 | 3400 x 2350 x 2400 | 3600 x 2250 x 2250 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 19500 | 19500 | 20500 | 20500 | 20500 |
| | Frequency Converter | 2220 | 3210 | 3390 | 3540 | 3540 |
| | Braking Resistor | 240 | 480 | 480 | 480 | 480 |
| | Transformer | 4300 | 5600 | 6000 | 6000 | 7000 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 26260 | 28790 | 30370 | 30520 | 31520 |
| LT-water flow ($m^3/h$) | Motor | 23 | 23 | 23 | 23 | 23 |
| | Frequency Converter | 3,5 | 5,4 | 6,2 | 7,0 | 7,0 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 6 | 7 | 5,5 | 5,5 | 8 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 76 | 88 | 90 | 101 | 108 |
| | Frequency Converter | 34 | 44 | 55 | 66 | 66 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 35 | 40 | 46 | 46 | 67 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 110 | 132 | 145 | 167 | 174 |
| Losses to ambient (kW) | Motor | 10 | 11 | 11 | 12 | 13 |
| | Frequency Converter | 2,5 | 3,3 | 4,2 | 5,0 | 5,9 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | 5,1 | 6,1 | 6,4 | 6,4 | 6,2 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 17,5 | 20,4 | 21,6 | 23,5 | 25,1 |



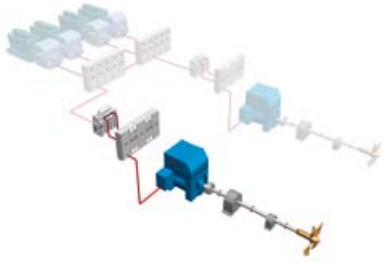


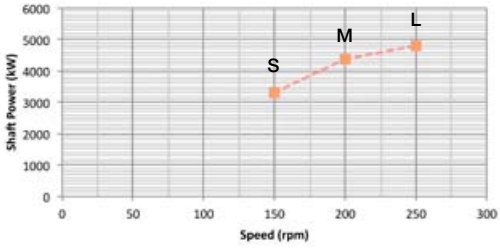

| Direct Drive 800 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 1730 | 2305 | 2880 | 3460 | 4040 |
| | Maximum Torque (kNm) | 109,7 | 110,0 | 109,9 | 110,4 | 110,4 |
| | Drive (kVA) | 2680 | 3330 | 3970 | 4630 | 5960 |
| | Transformer (kVA) | 2300 | 2900 | 3700 | 4100 | 4800 |
| | Braking Capacity (MJ) | 21,6 | 21,6 | 21,6 | 21,6 | 21,6 |
| Drivetrain Efficiency (%) | Motor | 93 | 94,6 | 95,3 | 95,6 | 96,4 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98 |
| | Transformer | 99 | 99 | 99 | 99 | 99 |
| | Total Electrical Efficiency | 90,2 | 91,8 | 92,5 | 92,8 | 93,5 |
| Main Connection | Input Voltage (VAC) | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 2018 | 2644 | 3279 | 3927 | 4547 |
| | Input Current (A) | 1689 / 354 / 177 / 106 | 2213 / 463 / 232 / 139 | 2744 / 574 / 287 / 173 | 3286 / 688 / 344 / 207 | 3805 / 796 / 398 / 239 |
| Footprint ($m^2$) | Motor | 12,6 | 12,6 | 12,6 | 12,6 | 12,6 |
| | Frequency Converter | 3,3 | 3,6 | 3,8 | 4,4 | 4,7 |
| | Braking Resistor | 1,2 | 1,2 | 1,2 | 1,2 | 1,2 |
| | Transformer | 7,3 | 8,0 | 8,1 | 8,0 | 8,6 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 24,4 | 25,4 | 25,6 | 26,1 | 27,1 |
| Dimensions (L x W xH) | Motor | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 | 4088 x 3086 x 3310 |
| | Frequency Converter | 4630 x 718 x 2088 | 5030 x 718 x 2088 | 5230 x 718 x 2088 | 6130 x 718 x 2088 | 6530 x 718 x 2088 |
| | Braking Resistor | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 |
| | Transformer | 3250 x 2250 x 2400 | 3400 x 2350 x 2400 | 3600 x 2250 x 2250 | 3700 x 2150 x 2550 | 3600 x 2400 x 2650 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 28500 | 28500 | 28500 | 28500 | 28500 |
| | Frequency Converter | 3210 | 3390 | 3540 | 4470 | 4860 |
| | Braking Resistor | 480 | 480 | 480 | 480 | 480 |
| | Transformer | 5600 | 6000 | 7000 | 7900 | 8500 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 37790 | 38370 | 39520 | 41350 | 42340 |
| LT-water flow ($m^3/h$) | Motor | 23 | 23 | 23 | 23 | 23 |
| | Frequency Converter | 5,4 | 6,2 | 7,0 | 8,9 | 10,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 7 | 5,5 | 8 | 10 | 13 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 106 | 116 | 120 | 142 | 134 |
| | Frequency Converter | 44 | 55 | 66 | 76 | 99 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 40 | 46 | 67 | 90 | 100 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 150 | 171 | 186 | 218 | 233 |
| Losses to ambient (kW) | Motor | 13 | 13 | 14 | 15 | 15 |
| | Frequency Converter | 3,5 | 4,6 | 5,8 | 6,9 | 8,1 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | 6,1 | 6,4 | 6,2 | 6,8 | 7,3 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 22,5 | 24,0 | 26,0 | 28,7 | 30,4 |



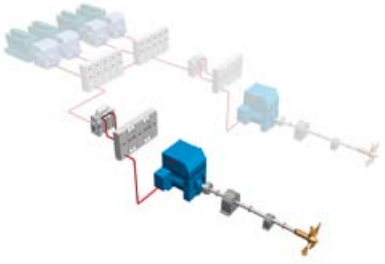


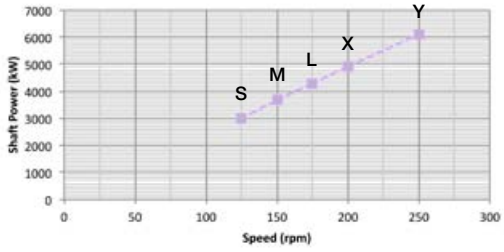

| Direct Drive 900 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 2360 | 3150 | 3930 | 4400 | 5900 |
| | Maximum Torque (kNm) | 150,3 | 150,2 | 149,9 | 140,2 | 161,0 |
| | Drive (kVA) | 3330 | 4630 | 5300 | 5960 | 9000 |
| | Transformer (kVA) | 2900 | 3700 | 4600 | 5200 | 7000 |
| | Braking Capacity (MJ) | 21,6 | 21,6 | 21,6 | 21,6 | 30 |
| Drivetrain Efficiency (%) | Motor | 94,1 | 95,4 | 95,9 | 96,2 | 96,7 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98,5 |
| | Transformer | 99 | 99 | 99 | 99 | 99 |
| | Total Electrical Efficiency | 91,3 | 92,6 | 93,0 | 93,3 | 94,3 |
| Main Connection | Input Voltage (VAC) | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 6600 / 11000 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 2721 | 3582 | 4446 | 4962 | 6586 |
| | Input Current (A) | 2277 / 477 / 239 / 143 | 2998 / 627 / 314 / 189 | 3721 / 778 / 389 / 234 | 4153 / 869 / 435 / 261 | 577 / 346 |
| Footprint ($m^2$) | Motor | 14,2 | 14,2 | 14,2 | 14,2 | 14,2 |
| | Frequency Converter | 3,6 | 4,4 | 4,5 | 4,7 | 7,9 |
| | Braking Resistor | 1,2 | 1,2 | 1,2 | 1,2 | 1,6 |
| | Transformer | 8,0 | 8,1 | 8,6 | 8,9 | 10,5 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 27,0 | 27,9 | 28,6 | 29,0 | 34,3 |
| Dimensions (L x W xH) | Motor | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 | 4330 x 3286 x 3700 |
| | Frequency Converter | 5030 x 718 x 2088 | 6130 x 718 x 2088 | 6330 x 718 x 2088 | 6530 x 718 x 2088 | 6730 x 1176 x 2475 |
| | Braking Resistor | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1800 x 900 x 1700 |
| | Transformer | 3400 x 2350 x 2400 | 3600 x 2250 x 2250 | 3600 x 2400 x 2650 | 3700 x 2400 x 2700 | 4200 x 2500 x 2800 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 39500 | 39500 | 39500 | 36500 | 33110 |
| | Frequency Converter | 3390 | 4470 | 4620 | 4860 | 6300 |
| | Braking Resistor | 480 | 480 | 480 | 480 | 620 |
| | Transformer | 6000 | 7000 | 8500 | 9800 | 11500 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 49370 | 51450 | 53100 | 51640 | 51530 |
| LT-water flow ($m^3/h$) | Motor | 25 | 25 | 25 | 25 | 25 |
| | Frequency Converter | 6,2 | 8,9 | 9,7 | 10,4 | 0,0 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 5,5 | 8 | 13 | 15 | 12 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 130 | 135 | 150 | 156 | 140 |
| | Frequency Converter | 55 | 76 | 87 | 99 | 83,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 46 | 67 | 100 | 115 | 123 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 185 | 211 | 237 | 255 | 223,4 |
| Losses to ambient (kW) | Motor | 15 | 15 | 16 | 16 | 16 |
| | Frequency Converter | 4,7 | 6,3 | 7,9 | 8,8 | 7,1 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | 6,4 | 6,2 | 7,3 | 7,5 | 8,9 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 26,1 | 27,5 | 31,1 | 32,3 | 32,0 |



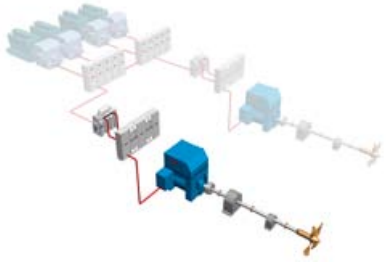


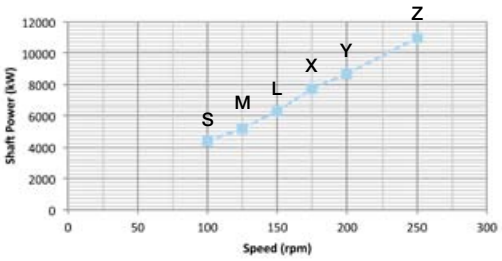

| Direct Drive 1000 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | ≥300 | ≥350 |
| | Maximum Power (kW) | 3300 | 4400 | 4800 | - | - |
| | Maximum Torque (kNm) | 209,9 | 209,7 | 182,7 | - | - |
| | Drive (kVA) | 4630 | 5960 | 6620 | - | - |
| | Transformer (kVA) | 3800 | 5200 | 5800 | - | - |
| | Braking Capacity (MJ) | 21,6 | 21,6 | 21,6 | - | - |
| Drivetrain Efficiency (%) | Motor | 94,8 | 95,7 | 96,3 | - | - |
| | Frequency Converter | 98 | 98 | 98 | - | - |
| | Transformer | 99 | 99 | 99 | - | - |
| | Total Electrical Efficiency | 92,0 | 92,8 | 93,4 | - | - |
| Main Connection | Input Voltage (VAC) | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | - | - |
| | Power factor | 0,95 | 0,95 | 0,95 | - | - |
| | Input power (kVA) | 3777 | 4988 | 5408 | - | - |
| | Input Current (A) | 3161 / 661 / 331 / 199 | 4174 / 873 / 437 / 262 | 4526 / 947 / 474 / 284 | - | - |
| Footprint ($m^2$) | Motor | 15,1 | 15,1 | 15,1 | - | - |
| | Frequency Converter | 4,4 | 4,7 | 5,0 | - | - |
| | Braking Resistor | 1,2 | 1,2 | 1,2 | - | - |
| | Transformer | 8,6 | 8,9 | 9,4 | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 29,3 | 29,9 | 30,7 | - | - |
| Dimensions (L x W xH) | Motor | 4980 x 3035 x 3285 | 4980 x 3035 x 3285 | 4980 x 3035 x 3285 | - | - |
| | Frequency Converter | 6130 x 718 x 2088 | 6530 x 718 x 2088 | 7030 x 718 x 2088 | - | - |
| | Braking Resistor | 1630 x 718 x 2088 | 1630 x 718 x 2088 | 1630 x 718 x 2088 | - | - |
| | Transformer | 3680 x 2330 x 2300 | 3700 x 2400 x 2700 | 3900 x 2400 x 2800 | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 55000 | 55000 | 48000 | - | - |
| | Frequency Converter | 4470 | 4860 | 5150 | - | - |
| | Braking Resistor | 480 | 480 | 480 | - | - |
| | Transformer | 7200 | 9800 | 10300 | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 67150 | 70140 | 63930 | - | - |
| LT-water flow ($m^3/h$) | Motor | 25 | 25 | 25 | - | - |
| | Frequency Converter | 8,9 | 10,4 | 6,7 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 10 | 15 | 12 | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 160 | 180 | 166 | - | - |
| | Frequency Converter | 76 | 99 | 112 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 77 | 100 | 100 | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 236 | 279 | 278 | - | - |
| Losses to ambient (kW) | Motor | 18 | 19 | 18 | - | - |
| | Frequency Converter | 6,6 | 8,8 | 9,6 | - | - |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | - | - |
| | Transformer | 6,5 | 7,5 | 8,0 | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 31,1 | 35,3 | 35,6 | - | - |



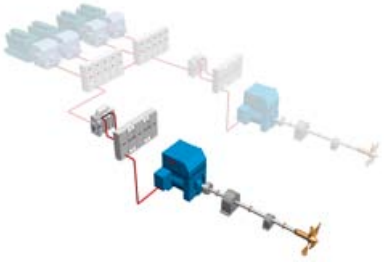


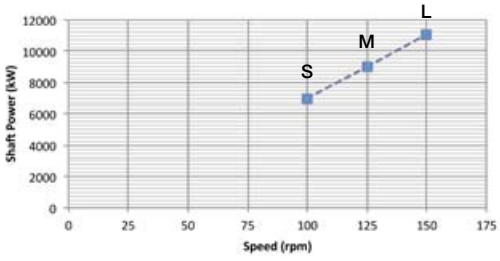

| Direct Drive 1120 asymmetric cooling - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥125 | ≥150 | ≥175 | ≥200 | ≥250 |
| | Maximum Power (kW) | 3000 | 3700 | 4300 | 4900 | 6100 |
| | Maximum Torque (kNm) | 229,0 | 235,5 | 234,6 | 234,0 | 233,0 |
| | Drive (kVA) | 5000 | 5000 | 7000 | 7000 | 9000 |
| | Transformer (kVA) | 3700 | 4400 | 5200 | 5800 | 7000 |
| | Braking Capacity (MJ) | 30 | 30 | 30 | 30 | 30 |
| Drivetrain Efficiency (%) | Motor | 94,5 | 95,4 | 95,9 | 96,4 | 97,0 |
| | Frequency Converter | 98,5 | 98,5 | 98,5 | 98,5 | 98,5 |
| | Transformer | 99 | 99 | 99 | 99 | 99 |
| | Total Electrical Efficiency | 92,2 | 93,1 | 93,5 | 94,0 | 94,6 |
| Main Connection | Input Voltage (VAC) | 6600 / 11000 | 6600 / 11000 | 6600 / 11000 | 6600 / 11000 | 6600 / 11000 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 3426 | 4185 | 4841 | 5487 | 6786 |
| | Input Current (A) | 300 / 180 | 367 / 220 | 424 / 255 | 480 / 288 | 594 / 357 |
| Footprint ($m^2$) | Motor | 17,0 | 17,0 | 17,0 | 17,0 | 17,0 |
| | Frequency Converter | 7,6 | 7,6 | 9,3 | 9,3 | 9,3 |
| | Braking Resistor | 1,6 | 1,6 | 1,6 | 1,6 | 1,6 |
| | Transformer | 7,7 | 9,1 | 9,6 | 9,8 | 10,5 |
| | Excitation Transformer | 0,8 | 0,8 | 0,8 | 0,8 | 0,8 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 34,7 | 36,2 | 38,4 | 38,6 | 39,3 |
| Dimensions (L x W xH) | Motor | 4820 x 3550 x 3345 | 4820 x 3550 x 3345 | 4820 x 3550 x 3345 | 4820 x 3550 x 3345 | 4820 x 3550 x 3345 |
| | Frequency Converter | 6430 x 1176 x 2475 | 6430 x 1176 x 2475 | 7930 x 1176 x 2475 | 7930 x 1176 x 2475 | 7930 x 1176 x 2475 |
| | Braking Resistor | 1800 x 900 x 1700 | 1800 x 900 x 1700 | 1800 x 900 x 1700 | 1800 x 900 x 1700 | 1800 x 900 x 1700 |
| | Transformer | 3650 x 2100 x 2350 | 3800 x 2400 x 2600 | 4000 x 2400 x 2850 | 4000 x 2450 x 2900 | 4200 x 2500 x 2800 |
| | Excitation Transformer | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1230 x 670 x 1355 |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 38450 | 38500 | 38500 | 38550 | 38450 |
| | Frequency Converter | 5500 | 5500 | 6600 | 6600 | 6600 |
| | Braking Resistor | 620 | 620 | 620 | 620 | 620 |
| | Transformer | 8000 | 8500 | 10200 | 10500 | 11500 |
| | Excitation Transformer | 1330 | 1330 | 1330 | 1330 | 1330 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 52570 | 53120 | 55920 | 56270 | 57170 |
| LT-water flow ($m^3/h$) | Motor | 32 | 33 | 34 | 34 | 35 |
| | Frequency Converter | 6,8 | 6,8 | 8,5 | 8,5 | 9,9 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 8 | 13 | 8 | 13 | 12 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 165 | 168 | 176 | 176 | 177 |
| | Frequency Converter | 57 | 57 | 70,6 | 70,6 | 82,6 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 67 | 100 | 115 | 123 | 123 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 222 | 225 | 246 | 247 | 260 |
| Losses to ambient (kW) | Motor | 9 | 9 | 9 | 9 | 9 |
| | Frequency Converter | 9,0 | 9,0 | 10,0 | 10,0 | 10,9 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | 6,2 | 7,1 | 8,3 | 8,6 | 8,9 |
| | Excitation Transformer | 5,4 | 5,4 | 5,4 | 5,4 | 5,4 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 29,3 | 30,4 | 32,9 | 33,3 | 34,5 |



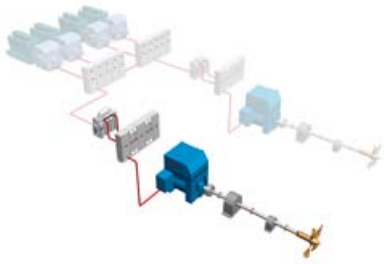


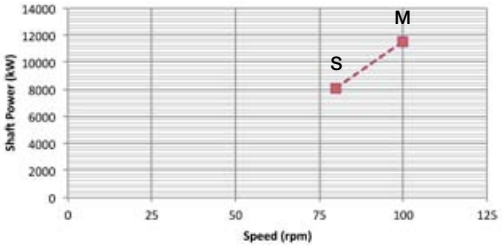

| Direct Drive 1120 symmetric cooling - Single Drive (with Transformer) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y | Z |
| | Propeller Speed (rpm) | ≥100 | ≥125 | ≥150 | ≥175 | ≥200 | ≥250 |
| | Maximum Power (kW) | 4400 | 5200 | 6300 | 7700 | 8700 | 11000 |
| | Maximum Torque (kNm) | 420,0 | 397,0 | 401,0 | 420,2 | 415,4 | 420 |
| | Drive (kVA) | 7000 | 7000 | 9000 | 9000 | 11000 | 14000 |
| | Transformer (kVA) | 5200 | 6400 | 8000 | 9000 | 10000 | 14000 |
| | Braking Capacity (MJ) | 30 | 30 | 30 | 46 | 46 | 46 |
| Drivetrain Efficiency (%) | Motor | 94,4 | 95,0 | 95,7 | 96,3 | 96,6 | 97,2 |
| | Frequency Converter | 98,5 | 98,5 | 98,5 | 98,5 | 98,5 | 98,5 |
| | Transformer | 99 | 99 | 99 | 99 | 99 | 99 |
| | Total Electrical Efficiency | 92,0 | 92,6 | 93,3 | 93,9 | 94,2 | 94,8 |
| Main Connection | Input Voltage (VAC) | 6600 / 11000 | 6600 / 11000 | 6600 / 11000 | 6600 / 11000 | 6600 / 11000 | 6600 / 11000 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 5032 | 5910 | 7107 | 8632 | 9719 | 12211 |
| | Input Current (A) | 441 / 265 | 518 / 311 | 622 / 374 | 756 / 454 | 851 / 511 | 1069 / 641 |
| Footprint ($m^2$) | Motor | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 | 19,6 |
| | Frequency Converter | 9,3 | 9,3 | 9,3 | 9,3 | 9,8 | 12,7 |
| | Braking Resistor | 1,6 | 1,6 | 1,6 | 2,0 | 2,0 | 2,0 |
| | Transformer | 9,6 | 9,6 | 10,9 | 10,8 | 11,9 | 13,3 |
| | Excitation Transformer | 0,8 | 0,8 | 0,8 | 0,8 | 0,8 | 1,5 |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 41,0 | 41,0 | 42,3 | 42,6 | 44,1 | 49,0 |
| Dimensions (L x W xH) | Motor | 5530 x 3550 x 3345 | 5530 x 3550 x 3345 | 5530 x 3550 x 3345 | 5530 x 3550 x 3345 | 5530 x 3550 x 3345 | 5530 x 3550 x 3345 |
| | Frequency Converter | 7930 x 1176 x 2475 | 7930 x 1176 x 2475 | 7930 x 1176 x 2475 | 7930 x 1176 x 2475 | 8330 x 1176 x 2475 | 10830 x 1176 x 2475 |
| | Braking Resistor | 1800 x 900 x 1700 | 1800 x 900 x 1700 | 1800 x 900 x 1700 | 2200 x 900 x 1700 | 2200 x 900 x 1700 | 2200 x 900 x 1700 |
| | Transformer | 4000 x 2400 x 2850 | 4000 x 2400 x 3000 | 4200 x 2600 x 2950 | 4500 x 2400 x 3100 | 4750 x 2500 x 3300 | 5300 x 2500 x 3500 |
| | Excitation Transformer | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1240 x 1170 x 1555 |
| | Harmonic Filter | - | - | - | - | - | - |
| Weight (kg) | Motor | 52650 | 52050 | 52100 | 52150 | 52150 | 52300 |
| | Frequency Converter | 6600 | 6600 | 6600 | 6600 | 6800 | 8900 |
| | Braking Resistor | 620 | 620 | 620 | 750 | 750 | 750 |
| | Transformer | 10200 | 11000 | 12500 | 13200 | 15800 | 18500 |
| | Excitation Transformer | 1330 | 1330 | 1330 | 1330 | 1330 | 1720 |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 70070 | 70270 | 71820 | 72700 | 75500 | 80450 |
| LT-water flow ($m^3/h$) | Motor | 48 | 50 | 51 | 53 | 0 | 56 |
| | Frequency Converter | 8,5 | 8,5 | 10,4 | 12,1 | 15,0 | 17,6 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | 8 | 13 | 19 | 19 | 19 | 19 |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Losses to water (kW) | Motor | 248 | 262 | 270 | 282 | 288 | 297 |
| | Frequency Converter | 70,6 | 70,6 | 86,5 | 101,1 | 124,7 | 146,8 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | 72 | 123 | 158 | 158 | 158 | 158 |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 319 | 332 | 356 | 383 | 413 | 443 |
| Losses to ambient (kW) | Motor | 13 | 14 | 14 | 15 | 15 | 16 |
| | Frequency Converter | 10,0 | 10,0 | 11,2 | 12,3 | 14,1 | 15,8 |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | 8,3 | 8,9 | 9,2 | 9,6 | 10,8 | 12,2 |
| | Excitation Transformer | 5,4 | 5,4 | 5,4 | 5,4 | 5,4 | 7 |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 36,8 | 38,1 | 40,0 | 42,2 | 45,4 | 50,6 |



