5.3 Variable frequency drive for cooling systems

Using a Variable Frequency Drive to match the power demand to the operational conditions is the most effective method to optimize the on board systems.

Energy efficiency as part of the design criteria
Until recently, energy efficiency in auxiliary systems was not considered during the design process or construction of marine vessels. For this reason, the systems on existing ships are not energy efficient and have not been fully optimized to minimize overall fuel consumption. Many of the ships currently in production continue to be built with little emphasis on energy efficient solutions.

Additionally, shipyards typically do not focus on the long term cost of a vessel's ownership. Unless the owners define the technologies to be included in the specifications, the ship's energy efficiencies capabilities will be limited. To date, most marine installations adjust for changes in environmental conditions by inefficient methods, such as by using 'throttling' and 'by-pass loops'.

The on board ship systems best suited to improving energy efficiency are systems with large pumps and fans, which are not required to run continuously or at full capacity. Where applicable, electric motors could be fitted with VFD to operate pumps and fans more efficiently at partial loads, for example during slower sailing speeds or with reduced ventilation requirements.

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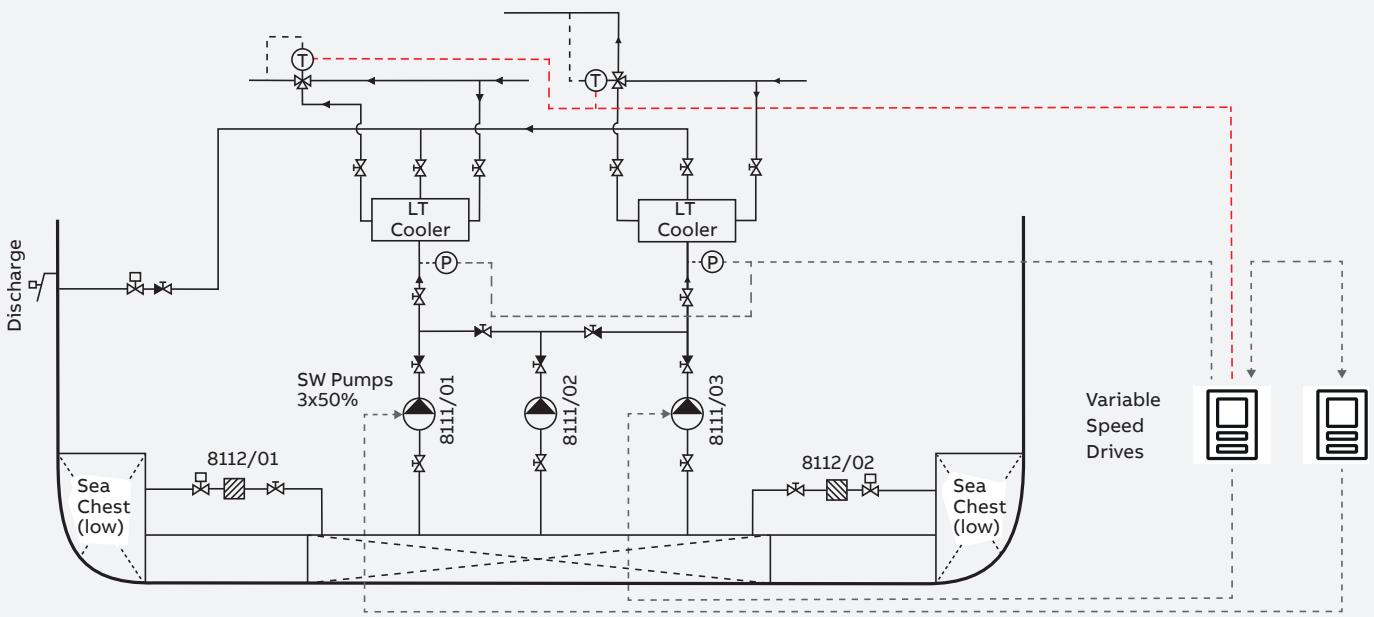
A typical seawater cooling system.



The electric power consumption of a pump is related to the pump volumetric flow according to affinity laws. The reduction of pump speed will affect the system pressure, Head, to the power of two and the electric power consumption to the power of three.

Pumps and fans are vital parts of the processes on board a vessel

Pumps and fans on board vessels often perform vital functions. If these are not working, the vessel is not sailing. On board vessels there are many different kinds of pump applications. Seawater cooling pumps, boiler feed pumps, HVAC pumps, bilge water pumps, lubrications pumps, fire pumps, waste water pumps and many other kinds. It is common for pump applications to be over-dimensioned. This is simply because the design criterion is set to cope with the extreme conditions in which the vessel may operate. For example, the seawater temperature is generally dimensioned for above normal operating conditions.