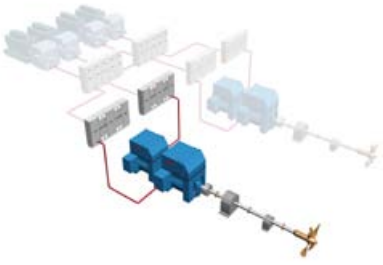


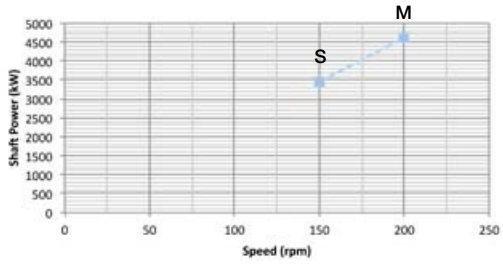

| Direct Drive 1250 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥100 | ≥125 | ≥150 | - | - |
| | Maximum Power (kW) | 7000 | 9000 | 11100 | - | - |
| | Maximum Torque (kNm) | 669,0 | 687,5 | 706,6 | - | - |
| | Drive (kVA) | 9000 | 11000 | 14000 | - | - |
| | Transformer (kVA) | 8000 | 12000 | 14000 | - | - |
| | Braking Capacity (MJ) | 30 | 46 | 46 | - | - |
| Drivetrain Efficiency (%) | Motor | 94,69 | 95,6 | 96,53 | - | - |
| | Frequency Converter | 98,5 | 98,5 | 98,5 | - | - |
| | Transformer | 99 | 99 | 99 | - | - |
| | Total Electrical Efficiency | 92,3 | 93,2 | 94,1 | - | - |
| Main Connection | Input Voltage (VAC) | 6600 / 11000 | 6600 / 11000 | 6600 / 11000 | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | - | - |
| | Power factor | 0,95 | 0,95 | 0,95 | - | - |
| | Input power (kVA) | 7980 | 10162 | 12413 | - | - |
| | Input Current (A) | 699 / 419 | 889 / 534 | 1086 / 652 | - | - |
| Footprint ($m^2$) | Motor | 24,4 | 24,4 | 24,4 | - | - |
| | Frequency Converter | 9,3 | 9,8 | 12,7 | - | - |
| | Braking Resistor | 1,6 | 2,0 | 2,0 | - | - |
| | Transformer | 10,9 | 12,5 | 13,3 | - | - |
| | Excitation Transformer | 0,8 | 0,8 | 1,5 | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 47,0 | 49,5 | 53,8 | - | - |
| Dimensions (L x W xH) | Motor | 5940 x 4100 x 3925 | 5940 x 4100 x 3925 | 5940 x 4100 x 3925 | - | - |
| | Frequency Converter | 7930 x 1176 x 2475 | 8330 x 1176 x 2475 | 10830 x 1176 x 2475 | - | - |
| | Braking Resistor | 1800 x 900 x 1700 | 2200 x 900 x 1700 | 2200 x 900 x 1700 | - | - |
| | Transformer | 4200 x 2600 x 2950 | 5000 x 2500 x 3300 | 5300 x 2500 x 3500 | - | - |
| | Excitation Transformer | 1230 x 670 x 1355 | 1230 x 670 x 1355 | 1240 x 1170 x 1555 | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 84050 | 84100 | 84100 | - | - |
| | Frequency Converter | 6600 | 6800 | 8900 | - | - |
| | Braking Resistor | 620 | 750 | 750 | - | - |
| | Transformer | 12500 | 17200 | 18500 | - | - |
| | Excitation Transformer | 1330 | 1330 | 1720 | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 103770 | 108850 | 112250 | - | - |
| LT-water flow ($m^3/h$) | Motor | 70 | 73 | 71 | - | - |
| | Frequency Converter | 12,1 | 15,0 | 17,6 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 19 | 19 | 19 | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 373 | 394 | 379 | - | - |
| | Frequency Converter | 101,1 | 124,7 | 146,8 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 158 | 158 | 158 | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 474 | 518 | 526 | - | - |
| Losses to ambient (kW) | Motor | 20 | 21 | 20 | - | - |
| | Frequency Converter | 12,3 | 14,1 | 15,8 | - | - |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | - | - |
| | Transformer | 9,2 | 11,2 | 12,2 | - | - |
| | Excitation Transformer | 5,4 | 5,4 | 7 | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 46,5 | 51,4 | 55,0 | - | - |



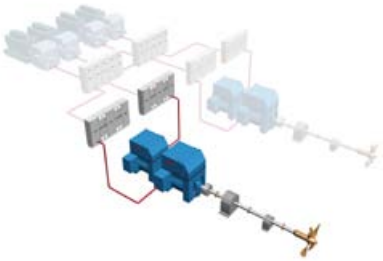


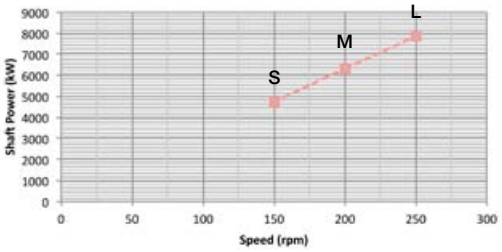

| Direct Drive 1600 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥80 | ≥100 | - | - | - |
| | Maximum Power (kW) | 8100 | 11500 | - | - | - |
| | Maximum Torque (kNm) | 966,8 | 1002,7 | - | - | - |
| | Drive (kVA) | 11000 | 14000 | - | - | - |
| | Transformer (kVA) | 10000 | 14000 | - | - | - |
| | Braking Capacity (MJ) | 46 | 46 | - | - | - |
| Drivetrain Efficiency (%) | Motor | 94,85 | 95,94 | - | - | - |
| | Frequency Converter | 98,5 | 98,5 | - | - | - |
| | Transformer | 99 | 99 | - | - | - |
| | Total Electrical Efficiency | 92,5 | 93,6 | - | - | - |
| Main Connection | Input Voltage (VAC) | 6600 / 11000 | 6600 / 11000 | - | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | - | - | - |
| | Power factor | 0,95 | 0,95 | - | - | - |
| | Input power (kVA) | 9218 | 12939 | - | - | - |
| | Input Current (A) | 807 / 484 | 1132 / 680 | - | - | - |
| Footprint ($m^2$) | Motor | 29,1 | 29,1 | - | - | - |
| | Frequency Converter | 9,8 | 12,7 | - | - | - |
| | Braking Resistor | 2,0 | 2,0 | - | - | - |
| | Transformer | 11,9 | 13,3 | - | - | - |
| | Excitation Transformer | 0,8 | 1,5 | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 53,5 | 58,5 | - | - | - |
| Dimensions (L x W xH) | Motor | 6150 x 4724 x 4145 | 6150 x 4724 x 4145 | - | - | - |
| | Frequency Converter | 8330 x 1176 x 2475 | 10830 x 1176 x 2475 | - | - | - |
| | Braking Resistor | 2200 x 900 x 1700 | 2200 x 900 x 1700 | - | - | - |
| | Transformer | 4750 x 2500 x 3300 | 5300 x 2500 x 3500 | - | - | - |
| | Excitation Transformer | 1230 x 670 x 1355 | 1240 x 1170 x 1555 | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 110355 | 122255 | - | - | - |
| | Frequency Converter | 6800 | 8900 | - | - | - |
| | Braking Resistor | 750 | 750 | - | - | - |
| | Transformer | 15800 | 18500 | - | - | - |
| | Excitation Transformer | 1330 | 1720 | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 133705 | 150405 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 80 | 88 | - | - | - |
| | Frequency Converter | 15,0 | 17,6 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 19 | 19 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 418 | 462 | - | - | - |
| | Frequency Converter | 124,7 | 146,8 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 158 | 158 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 543 | 609 | - | - | - |
| Losses to ambient (kW) | Motor | 22 | 24 | - | - | - |
| | Frequency Converter | 14,1 | 15,8 | - | - | - |
| | Braking Resistor | Intermittent | Intermittent | - | - | - |
| | Transformer | 10,8 | 12,2 | - | - | - |
| | Excitation Transformer | 5,4 | 7 | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 52,2 | 59,3 | - | - | - |



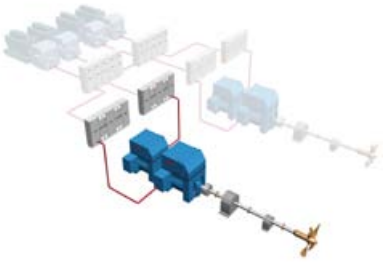


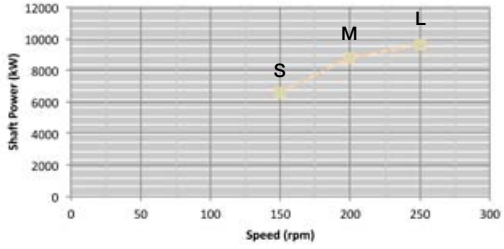

| Direct Drive 800 - Tandem Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | - | - | - |
| | Maximum Power (kW) | 3460 | 4610 | - | - | - |
| | Maximum Torque (kNm) | 219,4 | 220,0 | - | - | - |
| | Drive (kVA) | 2 x 2680 | 2 x 3330 | - | - | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | 2 x 21,6 | 2 x 21,6 | - | - | - |
| Drivetrain Efficiency (%) | Motor | 93 | 94,6 | - | - | - |
| | Frequency Converter | 98 | 98 | - | - | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 91,1 | 92,7 | - | - | - |
| Main Connection | Input Voltage (VAC) | 690 | 690 | - | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | - | - | - |
| | Power factor | 0,95 | 0,95 | - | - | - |
| | Input power (kVA) | 3996 | 5234 | - | - | - |
| | Input Current (A) | 2 x 1672 | 2 x 2190 | - | - | - |
| Footprint ($m^2$) | Motor | 2 x 12,6 | 2 x 12,6 | - | - | - |
| | Frequency Converter | 2 x 3,3 | 2 x 3,6 | - | - | - |
| | Braking Resistor | 2 x 1,2 | 2 x 1,2 | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2,6 | 2,6 | - | - | - |
| | Total | 36,8 | 37,4 | - | - | - |
| Dimensions (L x W xH) | Motor | 2 x (4088 x 3086 x 3310) | 2 x (4088 x 3086 x 3310) | - | - | - |
| | Frequency Converter | 2x (4630 x 718 x 2088) | 2 x (5030 x 718 x 2088) | - | - | - |
| | Braking Resistor | 2 x (1630 x 718 x 2088) | 2 x (1630 x 718 x 2088) | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 3440 x 760 x 2090 | 3440 x 760 x 2090 | - | - | - |
| Weight (kg) | Motor | 2 x 28500 | 2 x 28500 | - | - | - |
| | Frequency Converter | 2 x 3210 | 2 x 3390 | - | - | - |
| | Braking Resistor | 2 x 480 | 2 x 480 | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1700 | 1700 | - | - | - |
| | Total | 66080 | 66440 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 2 x 23 | 2 x 23 | - | - | - |
| | Frequency Converter | 2 x 5,4 | 2 x 6,18 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 2 x 106 | 2 x 166 | - | - | - |
| | Frequency Converter | 2 x 44 | 2 x 55 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 300 | 342 | - | - | - |
| Losses to ambient (kW) | Motor | 2 x 13 | 2 x 13 | - | - | - |
| | Frequency Converter | 2 x 3,5 | 2 x 4,6 | - | - | - |
| | Braking Resistor | Intermittent | Intermittent | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | - | - | - |
| | Total | 34,7 | 37,0 | - | - | - |



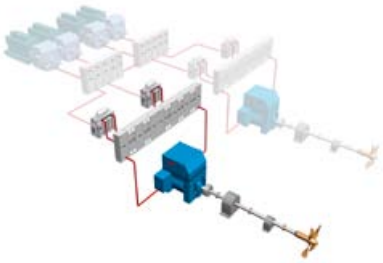


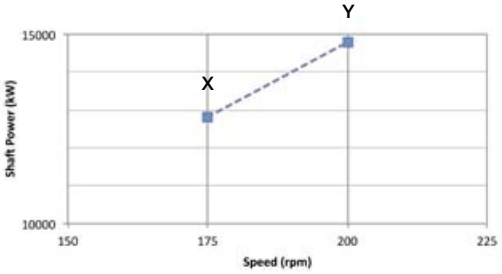

| Direct Drive 900 - Tandem Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | - | - |
| | Maximum Power (kW) | 4720 | 6300 | 7860 | - | - |
| | Maximum Torque (kNm) | 300,6 | 300,4 | 299,8 | - | - |
| | Drive (kVA) | 2 x 3330 | 2 x 4630 | 2 x 5300 | - | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | 2 x 21,6 | 2 x 21,6 | 2 x 21,6 | - | - |
| Drivetrain Efficiency (%) | Motor | 94,1 | 95,4 | 95,9 | - | - |
| | Frequency Converter | 98 | 98 | 98 | - | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 92,2 | 93,5 | 94,0 | - | - |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | - | - |
| | Power factor | 0,95 | 0,95 | 0,95 | - | - |
| | Input power (kVA) | 5388 | 7093 | 8803 | - | - |
| | Input Current (A) | 2 x 2255 | 2 x 2968 | 2 x 3684 | - | - |
| Footprint ($m^2$) | Motor | 2 x 14,2 | 2 x 14,2 | 2 x 14,2 | - | - |
| | Frequency Converter | 2 x 3,6 | 2 x 4,4 | 2 x 4,5 | - | - |
| | Braking Resistor | 2 x 1,2 | 2 x 1,2 | 2 x 1,2 | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2,6 | 2,6 | 2,6 | - | - |
| | Total | 40,6 | 42,2 | 42,5 | - | - |
| Dimensions (L x W xH) | Motor | 2 x (4330 x 3286 x 3700) | 2 x (4330 x 3286 x 3700) | 2 x (4330 x 3286 x 3700) | - | - |
| | Frequency Converter | 2 x (5030 x 718 x 2088) | 2 x (6130 x 718 x 2088) | 2 x (6330 x 718 x 2088) | - | - |
| | Braking Resistor | 2 x (1630 x 718 x 2088) | 2 x (1630 x 718 x 2088) | 2 x (1630 x 718 x 2088) | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 3440 x 760 x 2090 | 3440 x 760 x 2090 | 3440 x 760 x 2090 | - | - |
| Weight (kg) | Motor | 2 x 39500 | 2 x 39500 | 2 x 39500 | - | - |
| | Frequency Converter | 2 x 3390 | 2 x 4470 | 2 x 4920 | - | - |
| | Braking Resistor | 2 x 480 | 2 x 480 | 2 x 480 | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1700 | 1700 | 1700 | - | - |
| | Total | 88440 | 90600 | 91500 | - | - |
| LT-water flow ($m^3/h$) | Motor | 2 x 25 | 2 x 25 | 2 x 25 | - | - |
| | Frequency Converter | 2 x 6,18 | 2 x 8,88 | 2 x 9,66 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 2 x 130 | 2 x 135 | 2 x 150 | - | - |
| | Frequency Converter | 2 x 55 | 2 x 76 | 2 x 87 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 370 | 422 | 474 | - | - |
| Losses to ambient (kW) | Motor | 2 x 15 | 2 x 15 | 2 x 16 | - | - |
| | Frequency Converter | 2 x 4,7 | 2 x 6,3 | 2 x 7,8 | - | - |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | - | - |
| | Total | 41,2 | 44,4 | 49,5 | - | - |



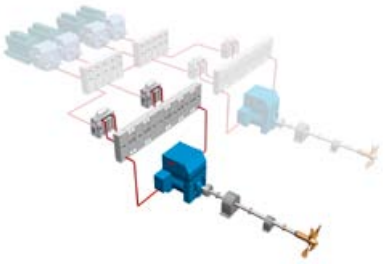


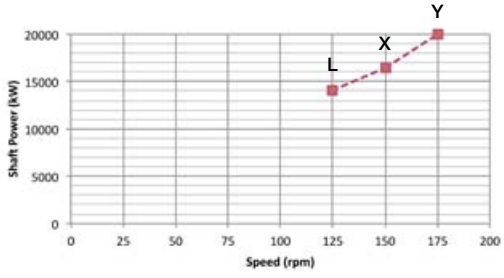

| Direct Drive 1000 - Tandem Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥150 | ≥200 | ≥250 | - | - |
| | Maximum Power (kW) | 6600 | 8800 | 9600 | - | - |
| | Maximum Torque (kNm) | 419,8 | 419,4 | 365,4 | - | - |
| | Drive (kVA) | 2 x 4630 | 2 x 5960 | 2 x 6620 | - | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | 2 x 21,6 | 2 x 21,6 | 2 x 21,6 | - | - |
| Drivetrain Efficiency (%) | Motor | 94,8 | 95,7 | 96,3 | - | - |
| | Frequency Converter | 98 | 98 | 98 | - | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 92,9 | 93,8 | 94,4 | - | - |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | - | - |
| | Power factor | 0,95 | 0,95 | 0,95 | - | - |
| | Input power (kVA) | 7478 | 9877 | 10708 | - | - |
| | Input Current (A) | 2 x 3129 | 2 x 4133 | 2 x 4480 | - | - |
| Footprint ($m^2$) | Motor | 2 x 15,1 | 2 x 15,1 | 2 x 15,1 | - | - |
| | Frequency Converter | 2 x 4,4 | 2 x 4,7 | 2 x 5,0 | - | - |
| | Braking Resistor | 2 x 1,2 | 2 x 1,2 | 2 x 1,2 | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2,6 | 2,6 | 2,6 | - | - |
| | Total | 41,4 | 42,0 | 42,6 | - | - |
| Dimensions (L x W xH) | Motor | 2 x (4980 x 3035 x 3285) | 2 x (4980 x 3035 x 3285) | 2 x (4980 x 3035 x 3285) | - | - |
| | Frequency Converter | 2 x (6130 x 718 x 2088) | 2 x (6530 x 718 x 2088) | 2 x (7030 x 718 x 2088) | - | - |
| | Braking Resistor | 2 x (1630 x 718 x 2088) | 2 x (1630 x 718 x 2088) | 2 x (1630 x 718 x 2088) | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 3440 x 760 x 2090 | 3440 x 760 x 2090 | 3440 x 760 x 2090 | - | - |
| Weight (kg) | Motor | 2 x 55000 | 2 x 55000 | 2 x 48000 | - | - |
| | Frequency Converter | 2 x 4470 | 2 x 4860 | 2 x 5150 | - | - |
| | Braking Resistor | 2 x 480 | 2 x 480 | 2 x 480 | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1700 | 1700 | 1700 | - | - |
| | Total | 121600 | 122380 | 108960 | - | - |
| LT-water flow ($m^3/h$) | Motor | 2 x 25 | 2 x 25 | 2 x 25 | - | - |
| | Frequency Converter | 2 x 8,88 | 2 x 10,44 | 2 x 6,72 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 2 x 160 | 2 x 180 | 2 x 166 | - | - |
| | Frequency Converter | 2 x 76 | 2 x 99 | 2 x 112 | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 472 | 558 | 556 | - | - |
| Losses to ambient (kW) | Motor | 2 x 18 | 2 x 19 | 2 x 18 | - | - |
| | Frequency Converter | 2 x 6,6 | 2 x 8,8 | 2 x 9,6 | - | - |
| | Braking Resistor | Intermittent | Intermittent | Intermittent | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | - | - |
| | Total | 51,0 | 57,4 | 57,0 | - | - |



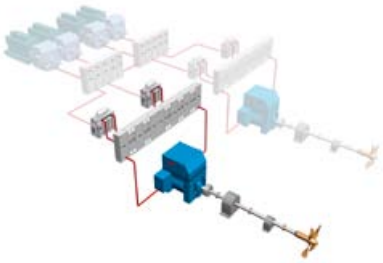


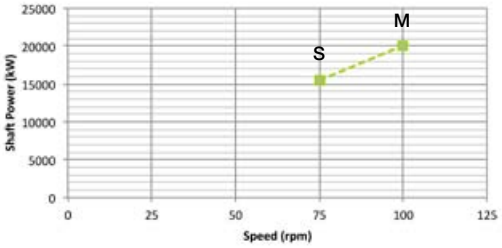

| Direct Drive 1250 - Single Drive (twin in/out) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | - | - | - | ≥175 | ≥200 |
| | Maximum Power (kW) | - | - | - | 12800 | 14800 |
| | Maximum Torque (kNm) | - | - | - | 698,5 | 707,0 |
| | Drive (kVA) | - | - | - | 18000 | 18000 |
| | Transformer (kVA) | - | - | - | 2 x 8000 | 2 x 9000 |
| | Braking Capacity (MJ) | - | - | - | 60 | 60 |
| Drivetrain Efficiency (%) | Motor | - | - | - | 96,77 | 97,27 |
| | Frequency Converter | - | - | - | 98,5 | 98,5 |
| | Transformer | - | - | - | 99 | 99 |
| | Total Electrical Efficiency | - | - | - | 95,3 | 94,9 |
| Main Connection | Input Voltage (VAC) | - | - | - | 6600 / 11000 | 6600 / 11000 |
| | Frequency (Hz) | - | - | - | 50/60 | 50/60 |
| | Power factor | - | - | - | 0,95 | 0,95 |
| | Input power (kVA) | - | - | - | 14135 | 16424 |
| | Input Current (A) | - | - | - | 2 x 619 / 2 x 371 | 2 x 719 / 2 x 432 |
| Footprint ($m^2$) | Motor | - | - | - | 24,4 | 24,4 |
| | Frequency Converter | - | - | - | 16,0 | 16,0 |
| | Braking Resistor | - | - | - | 2,0 | 2,0 |
| | Transformer | - | - | - | 2 x 10,9 | 2 x 11,7 |
| | Excitation Transformer | - | - | - | 1,5 | 1,5 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | - | 65,6 | 67,2 |
| Dimensions (L x W xH) | Motor | - | - | - | 5940 x 4100 x 3925 | 5940 x 4100 x 3925 |
| | Frequency Converter | - | - | - | 13630 x 1176 x 2475 | 13630 x 1176 x 2475 |
| | Braking Resistor | - | - | - | 2200 x 900 x 2000 | 2200 x 900 x 2000 |
| | Transformer | - | - | - | 2 x (4200 x 2600 x 2950) | 2 x (4500 x 2400 x 3100) |
| | Excitation Transformer | - | - | - | 1240 x 1170 x 1555 | 1240 x 1170 x 1555 |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | - | - | - | 84150 | 84200 |
| | Frequency Converter | - | - | - | 11400 | 11400 |
| | Braking Resistor | - | - | - | 860 | 860 |
| | Transformer | - | - | - | 2 x 12500 | 2 x 13200 |
| | Excitation Transformer | - | - | - | 1720 | 1720 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | - | 123130 | 124580 |
| LT-water flow ($m^3/h$) | Motor | - | - | - | 75 | 73 |
| | Frequency Converter | - | - | - | 22,0 | 22,0 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | 2 x 19 | 2 x 19 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | - | - | - | 406 | 395 |
| | Frequency Converter | - | - | - | 183,5 | 183,5 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | 2 x 158 | 2 x 158 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | - | 839 | 828 |
| Losses to ambient (kW) | Motor | - | - | - | 21 | 21 |
| | Frequency Converter | - | - | - | 18,5 | 18,5 |
| | Braking Resistor | - | - | - | Intermittent | Intermittent |
| | Transformer | - | - | - | 2 x 9,2 | 2 x 9,6 |
| | Excitation Transformer | - | - | - | 7 | 7 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | - | 65,3 | 65,5 |



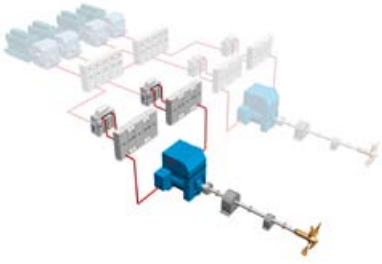


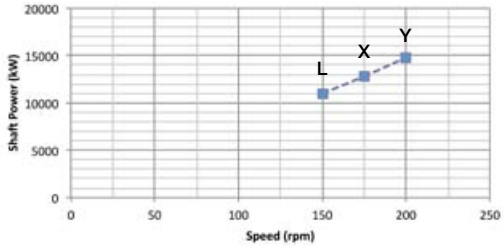

| Direct Drive 1600 - Single Drive (twin in/out) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | - | - | ≥125 | ≥150 | ≥175 |
| | Maximum Power (kW) | - | - | 14000 | 16500 | 20000 |
| | Maximum Torque (kNm) | - | - | 1070,0 | 1050,0 | 1091,0 |
| | Drive (kVA) | - | - | 18000 | 22000 | 22000 |
| | Transformer (kVA) | - | - | 2 x 9000 | 2 x 10000 | 2 x 12000 |
| | Braking Capacity (MJ) | - | - | 60 | 100 | 100 |
| Drivetrain Efficiency (%) | Motor | - | - | 96,5 | 97,04 | 97,49 |
| | Frequency Converter | - | - | 98,5 | 98,5 | 98,5 |
| | Transformer | - | - | 99 | 99 | 99 |
| | Total Electrical Efficiency | - | - | 94,1 | 94,6 | 95,1 |
| Main Connection | Input Voltage (VAC) | - | - | 6600 / 11000 | 11000 | 11000 |
| | Frequency (Hz) | - | - | 50/60 | 50/60 | 50/60 |
| | Power factor | - | - | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | - | - | 15661 | 18354 | 22145 |
| | Input Current (A) | - | - | 2 x 685 / 2 x 411 | 2 x 482 | 2 x 582 |
| Footprint ($m^2$) | Motor | - | - | 29,1 | 29,1 | 29,1 |
| | Frequency Converter | - | - | 16,0 | 17,0 | 17,0 |
| | Braking Resistor | - | - | 2,0 | 2,6 | 2,6 |
| | Transformer | - | - | 2 x 11,7 | 2 x 11,9 | 2 x 12,5 |
| | Excitation Transformer | - | - | 1,5 | 1,5 | 1,5 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | 71,9 | 73,9 | 75,1 |
| Dimensions (L x W xH) | Motor | - | - | 6150 x 4724 x 4145 | 6150 x 4724 x 4145 | 6150 x 4724 x 4145 |
| | Frequency Converter | - | - | 13630 x 1176 x 2475 | 14430 x 1176 2475 | 14430 x 1176 2475 |
| | Braking Resistor | - | - | 2200 x 900 x 2000 | 2200 x 1200 x 2200 | 2200 x 1200 x 2200 |
| | Transformer | - | - | 2 x (4500 x 2400 x 3100) | 2 x (4750 x 2500 x 3300) | 2 x (5000 x 2500 x 3300) |
| | Excitation Transformer | - | - | 1240 x 1170 x 1555 | 1240 x 1170 x 1555 | 1240 x 1170 x 1555 |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | - | - | 119105 | 119105 | 122255 |
| | Frequency Converter | - | - | 11400 | 11800 | 11800 |
| | Braking Resistor | - | - | 860 | 1200 | 1200 |
| | Transformer | - | - | 2 x 13200 | 2 x 15800 | 2 x 17200 |
| | Excitation Transformer | - | - | 1720 | 1720 | 1720 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | 159485 | 165425 | 171375 |
| LT-water flow ($m^3/h$) | Motor | - | - | 91 | 90 | 92 |
| | Frequency Converter | - | - | 22,0 | 38,0 | 38,0 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | 2 x 19 | 2 x 19 | 2 x 19 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | - | - | 482 | 478 | 489 |
| | Frequency Converter | - | - | 183,5 | 266,4 | 266,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | 2 x 158 | 2 x 158 | 2 x 158 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | 916 | 995 | 1006 |
| Losses to ambient (kW) | Motor | - | - | 25 | 25 | 26 |
| | Frequency Converter | - | - | 18,5 | 24,8 | 24,8 |
| | Braking Resistor | - | - | Intermittent | Intermittent | Intermittent |
| | Transformer | - | - | 2 x 9,6 | 2 x 10,8 | 2 x 11,6 |
| | Excitation Transformer | - | - | 7 | 7 | 7 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | 70,1 | 78,6 | 80,7 |



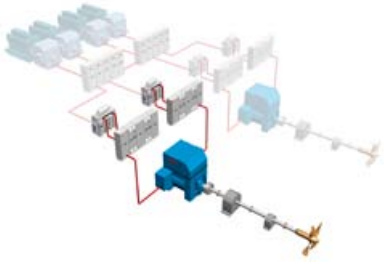


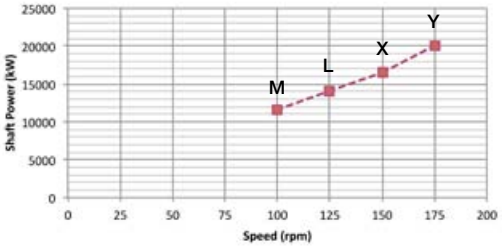

| Direct Drive 2000 - Single Drive (twin in/out) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥75 | ≥100 | - | - | - |
| | Maximum Power (kW) | 15500 | 20000 | - | - | - |
| | Maximum Torque (kNm) | 1974,0 | 1909,9 | - | - | - |
| | Drive (kVA) | 18000 | 22000 | - | - | - |
| | Transformer (kVA) | 2 x 9000 | 2 x 12000 | - | - | - |
| | Braking Capacity (MJ) | 100 | 100 | - | - | - |
| Drivetrain Efficiency (%) | Motor | 95,76 | 96,9 | - | - | - |
| | Frequency Converter | 98,5 | 98,5 | - | - | - |
| | Transformer | 99 | 99 | - | - | - |
| | Total Electrical Efficiency | 93,4 | 94,5 | - | - | - |
| Main Connection | Input Voltage (VAC) | 11000 | 11000 | - | - | - |
| | Frequency (Hz) | 50/60 Hz | 50/60 Hz | - | - | - |
| | Power factor | 0,95 | 0,95 | - | - | - |
| | Input power (kVA) | 17472 | 22280 | - | - | - |
| | Input Current (A) | 2 x 459 | 2 x 585 | - | - | - |
| Footprint ($m^2$) | Motor | 37,3 | 37,3 | - | - | - |
| | Frequency Converter | 17,0 | 17,0 | - | - | - |
| | Braking Resistor | 2,6 | 2,6 | - | - | - |
| | Transformer | 2 x 11,7 | 2 x 12,5 | - | - | - |
| | Excitation Transformer | 1,5 | 1,5 | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 81,8 | 83,4 | - | - | - |
| Dimensions (L x W xH) | Motor | 6515 x 5724 x 5045 | 6515 x 5724 x 5045 | - | - | - |
| | Frequency Converter | 14430 x 1176 2475 | 14430 x 1176 2475 | - | - | - |
| | Braking Resistor | 2200 x 1200 x 2200 | 2200 x 1200 x 2200 | - | - | - |
| | Transformer | 2 x (4500 x 2400 x 3100) | 2 x (5000 x 2500 x 3300) | - | - | - |
| | Excitation Transformer | 1240 x 1170 x 1555 | 1240 x 1170 x 1555 | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 154486 | 153500 | - | - | - |
| | Frequency Converter | 11800 | 11800 | - | - | - |
| | Braking Resistor | 1200 | 1200 | - | - | - |
| | Transformer | 2 x 13200 | 2 x 17200 | - | - | - |
| | Excitation Transformer | 1720 | 1720 | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 195606 | 200900 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 123 | 96 | - | - | - |
| | Frequency Converter | 22,0 | 38,0 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 2 x 19 | 2 x 19 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 652 | 608 | - | - | - |
| | Frequency Converter | 183,5 | 266,4 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 2 x 158 | 2 x 158 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 1085 | 1124 | - | - | - |
| Losses to ambient (kW) | Motor | 34 | 32 | - | - | - |
| | Frequency Converter | 24,8 | 24,8 | - | - | - |
| | Braking Resistor | Intermittent | Intermittent | - | - | - |
| | Transformer | 2 x 9,6 | 2 x 11,6 | - | - | - |
| | Excitation Transformer | 7 | 7 | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 85,3 | 87,0 | - | - | - |



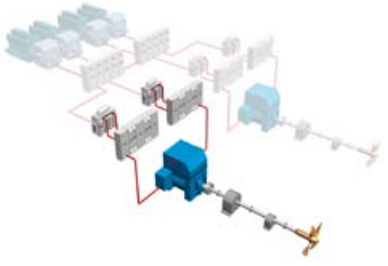


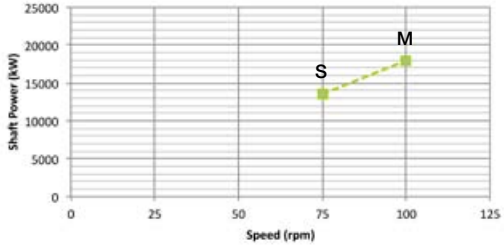

| Direct Drive 1250 - Full Redundant Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | - | - | ≥150 | ≥175 | ≥200 |
| | Maximum Power (kW) | - | - | 11100 | 12800 | 14800 |
| | Maximum Torque (kNm) | - | - | 707,0 | 698,0 | 707,0 |
| | Drive (kVA) | - | - | 2 x 7000 | 2 x 9000 | 2 x 9000 |
| | Transformer (kVA) | - | - | 2 x 7000 | 2 x 8000 | 2 x 9000 |
| | Braking Capacity (MJ) | - | - | 2 x 30 | 2 x 30 | 2 x 30 |
| Drivetrain Efficiency (%) | Motor | - | - | 96,5 | 96,8 | 97,3 |
| | Frequency Converter | - | - | 98,5 | 98,5 | 98,5 |
| | Transformer | - | - | 99 | 99 | 99 |
| | Total Electrical Efficiency | - | - | 94,1 | 94,4 | 94,9 |
| Main Connection | Input Voltage (VAC) | - | - | 6600 / 11000 | 6600 / 11000 | 6600 / 11000 |
| | Frequency (Hz) | - | - | 50/60 | 50/60 | 50/60 |
| | Power factor | - | - | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | - | - | 12413 | 14278 | 16424 |
| | Input Current (A) | - | - | 2 x 543 / 2 x 326 | 2 x 625 / 2 x 375 | 2 x 719 / 2 x 432 |
| Footprint ($m^2$) | Motor | - | - | 24,4 | 24,4 | 24,4 |
| | Frequency Converter | - | - | 2 x 9,3 | 2 x 9,3 | 2 x 9,3 |
| | Braking Resistor | - | - | 2 x 1,6 | 2 x 1,6 | 2 x 1,6 |
| | Transformer | - | - | 2 x 10,5 | 2 x 10,9 | 2 x 10,8 |
| | Excitation Transformer | - | - | 2 x 1,5 | 2 x 1,5 | 2 x 1,5 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | 70,2 | 71,0 | 70,8 |
| Dimensions (L x W xH) | Motor | - | - | 5940 x 4100 x 3925 | 5940 x 4100 x 3925 | 5940 x 4100 x 3925 |
| | Frequency Converter | - | - | 2 x (7930 x 1176 x 2475) | 2 x (7930 x 1176 x 2475) | 2 x (7930 x 1176 x 2475) |
| | Braking Resistor | - | - | 2 x (1800 x 900 x 1700) | 2 x (1800 x 900 x 1700) | 2 x (1800 x 900 x 1700) |
| | Transformer | - | - | 2 x (4200 x 2500 x 2900) | 2 x (4200 x 2600 x 2950) | 2 x (4500 x 2400 x 3100) |
| | Excitation Transformer | - | - | 2 x (1240 x 1170 x 1555) | 2 x (1240 x 1170 x 1555) | 2 x (1240 x 1170 x 1555) |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | - | - | 84100 | 84150 | 84200 |
| | Frequency Converter | - | - | 2 x 6600 | 2 x 6600 | 2 x 6600 |
| | Braking Resistor | - | - | 2 x 620 | 2 x 620 | 2 x 620 |
| | Transformer | - | - | 2 x 11500 | 2 x 12500 | 2 x 13200 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | 121540 | 123590 | 125040 |
| LT-water flow ($m^3/h$) | Motor | - | - | 71 | 75 | 73 |
| | Frequency Converter | - | - | 2 x 8,5 | 2 x 9,9 | 2 x 9,9 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | 2 x 12 | 2 x 19 | 2 x 19 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | - | - | 379 | 406 | 395 |
| | Frequency Converter | - | - | 2 x 70,6 | 2 x 82,6 | 2 x 82,6 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | 2 x 72 | 2 x 158 | 2 x 158 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | 664 | 887 | 876 |
| Losses to ambient (kW) | Motor | - | - | 20,0 | 21,4 | 20,8 |
| | Frequency Converter | - | - | 2 x 10,0 | 2 x 12,3 | 2 x 12,3 |
| | Braking Resistor | - | - | Intermittent | Intermittent | Intermittent |
| | Transformer | - | - | 2 x 8,9 | 2 x 9,2 | 2 x 9,6 |
| | Excitation Transformer | - | - | 7,0 | 7,0 | 7,0 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | - | 64,8 | 71,4 | 71,6 |






| Direct Drive 1600 - Full Redundant Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | - | ≥100 | ≥125 | ≥150 | ≥175 |
| | Maximum Power (kW) | - | 11500 | 14000 | 16500 | 20000 |
| | Maximum Torque (kNm) | - | 1098,0 | 1070,0 | 1050,0 | 1091,0 |
| | Drive (kVA) | - | 2 x 7000 | 2 x 9000 | 2 x 11000 | 2 x 11000 |
| | Transformer (kVA) | - | 2 x 7000 | 2 x 9000 | 2 x 10000 | 2 x 12000 |
| | Braking Capacity (MJ) | - | 2 x 30 | 2 x 30 | 2 x 46 | 2 x 46 |
| Drivetrain Efficiency (%) | Motor | - | 95,9 | 96,5 | 97,0 | 97,5 |
| | Frequency Converter | - | 98,5 | 98,5 | 98,5 | 98,5 |
| | Transformer | - | 99 | 99 | 99 | 99 |
| | Total Electrical Efficiency | - | 93,6 | 94,1 | 94,6 | 95,1 |
| Main Connection | Input Voltage (VAC) | - | 6600 / 11000 | 6600 / 11000 | 11000 | 11000 |
| | Frequency (Hz) | - | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | - | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | - | 12939 | 15661 | 18354 | 22145 |
| | Input Current (A) | - | 2 x 566 / 2 x 340 | 2 x 685 / 2 x 411 | 2 x 482 | 2 x 582 |
| Footprint ($m^2$) | Motor | - | 29,1 | 29,1 | 29,1 | 29,1 |
| | Frequency Converter | - | 2 x 9,3 | 2 x 9,3 | 2 x 9,8 | 2 x 9,8 |
| | Braking Resistor | - | 2 x 1,6 | 2 x 1,6 | 2 x 2,0 | 2 x 2,0 |
| | Transformer | - | 2 x 10,5 | 2 x 10,8 | 2 x 11,9 | 2 x 12,5 |
| | Excitation Transformer | - | 2 x 1,5 | 2 x 1,5 | 2 x 1,5 | 2 x 1,5 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 74,9 | 75,5 | 79,5 | 80,7 |
| Dimensions (L x W xH) | Motor | - | 6150 x 4724 x 4145 | 6150 x 4724 x 4145 | 6150 x 4724 x 4145 | 6150 x 4724 x 4145 |
| | Frequency Converter | - | 2 x (7930 x 1176 x 2475) | 2 x (7930 x 1176 x 2475) | 2 x (8330 x 1176 x 2475) | 2 x (8330 x 1176 x 2475) |
| | Braking Resistor | - | 2 x (1800 x 900 x 1700) | 2 x (1800 x 900 x 1700) | 2 x (2200 x 900 x 1700) | 2 x (2200 x 900 x 1700) |
| | Transformer | - | 2 x (4200 x 2500 x 2900) | 2 x (4500 x 2400 x 3100) | 2 x (4750 x 2500 x 3300) | 2 x (5000 x 2500 x 3300) |
| | Excitation Transformer | - | 2 x (1240 x 1170 x 1555) | 2 x (1240 x 1170 x 1555) | 2 x (1240 x 1170 x 1555) | 2 x (1240 x 1170 x 1555) |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | - | 122255 | 119105 | 119105 | 122255 |
| | Frequency Converter | - | 2 x 6600 | 2 x 6600 | 2 x 6800 | 2 x 6800 |
| | Braking Resistor | - | 2 x 620 | 2 x 620 | 2 x 750 | 2 x 750 |
| | Transformer | - | 2 x 11500 | 2 x 13200 | 2 x 15800 | 2 x 17200 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 159695 | 159945 | 165805 | 168955 |
| LT-water flow ($m^3/h$) | Motor | - | 88 | 91 | 90 | 92 |
| | Frequency Converter | - | 2 x 8,5 | 2 x 9,9 | 2 x 15,0 | 2 x 15,0 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 2 12 | 2 x 19 | 2 x 19 | 2 x 19 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | - | 462 | 482 | 478 | 489 |
| | Frequency Converter | - | 2 x 70,6 | 2 x 82,6 | 2 x 124,7 | 2 x 124,7 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 2 x 72 | 2 x 158 | 2 x 158 | 2 x 158 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 748 | 964 | 1044 | 1055 |
| Losses to ambient (kW) | Motor | - | 24,3 | 25,4 | 25,2 | 25,7 |
| | Frequency Converter | - | 2 x 10,0 | 2 x 12,3 | 2 x 14,1 | 2 x 14,1 |
| | Braking Resistor | - | Intermittent | Intermittent | Intermittent | Intermittent |
| | Transformer | - | 2 x 8,9 | 2 x 9,6 | 2 x 10,8 | 2 x 11,2 |
| | Excitation Transformer | - | 7,0 | 7,0 | 7,0 | 7,0 |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 69,1 | 76,2 | 82,0 | 83,3 |

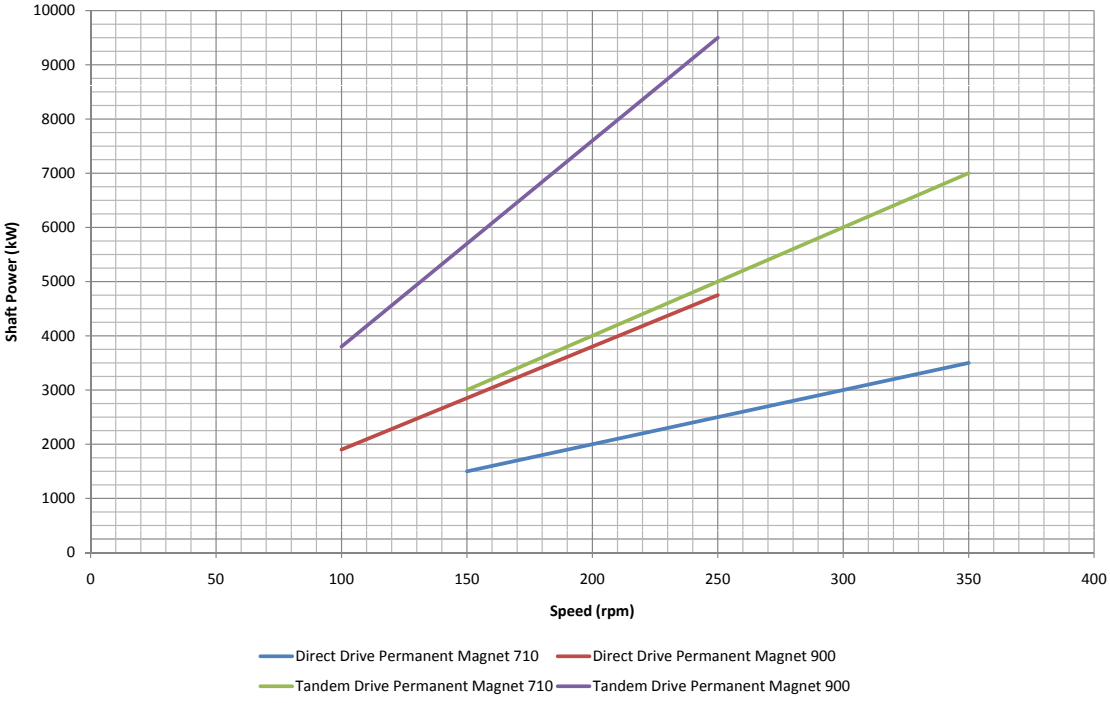





| Direct Drive 2000 - Full Redundant Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Propeller Speed (rpm) | ≥75 | ≥100 | - | - | - |
| | Maximum Power (kW) | 13550 | 18000 | - | - | - |
| | Maximum Torque (kNm) | 1725,0 | 1719,0 | - | - | - |
| | Drive (kVA) | 2 x 9000 | 2 x 11000 | - | - | - |
| | Transformer (kVA) | 2 x 9000 | 2 x 12000 | - | - | - |
| | Braking Capacity (MJ) | 2 x 46 | 2 x 46 | - | - | - |
| Drivetrain Efficiency (%) | Motor | 95,8 | 96,8 | - | - | - |
| | Frequency Converter | 98,5 | 98,5 | - | - | - |
| | Transformer | 99 | 99 | - | - | - |
| | Total Electrical Efficiency | 93,4 | 94,4 | - | - | - |
| Main Connection | Input Voltage (VAC) | 11000 | 11000 | - | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | - | - | - |
| | Power factor | 0,95 | 0,95 | - | - | - |
| | Input power (kVA) | 15268 | 20073 | - | - | - |
| | Input Current (A) | 2 x 401 | 2 x 527 | - | - | - |
| Footprint ($m^2$) | Motor | 37,3 | 37,3 | - | - | - |
| | Frequency Converter | 2 x 9,3 | 2 x 9,8 | - | - | - |
| | Braking Resistor | 2 x 2,0 | 2 x 2,0 | - | - | - |
| | Transformer | 2 x 10,8 | 2 x 12,5 | - | - | - |
| | Excitation Transformer | 2 x 1,5 | 2 x 1,5 | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 84,5 | 88,9 | - | - | - |
| Dimensions (L x W xH) | Motor | 6515 x 5724 x 5045 | 6515 x 5724 x 5045 | - | - | - |
| | Frequency Converter | 2 x (7930 x 1176 x 2475) | 2 x (8330 x 1176 x 2475) | - | - | - |
| | Braking Resistor | 2 x (2200 x 900 x 1700) | 2 x (2200 x 900 x 1700) | - | - | - |
| | Transformer | 2 x (4500 x 2400 x 3100) | 2 x (5000 x 2500 x 3300) | - | - | - |
| | Excitation Transformer | 2 x (1240 x 1170 x 1555) | 2 x (1240 x 1170 x 1555) | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 165250 | 165500 | - | - | - |
| | Frequency Converter | 2 x 6600 | 2 x 6800 | - | - | - |
| | Braking Resistor | 2 x 750 | 2 x 750 | - | - | - |
| | Transformer | 2 x 13200 | 2 x 17200 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 206350 | 215000 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 106 | 89 | - | - | - |
| | Frequency Converter | 2 x 9,9 | 2 x 15,0 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 2 x 19 | 2 x 19 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 564 | 565 | - | - | - |
| | Frequency Converter | 2 x 82,6 | 2 x 124,7 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 2 x 158 | 2 x 158 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 1046 | 1131 | - | - | - |
| Losses to ambient (kW) | Motor | 29,7 | 29,8 | - | - | - |
| | Frequency Converter | 2 x 12,3 | 2 x 14,1 | - | - | - |
| | Braking Resistor | Intermittent | Intermittent | - | - | - |
| | Transformer | 2 x 9,6 | 2 x 11,2 | - | - | - |
| | Excitation Transformer | 7,0 | 7,0 | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 80,5 | 87,4 | - | - | - |

# 14 Technical specification for Direct Drive Permanent Magnet

The performance range for Direct Drive Permanent Magnet is charted below. (Figure 3)




Power range (MW) for each system (check performance limits from figure 3)

| | Single Drive | Single Drive (AFE) | Single Drive (with transformer) | Tandem Drive |
|---|---|---|---|---|
| 710 | 1.5…3.5 | 1.5…3.5 | 1.5…3.5 | 3.0…7.0 |
| 900 | 1.9…4.75 | 1.9…4.75 | 1.9…4.75 | 3.8…9.5 |

Availability of Direct Drive Permanent Magnet systems

The table below summarizes the main components in each system.

| Number of main components – Direct Drive Permanent Magnet | | | | |
|---|---|---|---|---|
| | Single Drive | Single Drive (AFE) | Single Drive (with transformer) | Tandem Drive |
| Motor | 1 | 1 | 1 | 2 |
| Frequency converter | 1 | 1 | 1 | 2 |
| Braking resistor | 1 | 0 | 1 | 2 |
| Transformer | 0 | 0 | 1 | 0 |
| Excitation transformer | 0 | 0 | 0 | 0 |
| Harmonic filter | 1 | 0 | 0 | 1 |

| System features – Direct Drive Permanent Magnet | | | | |
|---|---|---|---|---|
| | Single Drive | Single Drive (AFE) | Single Drive (with transformer) | Tandem Drive |
| Motor | Permanent magnet | | | |
| Stator system(s) in a motor | 1 | | | |
| Frequency converter | LV | | | |
| Pulse number | 6 | AFE | 12 | 6 |
| Propulsion control | Drive Control Unit (DCU), Propulsion Control Unit (PCU) as an option | | | |
| Remote Control System | Interface towards Remote Control System, RCS as an option | | | |
| Uninterrupted Power Supply | UPS as an option | | | |

Technical data for the main components

| Technical data – Direct Drive Permanent Magnet | | | | | | |
|---|---|---|---|---|---|---|
| | Motor | Frequency converter | Braking resistor | Transformer | Excitation transformer | Harmonic filter |
| Max. ambient temperature (°C) | 50 | 45 | 45 | 45 | 45 | 45 |
| Max. cooling water temperature (°C) | 36 | 36 | N/A | 36 | N/A | 36 |
| Method of cooling | IC86W | Direct Liquid Cooling | Air cooled | AFWF | AN | Air cooled |
| Installation | IM1001 | One Lineup | Wall standing | Feet for welding | Feet for welding | Wall standing |
| Enclosure | IP44 | IP42 | IP23 | IP44 | IP23 | IP23 |
| Color | MUNSELL8B | RAL7035 | RAL7035 | RAL7035 | RAL7035 | RAL7035 |
| Insulation class [1)] | F | N/A | N/A | F | F | N/A |
| Temperature rise class [1)] | F | N/A | N/A | F | F | N/A |
| Cabling direction | Bottom | Bottom | Bottom | Bottom | Bottom | Bottom |
| Piping direction | Side | Side | N/A | Side | N/A | N/A |

1) According to DNV

**REMARK:**

High Speed Drive is a pre-engineered solution and to guarantee a successful delivery, ABB's installation, cabling and operation instructions must be followed.