Although it is necessary for a ship to be able to operate in extreme cases and environments, everyday operations rarely come close to such conditions. While the maximum allowed engine load is typically 75…90% of maximum, heat is always recovered from the system. Seawater temperature very seldom reaches the design value.

A lot of energy can easily be saved by controlling pumps and fans with a VFD, either standalone or with a pressure or temperature sensor loop control. Using a VFD to match the power demand to the operational conditions is the most effective method to optimize the on board systems.

Displacement pumps and centrifugal pumps are the two most common types of pump used on ships, but around 80% of all pumps on board ships are centrifugal pumps. This kind of pump has the same duty characteristics as a fan. Fans are used for ventilation in the engine room, on the car deck, in cargo spaces and in other places where forced ventilation is needed. When operating a centrifugal pump or a fan you can achieve a fairly large reduction in energy consumption by making just a small reduction in rpm of the pump.

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Cavitations are another important issue when considering pumps and their dimensioning. If the pump is too large, the suction capability will be weak, making the risk of cavitations very high.

Cavitations appear as a result of evaporation of the fluid which occurs when the static pressure drops below the actual steam pressure inside the pump. Cavitations inside a pump can cause severe damage to the materials and, particularly, the impeller is often badly damaged. In some cases, damage to the impeller can cause the pump to fail within a couple of months. When using a VFD to decrease the pump speed you will also reduce the chance of cavitations, and the risk of damage to the pump.

By far the most commonly used flow control in pump applications is throttle control and by-pass loops to control the temperature. As a consequence pumps are running at 100% load continuously, even though the requirement would actually be about 40% on average. Using these antiquated control methods is as ineffective as controlling a car's speed with the brakes while the engine is going at full throttle. In other words, not only does it waste energy but also accelerates equipment wear.

Reducing emissions doesn't mean reengineering your existing vessel

Retrofitting existing vessels with VFD is a task which demands knowledge of the process to be modified as well as good system knowledge of VFD, motors and pumps/fans. Sometimes it is necessary to replace the existing motor with a new motor designed for VFD use. This depends very much on the voltage level and power demand of the pump. Generally, ABB random wound motors with a voltage rating less than 500 V are good for VFD use as such, whilst other motor types should be checked case by case for suitabil-

ity. ABB can provide expert insight on the cost / benefit trade-off of replacing motors. Market expansion of energy efficient motors has in effect reduced the price of these special motors.

The control method of the VFD depends on the existing automation system. In some cases it may be beneficial to install an independent control system for the modified processes.
The ABB Marine Service can retrofit complete energy efficient design packages tailored to the customer's requirements. These packages may include ABB's products, project services and all site activities.
In vessels built between 1988 and 2008 and which are still sailing, approximately 2% of the main sea water cooling systems have VFD control. By modifying these systems, which is quite simple, substantial reductions in emissions and costs can be achieved. Small changes to the system can make a big impact on emission reduction.

Marine type approved drive
ABB's variable frequency drive is type tested and approved for marine drive applications. The type approval test is required for essential applications on board. Essential applications are those which are related to navigation, propulsion, safety of the ship and passenger, cargo and crew. Examples of essential applications are ballast pumps, bilge pumps, circulating and cooling water pumps.

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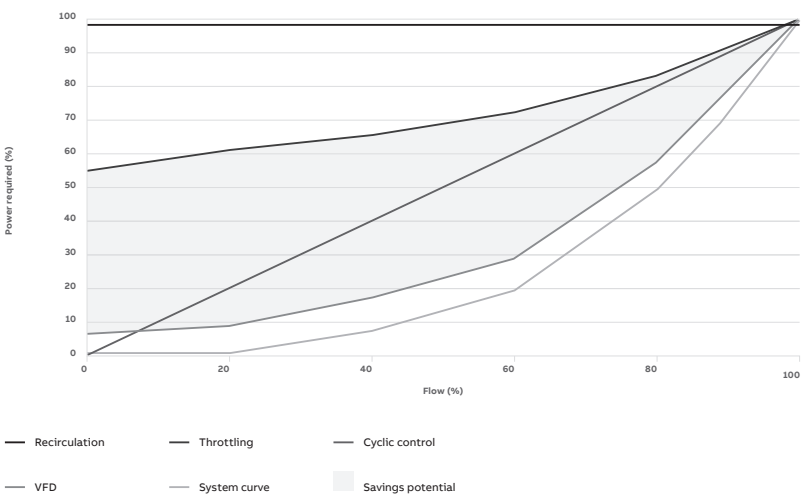
The power consumption for different flow control methods. The grey area represents the energy savings generated by using a VFD instead of manual throttling.