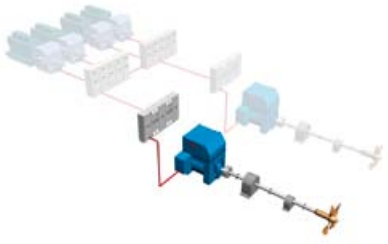
# 14.1 Technical data sheets – Direct Drive Permanent Magnet

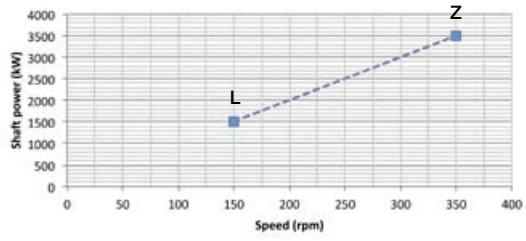
Direct Drive Permanent Magnet 710 - Single Drive ..... 216
Direct Drive Permanent Magnet 900 - Single Drive ..... 217

Direct Drive Permanent Magnet 710 - Single Drive (AFE)..... 218
Direct Drive Permanent Magnet 900 - Single Drive (AFE)..... 219

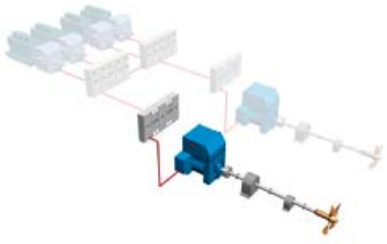
Direct Drive Permanent Magnet 710 - Single Drive (with Transformer)..... 220
Direct Drive Permanent Magnet 900 - Single Drive (with Transformer)..... 221

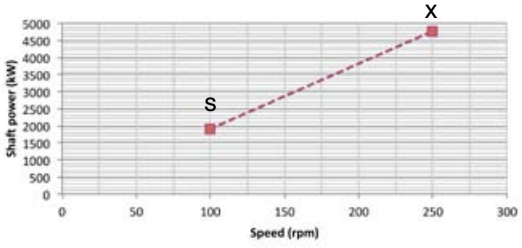
Direct Drive Permament Magnet 710 - Tandem Drive..... 222
Direct Drive Permament Magnet 900 - Tandem Drive..... 223



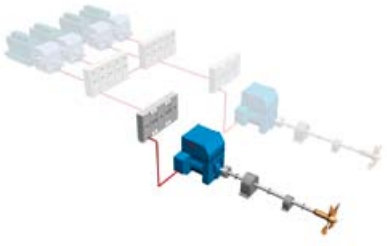


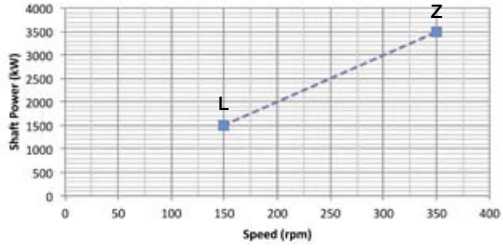

| Direct Drive Permanent Magnet 710 - Single Drive | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y | Z |
| | Propeller Speed (rpm) | - | - | ≥150 | - | - | ≥350 |
| | Maximum Power (kW) | - | - | 1500 | - | - | 3500 |
| | Maximum Torque (kNm) | - | - | 95,5 | - | - | 95,5 |
| | Drive (kVA) | - | - | 2030 | - | - | 4630 |
| | Transformer (kVA) | - | - | - | - | - | - |
| | Braking Capacity (MJ) | - | - | 10,8 | - | - | 21,6 |
| Drivetrain Efficiency (%) | Motor | - | - | 96,5 | - | - | 98,1 |
| | Frequency Converter | - | - | 98,0 | - | - | 98,0 |
| | Transformer | - | - | - | - | - | - |
| | Total Electrical Efficiency | - | - | 94,6 | - | - | 96,1 |
| Main Connection | Input Voltage (VAC) | - | - | 690 | - | - | 690 |
| | Frequency (Hz) | - | - | 50/60 | - | - | 50/60 |
| | Power factor | - | - | 0,95 | - | - | 0,95 |
| | Input power (kVA) | - | - | 1670 | - | - | 3832 |
| | Input Current (A) | - | - | 1397 | - | - | 3207 |
| Footprint ($m^2$) | Motor | - | - | 8,6 | - | - | 8,6 |
| | Frequency Converter | - | - | 2,5 | - | - | 4,4 |
| | Braking Resistor | - | - | 0,6 | - | - | 1,2 |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | 1,7 | - | - | 1,7 |
| | Total | - | - | 13,4 | - | - | 14,8 |
| Dimensions (L x W xH) | Motor | - | - | 3590 x 2400 x 2580 | - | - | 3590 x 2400 x 2580 |
| | Frequency Converter | - | - | 3430 x 718 x 2088 | - | - | 6130 x 718 x 2088 |
| | Braking Resistor | - | - | 830 x 718 x 2088 | - | - | 1630 x 718 x 2088 |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | 2240 x 760 x 2090 | - | - | 2240 x 760 x 2090 |
| Weight (kg) | Motor | - | - | 19000 | - | - | 19000 |
| | Frequency Converter | - | - | 2320 | - | - | 4470 |
| | Braking Resistor | - | - | 240 | - | - | 480 |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | 1100 | - | - | 1100 |
| | Total | - | - | 22660 | - | - | 25050 |
| LT-water flow ($m^3/h$) | Motor | - | - | 8,1 | - | - | 10,2 |
| | Frequency Converter | - | - | 3,5 | - | - | 8,9 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Losses to water (kW) | Motor | - | - | 52 | - | - | 64 |
| | Frequency Converter | - | - | 34 | - | - | 76 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | - | - | 86 | - | - | 140 |
| Losses to ambient (kW) | Motor | - | - | 2,7 | - | - | 3,4 |
| | Frequency Converter | - | - | 3,0 | - | - | 7 |
| | Braking Resistor | - | - | Intermittent | - | - | Intermittent |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | 1,8 | - | - | 1,8 |
| | Total | - | - | 7,5 | - | - | 12,2 |



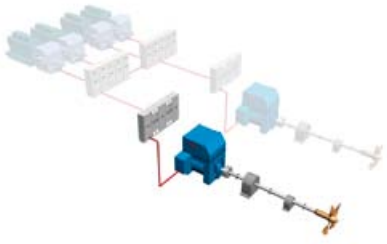


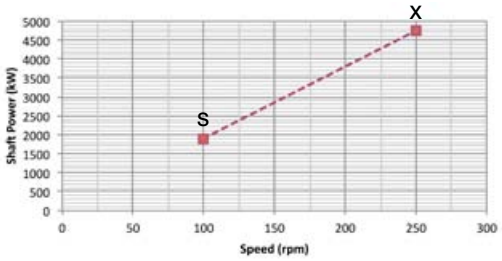

| Direct Drive Permanent Magnet 900 - Single Drive | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y | Z |
| | Propeller Speed (rpm) | ≥100 | - | - | ≥250 | - | - |
| | Maximum Power (kW) | 1900 | - | - | 4750 | - | - |
| | Maximum Torque (kNm) | 181,4 | - | - | 181,4 | - | - |
| | Drive (kVA) | 2680 | - | - | 5960 | - | - |
| | Transformer (kVA) | - | - | - | - | - | - |
| | Braking Capacity (MJ) | 10,8 | - | - | 21,6 | - | - |
| Drivetrain Efficiency (%) | Motor | 96,3 | - | - | 97,9 | - | - |
| | Frequency Converter | 98,0 | - | - | 98,0 | - | - |
| | Transformer | - | - | - | - | - | - |
| | Total Electrical Efficiency | 94,4 | - | - | 95,9 | - | - |
| Main Connection | Input Voltage (VAC) | 690 | - | - | 690 | - | - |
| | Frequency (Hz) | 50/60 | - | - | 50/60 | - | - |
| | Power factor | 0,95 | - | - | 0,95 | - | - |
| | Input power (kVA) | 2119 | - | - | 5211 | - | - |
| | Input Current (A) | 1773 | - | - | 4361 | - | - |
| Footprint ($m^2$) | Motor | 12,6 | - | - | 12,6 | - | - |
| | Frequency Converter | 3,3 | - | - | 4,7 | - | - |
| | Braking Resistor | 0,6 | - | - | 1,2 | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | 1,7 | - | - | 1,7 | - | - |
| | Total | 18,2 | - | - | 20,2 | - | - |
| Dimensions (L x W xH) | Motor | 4800 x 2630 x 3500 | - | - | 4800 x 2630 x 3500 | - | - |
| | Frequency Converter | 4630 x 718 x 2088 | - | - | 6530 x 718 x 2088 | - | - |
| | Braking Resistor | 830 x 718 x 2088 | - | - | 1630 x 718 x 2088 | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | - | - | 2240 x 760 x 2090 | - | - |
| Weight (kg) | Motor | 33000 | - | - | 33000 | - | - |
| | Frequency Converter | 3210 | - | - | 4860 | - | - |
| | Braking Resistor | 240 | - | - | 480 | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | 1100 | - | - | 1100 | - | - |
| | Total | 37550 | - | - | 39440 | - | - |
| LT-water flow ($m^3/h$) | Motor | 10,9 | - | - | 15,3 | - | - |
| | Frequency Converter | 5,4 | - | - | 10,4 | - | - |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Losses to water (kW) | Motor | 69 | - | - | 97 | - | - |
| | Frequency Converter | 44 | - | - | 99 | - | - |
| | Braking Resistor | - | - | - | 0 | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 113 | - | - | 196 | - | - |
| Losses to ambient (kW) | Motor | 3,7 | - | - | 5,1 | - | - |
| | Frequency Converter | 3,8 | - | - | 9,5 | - | - |
| | Braking Resistor | Intermittent | - | - | Intermittent | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | 1,8 | - | - | 1,8 | - | - |
| | Total | 9,3 | - | - | 16,4 | - | - |



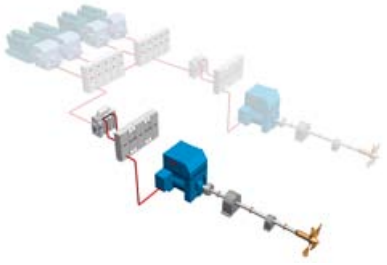


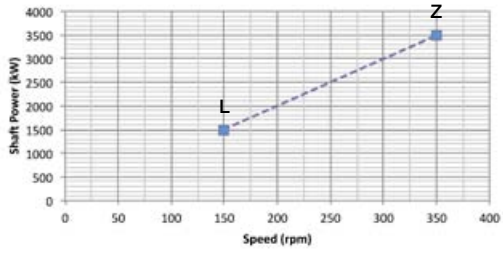

| Direct Drive Permanent Magnet 710 - Single Drive (AFE) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y | Z |
| | Propeller Speed (rpm) | - | - | ≥150 | - | - | ≥350 |
| | Maximum Power (kW) | - | - | 1500 | - | - | 3500 |
| | Maximum Torque (kNm) | - | - | 95,5 | - | - | 95,5 |
| | Drive (kVA) | - | - | 1840 | - | - | 4630 |
| | Transformer (kVA) | - | - | - | - | - | - |
| | Networking Braking | - | - | Yes | - | - | Yes |
| Drivetrain Efficiency (%) | Motor | - | - | 96,5 | - | - | 98,1 |
| | Frequency Converter | - | - | 97,0 | - | - | 97,0 |
| | Transformer | - | - | - | - | - | - |
| | Total Electrical Efficiency | - | - | 93,6 | - | - | 95,157 |
| Main Connection | Input Voltage (VAC) | - | - | 690 | - | - | 690 |
| | Frequency (Hz) | - | - | 50/60 | - | - | 50/60 |
| | Power factor | - | - | 0,99 | - | - | 0,99 |
| | Input power (kVA) | - | - | 1619 | - | - | 3715 |
| | Input Current (A) | - | - | 1354 | - | - | 3109 |
| Footprint ($m^2$) | Motor | - | - | 8,6 | - | - | 8,6 |
| | Frequency Converter | - | - | 3,1 | - | - | 6,2 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | - | - | 11,7 | - | - | 14,8 |
| Dimensions (L x W xH) | Motor | - | - | 3590 x 2400 x 2580 | - | - | 3590 x 2400 x 2580 |
| | Frequency Converter | - | - | 4330 x 718 x 2088 | - | - | 8630 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Weight (kg) | Motor | - | - | 19000 | - | - | 19000 |
| | Frequency Converter | - | - | 3350 | - | - | 7495 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | - | - | 22350 | - | - | 26495 |
| LT-water flow ($m^3/h$) | Motor | - | - | 8,1 | - | - | 10,2 |
| | Frequency Converter | - | - | 7,0 | - | - | 17,46 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Losses to water (kW) | Motor | - | - | 52 | - | - | 64 |
| | Frequency Converter | - | - | 56,2 | - | - | 146,5 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | - | - | 108,2 | - | - | 210,5 |
| Losses to ambient (kW) | Motor | - | - | 2,7 | - | - | 3,4 |
| | Frequency Converter | - | - | 3,0 | - | - | 7,0 |
| | Braking Resistor | - | - | Intermittent | - | - | Intermittent |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | - | - | 5,7 | - | - | 10,4 |



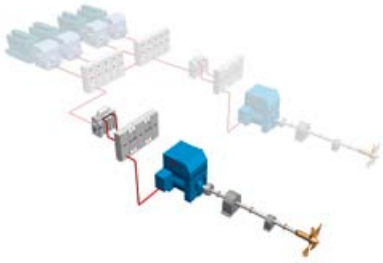


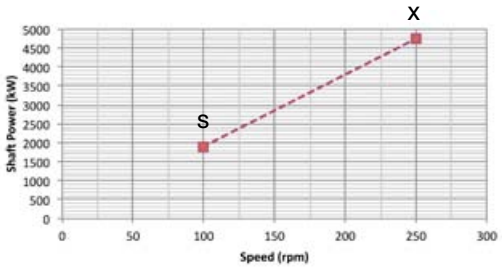

| Direct Drive Permanent Magnet 900 - Single Drive (AFE) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y | Z |
| | Propeller Speed (rpm) | ≥100 | - | - | ≥250 | - | - |
| | Maximum Power (kW) | 1900 | - | - | 4750 | - | - |
| | Maximum Torque (kNm) | 181,4 | - | - | 181,4 | - | - |
| | Drive (kVA) | 2430 | - | - | 5960 | - | - |
| | Transformer (kVA) | - | - | - | - | - | - |
| | Networking Braking | Yes | - | - | Yes | - | - |
| Drivetrain Efficiency (%) | Motor | 96,3 | - | - | 97,9 | - | - |
| | Frequency Converter | 97,0 | - | - | 97,0 | - | - |
| | Transformer | - | - | - | - | - | - |
| | Total Electrical Efficiency | 93,4 | - | - | 95,0 | - | - |
| Main Connection | Input Voltage (VAC) | 690 | - | - | 690 | - | - |
| | Frequency (Hz) | 50/60 | - | - | 50/60 | - | - |
| | Power factor | 0,99 | - | - | 0,99 | - | - |
| | Input power (kVA) | 2055 | - | - | 5052 | - | - |
| | Input Current (A) | 1719 | - | - | 4228 | - | - |
| Footprint ($m^2$) | Motor | 12,6 | - | - | 12,6 | - | - |
| | Frequency Converter | 3,8 | - | - | 7,5 | - | - |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 16,4 | - | - | 20,1 | - | - |
| Dimensions (L x W xH) | Motor | 4800 x 2630 x 3500 | - | - | 4800 x 2630 x 3500 | - | - |
| | Frequency Converter | 5230 x 718 x 2088 | - | - | 10430 x 718 x 2088 | - | - |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Weight (kg) | Motor | 33000 | - | - | 33000 | - | - |
| | Frequency Converter | 4480 | - | - | 9145 | - | - |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 37480 | - | - | 42145 | - | - |
| LT-water flow ($m^3/h$) | Motor | 10,9 | - | - | 15,3 | - | - |
| | Frequency Converter | 9,1 | - | - | 21,8 | - | - |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Losses to water (kW) | Motor | 69 | - | - | 97 | - | - |
| | Frequency Converter | 77,9 | - | - | 184 | - | - |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 146,9 | - | - | 281 | - | - |
| Losses to ambient (kW) | Motor | 3,7 | - | - | 5,1 | - | - |
| | Frequency Converter | 3,8 | - | - | 9,5 | - | - |
| | Braking Resistor | Intermittent | - | - | Intermittent | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 7,5 | - | - | 14,6 | - | - |



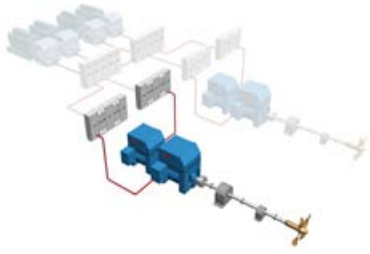


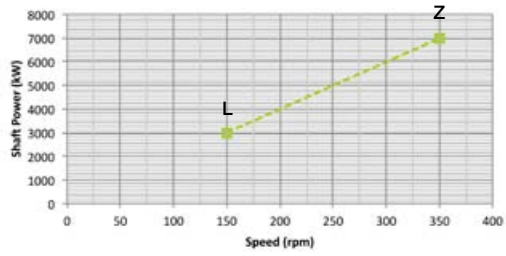

| Direct Drive Permanent Magnet 710 - Single Drive (with Transformer) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y | Z |
| | Propeller Speed (rpm) | - | - | ≥150 | - | - | ≥350 |
| | Maximum Power (kW) | - | - | 1500 | - | - | 3500 |
| | Maximum Torque (kNm) | - | - | 95,5 | - | - | 95,5 |
| | Drive (kVA) | - | - | 2030 | - | - | 4630 |
| | Transformer (kVA) | - | - | 1850 | - | - | 4100 |
| | Braking Capacity (MJ) | - | - | 10,8 | - | - | 21,6 |
| Drivetrain Efficiency (%) | Motor | - | - | 96,5 | - | - | 98,1 |
| | Frequency Converter | - | - | 98,0 | - | - | 98,0 |
| | Transformer | - | - | 99,0 | - | - | 99,0 |
| | Total Electrical Efficiency | - | - | 93,6 | - | - | 95,2 |
| Main Connection | Input Voltage (VAC) | - | - | 690 / 3300 / 6600 / 11000 | - | - | 690 / 3300 / 6600 / 11000 |
| | Frequency (Hz) | - | - | 50/60 | - | - | 50/60 |
| | Power factor | - | - | 0,95 | - | - | 0,95 |
| | Input power (kVA) | - | - | 1686 | - | - | 3871 |
| | Input Current (A) | - | - | 1412 / 296 / 148 / 89 | - | - | 3239 / 678 / 339 / 204 |
| Footprint ($m^2$) | Motor | - | - | 8,6 | - | - | 8,6 |
| | Frequency Converter | - | - | 2,5 | - | - | 4,4 |
| | Braking Resistor | - | - | 0,6 | - | - | 1,2 |
| | Transformer | - | - | 6,9 | - | - | 8,0 |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | - | - | 18,6 | - | - | 22,1 |
| Dimensions (L x W xH) | Motor | - | - | 3590 x 2400 x 2580 | - | - | 3590 x 2400 x 2580 |
| | Frequency Converter | - | - | 3430 x 718 x 2088 | - | - | 6130 x 718 x 2088 |
| | Braking Resistor | - | - | 830 x 718 x 2088 | - | - | 1630 x 718 x 2088 |
| | Transformer | - | - | 3150 x 2200 x 2250 | - | - | 3700 x 2150 x 2550 |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Weight (kg) | Motor | - | - | 19000 | - | - | 19000 |
| | Frequency Converter | - | - | 2320 | - | - | 4470 |
| | Braking Resistor | - | - | 240 | - | - | 480 |
| | Transformer | - | - | 4900 | - | - | 7900 |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | - | - | 26460 | - | - | 31850 |
| LT-water flow ($m^3/h$) | Motor | - | - | 8,1 | - | - | 10,2 |
| | Frequency Converter | - | - | 3,5 | - | - | 8,9 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | 7 | - | - | 10 |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Losses to water (kW) | Motor | - | - | 52 | - | - | 64 |
| | Frequency Converter | - | - | 34 | - | - | 76 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | 40,3 | - | - | 89,5 |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | - | - | 126,3 | - | - | 229,5 |
| Losses to ambient (kW) | Motor | - | - | 2,7 | - | - | 3,4 |
| | Frequency Converter | - | - | 3,0 | - | - | 7 |
| | Braking Resistor | - | - | Intermittent | - | - | Intermittent |
| | Transformer | - | - | 5,6 | - | - | 6,8 |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | - | - | 11,3 | - | - | 17,2 |



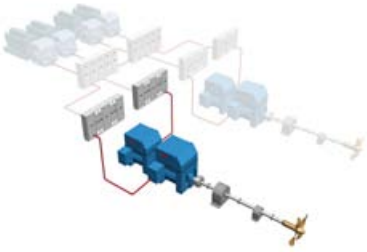


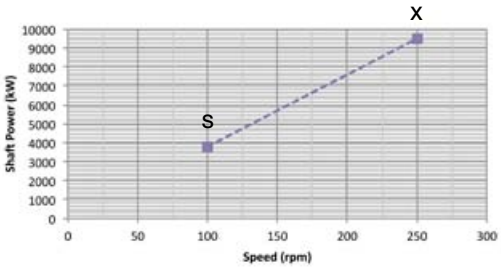

| Direct Drive Permanent Magnet 900 - Single Drive (with Transformer) | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y | Z |
| | Propeller Speed (rpm) | ≥100 | - | - | ≥250 | - | - |
| | Maximum Power (kW) | 1900 | - | - | 4750 | - | - |
| | Maximum Torque (kNm) | 181,4 | - | - | 181,4 | - | - |
| | Drive (kVA) | 2680 | - | - | 5960 | - | - |
| | Transformer (kVA) | 2300 | - | - | 5800 | - | - |
| | Braking Capacity (MJ) | 10,8 | - | - | 21,6 | - | - |
| Drivetrain Efficiency (%) | Motor | 96,3 | - | - | 97,9 | - | - |
| | Frequency Converter | 98,0 | - | - | 98,0 | - | - |
| | Transformer | 99,0 | - | - | 99,0 | - | - |
| | Total Electrical Efficiency | 93,4 | - | - | 95,0 | - | - |
| Main Connection | Input Voltage (VAC) | 690 / 3300 / 6600 / 11000 | - | - | 6600 / 11000 | - | - |
| | Frequency (Hz) | 50/60 | - | - | 50/60 | - | - |
| | Power factor | 0,95 | - | - | 0,95 | - | - |
| | Input power (kVA) | 2141 | - | - | 5264 | - | - |
| | Input Current (A) | 1792 / 375 / 188 / 113 | - | - | 4405 / 921 / 461 / 277 | - | - |
| Footprint ($m^2$) | Motor | 12,6 | - | - | 12,6 | - | - |
| | Frequency Converter | 3,3 | - | - | 4,7 | - | - |
| | Braking Resistor | 0,6 | - | - | 1,2 | - | - |
| | Transformer | 7,3 | - | - | 9,4 | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 23,9 | - | - | 27,8 | - | - |
| Dimensions (L x W xH) | Motor | 4800 x 2630 x 3500 | - | - | 4800 x 2630 x 3500 | - | - |
| | Frequency Converter | 4630 x 718 x 2088 | - | - | 6530 x 718 x 2088 | - | - |
| | Braking Resistor | 830 x 718 x 2088 | - | - | 1630 x 718 x 2088 | - | - |
| | Transformer | 3250 x 2250 x 2400 | - | - | 3900 x 2400 x 2800 | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Weight (kg) | Motor | 33000 | - | - | 33000 | - | - |
| | Frequency Converter | 3210 | - | - | 4860 | - | - |
| | Braking Resistor | 240 | - | - | 480 | - | - |
| | Transformer | 5600 | - | - | 10300 | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 42050 | - | - | 48640 | - | - |
| LT-water flow ($m^3$/h) | Motor | 10,9 | - | - | 15,3 | - | - |
| | Frequency Converter | 5,4 | - | - | 10,4 | - | - |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | 7 | - | - | 12 | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Losses to water (kW) | Motor | 69 | - | - | 97 | - | - |
| | Frequency Converter | 44 | - | - | 99 | - | - |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | 40,3 | - | - | 122,8 | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 153,3 | - | - | 318,8 | - | - |
| Losses to ambient (kW) | Motor | 3,7 | - | - | 5,1 | - | - |
| | Frequency Converter | 3,8 | - | - | 9,5 | - | - |
| | Braking Resistor | Intermittent | - | - | Intermittent | - | - |
| | Transformer | 6,1 | - | - | 8,0 | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 13,6 | - | - | 22,6 | - | - |






| Direct Drive Permament Magnet 710 - Tandem Drive | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y | Z |
| | Propeller Speed (rpm) | - | - | ≥150 | - | - | ≥350 |
| | Maximum Power (kW) | - | - | 3000 | - | - | 7000 |
| | Maximum Torque (kNm) | - | - | 191,0 | - | - | 191 |
| | Drive (kVA) | - | - | 2 x2030 | - | - | 2 x4630 |
| | Transformer (kVA) | - | - | - | - | - | - |
| | Braking Capacity (MJ) | - | - | 2 x 10,8 | - | - | 2 x 21,6 |
| Drivetrain Efficiency (%) | Motor | - | - | 96,5 | - | - | 98,1 |
| | Frequency Converter | - | - | 98 | - | - | 98 |
| | Transformer | - | - | - | - | - | - |
| | Total Electrical Efficiency | - | - | 94,6 | - | - | 96,138 |
| Main Connection | Input Voltage (VAC) | - | - | 690 | - | - | 690 |
| | Frequency (Hz) | - | - | 50/60 | - | - | 50/60 |
| | Power factor | - | - | 0,95 | - | - | 0,95 |
| | Input power (kVA) | - | - | 3339 | - | - | 7664 |
| | Input Current (A) | - | - | 2 x 1398 | - | - | 2 x 3207 |
| Footprint ($m^2$) | Motor | - | - | 2 x 8,6 | - | - | 2 x 8,6 |
| | Frequency Converter | - | - | 2 x 2,5 | - | - | 2 x 4,4 |
| | Braking Resistor | - | - | 2 x 0,6 | - | - | 2 x 1,2 |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | 2,6 | - | - | 2,6 |
| | Total | - | - | 26,0 | - | - | 31,0 |
| Dimensions (L x W xH) | Motor | - | - | 2 x (3590 x 2400 x 2580) | - | - | 2 x (3590 x 2400 x 2580) |
| | Frequency Converter | - | - | 2 x (3430 x 718 x 2088) | - | - | 2 x (6130 x 718 x 2088) |
| | Braking Resistor | - | - | 2 x (830 x 718 x 2088) | - | - | 2 x (1630 x 718 x 2088) |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | 3440 x 760 x 2090 | - | - | 3440 x 760 x 2090 |
| Weight (kg) | Motor | - | - | 2 x 19000 | - | - | 2 x 19000 |
| | Frequency Converter | - | - | 2 x 2320 | - | - | 2 x 4470 |
| | Braking Resistor | - | - | 2 x 240 | - | - | 2 x 480 |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | 1700 | - | - | 1700 |
| | Total | - | - | 44820 | - | - | 49600 |
| LT-water flow ($m^3/h$) | Motor | - | - | 2 x 8,1 | - | - | 2 x 10,2 |
| | Frequency Converter | - | - | 2 x 3,5 | - | - | 2 x 8,9 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Losses to water (kW) | Motor | - | - | 2 x 52 | - | - | 2 x 64 |
| | Frequency Converter | - | - | 2 x 34 | - | - | 2 x 76 |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | - | - | 172 | - | - | 280 |
| Losses to ambient (kW) | Motor | - | - | 2 x 2,7 | - | - | 2 x 3,4 |
| | Frequency Converter | - | - | 2 x 6 | - | - | 2 x 14 |
| | Braking Resistor | - | - | Intermittent | - | - | Intermittent |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | 1,8 | - | - | 1,8 |
| | Total | - | - | 19,2 | - | - | 36,6 |

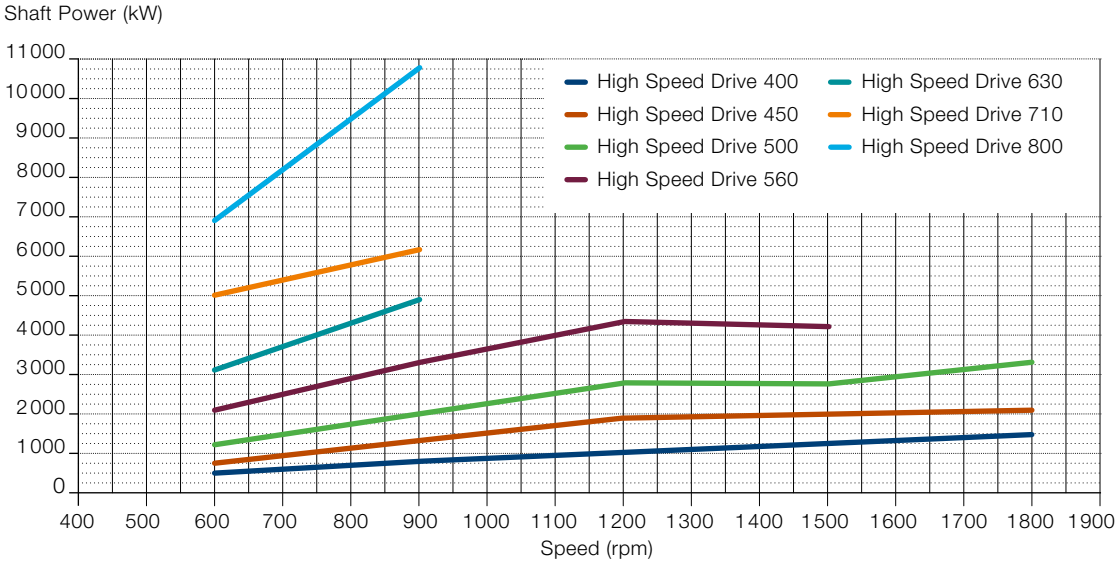





| Direct Drive Permanent Magnet 900 - Tandem Drive | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y | Z |
| | Propeller Speed (rpm) | ≥100 | - | - | ≥250 | - | - |
| | Maximum Power (kW) | 3800 | - | - | 9500 | - | - |
| | Maximum Torque (kNm) | 362,8 | - | - | 362,8 | - | - |
| | Drive (kVA) | 2 x 2680 | - | - | 2 x 5960 | - | - |
| | Transformer (kVA) | - | - | - | - | - | - |
| | Braking Capacity (MJ) | 2 x 10,8 | - | - | 2 x 21,6 | - | - |
| Drivetrain Efficiency (%) | Motor | 96,3 | - | - | 97,9 | - | - |
| | Frequency Converter | 98 | - | - | 98 | - | - |
| | Transformer | - | - | - | - | - | - |
| | Total Electrical Efficiency | 94,4 | - | - | 95,9 | - | - |
| Main Connection | Input Voltage (VAC) | 690 | - | - | 690 | - | - |
| | Frequency (Hz) | 50/60 | - | - | 50/60 | - | - |
| | Power factor | 0,95 | - | - | 0,95 | - | - |
| | Input power (kVA) | 4238 | - | - | 10423 | - | - |
| | Input Current (A) | 2 x 1774 | - | - | 2 x 4361 | - | - |
| Footprint ($m^2$) | Motor | 2 x 12,6 | - | - | 2 x 12,6 | - | - |
| | Frequency Converter | 2 x 3,3 | - | - | 2 x 4,7 | - | - |
| | Braking Resistor | 2 x 0,6 | - | - | 2 x 1,2 | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | 2,6 | - | - | 2,6 | - | - |
| | Total | 35,6 | - | - | 39,6 | - | - |
| Dimensions (L x W xH) | Motor | 2 x (4800 x 2630 x 3500) | - | - | 2 x (4800 x 2630 x 3500) | - | - |
| | Frequency Converter | 2 x (4630 x 718 x 2088) | - | - | 2 x (6530 x 718 x 2088) | - | - |
| | Braking Resistor | 2 x (830 x 718 x 2088) | - | - | 2 x (1630 x 718 x 2088) | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | 3440 x 760 x 2090 | - | - | 3440 x 760 x 2090 | - | - |
| Weight (kg) | Motor | 2 x 33000 | - | - | 2 x 33000 | - | - |
| | Frequency Converter | 2 x 3210 | - | - | 2 x 4860 | - | - |
| | Braking Resistor | 2 x 240 | - | - | 2 x 480 | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | 1700 | - | - | 1700 | - | - |
| | Total | 74600 | - | - | 78380 | - | - |
| LT-water flow ($m^3/h$) | Motor | 2 x 10,9 | - | - | 2 x 15,3 | - | - |
| | Frequency Converter | 2 x 5,4 | - | - | 2 x 10,4 | - | - |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| Losses to water (kW) | Motor | 2 x 69 | - | - | 2 x 97 | - | - |
| | Frequency Converter | 2 x 44 | - | - | 2 x 99 | - | - |
| | Braking Resistor | - | - | - | - | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - | - |
| | Total | 226 | - | - | 392 | - | - |
| Losses to ambient (kW) | Motor | 2 x 3,7 | - | - | 2 x 5,1 | - | - |
| | Frequency Converter | 2 x 7,6 | - | - | 2 x 19 | - | - |
| | Braking Resistor | Intermittent | - | - | Intermittent | - | - |
| | Transformer | - | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - | - |
| | Harmonic Filter | 1,8 | - | - | 1,8 | - | - |
| | Total | 24,4 | - | - | 50,0 | - | - |

# 15 Technical specification for High Speed Drive

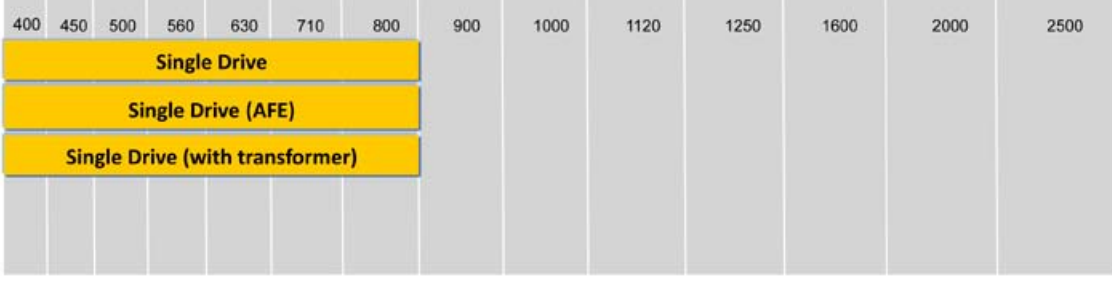
The performance range for High Speed Drive is charted below. (Figure 4)




Power range (MW) for each system (check performance limits from figure 4)

| | Single Drive | Single Drive (AFE) | Single Drive (with Transformer) |
|---|---|---|---|
| Power | 0.5 … 6.5 | 0.5 … 5.3 | 0.8 … 10.8 |

Availability of High Speed Drive systems



| Number of main components – High Speed Drive | | | |
|---|---|---|---|
| | Single Drive | Single Drive (AFE) | Single Drive (with transformer) |
| Motor | 1 | 1 | 1 |
| Frequency converter | 1 | 1 | 1 |
| Braking resistor | 0 | 0 | 0 |
| Transformer | 0 | 0 | 1 |
| Excitation transformer | 0 | 0 | 0 |
| Harmonic filter | 1 | 0 | 0 |

| System features – High Speed Drive | | | |
|---|---|---|---|
| | Single Drive | Single Drive (AFE) | Single Drive (with Transformer) |
| Motor | Induction | | |
| Stator system(s) in a motor | 1 | | |
| Frequency converter | LV ≤ ~5 MW<br>MV ≥ ~5 MW | LV | LV ≤ ~5 MW<br>MV ≥ ~5 MW |
| Pulse number | 6 | AFE | 12 |
| Propulsion control | Drive Control Unit (DCU),<br>Propulsion Control Unit (PCU) as an option | | |
| Remote Control System | Interface towards Remote Control System,<br>RCS as an option | | |
| Uninterrupted Power Supply | UPS as an option | | |

Technical data for the main components

| Technical data – Direct Drive | | | | |
|---|---|---|---|---|
| | Motor | Frequency converter | Transformer | Harmonic filter |
| Max. ambient temperature (°C) | 50 | 45 | 45 | 45 |
| Max. cooling water temperature (°C) | 36 | 36 | 36 | 36 |
| Method of cooling | IC81W | Direct Liquid Cooling | AFWF | Air cooled |
| Installation | IM1001 | One Lineup | Feet for welding | Wall standing |
| Enclosure | IP44 | IP42 / IP32, 2) | IP44 | IP23 |
| Color | MUNSELL8B | RAL7035 | RAL7035 | RAL7035 |
| Insulation class, 1) | F | N/A | F | N/A |
| Temperature rise class, 1) | F | N/A | F | N/A |
| Cabling direction | Bottom | Bottom | Bottom | Bottom |
| Piping direction | Side | Side | Side | N/A |

1) According to DNV
2) Low voltage converter IP42, Medium voltage converter IP32

**REMARK:**

High Speed Drive is a pre-engineered solution and to guarantee a successful delivery, ABB's installation, cabling and operation instructions must be followed.

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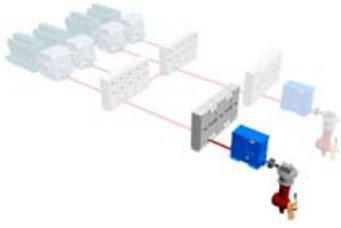
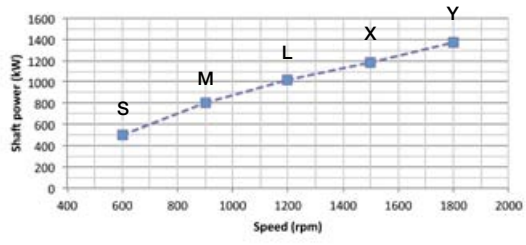
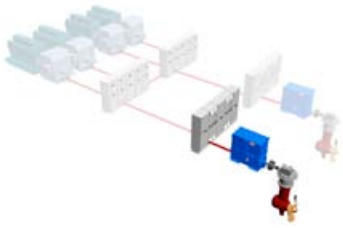
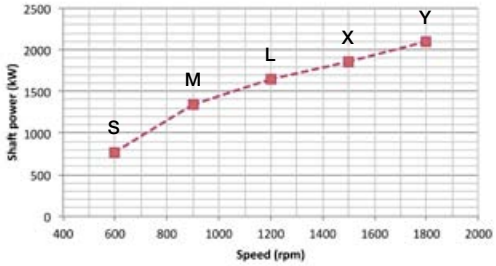


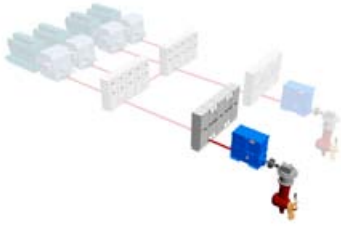


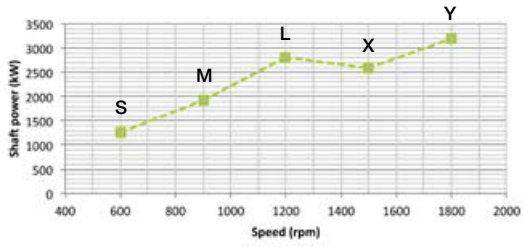

| High Speed Drive 400 - Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | ≥1200 | ≥1500 | ≥1800 |
| | Maximum Power (kW) | 500 | 810 | 1020 | 1180 | 1370 |
| | Maximum Torque (kNm) | 8,0 | 8,6 | 8,1 | 7,5 | 7,3 |
| | Drive (kVA) | 940 | 1370 | 1590 | 1590 | 2030 |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 94,1 | 94,9 | 95,1 | 95,5 | 95,7 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 92,2 | 93,0 | 93,2 | 93,6 | 93,8 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 571 | 917 | 1152 | 1327 | 1538 |
| | Input Current (A) | 478 | 767 | 964 | 1111 | 1287 |
| Footprint ($m^2$) | Motor | 3,1 | 3,1 | 3,1 | 3,1 | 3,1 |
| | Frequency Converter | 2,0 | 2,0 | 2,2 | 2,2 | 2,2 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | 1,7 | 1,7 | 1,7 |
| | Total | 6,8 | 6,8 | 7,0 | 7,0 | 7,0 |
| Dimensions (L x W xH) | Motor | 2100 x 1470 x 1670 | 2100 x 1470 x 1670 | 2100 x 1470 x 1670 | 2100 x 1470 x 1670 | 2100 x 1470 x 1670 |
| | Frequency Converter | 2830 x 718 x 2088 | 2830 x 718 x 2088 | 3030 x 718 x 2088 | 3030 x 718 x 2088 | 3030 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 |
| Weight (kg) | Motor | 3440 | 3410 | 3320 | 3330 | 3320 |
| | Frequency Converter | 1870 | 1870 | 2020 | 2020 | 2020 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1100 | 1100 | 1100 | 1100 |
| | Total | 6410 | 6380 | 6440 | 6450 | 6440 |
| LT-water flow ($m^3/h$) | Motor | 4,6 | 6,3 | 7,5 | 7,9 | 8,9 |
| | Frequency Converter | 2,7 | 2,7 | 3,5 | 3,5 | 3,5 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 28,2 | 38,4 | 44,4 | 44,7 | 48,3 |
| | Frequency Converter | 17 | 22 | 28 | 28 | 34 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 45,2 | 60,4 | 72,4 | 72,7 | 82,3 |
| Losses to ambient (kW) | Motor | 2,4 | 3,3 | 3,9 | 4,2 | 4,7 |
| | Frequency Converter | 1,0 | 1,6 | 2,0 | 2,4 | 2,7 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | 1,8 | 1,8 |
| | Total | 5,2 | 6,7 | 7,7 | 8,3 | 9,2 |



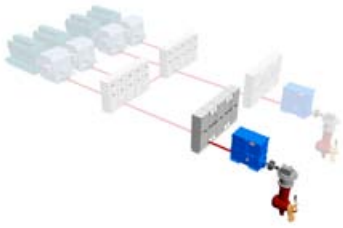


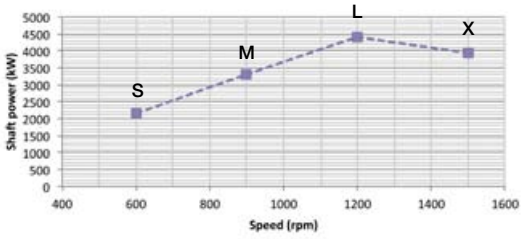

| High Speed Drive 450 - Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | ≥1200 | ≥1500 | ≥1800 |
| | Maximum Power (kW) | 770 | 1340 | 1650 | 1850 | 2100 |
| | Maximum Torque (kNm) | 12,3 | 14,2 | 13,1 | 11,8 | 11,1 |
| | Drive (kVA) | 1070 | 2030 | 2680 | 2680 | 3330 |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 94,8 | 95,6 | 95,8 | 95,8 | 96,2 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 92,9 | 93,7 | 93,9 | 93,9 | 94,3 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 872 | 1506 | 1850 | 2074 | 2345 |
| | Input Current (A) | 730 | 1260 | 1548 | 1736 | 1962 |
| Footprint ($m^2$) | Motor | 3,6 | 3,6 | 3,6 | 3,6 | 3,6 |
| | Frequency Converter | 2,0 | 2,2 | 2,7 | 2,7 | 3,0 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | 1,7 | 1,7 | 1,7 |
| | Total | 7,3 | 7,4 | 8,0 | 8,0 | 8,3 |
| Dimensions (L x W xH) | Motor | 2275 x 1570 x 1870 | 2275 x 1570 x 1870 | 2275 x 1570 x 1870 | 2275 x 1570 x 1870 | 2275 x 1570 x 1870 |
| | Frequency Converter | 2830 x 718 x 2088 | 3030 x 718 x 2088 | 3830 x 718 x 2088 | 3830 x 718 x 2088 | 4230 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 |
| Weight (kg) | Motor | 4490 | 4500 | 4350 | 4250 | 4510 |
| | Frequency Converter | 1870 | 2020 | 2810 | 2810 | 2990 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1100 | 1100 | 1100 | 1100 |
| | Total | 7460 | 7620 | 8260 | 8160 | 8600 |
| LT-water flow ($m^3/h$) | Motor | 6,2 | 8,9 | 10,4 | 11,7 | 11,8 |
| | Frequency Converter | 2,7 | 3,5 | 5,4 | 5,4 | 6,2 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 38,1 | 53,7 | 59,2 | 61,9 | 63,4 |
| | Frequency Converter | 19 | 34 | 44 | 44 | 55 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 57,1 | 87,7 | 103,2 | 105,9 | 118,4 |
| Losses to ambient (kW) | Motor | 3,2 | 4,6 | 5,4 | 6,1 | 6,2 |
| | Frequency Converter | 1,5 | 2,7 | 3,3 | 3,7 | 4,2 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | 1,8 | 1,8 |
| | Total | 6,5 | 9,0 | 10,5 | 11,6 | 12,2 |



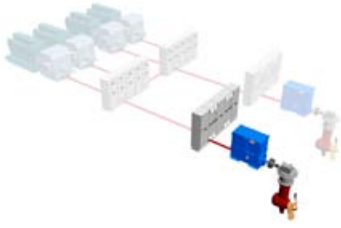


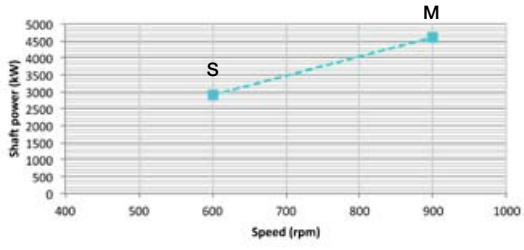

| High Speed Drive 500 - Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | ≥1200 | ≥1500 | ≥1800 |
| | Maximum Power (kW) | 1250 | 1930 | 2800 | 2600 | 3200 |
| | Maximum Torque (kNm) | 19,9 | 20,5 | 22,3 | 16,6 | 17,0 |
| | Drive (kVA) | 2030 | 2680 | 3970 | 3330 | 4630 |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 95,3 | 96 | 96,3 | 96 | 96,3 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 93,4 | 94,1 | 94,4 | 94,1 | 94,4 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 1409 | 2159 | 3123 | 2909 | 3569 |
| | Input Current (A) | 1179 | 1807 | 2613 | 2434 | 2987 |
| Footprint ($m^2$) | Motor | 4,6 | 4,6 | 4,6 | 4,6 | 4,6 |
| | Frequency Converter | 2,2 | 2,7 | 3,2 | 3,0 | 3,8 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | 1,7 | 1,7 | 1,7 |
| | Total | 8,5 | 9,1 | 9,5 | 9,4 | 10,1 |
| Dimensions (L x W xH) | Motor | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 |
| | Frequency Converter | 3030 x 718 x 2088 | 3830 x 718 x 2088 | 4430 x 718 x 2088 | 4230 x 718 x 2088 | 5330 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 |
| Weight (kg) | Motor | 6190 | 6040 | 6040 | 5890 | 5910 |
| | Frequency Converter | 2020 | 2810 | 3140 | 2990 | 4070 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1100 | 1100 | 1100 | 1100 |
| | Total | 9310 | 9950 | 10280 | 9980 | 11080 |
| LT-water flow ($m^3/h$) | Motor | 8,9 | 11,5 | 15,5 | 15,4 | 16,9 |
| | Frequency Converter | 3,5 | 5,4 | 7,0 | 6,2 | 8,9 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 55,3 | 68,9 | 88,8 | 82,4 | 90,1 |
| | Frequency Converter | 34 | 44 | 66 | 55 | 76 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 89,3 | 112,9 | 154,8 | 137,4 | 166,1 |
| Losses to ambient (kW) | Motor | 4,7 | 6 | 8,1 | 8,1 | 9,2 |
| | Frequency Converter | 2,5 | 3,9 | 5,6 | 5,2 | 6,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | 1,8 | 1,8 |
| | Total | 9,0 | 11,6 | 15,5 | 15,1 | 17,4 |



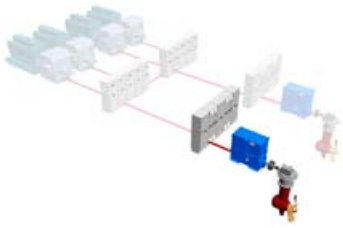


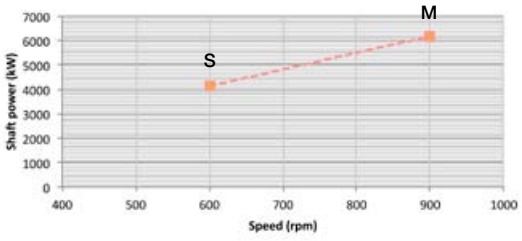

| High Speed Drive 560 - Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | ≥1200 | ≥1500 | - |
| | Maximum Power (kW) | 2150 | 3300 | 4400 | 3950 | - |
| | Maximum Torque (kNm) | 34,2 | 35,0 | 35,0 | 25,1 | - |
| | Drive (kVA) | 3330 | 4630 | 5960 | 5300 | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 96,3 | 96,6 | 96,7 | 96,5 | - |
| | Frequency Converter | 98 | 98 | 98 | 98 | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 94,4 | 94,7 | 94,8 | 94,6 | - |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | - |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | - |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | - |
| | Input power (kVA) | 2398 | 3669 | 4887 | 4397 | - |
| | Input Current (A) | 2007 | 3070 | 4089 | 3679 | - |
| Footprint ($m^2$) | Motor | 8,3 | 8,3 | 8,3 | 8,3 | - |
| | Frequency Converter | 3,0 | 3,8 | 4,1 | 4,0 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | 1,7 | 1,7 | - |
| | Total | 13,0 | 13,8 | 14,1 | 14,0 | - |
| Dimensions (L x W xH) | Motor | 3190 x 2605 x 2095 | 3190 x 2605 x 2095 | 3190 x 2605 x 2095 | 3190 x 2605 x 2095 | - |
| | Frequency Converter | 4230 x 718 x 2088 | 5330 x 718 x 2088 | 5730 x 718 x 2088 | 5530 x 718 x 2088 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | 2240 x 760 x 2090 | - |
| Weight (kg) | Motor | 9080 | 8970 | 8950 | 8470 | - |
| | Frequency Converter | 2990 | 4070 | 4370 | 4220 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1100 | 0 | 0 | - |
| | Total | 13170 | 14140 | 13320 | 12690 | - |
| LT-water flow ($m^3/h$) | Motor | 11,9 | 16,8 | 21,7 | 20,3 | - |
| | Frequency Converter | 6,2 | 8,9 | 10,4 | 9,7 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 73,4 | 98,5 | 118 | 105,5 | - |
| | Frequency Converter | 55 | 76 | 99 | 87 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 128,4 | 174,5 | 217 | 192,5 | - |
| Losses to ambient (kW) | Motor | 6,3 | 8,8 | 11,3 | 10,6 | - |
| | Frequency Converter | 4,3 | 6,6 | 8,8 | 7,9 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | 1,8 | 1,8 | - |
| | Total | 12,4 | 17,2 | 21,9 | 20,3 | - |



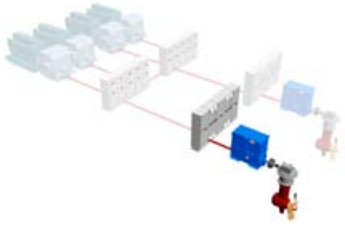


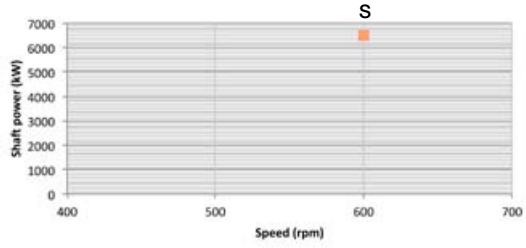

| High Speed Drive 630 - Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | - | - | - |
| | Maximum Power (kW) | 2900 | 4600 | - | - | - |
| | Maximum Torque (kNm) | 46,2 | 48,8 | - | - | - |
| | Drive (kVA) | 3970 | 5960 | - | - | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 96,4 | 96,9 | - | - | - |
| | Frequency Converter | 98 | 98 | - | - | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 94,5 | 95,0 | - | - | - |
| Main Connection | Input Voltage (VAC) | 690 | 690 | - | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | - | - | - |
| | Power factor | 0,95 | 0,95 | - | - | - |
| | Input power (kVA) | 3231 | 5099 | - | - | - |
| | Input Current (A) | 2704 | 4267 | - | - | - |
| Footprint ($m^2$) | Motor | 8,9 | 8,9 | - | - | - |
| | Frequency Converter | 3,2 | 4,1 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | - | - | - |
| | Total | 13,8 | 14,7 | - | - | - |
| Dimensions (L x W xH) | Motor | 3490 x 2555 x 2330 | 3490 x 2555 x 2330 | - | - | - |
| | Frequency Converter | 4430 x 718 x 2088 | 5730 x 718 x 2088 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 2240 x 760 x 2090 | - | - | - |
| Weight (kg) | Motor | 12600 | 12480 | - | - | - |
| | Frequency Converter | 3140 | 4370 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1100 | - | - | - |
| | Total | 16840 | 17950 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 15,4 | 21,4 | - | - | - |
| | Frequency Converter | 7,0 | 10,4 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 95 | 122,1 | - | - | - |
| | Frequency Converter | 66 | 99 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 161 | 221,1 | - | - | - |
| Losses to ambient (kW) | Motor | 8,1 | 11,2 | - | - | - |
| | Frequency Converter | 5,8 | 9,2 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | - | - | - |
| | Total | 15,7 | 22,2 | - | - | - |



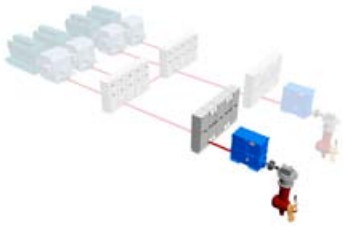


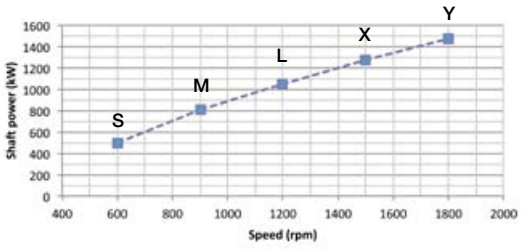

| High Speed Drive 710 - Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | - | - | - |
| | Maximum Power (kW) | 4150 | 6200 | - | - | - |
| | Maximum Torque (kNm) | 66,0 | 65,8 | - | - | - |
| | Drive (kVA) | 5960 | 9000 | - | - | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 96,9 | 96,7 | - | - | - |
| | Frequency Converter | 98 | 98,5 | - | - | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 95,0 | 95,2 | - | - | - |
| Main Connection | Input Voltage (VAC) | 690 | 3300 | - | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | - | - | - |
| | Power factor | 0,95 | 0,95 | - | - | - |
| | Input power (kVA) | 4600 | 6852 | - | - | - |
| | Input Current (A) | 3849 | 1199 | - | - | - |
| Footprint ($m^2$) | Motor | 9,5 | 9,5 | - | - | - |
| | Frequency Converter | 4,1 | 7,7 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 2,6 | - | - | - |
| | Total | 15,3 | 19,8 | - | - | - |
| Dimensions (L x W xH) | Motor | 3550 x 2665 x 2650 | 3550 x 2665 x 2650 | - | - | - |
| | Frequency Converter | 5730 x 718 x 2088 | 6530 x 1176 x 2475 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2240 x 760 x 2090 | 3440 x 760 x 2090 | - | - | - |
| Weight (kg) | Motor | 15000 | 12210 | - | - | - |
| | Frequency Converter | 4370 | 6300 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1100 | 1800 | - | - | - |
| | Total | 20470 | 20310 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 23 | 23 | - | - | - |
| | Frequency Converter | 10,4 | 10,0 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 117 | 190 | - | - | - |
| | Frequency Converter | 99 | 83,6 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 216 | 274,0 | - | - | - |
| Losses to ambient (kW) | Motor | 11 | 21 | - | - | - |
| | Frequency Converter | 8,3 | 7,2 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | 1,8 | - | - | - |
| | Total | 21,1 | 30,2 | - | - | - |