ABB's variable frequency drive is type tested and approved by:
- DNV (Det Norske Veritas)
- LR (Lloyd's Register of Shipping)
- ABS (American Bureau of Shipping)
- RINA (Registro Italiano Navale)
- BV (Bureau Veritas)
- GL (Germanischer Lloyd)

Intelligent pump control to further enhance the energy savings
To further enhance the energy saving potential in pump and fan applications, ABB have introduced an Intelligent Pump Control solution (IPC). IPC is an optional software package for ABB low voltage variable frequency drives. Incorporating all of the most common functions required by pump or fan users, it eliminates the need for an external PLC and other additional components. A pump system with fewer electrical components will be more reliable, especially in the harsh environment typical of marine applications. IPC can help save energy, reduce downtime and prevent pump jamming and pipeline blocking.

Control logic of level control mode
The key issue is to run pumps with efficiency speed as far as possible. If the temperature demand in the cooling circuit varies so that more cooling water is needed, more pumps are switched on and they run at efficiency speed. In a situation where all pumps are running at efficiency speed and the cooling demand still increases, all pumps start to run at high speed.

With this method, according to the theory presented earlier, it is possible to achieve almost 20…30% more energy savings and keep the cooling control flexible for highly varying cooling requirements.

Other benefits with intelligent pump control
Dimensioning a cooling system with parallel pumps provides redundancy in the system. With the cooling demand control of the IPC solution, there is 100% redundancy in the system. If one of the pumps, motors, or drives switches off, the system will continue to operate uninterrupted. Even if the master parallel drive fails, it takes only 500 ms to activate the backup drive. This is made

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There is huge potential for retrofitting existing ships with new fuel-reducing technologies. For example, only around 2% of the global fleet is currently equipped with variable frequency drives for their seawater cooling pumps, which means that 98% of the fleet is missing an opportunity to reap high fuel savings and environmental rewards.

possible by a fast fiber optic connection between the drives. 100% redundancy in the system ensures continuous and risk-free operation of the pump system even in fault situations.

The anti-jam function enables the drive to perform preventive maintenance on the pump. When the function is triggered, the pump is run at high speed and then either reversed or stopped in a sequence of user-defined cleaning cycles. This helps to prevent congestion through the build-up of particles inside the pump. The trigger parameters (high current, run-on-time, external input and every start) are set by the user.

When operating with liquids containing particles there is always a risk that pipelines will get blocked – especially when running with smooth control and/or slow speeds. With Level Control fast mode fast ramp in starting creates a flush effect which keeps the pipelines clear. When the pumps are running, they are always operating at close to the nominal point where the risk of pipeline problems is reduced due to higher flow.

Pump priority control balances the operating time across all of the pumps in the system over a long time period. This facilitates maintenance planning and can boost energy efficiency by operating pumps at close to their best efficiency point. In a system where the consumption rate is higher during the sea voyage, for example, the drive can be programmed to operate higher capacity pumps during the sea voyage and smaller units at harbor time.

On board pump and fan applications suitable for VFD

- Seawater pumps
- High and low temperature cooling water pumps
- Boiler feed pumps
- Bilge water pumps
- Waste water pumps
- Engine room ventilation fans
- Cargo area fans
- Air handling units, such as air conditioning systems on board cruise ships and passenger vessels
- Hotel auxiliary system pumps and fans (mainly in passenger vessels)

Major benefits from installing a VFD

- Soft starting – no high starting currents causing disturbance on the network
- No process disturbance due to voltage drops; no trips of other electrical devices connected to same bus
- No excessive thermo-mechanical stress on the motor; longer lifetime of the motor
- Immediate start-up without warming-up delays (e.g. steam turbines)
- Controlled and smooth start-up
- Accurate process control – flow based on production need
- Mechanical wear of piping is minimized
- Risk of cavitations in the pump is minimized
- Passenger comfort (in air conditioning application)
- Reliability/technical improvement
- Environmental compliancy
- Lower energy bills

Savings and payback time

ABB's VFD solution reduces a ship's energy and fuel consumption, bringing savings in operational costs. Based on affinity laws, a linear reduction of pump or fan speed leads to a cubic reduction of electric power. Consequently, a 10% reduction of pump speed can save 27% of the energy cost related to the pump.

ABB's VFD solution typically has a 6-18 months payback time.