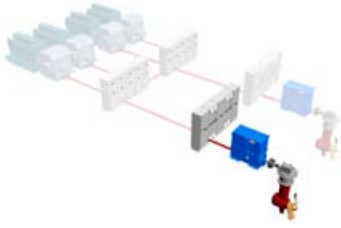


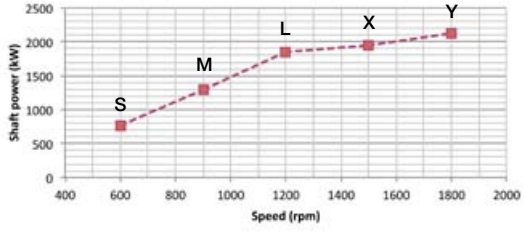

| High Speed Drive 800 - Single Drive | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | - | - | - | - |
| | Maximum Power (kW) | 6500 | - | - | - | - |
| | Maximum Torque (kNm) | 103,5 | - | - | - | - |
| | Drive (kVA) | 9000 | - | - | - | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 96,9 | - | - | - | - |
| | Frequency Converter | 98,5 | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 95,4 | - | - | - | - |
| Main Connection | Input Voltage (VAC) | 3300 | - | - | - | - |
| | Frequency (Hz) | 50/60 | - | - | - | - |
| | Power factor | 0,95 | - | - | - | - |
| | Input power (kVA) | 7169 | - | - | - | - |
| | Input Current (A) | 1254 | - | - | - | - |
| Footprint ($m^2$) | Motor | 11,4 | - | - | - | - |
| | Frequency Converter | 7,7 | - | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 2,6 | - | - | - | - |
| | Total | 21,7 | - | - | - | - |
| Dimensions (L x W xH) | Motor | 4350 x 2630 x 2930 | - | - | - | - |
| | Frequency Converter | 6530 x 1176 x 2475 | - | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 3440 x 760 x 2090 | - | - | - | - |
| Weight (kg) | Motor | 20800 | - | - | - | - |
| | Frequency Converter | 6300 | - | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1800 | - | - | - | - |
| | Total | 28900 | - | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 23 | - | - | - | - |
| | Frequency Converter | 10,4 | - | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 187 | - | - | - | - |
| | Frequency Converter | 86,6 | - | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 273,8 | - | - | - | - |
| Losses to ambient (kW) | Motor | 21 | - | - | - | - |
| | Frequency Converter | 7,2 | - | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,8 | - | - | - | - |
| | Total | 29,8 | - | - | - | - |



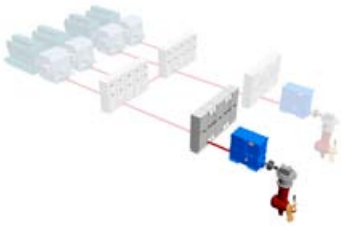


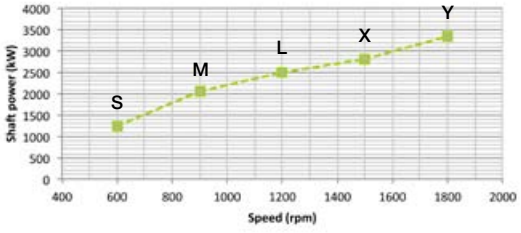

| High Speed Drive 400 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | ≥1200 | ≥1500 | ≥1800 |
| | Maximum Power (kW) | 500 | 810 | 1050 | 1280 | 1470 |
| | Maximum Torque (kNm) | 8,0 | 8,6 | 8,4 | 8,2 | 7,8 |
| | Drive (kVA) | 950 | 1240 | 1840 | 1840 | 1840 |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Limited | Limited | Limited | Limited | Limited |
| Drivetrain Efficiency (%) | Motor | 94,2 | 94,9 | 95,2 | 95,6 | 95,8 |
| | Frequency Converter | 97 | 97 | 97 | 97 | 97 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 91,4 | 92,1 | 92,3 | 92,7 | 92,9 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| | Input power (kVA) | 553 | 889 | 1149 | 1394 | 1598 |
| | Input Current (A) | 462 | 744 | 961 | 1167 | 1337 |
| Footprint ($m^2$) | Motor | 3,1 | 3,1 | 3,1 | 3,1 | 3,1 |
| | Frequency Converter | 2,7 | 2,7 | 3,1 | 3,1 | 3,1 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 5,8 | 5,8 | 6,2 | 6,2 | 6,2 |
| Dimensions (L x W xH) | Motor | 2100 x 1470 x 1670 | 2100 x 1470 x 1670 | 2100 x 1470 x 1670 | 2100 x 1470 x 1670 | 2100 x 1470 x 1670 |
| | Frequency Converter | 3830 x 718 x 2088 | 3830 x 718 x 2088 | 4330 x 718 x 2088 | 4330 x 718 x 2088 | 4330 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 3450 | 3420 | 3430 | 3430 | 3420 |
| | Frequency Converter | 2950 | 2950 | 3350 | 3350 | 3350 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 6400 | 6370 | 6780 | 6780 | 6770 |
| LT-water flow ($m^3/h$) | Motor | 4,5 | 6,3 | 7,5 | 8,3 | 9,2 |
| | Frequency Converter | 4,2 | 4,7 | 7,0 | 7,0 | 7,0 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 27,8 | 38,5 | 44,4 | 47,4 | 50,8 |
| | Frequency Converter | 34,8 | 39,5 | 56,2 | 56,2 | 56,2 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 62,6 | 78 | 100,6 | 103,6 | 107 |
| Losses to ambient (kW) | Motor | 2,3 | 3,3 | 3,9 | 4,4 | 4,8 |
| | Frequency Converter | 1,0 | 1,6 | 2,1 | 2,6 | 2,9 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 3,3 | 4,9 | 6,0 | 7,0 | 7,7 |



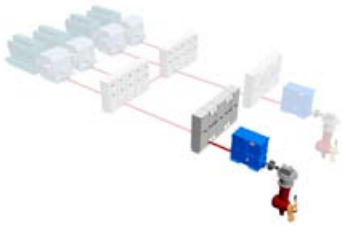


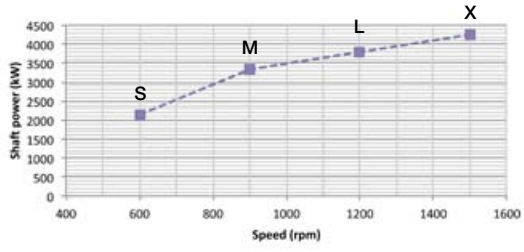

| High Speed Drive 450 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | ≥1200 | ≥1500 | ≥1800 |
| | Maximum Power (kW) | 770 | 1300 | 1850 | 1950 | 2120 |
| | Maximum Torque (kNm) | 12,3 | 13,8 | 14,2 | 12,4 | 11,2 |
| | Drive (kVA) | 950 | 1840 | 2430 | 2430 | 3620 |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Limited | Limited | Limited | Limited | Limited |
| Drivetrain Efficiency (%) | Motor | 94,8 | 95,6 | 95,9 | 95,8 | 96 |
| | Frequency Converter | 97 | 97 | 97 | 97 | 97 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 92,0 | 92,7 | 93,0 | 92,9 | 93,1 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| | Input power (kVA) | 846 | 1416 | 2009 | 2120 | 2300 |
| | Input Current (A) | 708 | 1185 | 1681 | 1774 | 1924 |
| Footprint ($m^2$) | Motor | 3,6 | 3,6 | 3,6 | 3,6 | 3,6 |
| | Frequency Converter | 2,7 | 3,1 | 3,8 | 3,8 | 4,8 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 6,3 | 6,7 | 7,3 | 7,3 | 8,3 |
| Dimensions (L x W xH) | Motor | 2275 x 1570 x 1870 | 2275 x 1570 x 1870 | 2275 x 1570 x 1870 | 2275 x 1570 x 1870 | 2275 x 1570 x 1870 |
| | Frequency Converter | 3830 x 718 x 2088 | 4330 x 718 x 2088 | 5230 x 718 x 2088 | 5230 x 718 x 2088 | 6630 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 4480 | 4480 | 4470 | 4470 | 4460 |
| | Frequency Converter | 2950 | 3350 | 4480 | 4480 | 5315 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 7430 | 7830 | 8950 | 8950 | 9775 |
| LT-water flow ($m^3/h$) | Motor | 6,2 | 8,8 | 11,4 | 12,2 | 12,5 |
| | Frequency Converter | 4,2 | 7,0 | 9,1 | 9,1 | 13,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 38,1 | 52,6 | 65,9 | 64,4 | 65,6 |
| | Frequency Converter | 34,8 | 56,2 | 77,9 | 77,9 | 111 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 72,9 | 108,8 | 143,8 | 142,3 | 176,6 |
| Losses to ambient (kW) | Motor | 3,2 | 4,6 | 5,9 | 6,4 | 6,5 |
| | Frequency Converter | 1,5 | 2,6 | 3,7 | 3,9 | 4,2 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 4,7 | 7,2 | 9,6 | 10,3 | 10,7 |



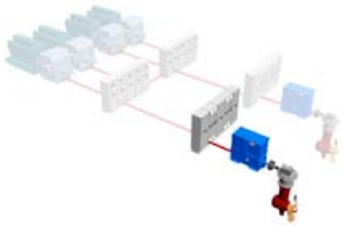


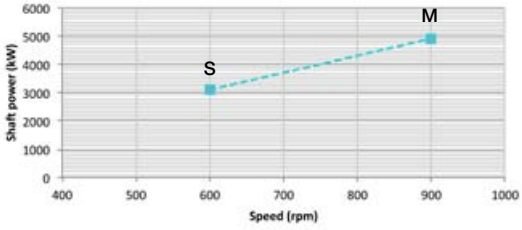

| High Speed Drive 500 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | ≥1200 | ≥1500 | ≥1800 |
| | Maximum Power (kW) | 1250 | 2050 | 2500 | 2800 | 3350 |
| | Maximum Torque (kNm) | 19,9 | 21,7 | 19,9 | 17,8 | 17,8 |
| | Drive (kVA) | 1840 | 3620 | 3620 | 3620 | 4630 |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Limited | Limited | Limited | Limited | Limited |
| Drivetrain Efficiency (%) | Motor | 95,2 | 96 | 96,1 | 96,1 | 96,3 |
| | Frequency Converter | 97 | 97 | 97 | 97 | 97 |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 92,3 | 93,1 | 93,2 | 93,2 | 93,4 |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | 690 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,99 | 0,99 | 0,99 | 0,99 | 0,99 |
| | Input power (kVA) | 1367 | 2224 | 2709 | 3034 | 3623 |
| | Input Current (A) | 1144 | 1861 | 2267 | 2539 | 3031 |
| Footprint ($m^2$) | Motor | 4,6 | 4,6 | 4,6 | 4,6 | 4,6 |
| | Frequency Converter | 3,1 | 4,8 | 4,8 | 4,8 | 6,2 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 7,7 | 9,4 | 9,4 | 9,4 | 10,8 |
| Dimensions (L x W xH) | Motor | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 |
| | Frequency Converter | 4330 x 718 x 2088 | 6630 x 718 x 2088 | 6630 x 718 x 2088 | 6630 x 718 x 2088 | 8630 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 6190 | 6150 | 6000 | 6050 | 6040 |
| | Frequency Converter | 3350 | 5315 | 5315 | 5315 | 7495 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 9540 | 11465 | 11315 | 11365 | 13535 |
| LT-water flow ($m^3/h$) | Motor | 9,1 | 12,4 | 14,5 | 16,1 | 16,9 |
| | Frequency Converter | 7,0 | 13,4 | 13,4 | 13,4 | 17,5 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 56,1 | 74,1 | 82,7 | 86,7 | 94,8 |
| | Frequency Converter | 56,2 | 111 | 111 | 111 | 146,5 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 112,3 | 185,1 | 193,7 | 197,7 | 241,3 |
| Losses to ambient (kW) | Motor | 4,7 | 6,4 | 6,9 | 8,4 | 9,2 |
| | Frequency Converter | 2,5 | 4,1 | 5,0 | 5,6 | 6,7 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 7,2 | 10,5 | 11,9 | 14,0 | 15,9 |



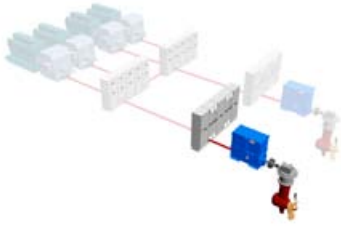


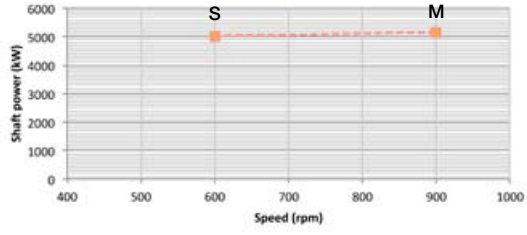

| High Speed Drive 560 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | ≥1200 | ≥1500 | - |
| | Maximum Power (kW) | 2150 | 3350 | 3800 | 4250 | - |
| | Maximum Torque (kNm) | 34,2 | 35,5 | 30,2 | 27,0 | - |
| | Drive (kVA) | 3620 | 4630 | 4630 | 5300 | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Limited | Limited | Limited | Limited | - |
| Drivetrain Efficiency (%) | Motor | 96,2 | 96,5 | 96,5 | 96,7 | - |
| | Frequency Converter | 97 | 97 | 97 | 97 | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 93,3 | 93,6 | 93,6 | 93,8 | - |
| Main Connection | Input Voltage (VAC) | 690 | 690 | 690 | 690 | - |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | - |
| | Power factor | 0,99 | 0,99 | 0,99 | 0,99 | - |
| | Input power (kVA) | 2327 | 3615 | 4101 | 4577 | - |
| | Input Current (A) | 1947 | 3025 | 3431 | 3830 | - |
| Footprint ($m^2$) | Motor | 8,3 | 8,3 | 8,3 | 8,3 | - |
| | Frequency Converter | 4,8 | 6,2 | 6,2 | 6,4 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 13,1 | 14,5 | 14,5 | 14,7 | - |
| Dimensions (L x W xH) | Motor | 3190 x 2605 x 2095 | 3190 x 2605 x 2095 | 3190 x 2605 x 2095 | 3190 x 2605 x 2095 | - |
| | Frequency Converter | 6630 x 718 x 2088 | 8630 x 718 x 2088 | 8630 x 718 x 2088 | 8930 x 718 x 2088 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 9440 | 9180 | 8390 | 8670 | - |
| | Frequency Converter | 5315 | 7495 | 7495 | 7295 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 14755 | 16675 | 15885 | 15965 | - |
| LT-water flow ($m^3/h$) | Motor | 12,2 | 17,3 | 19,6 | 21 | - |
| | Frequency Converter | 13,4 | 17,5 | 17,5 | 19,7 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 75,3 | 101,6 | 104,9 | 110,2 | - |
| | Frequency Converter | 111 | 146,5 | 146,5 | 157,1 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 186,3 | 248,1 | 251,4 | 267,3 | - |
| Losses to ambient (kW) | Motor | 6,4 | 9 | 10,2 | 11 | - |
| | Frequency Converter | 4,3 | 6,7 | 7,6 | 8,5 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 10,7 | 15,7 | 17,8 | 19,5 | - |



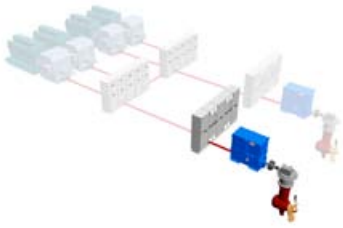


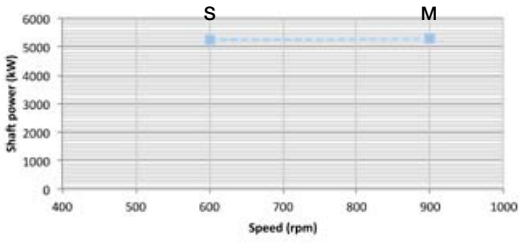

| High Speed Drive 630 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | - | - | - |
| | Maximum Power (kW) | 3100 | 4900 | - | - | - |
| | Maximum Torque (kNm) | 49,3 | 52,0 | - | - | - |
| | Drive (kVA) | 4630 | 5960 | - | - | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Limited | Limited | - | - | - |
| Drivetrain Efficiency (%) | Motor | 96,5 | 96,9 | - | - | - |
| | Frequency Converter | 97 | 97 | - | - | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 93,6 | 94,0 | - | - | - |
| Main Connection | Input Voltage (VAC) | 690 | 690 | - | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | - | - | - |
| | Power factor | 0,99 | 0,99 | - | - | - |
| | Input power (kVA) | 3345 | 5266 | - | - | - |
| | Input Current (A) | 2799 | 4406 | - | - | - |
| Footprint ($m^2$) | Motor | 8,9 | 8,9 | - | - | - |
| | Frequency Converter | 6,2 | 7,5 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | 1,7 | 1,7 | - | - | - |
| | Total | 16,8 | 18,1 | - | - | - |
| Dimensions (L x W xH) | Motor | 3490 x 2555 x 2330 | 3490 x 2555 x 2330 | - | - | - |
| | Frequency Converter | 8630 x 718 x 2088 | 104830 x 718 x 2088 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 13090 | 12730 | - | - | - |
| | Frequency Converter | 7495 | 9145 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 20585 | 21875 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 16,1 | 22,3 | - | - | - |
| | Frequency Converter | 17,5 | 21,8 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 98,6 | 128,1 | - | - | - |
| | Frequency Converter | 146,5 | 184 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 245,1 | 312,1 | - | - | - |
| Losses to ambient (kW) | Motor | 8,4 | 11,6 | - | - | - |
| | Frequency Converter | 6,2 | 9,8 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 14,6 | 21,4 | - | - | - |



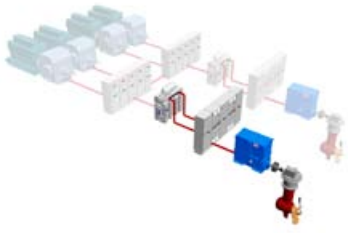


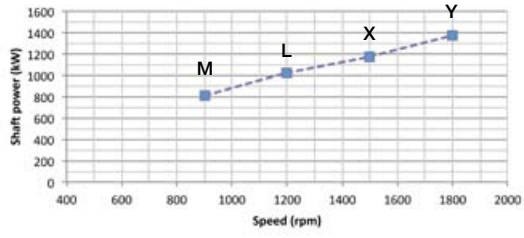

| High Speed Drive 710 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | - | - | - |
| | Maximum Power (kW) | 5030 | 5140 | - | - | - |
| | Maximum Torque (kNm) | 80,1 | 54,5 | - | - | - |
| | Drive (kVA) | 6620 | 6620 | - | - | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Limited | Limited | - | - | - |
| Drivetrain Efficiency (%) | Motor | 97 | 97,2 | - | - | - |
| | Frequency Converter | 97 | 97 | - | - | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 94,1 | 94,3 | - | - | - |
| Main Connection | Input Voltage (VAC) | 690 | 690 | - | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | - | - | - |
| | Power factor | 0,99 | 0,99 | - | - | - |
| | Input power (kVA) | 5400 | 5507 | - | - | - |
| | Input Current (A) | 4518 | 4608 | - | - | - |
| Footprint ($m^2$) | Motor | 9,5 | 9,5 | - | - | - |
| | Frequency Converter | 8,4 | 8,4 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 17,9 | 17,9 | - | - | - |
| Dimensions (L x W xH) | Motor | 3550 x 2665 x 2650 | 3550 x 2665 x 2650 | - | - | - |
| | Frequency Converter | 11730 x 718 x 2088 | 11730 x 718 x 2088 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 20500 | 13500 | - | - | - |
| | Frequency Converter | 9885 | 9885 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 30385 | 23385 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 23 | 23 | - | - | - |
| | Frequency Converter | 24,7 | 24,7 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 137 | 130 | - | - | - |
| | Frequency Converter | 215 | 215 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 352 | 345 | - | - | - |
| Losses to ambient (kW) | Motor | 16 | 14 | - | - | - |
| | Frequency Converter | 10,1 | 10,3 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 26,1 | 24,3 | - | - | - |



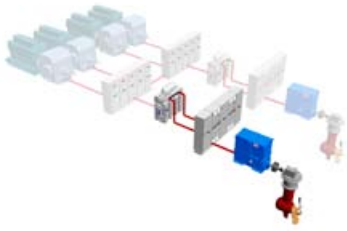


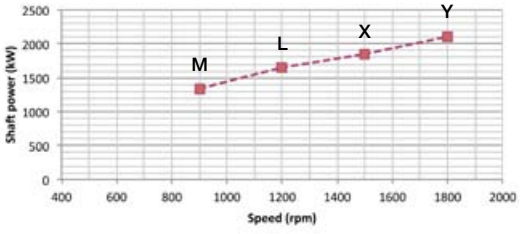

| High Speed Drive 800 - Single Drive (AFE) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | - | - | - |
| | Maximum Power (kW) | 5250 | 5300 | - | - | - |
| | Maximum Torque (kNm) | 83,6 | 56,2 | - | - | - |
| | Drive (kVA) | 6620 | 6620 | - | - | - |
| | Transformer (kVA) | - | - | - | - | - |
| | Networking Braking | Limited | Limited | - | - | - |
| Drivetrain Efficiency (%) | Motor | 97 | 96,9 | - | - | - |
| | Frequency Converter | 97 | 97 | - | - | - |
| | Transformer | - | - | - | - | - |
| | Total Electrical Efficiency | 94,1 | 94,0 | - | - | - |
| Main Connection | Input Voltage (VAC) | 690 | 690 | - | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | - | - | - |
| | Power factor | 0,99 | 0,99 | - | - | - |
| | Input power (kVA) | 5636 | 5696 | - | - | - |
| | Input Current (A) | 4716 | 4766 | - | - | - |
| Footprint ($m^2$) | Motor | 11,4 | 11,4 | - | - | - |
| | Frequency Converter | 8,4 | 8,4 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 19,9 | 19,9 | - | - | - |
| Dimensions (L x W xH) | Motor | 4350 x 2630 x 2930 | 4350 x 2630 x 2930 | - | - | - |
| | Frequency Converter | 11730 x 718 x 2088 | 11730 x 718 x 2088 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 21500 | 14000 | - | - | - |
| | Frequency Converter | 9885 | 9885 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 31385 | 23885 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 23 | 23 | - | - | - |
| | Frequency Converter | 24,7 | 24,7 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 142 | 147 | - | - | - |
| | Frequency Converter | 215 | 215 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 357 | 362 | - | - | - |
| Losses to ambient (kW) | Motor | 16 | 16 | - | - | - |
| | Frequency Converter | 10,5 | 10,6 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | - | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 26,5 | 26,6 | - | - | - |



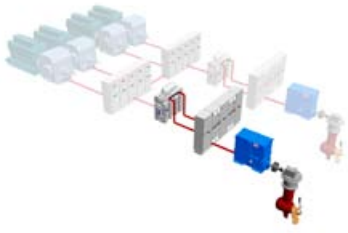


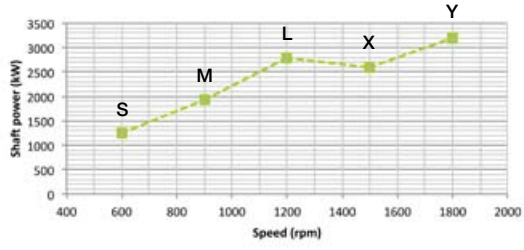

| High Speed Drive 400 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | - | ≥900 | ≥1200 | ≥1500 | ≥1800 |
| | Maximum Power (kW) | - | 810 | 1020 | 1180 | 1370 |
| | Maximum Torque (kNm) | - | 8,6 | 8,1 | 7,5 | 7,3 |
| | Drive (kVA) | - | 1370 | 1590 | 1590 | 2030 |
| | Transformer (kVA) | - | 1150 | 1450 | 1450 | 1850 |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | - | 94,9 | 95,1 | 95,5 | 95,7 |
| | Frequency Converter | - | 98 | 98 | 98 | 98 |
| | Transformer | - | 99 | 99 | 99 | 99 |
| | Total Electrical Efficiency | - | 93,0 | 93,2 | 93,6 | 93,8 |
| Main Connection | Input Voltage (VAC) | - | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 |
| | Frequency (Hz) | - | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | - | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | - | 917 | 1152 | 1327 | 1538 |
| | Input Current (A) | - | 768 / 161 / 81 / 49 | 964 / 202 / 101 / 61 | 1111 / 233 / 117 / 70 | 1287 / 270 / 135 / 81 |
| Footprint (m²) | Motor | - | 3,1 | 3,1 | 3,1 | 3,1 |
| | Frequency Converter | - | 2,0 | 2,2 | 2,2 | 2,2 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 5,9 | 6,5 | 6,5 | 6,9 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 11,0 | 11,7 | 11,7 | 12,2 |
| Dimensions (L x W xH) | Motor | - | 2100 x 1470 x 1670 | 2100 x 1470 x 1670 | 2100 x 1470 x 1670 | 2100 x 1470 x 1670 |
| | Frequency Converter | - | 2830 x 718 x 2088 | 3030 x 718 x 2088 | 3030 x 718 x 2088 | 3030 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 2800 x 2100 x 1950 | 3000 x 2150 x 2100 | 3000 x 2150 x 2100 | 3150 x 2200 x 2250 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | - | 3410 | 3320 | 3330 | 3320 |
| | Frequency Converter | - | 1870 | 2020 | 2020 | 2020 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 3650 | 4300 | 4300 | 4900 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 8930 | 9640 | 9650 | 10240 |
| LT-water flow (m³/h) | Motor | - | 6,3 | 7,5 | 7,9 | 8,9 |
| | Frequency Converter | - | 2,7 | 3,5 | 3,5 | 3,5 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 5 | 6 | 6 | 7 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | - | 38,4 | 44,4 | 44,7 | 48,3 |
| | Frequency Converter | - | 22 | 28 | 28 | 34 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 26 | 35 | 35 | 40 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 86,0 | 106,9 | 107,2 | 122,6 |
| Losses to ambient (kW) | Motor | - | 3,3 | 3,9 | 4,2 | 4,7 |
| | Frequency Converter | - | 1,6 | 2,0 | 2,4 | 2,7 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 4,5 | 5,1 | 5,1 | 5,6 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 9,4 | 11,0 | 11,6 | 13,0 |



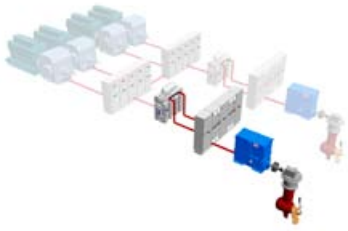


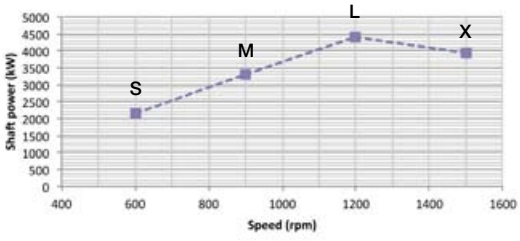

| High Speed Drive 450 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | - | ≥900 | ≥1200 | ≥1500 | ≥1800 |
| | Maximum Power (kW) | - | 1340 | 1650 | 1850 | 2100 |
| | Maximum Torque (kNm) | - | 14,2 | 13,1 | 11,8 | 11,1 |
| | Drive (kVA) | - | 2030 | 2680 | 2680 | 3330 |
| | Transformer (kVA) | - | 1850 | 2300 | 2300 | 2900 |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | - | 95,6 | 95,8 | 95,8 | 96,2 |
| | Frequency Converter | - | 98 | 98 | 98 | 98 |
| | Transformer | - | 99 | 99 | 99 | 99 |
| | Total Electrical Efficiency | - | 93,7 | 93,9 | 93,9 | 94,3 |
| Main Connection | Input Voltage (VAC) | - | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 |
| | Frequency (Hz) | - | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | - | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | - | 1506 | 1850 | 2074 | 2345 |
| | Input Current (A) | - | 1260 / 264 / 132 / 80 | 1548 / 324 / 162 / 98 | 1736 / 363 / 182 / 109 | 1962 / 411 / 206 / 124 |
| Footprint ($m^2$) | Motor | - | 3,6 | 3,6 | 3,6 | 3,6 |
| | Frequency Converter | - | 2,2 | 2,7 | 2,7 | 3,0 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 6,9 | 7,3 | 7,3 | 7,3 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 12,7 | 13,6 | 13,6 | 13,9 |
| Dimensions (L x W xH) | Motor | - | 2275 x 1570 x 1870 | 2275 x 1570 x 1870 | 2275 x 1570 x 1870 | 2275 x 1570 x 1870 |
| | Frequency Converter | - | 3030 x 718 x 2088 | 3830 x 718 x 2088 | 3830 x 718 x 2088 | 4230 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 3150 x 2200 x 2250 | 3250 x 2250 x 2400 | 3250 x 2250 x 2400 | 3250 x 2250 x 2400 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | - | 4500 | 4350 | 4250 | 4510 |
| | Frequency Converter | - | 2020 | 2810 | 2810 | 2990 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 4900 | 5600 | 5600 | 5600 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 11420 | 12760 | 12660 | 13100 |
| LT-water flow ($m^3/h$) | Motor | - | 8,9 | 10,4 | 11,7 | 11,8 |
| | Frequency Converter | - | 3,5 | 5,4 | 5,4 | 6,2 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 7 | 7 | 7 | 5,5 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | - | 53,7 | 59,2 | 61,9 | 63,4 |
| | Frequency Converter | - | 34 | 44 | 44 | 55 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 40 | 40 | 40 | 46 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 128,0 | 143,5 | 146,2 | 164,1 |
| Losses to ambient (kW) | Motor | - | 4,6 | 5,4 | 6,1 | 6,2 |
| | Frequency Converter | - | 2,7 | 3,3 | 3,7 | 4,2 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | - | 5,6 | 6,1 | 6,1 | 6,4 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | - | 12,9 | 14,8 | 15,9 | 16,8 |



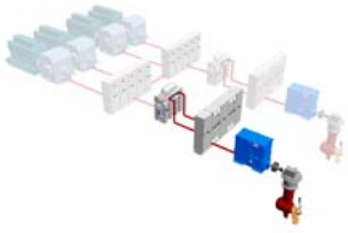


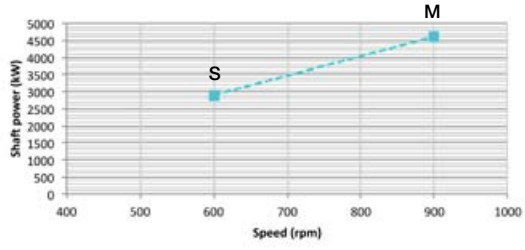

| High Speed Drive 500 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | ≥1200 | ≥1500 | ≥1800 |
| | Maximum Power (kW) | 1250 | 1930 | 2800 | 2600 | 3200 |
| | Maximum Torque (kNm) | 19,9 | 20,5 | 22,3 | 16,6 | 17,0 |
| | Drive (kVA) | 2030 | 2680 | 3970 | 3330 | 4630 |
| | Transformer (kVA) | 1450 | 2300 | 3250 | 3250 | 3700 |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 95,3 | 96 | 96,3 | 96 | 96,3 |
| | Frequency Converter | 98 | 98 | 98 | 98 | 98 |
| | Transformer | 99 | 99 | 99 | 99 | 99 |
| | Total Electrical Efficiency | 93,4 | 94,1 | 94,4 | 94,1 | 94,4 |
| Main Connection | Input Voltage (VAC) | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | 50/60 |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | 0,95 |
| | Input power (kVA) | 1409 | 2159 | 3123 | 2909 | 3569 |
| | Input Current (A) | 1179 / 247 / 124 / 74 | 1807 / 378 / 189 / 114 | 2614 / 547 / 274 / 164 | 2435 / 509 / 255 / 153 | 2987 / 625 / 313 / 188 |
| Footprint ($m^2$) | Motor | 4,6 | 4,6 | 4,6 | 4,6 | 4,6 |
| | Frequency Converter | 2,2 | 2,7 | 3,2 | 3,0 | 3,8 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 6,5 | 7,3 | 8,1 | 8,1 | 8,1 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 13,2 | 14,7 | 15,8 | 15,7 | 16,5 |
| Dimensions (L x W xH) | Motor | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 | 2595 x 1780 x 2070 |
| | Frequency Converter | 3030 x 718 x 2088 | 3830 x 718 x 2088 | 4430 x 718 x 2088 | 4230 x 718 x 2088 | 5330 x 718 x 2088 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 3000 x 2150 x 2100 | 3250 x 2250 x 2400 | 3500 x 2300 x 2400 | 3500 x 2300 x 2400 | 3600 x 2250 x 2250 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 6190 | 6040 | 6040 | 5890 | 5910 |
| | Frequency Converter | 2020 | 2810 | 3140 | 2990 | 4070 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 4300 | 5600 | 6500 | 6500 | 7000 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 12510 | 14450 | 15680 | 15380 | 16980 |
| LT-water flow ($m^3/h$) | Motor | 8,9 | 11,5 | 15,5 | 15,4 | 16,9 |
| | Frequency Converter | 3,5 | 5,4 | 7,0 | 6,2 | 8,9 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 6 | 7 | 8 | 8 | 8 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 55,3 | 68,9 | 88,8 | 82,4 | 90,1 |
| | Frequency Converter | 34 | 44 | 66 | 55 | 76 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 35 | 40 | 67 | 67 | 67 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 123,8 | 153,2 | 221,3 | 203,9 | 232,6 |
| Losses to ambient (kW) | Motor | 4,7 | 6 | 8,1 | 8,1 | 9,2 |
| | Frequency Converter | 2,5 | 3,9 | 5,6 | 5,2 | 6,4 |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 5,1 | 6,1 | 6,5 | 6,5 | 6,2 |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 12,3 | 15,9 | 20,2 | 19,8 | 21,8 |



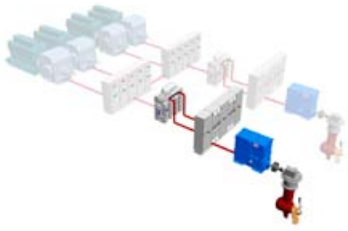


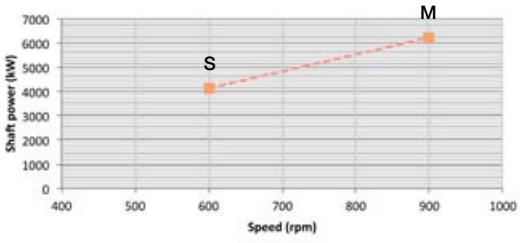

| High Speed Drive 560 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | ≥1200 | ≥1500 | - |
| | Maximum Power (kW) | 2150 | 3300 | 4400 | 3950 | - |
| | Maximum Torque (kNm) | 34,2 | 35,0 | 35,0 | 25,1 | - |
| | Drive (kVA) | 3330 | 4630 | 5960 | 5300 | - |
| | Transformer (kVA) | 2900 | 3800 | 5200 | 4600 | - |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 96,3 | 96,6 | 96,7 | 96,5 | - |
| | Frequency Converter | 98 | 98 | 98 | 98 | - |
| | Transformer | 99 | 99 | 99 | 99 | - |
| | Total Electrical Efficiency | 94,4 | 94,7 | 94,8 | 94,6 | - |
| Main Connection | Input Voltage (VAC) | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | - |
| | Frequency (Hz) | 50/60 | 50/60 | 50/60 | 50/60 | - |
| | Power factor | 0,95 | 0,95 | 0,95 | 0,95 | - |
| | Input power (kVA) | 2398 | 3669 | 4887 | 4397 | - |
| | Input Current (A) | 2007 / 420 / 210 / 126 | 3071 / 642 / 321 / 193 | 4090 / 856 / 428 / 257 | 3679 / 770 / 385 / 231 | - |
| Footprint ($m^2$) | Motor | 8,3 | 8,3 | 8,3 | 8,3 | - |
| | Frequency Converter | 3,0 | 3,8 | 4,1 | 4,0 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 8,0 | 8,6 | 8,9 | 8,6 | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 19,3 | 20,7 | 21,3 | 20,9 | - |
| Dimensions (L x W xH) | Motor | 3190 x 2605 x 2095 | 3190 x 2605 x 2095 | 3190 x 2605 x 2095 | 3190 x 2605 x 2095 | - |
| | Frequency Converter | 4230 x 718 x 2088 | 5330 x 718 x 2088 | 5730 x 718 x 2088 | 5530 x 718 x 2088 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 3400 x 2350 x 2400 | 3680 x 2330 x 2300 | 3700 x 2400 x 2700 | 3600 x 2400 x 2650 | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 9080 | 8970 | 8950 | 8470 | - |
| | Frequency Converter | 2990 | 4070 | 4370 | 4220 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 6000 | 7200 | 9800 | 8250 | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 18070 | 20240 | 23120 | 20940 | - |
| LT-water flow ($m^3/h$) | Motor | 11,9 | 16,8 | 21,7 | 20,3 | - |
| | Frequency Converter | 6,2 | 8,9 | 10,4 | 9,7 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 5,5 | 10 | 15 | 13 | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 73,4 | 98,5 | 118 | 105,5 | - |
| | Frequency Converter | 55 | 76 | 99 | 87 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 46 | 77 | 115 | 100 | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 174,1 | 251,2 | 332,1 | 292,3 | - |
| Losses to ambient (kW) | Motor | 6,3 | 8,8 | 11,3 | 10,6 | - |
| | Frequency Converter | 4,3 | 6,6 | 8,8 | 7,9 | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 6,4 | 6,5 | 7,5 | 7,3 | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 17,0 | 21,9 | 27,6 | 25,8 | - |



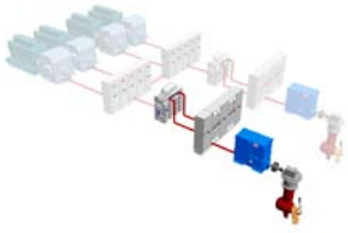


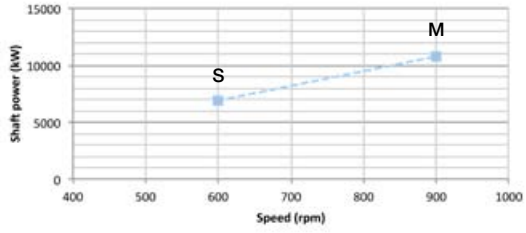

| High Speed Drive 630 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | - | - | - |
| | Maximum Power (kW) | 2900 | 4600 | - | - | - |
| | Maximum Torque (kNm) | 46,2 | 48,8 | - | - | - |
| | Drive (kVA) | 3970 | 5960 | - | - | - |
| | Transformer (kVA) | 3700 | 5800 | - | - | - |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 96,4 | 96,9 | - | - | - |
| | Frequency Converter | 98 | 98 | - | - | - |
| | Transformer | 99 | 99 | - | - | - |
| | Total Electrical Efficiency | 94,5 | 95,0 | - | - | - |
| Main Connection | Input Voltage (VAC) | 690 / 3300 / 6600 / 11000 | 690 / 3300 / 6600 / 11000 | - | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | - | - | - |
| | Power factor | 0,95 | 0,95 | - | - | - |
| | Input power (kVA) | 3231 | 5099 | - | - | - |
| | Input Current (A) | 2704 / 566 / 283 / 170 | 4267 / 893 / 447 / 268 | - | - | - |
| Footprint ($m^2$) | Motor | 8,9 | 8,9 | - | - | - |
| | Frequency Converter | 3,2 | 4,1 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 8,1 | 8,9 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 20,2 | 21,9 | - | - | - |
| Dimensions (L x W xH) | Motor | 3490 x 2555 x 2330 | 3490 x 2555 x 2330 | - | - | - |
| | Frequency Converter | 4430 x 718 x 2088 | 5730 x 718 x 2088 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 3600 x 2250 x 2250 | 3700 x 2400 x 2700 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 12600 | 12480 | - | - | - |
| | Frequency Converter | 3140 | 4370 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 7000 | 9800 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 22740 | 26650 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 15,4 | 21,4 | - | - | - |
| | Frequency Converter | 7,0 | 10,4 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 8 | 12 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 95 | 122,1 | - | - | - |
| | Frequency Converter | 66 | 99 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 67 | 123 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 227,5 | 343,9 | - | - | - |
| Losses to ambient (kW) | Motor | 8,1 | 11,2 | - | - | - |
| | Frequency Converter | 5,8 | 9,2 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 6,2 | 8,0 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 20,1 | 28,4 | - | - | - |






| High Speed Drive 710 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | - | - | - |
| | Maximum Power (kW) | 4150 | 6200 | - | - | - |
| | Maximum Torque (kNm) | 66,0 | 65,8 | - | - | - |
| | Drive (kVA) | 5960 | 9000 | - | - | - |
| | Transformer (kVA) | 4800 | 7000 | - | - | - |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 96,9 | 96,7 | - | - | - |
| | Frequency Converter | 98 | 98 | - | - | - |
| | Transformer | 99 | 99 | - | - | - |
| | Total Electrical Efficiency | 95,0 | 94,8 | - | - | - |
| Main Connection | Input Voltage (VAC) | 690 / 3300 / 6600 / 11000 | 6600 / 11000 | - | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | - | - | - |
| | Power factor | 0,95 | 0,95 | - | - | - |
| | Input power (kVA) | 4600 | 6887 | - | - | - |
| | Input Current (A) | 3850 / 805 / 403 / 242 | 603 / 362 | - | - | - |
| Footprint ($m^2$) | Motor | 9,5 | 9,5 | - | - | - |
| | Frequency Converter | 4,1 | 7,7 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 8,6 | 10,5 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 22,2 | 27,6 | - | - | - |
| Dimensions (L x W xH) | Motor | 3550 x 2665 x 2650 | 3550 x 2665 x 2650 | - | - | - |
| | Frequency Converter | 5730 x 718 x 2088 | 6530 x 1176 x 2475 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 3600 x 2400 x 2650 | 4200 x 2500 x 2800 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 12210 | 12210 | - | - | - |
| | Frequency Converter | 4370 | 5500 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 8250 | 11500 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 24830 | 29210 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 23 | 23 | - | - | - |
| | Frequency Converter | 10,4 | 10,3 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 13 | 12 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 117 | 190 | - | - | - |
| | Frequency Converter | 99 | 85,7 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 100 | 123 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 315,8 | 398,9 | - | - | - |
| Losses to ambient (kW) | Motor | 11,0 | 21,2 | - | - | - |
| | Frequency Converter | 8,3 | 7,2 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 7,3 | 8,9 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 26,6 | 37,2 | - | - | - |






| High Speed Drive 800 - Single Drive (with Transformer) | | | | | | |
|---|---|---|---|---|---|---|
| | Drive Step | S | M | L | X | Y |
| | Motor Speed (rpm) | ≥600 | ≥900 | - | - | - |
| | Maximum Power (kW) | 6900 | 10800 | - | - | - |
| | Maximum Torque (kNm) | 109,8 | 114,6 | - | - | - |
| | Drive (kVA) | 9000 | 14000 | - | - | - |
| | Transformer (kVA) | 8000 | 12000 | - | - | - |
| | Braking Capacity (MJ) | - | - | - | - | - |
| Drivetrain Efficiency (%) | Motor | 97 | 97,2 | - | - | - |
| | Frequency Converter | 98,5 | 98,5 | - | - | - |
| | Transformer | 99 | 99 | - | - | - |
| | Total Electrical Efficiency | 95,5 | 95,7 | - | - | - |
| Main Connection | Input Voltage (VAC) | 6600 / 11000 | 6600 / 11000 | - | - | - |
| | Frequency (Hz) | 50/60 | 50/60 | - | - | - |
| | Power factor | 0,95 | 0,95 | - | - | - |
| | Input power (kVA) | 7602 | 11874 | - | - | - |
| | Input Current (A) | 665 / 399 | 1039 / 624 | - | - | - |
| Footprint ($m^2$) | Motor | 11,4 | 11,4 | - | - | - |
| | Frequency Converter | 7,7 | 11,1 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 10,9 | 12,5 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 30,0 | 35,0 | - | - | - |
| Dimensions (L x W xH) | Motor | 4350 x 2630 x 2930 | 4350 x 2630 x 2930 | - | - | - |
| | Frequency Converter | 6530 x 1176 x 2475 | 9430 x 1176 x 2475 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 4200 x 2600 x 2950 | 5000 x 2500 x 3300 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Weight (kg) | Motor | 20800 | 20800 | - | - | - |
| | Frequency Converter | 5500 | 7700 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 12500 | 17200 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 38800 | 45700 | - | - | - |
| LT-water flow ($m^3/h$) | Motor | 25 | 25 | - | - | - |
| | Frequency Converter | 11,3 | 17,2 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 19 | 19 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| Losses to water (kW) | Motor | 192 | 280 | - | - | - |
| | Frequency Converter | 94,5 | 143,2 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 158 | 158 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 444,5 | 581,2 | - | - | - |
| Losses to ambient (kW) | Motor | 21,3 | 31,1 | - | - | - |
| | Frequency Converter | 7,8 | 11,5 | - | - | - |
| | Braking Resistor | - | - | - | - | - |
| | Transformer | 9,2 | 11,2 | - | - | - |
| | Excitation Transformer | - | - | - | - | - |
| | Harmonic Filter | - | - | - | - | - |
| | Total | 38,3 | 53,8 | - | - | - |

# 16 Further usable design
# 16.1 Calculation assistance

## Electrical formulas, general:

Electric field

$$\boldsymbol{E = \frac{dF}{dQ} = \frac{D}{\epsilon} = \frac{J}{\sigma}}$$

Where D is the flux density, J is the current density of the conductors, $\epsilon = \epsilon_r \epsilon_0$ is the agent factor for dielectric nature, $\sigma$ is the electrical conductivity of the current carrying conductor

Magnetic field

$$\boldsymbol{H = \frac{B}{\mu}}$$

Where $\mu$ is the permeability of the agent material.

Potential, spot source Q

$$\boldsymbol{V = \frac{Q}{4\pi\epsilon r}}$$

Where r is the distance to the source middle.

The capacitance between two close current conductors

$$\boldsymbol{C = \frac{Q}{V_1 - V_2} = \frac{Q}{U}}$$

Magnetic field, approximate near the straight conductor, where r is the distance.

$$\boldsymbol{H \approx \frac{I}{2\pi r}}$$

The inductance of the source/return conductor

$$\boldsymbol{L = (\mu_0 l/\pi) \ln \frac{a}{r_0} + \frac{\mu l}{4\pi}}$$

The inductance of the winding with N rounds

$$\boldsymbol{L \approx \mu_0 N^2 \left( \frac{\pi r^2}{l + 0,9r} - 0,9 \left( \frac{sr}{l} \right) \right)}$$

Where $s = r_{out} - r_{in}$ =winding side widht and r is the winding average radius.

## Electrical formulas – circuit theory

**Direct current DC**

Ohm's law $U = IR$

Power $P = UI = I^2R = \frac{U^2}{R}$

**Alternating current AC**

Ohm's law $I = \frac{U}{Z}, \quad Z = \sqrt{R^2 + X^2}\,, X = \omega L - \frac{1}{\omega C}$

Active power (1-phase) $P = I^2R = UI\cos\varphi$

Reactive power (1-phase) $Q = UI\sin\varphi$

Total power (1-phase) $S = UI = \sqrt{P^2 + Q^2}$

Active power (3-phase) $P = \sqrt{3}UI\cos\varphi = 3U_{ph.}I_{ph.}\cos\varphi$

Reactive power (3-phase) $Q = \sqrt{3}UI\sin\varphi$

Total power (3-phase) $S = \sqrt{3}UI = \sqrt{P^2 + Q^2}$

Serial resonance situation $X = \omega L - \frac{1}{\omega C} = 0\,, Z = R\,, I = \frac{U}{R}\,, \cos\varphi = 1$

Parallel resonance situation $\frac{1}{X} = \frac{1}{\omega L} - \omega C = 0\,, X = \infty \text{ and } I = 0 (\text{even } R = 0)$

| | Serial connection | Parallel connection |
|---|---|---|
| Resistances | $R = R_1 + R_2 + \cdots$ | $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \cdots$ |
| Inductances | $L = L_1 + L_2 + \cdots$ | $\frac{1}{L} = \frac{1}{L_1} + \frac{1}{L_2} + \cdots$ |
| Capacitances | $\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \cdots$ | $C = C_1 + C_2 + \cdots$ |
| Reactances | $X = X_1 + X_2 + \cdots$ | $\frac{1}{X} = \frac{1}{X_1} + \frac{1}{X_2} + \cdots$ |

## Electrical formulas – conversion equations

Star-delta transformation $$\boldsymbol{Z_{ij} = Z_i + Z_j + \frac{Z_i Z_j}{Z_k}}$$

Where $Z_{ij}$ is the impedance between delta's corners i and j and $Z_i$ is the impedance of i-branch.

Reverse transformation $$\boldsymbol{Z_i = Z_{ij} Z_{ki} / (Z_{ij} + Z_{jk} + Z_{ki})}$$

## Electrical theorems

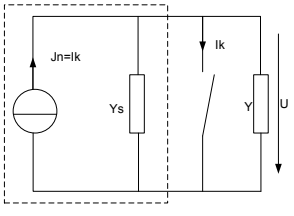
Kirchhoff's 1st law (Current law)
The algebraic sum of currents in a network of conductors meeting at a point is zero.

$$\boldsymbol{\Sigma I_i = 0}$$

Kirchhoff's 2nd law (Voltage law)
The directed sum of the electrical potential differences (voltage) around any closed circuit is zero.

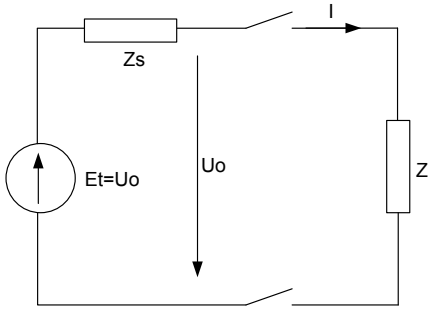
$$\boldsymbol{\Sigma U = 0 \, , U_i = I_i R_i}$$

Norton's theorem



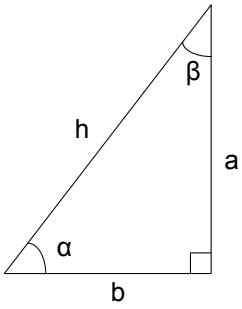

The network outside a single branch may be replaced by a single current source, when the voltage over the consumer is $U = \frac{I_k}{Y + Y_s'}$ and Ys is a network internal modulus of admittance (while Y $=0)=1/Z_{s'}$.

Thévenin's theorem




The network outside a single branch may be replaced by the single voltage source, when the branch current is $I = \frac{U_0}{Z + Z_s}$ , where $U_0$ is the open circuit voltage and $Z_s$ is the network impedance (while Z=0).

## Trigonometric




$$sin\alpha = \frac{a}{h}, \qquad cos\alpha = \frac{b}{h}, \qquad \tan\alpha = \frac{a}{b}$$

$$sin\theta = \cos\left(\frac{\pi}{2} - \theta\right), cos\theta = \sin\left(\frac{\pi}{2} - \theta\right), tan\theta = \frac{1}{cot\theta} = \frac{sin\theta}{cos\theta} = \cot\left(\frac{\pi}{2} - \theta\right)$$

## Shaft line angle / space for motor above propeller center level

| Shaft Angle | Shaft length 10 m | Shaft length 20 m | Shaft length 30 m | Shaft length 40 m | Shaft length 50 m | Shaft length 60 m |
|---|---|---|---|---|---|---|
| 1.5° | 0.26 m | 0.52 m | 0.78 m | 1.04 m | 1.30 m | 1.57 m |
| 2.0° | 0.34 m | 0.69 m | 1.04 m | 1.39 m | 1.74 m | 2.09 m |
| 2.5° | 0.43 m | 0.87 m | 1.30 m | 1.74 m | 2.18 m | 2.61 m |

## Hydro dynamic formulas

Effective power $P_e$: $$\boldsymbol{P_e = R_t * V_s}$$

Where $R_t$ is the bare hull resistance curve without a propulsor (without pods or without shaftlines and rudder) and $V_s$ is speed of the ship.

$$\boldsymbol{P_{e_podded} = k * R_t * V_s}$$

Where k is the difference between the hull form resistances of a shaftline vessel with rudders and an Azipod vessel. The design input value is 0.90 for a pod vessel and 1.00 for a shaftline vessel.

Propulsion efficiency $$\boldsymbol{\eta_D = \frac{P_e}{P_s}}$$

Where $P_s$ is the shaft power needed in selected system and $P_{s_podded} \neq P_{s_shaftline}$

Admiralty coefficient curve $$\boldsymbol{CA = \frac{Displacement^{\frac{2}{3}} * V_s^3}{P_s}}$$

Admiralty coefficient curve CA is normally presented as a function of Froude's number, which is

$$\boldsymbol{F_n = \frac{V_s}{\sqrt{g * L}}}$$

Where g is the gravity and L is the length of the ship.

Admiralty coefficient curve CA as a function of Froude's number creates a curve presenting the performance of the vessel.

Vessel thrust requirement T is $$\boldsymbol{T = \frac{R_T}{1-t}}$$

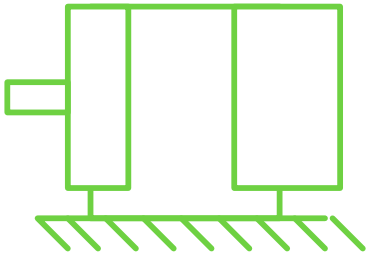
Where t is the thrust deduction, typically received from model tests and is an input for the propeller design.

# 16.2 Typical IM codes and installation instructions

The international mounting (IM) codes are defined in the IEC coding, IEC60034-7, for rotating electrical machines. This is the most widely known mounting coding and therefore it is our recommendation to follow this coding. If the content of the coding is unclear to any of the parties involved in the ship building deliveries, the danger of generating unnecessary costs at the final assembly phase is evident. Furthermore, we recommend that the number of the employed mountings is kept within the smaller, limited number of variations. This allows participants to know and understand the delivery, installation and maintenance aspects of the delivered equipment better. This is an important issue for the ship builder as well, who is in a better position to understand the installation and design consequences of all the mountings when variation is kept on a manageable level.

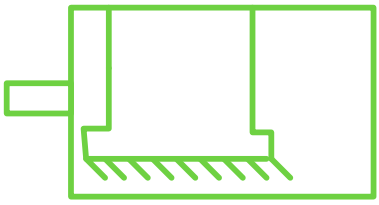
Typical mounting arrangements for our rotating machines are according to the options listed below:

**IM 1001:**



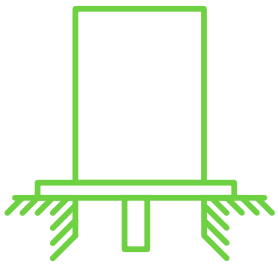
Shaft horizontal – Feet down
Normal feet – no gearbox
Two end-shield bearings

**IM 1011:**



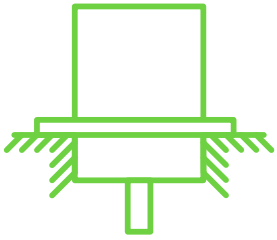
Shaft horizontal – Feet down
Raised feet – no gearbox
Two end-shield bearings

**IM 3011:**



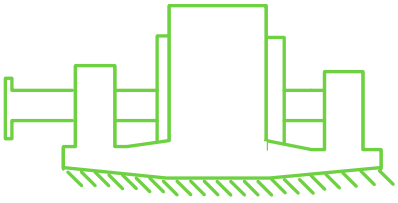
Shaft vertical – D-end down
Flange at D-end shield
Two end-shield bearings

**IM 4011:**



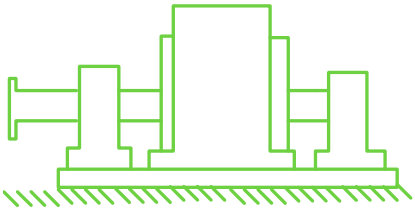
Shaft vertical – D-end down
Flange at D-end (separate from bearing flange)
Two end-shield bearings

**IM 7305:**



Shaft horizontal – feet down
Raised feet
One flanged shaft extension
Two integrated pedestal bearings

**IM 7315:**



Shaft horizontal – feet down
Raised feet
One flanged shaft extension
Two pedestal bearings on bed plate

The IM coding as presented above does not rule out the possibility of either a flexible or rigid installation. The selected bearing type has an important role in choosing between different types of installations. Our normal recommended combination of installations is the following:

**Propulsion motor installation – guidance**
We are often asked about the different types of bearing and installation combinations. The questions are typically about using sleeve bearings in several types of installations. We have listed some of our experiences of these cases below:

**Design 1**

- Fixed coupling to shaft
- Fixed installation to hull
- Sleeve bearings

This is the basic design when there are no special vibration, noise or alignment concerns and a sleeve bearing is requested. The shaft end has +/- 5...8 mm of free axial play depending on the bearing. There is no axial thrust carrying capability, which needs to be achieved at the main thrust bearing. The motor bearing may be either an end-shield-mounted bearing or a pedestal bearing.

**Design 2**

- Flexible coupling to shaft
- Sleeve bearings

This design is available only for medium/high speed solutions.

If there is a flexible coupling in the shaft (regardless of whether the motor is fixed or on resilient mounts) and sleeve bearings are requested, one of the sleeve bearings needs to be of the locating type. This means that it has to have an axial thrust surface to carry the weights of the machine and the coupling.

This solution is possible only if the motor speed is above 160 rpm at the minimum speed. In generators this is the standard solution as they run at a constant high speed.

**Design 3**
- Flexible coupling to shaft
- Flexible installation to hull
- Sleeve bearings

This design is available only for medium/high speed solutions.

If the motor is installed on flexible mounts, a flexible coupling is always required, too. If sleeve bearings are requested, one of them has to be of the locating type. This means that it has to have an axial thrust surface to carry the weights of the machine and the coupling.

This solution is possible only if the motor speed is above 160 rpm at the minimum speed. In generators this is the standard solution as they run at a constant high speed. With passenger vessels, this type of design is often implemented with roller bearings, on of which also carries some of the axial forces. The design with roller bearings enables a lower speed range. See also design four.

**Design 4**
- Flexible coupling to shaft
- (Possibly a flexible installation to hull)
- Sleeve bearings
- Roller bearing for the axial thrust

This design is possible for both low and high speeds.

When the shaftline needs to be equipped with a flexible coupling, a sleeve bearing is requested to be used as the main bearing, and slow speed rotation is required, a hybrid bearing design can be used. In this case a roller bearing carries some the axial load and the sleeve bearing acts as the main bearing. This combination allows operation at a low speed, provided that lubrication for the sleeve bearing is ensured.

**Design 5**
- Fixed coupling to shaft
- Vibration dampers between the stator and the frame

Separate pedestal sleeve bearings that stand on the base frame

This design is possible with large motors only. With large propulsion motors (shaft height >1250 mm) a pedestal sleeve bearing and a patented damping solution between the stator and the frame can be used. A fixed shaft installation is used, but the vibration level is decreased to the level required in comfort classes.

**Design 6**
- Flexible coupling to shaft
- Roller bearing

As is the case in passenger vessels, when the motor bearing is not designed to carry the main thrust, a flexible coupling between the motor and the shaft is required (the bearing has no axial play). Because of the flexible coupling, the motor can be installed on flexible mounts.

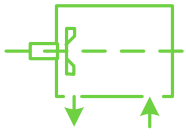
# 16.3 Typical IC codes

The international cooling (IC) codes are defined in the IEC coding, IEC60034-6, for rotating electrical machines. This is the most widely known cooling coding and therefore it is our recommendation to follow this coding. If the content of the coding is unclear to any of the parties involved in the ship building deliveries, the danger of generating unnecessary costs at the final assembly phase is evident.

Furthermore, we recommend that the number of the utilized cooling types is kept within the smaller, limited number of variations. This allows participants to know and understand the delivery, installation and maintenance aspects of the delivered equipment better. This is an important issue for the ship builder as well, who is in a better position to understand the installation and design consequences of all the installations when variation is kept on a manageable level.

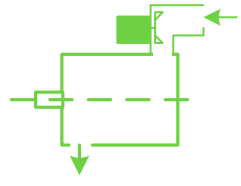
Typical cooling arrangements for our rotating machines are according to the options listed below:

**IC 01 or IC0A1**



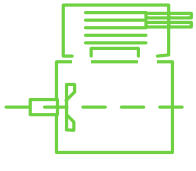
An air cooling type which is suitable for DOL-motors or motors running with a speed which is enough to cool the motor down by means of a shaft rotating impeller. The IP class is typically IP23 or lower to guarantee the needed air flow.

**IC 06 or IC0A6**



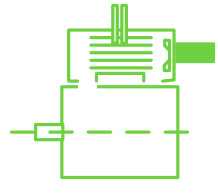
A forced air cooling type which is suitable for the frequency converter driven motors which utilize zero speed operation or a slow speed range that cannot be cooled down by means of a shaft impeller only. The IP class is typically IP23 or lower.

**IC 81W or IC8A1W7**



A closed air-to-water cooling type which is suitable when heat losses are needed to be transferred from the motor (typically 80-90% of losses to water) or the motor needs a higher IP class. This solution is also for motors with constant rotation while in operation.

**IC 86W or IC8A6W7**



A closed forced air-to-water cooling type which is suitable when heat losses are needed to be transferred from the motor (typically 80–90% of losses to water) or the motor needs a higher IP class. This solution is suitable for the frequency converter driven motors which utilize zero speed operation or a slow speed range that cannot be cooled down by means of a shaft impeller only.

Other cooling options are available on request.

ABB standard solution is to make generators (which run at a constant medium speed) with an axially connected impeller and the heat distributed into the LT water cooler (air-to-water cooler). In emergency conditions generators can be driven hatches open at the nominal power even if there is no auxiliary power or LT- water circulation.

ABB standard solution for propulsion motors (directly connected slow speed) is to equip them with a forced cooling LT air-to-water heat exchanger. This is to avoid heat spots in the low speed range, which is possible with the frequency converter driven solutions. Other cooling concepts are also possible with Z and L drives, as well as CPP shaft lines, which have a high minimum speed definition specified.

# 16.4 Typical IP codes for ABB equipment

The international protection (IP) codes for electrical equipment are defined in the IEC coding, IEC60092-101. This is the most widely known protection coding and therefore it is our recommendation to follow this coding. If the content of the coding is unclear to any of the parties involved in the ship building deliveries, the danger of generating unnecessary costs at the final assembly phase is evident.

The IP code consists of the following characteristics:

**First number**

| | |
|---|---|
| 0 | No protection |
| 1 | Protected from 50 mm solid objects |
| 2 | Protected from 12 mm solid objects |
| 3 | Protected from 2.5 mm solid objects |
| 4 | Protected from 1 mm solid objects |
| 5 | Dust protected, mainly protecting ingress of dust |
| 6 | Dust tight, no ingress of dust |

**Second number**

| | |
|---|---|
| 0 | No protection |
| 1 | Protected against dripping water |
| 2 | Protected against dripping water when tilted up to 15° |
| 3 | Protected against spraying water |
| 4 | Protected against splashing water |
| 5 | Protected against water jets |
| 6 | Protected against heavy seas |
| 7 | Protected against the effects of immersion |
| 8 | Protected against submersion |

ABB standard protection classes for electrical equipment are the following:

**Low voltage equipment:**

| | |
|---|---|
| • Main generators | IP23 or IP44 (IC8A1W7) |
| • Main switchboard | IP22, IP41, IP43 and IP53 |
| • Thruster motors | IP23 / IP44 |
| • Transformers | IP23 (IP00->) |
| • Frequency converters, small aux | IP20, IP21, IP55 |
| • Frequency converters, propulsion | IP21, IP22, IP42, IP54, IP54R |
| • Control equipment | IP23 or IP44 |
| • Propulsion motors | IP23 (air cooled), IP 44 (air-to-water) |

**Medium voltage equipment:**

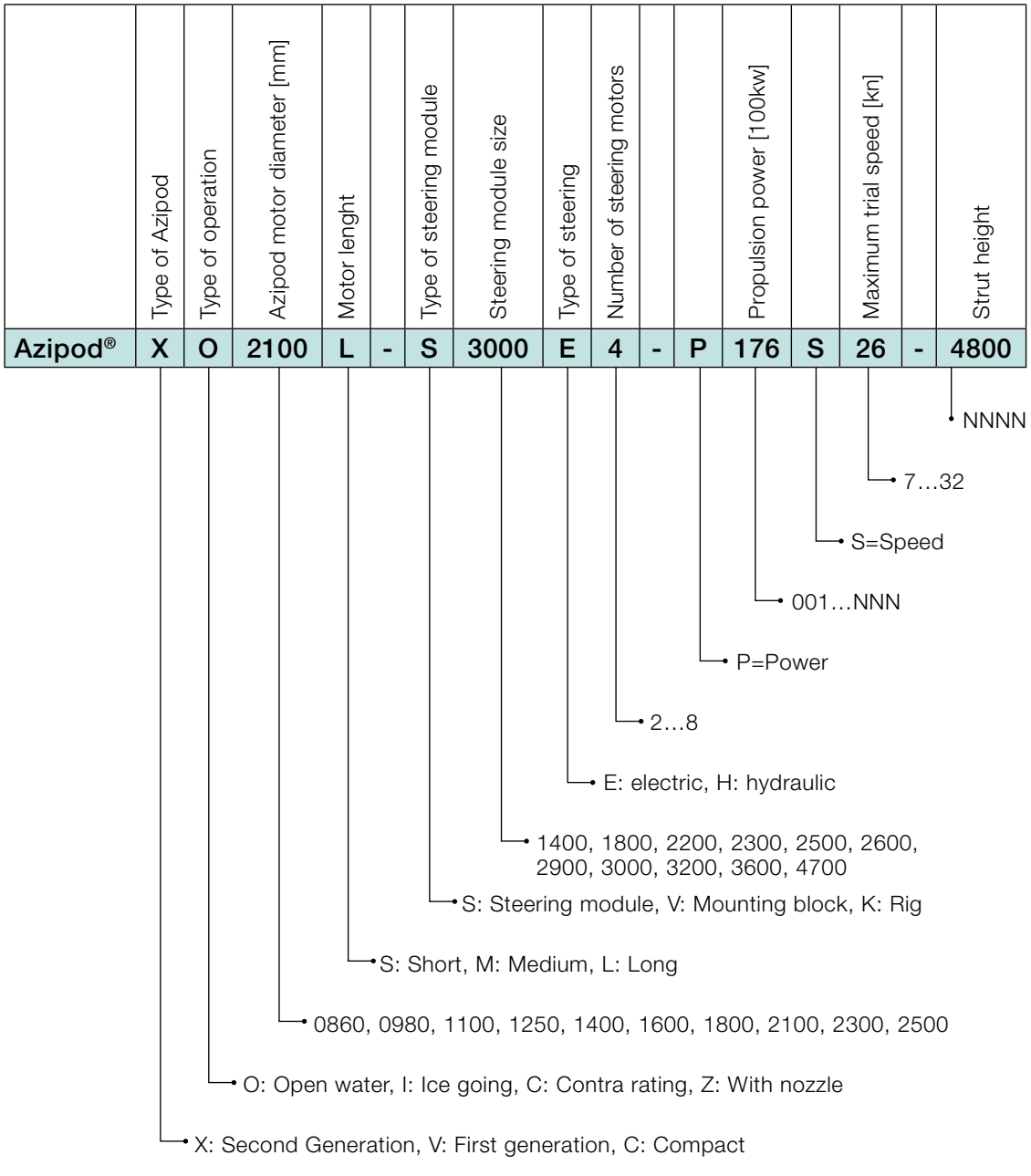
| | |
|---|---|
| • Main generators | IP44 (IP56 below shaft) |
| • Main switchboard | IP42 |
| • Thruster motors | IP23 / IP44 |
| • Transformers | IP23 (IP00->) |
| • Frequency converters, propulsion | IP32 |
| • Control equipment | IP23 or IP44 |
| • Propulsion motors | IP44 (IP56 below shaft) |

# 16.5 Protection functions reference table

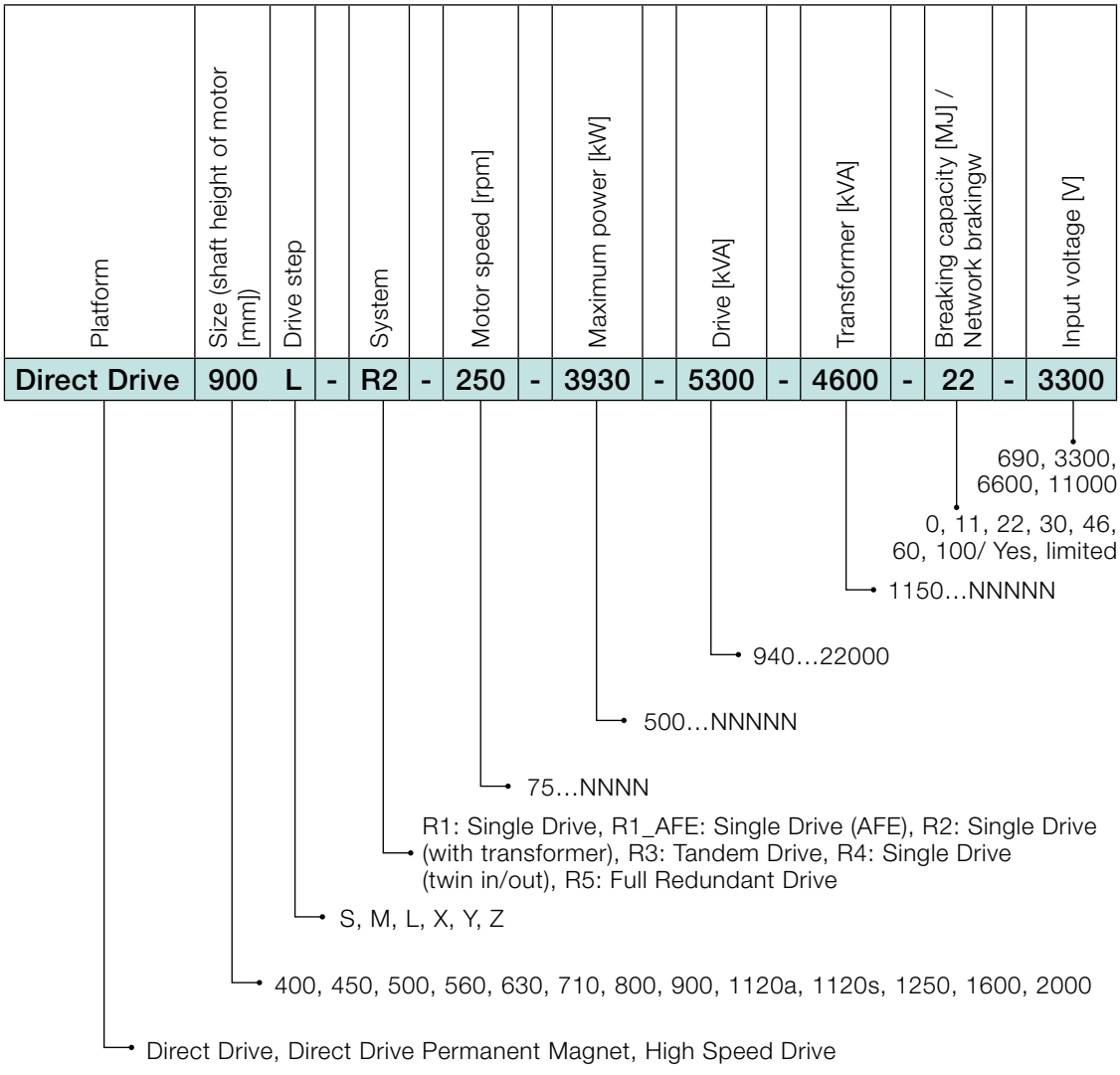
| Protection function descriptions | IEC symbol | IEEE symbol |
|---|---|---|
| Auto-reclosure | 0 → 1 | 79 |
| Phase discontinuity | ΔI> | 46 |
| Current unbalance protection for shunt capacitor banks | ΔI> | 51NC |
| Three-phase current unbalance protection for H-bridge connected shunt capacitor banks | 3ΔI> | 51NC |
| Directional earth-fault, low-set stage (or SEF=sensitive earth-fault protection) | $I_0$>→ /SEF | 67N/51N |
| Directional earth-fault, high-set stage | $I_0$>>→ | 67N |
| Directional earth-fault, instantaneous stage | $I_0$>>>→ | 67N |
| High-impedance or flux-balance based differential protection for generators and motors | 3DI> | 87G/87M |
| Stabilized three-phase differential protection for generators | 3DI> | 87G |
| Stabilized three-phase differential protection for transformers | 3DI> | 87T |
| Three-phase directional overcurrent, low-set stage | 3I>→ | 67 |
| Three-phase directional overcurrent, high-set stage | 3I>>→ | 67 |
| Three-phase directional overcurrent, instantaneous stage | 3I>>>→ | 67 |
| Underfrequency or overfrequency, stage 1 (incl. rate of change) | f</f>, df/dt | 81U/81O |
| Underfrequency or overfrequency, stage 2 (incl. rate of change) | f</f>, df/dt | 81U/81O |
| Underfrequency or overfrequency, stage 3 (incl. rate of change) | f</f>, df/dt | 81U/81O |
| Underfrequency or overfrequency, stage 4 (incl. rate of change) | f</f>, df/dt | 81U/81O |
| Underfrequency or overfrequency, stage 5 (incl. rate of change) | f</f>, df/dt | 81U/81O |
| Fuse failure supervision | FUSEF | 60 |
| Three-phase transformer inrush and motor start-up current detector | 3$I_{2f}$> | 68 |
| Three-phase start-up supervision for motors (incl. I2t and speed device modes, and start-up counter) | $I_s^2$t, n< | 48, 14, 66 |
| Non-directional earth-fault, low-set stage (or SEF=sensitive earth-fault protection) | $I_0$>/SEF | 51N |
| Non-directional earth-fault, high-set stage | $I_0$>> | 50N/51N |
| Non-directional earth-fault, instantaneous stage | $I_0$>>> | 50N |
| Three-phase non-directional overcurrent, low-set stage | 3I> | 51 |
| Three-phase non-directional overcurrent, high-set stage | 3I>> | 50/51/51B |

| Protection function descriptions | IEC symbol | IEEE symbol |
|---|---|---|
| Three-phase non-directional overcurrent, instantaneous stage | 3I>>> | 50/51B |
| Three-phase overload protection for shunt capacitor banks | 3I> 3I< | 51C, 37C, 68C |
| Negative-phase sequence, low-set stage | $I_2$> | 46 |
| Negative-phase sequence, high-set stage | $I_2$>> | 46 |
| Three-phase non-directional undercurrent, stage 1 | 3I< | 37 |
| Three-phase non-directional undercurrent, stage 2 | 3I< | 37 |
| Overexcitation, low-set stage | U/f> | 24 |
| Overexcitation, high-set stage | U/f>> | 24 |
| Three-phase directional overpower, stage 1 | P>→/Q>→ | 32P/32Q |
| Three-phase directional overpower, stage 2 | P>→/Q>→ | 32P/32Q |
| Three-phase directional overpower, stage 3 | P>→/Q>→ | 32P/32Q |
| Three-phase overvoltage, low-set stage | 3U> | 59 |
| Three-phase overvoltage, high-set stage | 3U>> | 59 |
| Phase reversal protection | 3I↶, 3I↷ | 46R |
| Phase-sequence voltage protection, stage 1 | $U_1$< $U_2$> $U_1$> | 27, 47, 59 |
| Phase-sequence voltage protection, stage 2 | $U_1$< $U_2$> $U_1$> | 27, 47, 59 |
| High-impedance based restricted earth-fault | $\Delta I_0$>, REF | 87N |
| Residual overvoltage, low-set stage | $U_0$> | 59N |
| Residual overvoltage, high-set stage | $U_0$>> | 59N |
| Residual overvoltage, instantaneous stage | $U_0$>>> | 59N |
| Synchro-check/ voltage check, stage 1 | SYNC | 25 |
| Synchro-check/ voltage check, stage 2 | SYNC | 25 |
| Three-phase thermal protection for cables | 3 ⌐ | 49F |
| Three-phase thermal protection for devices (motors, generators and transformers) | 3 ⌐ | 49M/49G/49T |
| Three-phase underexcitation protection, low-set stage | X< | 40 |
| Three-phase underexcitation protection, high-set stage | X<< | 40 |
| Three-phase underimpedance protection, low-set stage | Z< | 21G |
| Three-phase underimpedance protection, high-set stage | Z<< | 21G |
| Three-phase underpower or reverse power, stage 1 | P</P>← | 32 |
| Three-phase underpower or reverse power, stage 2 | P</P>← | 32 |
| Three-phase underpower or reverse power, stage 3 | P</P>← | 32 |
| Three-phase undervoltage, low-set stage | 3U< | 27 |
| Three-phase undervoltage, high-set stage | 3U<< | 27 |
| Voltage-dependent overcurrent, low-set stage | I(U)> | 51V |
| Voltage-dependent overcurrent, high-set stage | I(U)>> | 51V |

# 16.6 Azipod type code



# 16.7 Direct Drive type code



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