UNIVERSAL CONNECTIONS

Plugging in cruise liners and container vessels

At berth, a large ship can consume up to 20 MVA – usually supplied by its diesel engines. However, dockside air quality and noise are coming under regulatory scrutiny. Pre-engineered solutions based on ABB's ACS6000 medium-voltage converter family deliver compliant and reliable shore-to-ship power with the highest power quality at an optimized cost per MVA →1–2.

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Often, when in port, ocean-going vessels generate electrical power using their diesel engines. However, marine engines are not known for their environmental friendliness and dockside emissions and noise are increasingly subject to regulatory scrutiny – especially as ports are often located in sensitive marine environments or large, densely populated cities. Indeed, of the top 10 environmental priorities that the European Sea Ports Organization (ESPO) has identified for major ports to take into account, the first three places feature the management of air quality, energy efficiency and noise [1].

Shore-to-ship power

To reduce emissions when a ship is at berth, port authorities often provide a shore-to-ship power link. However, ultralarge – such as super-post-Panamax class – container vessels can consume as much as 7.5 MVA and large cruise ships 20 MVA. If several large container vessels are connected at the same time, the quayside energy provision can be considerable.

Supplying such power levels places high demands on port electrical infrastructure both in terms of capital outlay, equipment complexity, running costs and maintenance. Moreover, vessels can have a 50 Hz or 60 Hz onboard grid (the majority use 60 Hz), so the SFC must not only handle high power levels but also adapt the local grid frequency to that of each vessel.

ABB launched a project to integrate the ABB ACS6000 SFC medium-voltage drive platform into a range of pre-engineered, high-end static frequency conversion solutions.

ABB ACS6000 SFC

To address this high-power-consumption vessel segment and with the aim of delivering state-of-the-art, shore-to-ship power for customers, ABB launched a project to integrate the ABB ACS6000 modular medium-voltage drive product platform into a range of pre-engineered, high-end static frequency conversion solutions: the ACS6000 SFC.

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01 At berth, ships can consume large amounts of power. Often, this power is supplied by the vessel's diesel engines, which can have an adverse impact on the local environment.

These solutions ensure a reliable power supply of the highest power quality to vessels – in full compliance with global standards – at an optimized cost per MVA.

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To reduce emissions when a ship is at berth, port authorities often provide a shore-to-ship power link.

The ACS6000 SFC integrated shore-to-ship power solution can provide the following core functions:

- Static conversion of the 50/60 Hz three-phase port grid power to match the 60/50 Hz vessel network.
- Full active and reactive power control of the vessel grid.
- Load flow balance with parallel-connected frequency converter systems supplying the load-side distribution infrastructure.
- Defined short-circuit current to allow downstream protection devices to operate.
- Low harmonic performance grid side and vessel side

The enhanced ACS6000 SFC platform chosen for this application has 12 variants covering the entire range of power requirements: From that of a single container vessel through multiple container vessels right up to the biggest cruise vessels currently in service.

Important design considerations were to minimize the impact of grid-side harmonics and maximize the vessel-side power quality. To reduce harmonic content on the three-phase grid, either a twelve- or 24-pulse diode rectifier – line supply unit (LSU) – or a double/triple active rectifier unit (ARU) was used.

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Dockside emissions and noise are increasingly subject to regulatory scrutiny.

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On the vessel side, each inverter unit (INU) is connected to a separate winding of the output transformer, with the load-side windings in series connection to form the desired load-side grid. This series connection, combined with phase shifting of the individual windings in conjunction with

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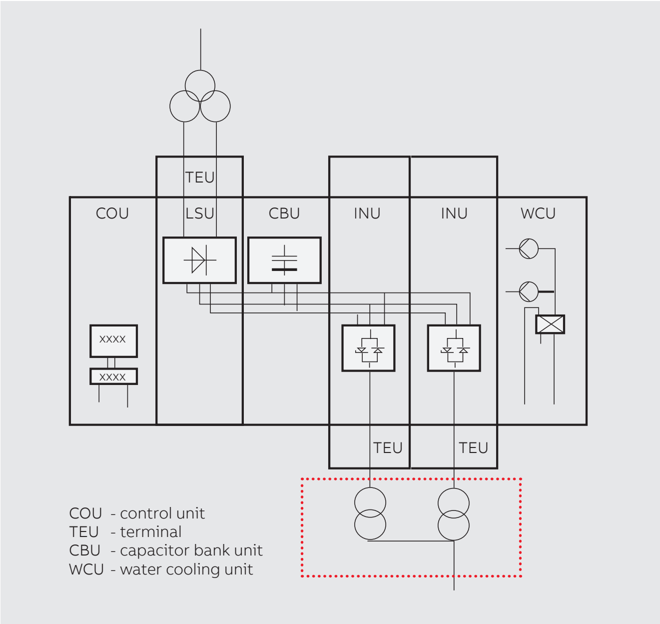
The solutions ensure a reliable power supply of the highest power quality to vessels – in full compliance with global standards – at an optimized cost per MVA.

a special design filter, allows characteristic converter harmonics to be greatly reduced. Standard ACS6000 SFC configurations are shown in →3. When selecting the SFC, high importance was given to its efficiency in order to minimize end-user OPEX. The selection of the converter cooling method is of significance here: with a water-cooled SFC, a conversion efficiency higher than 98 percent can be achieved. Moreover, when compared to a rotating frequency converter, efficiency at partial load is close to the maximum, at over 97 percent, even down to a 30 percent loading factor.

ACS6000 SFC integration into the port grid takes into account the most stringent requirements of the global standard IEC/ISO/IEEE 80005-1 “High Voltage Shore Connection” and the class rules for the vessel defined by the certification companies. As an example, the optimized pulse pattern used to generate the sinusoidal waveform for the vessel is chosen such that the low-end harmonics – up to the 50th – are either eliminated or controlled to an acceptable level. A custom RC or RLC filter is then added to attenuate the remaining higher-order harmonics (up to the 100th) to achieve total voltage harmonic distortion levels of below 4 percent. The choice of frequency conversion platform is only the first step in delivering a reliable solution to shore-to-ship power system to end-users.



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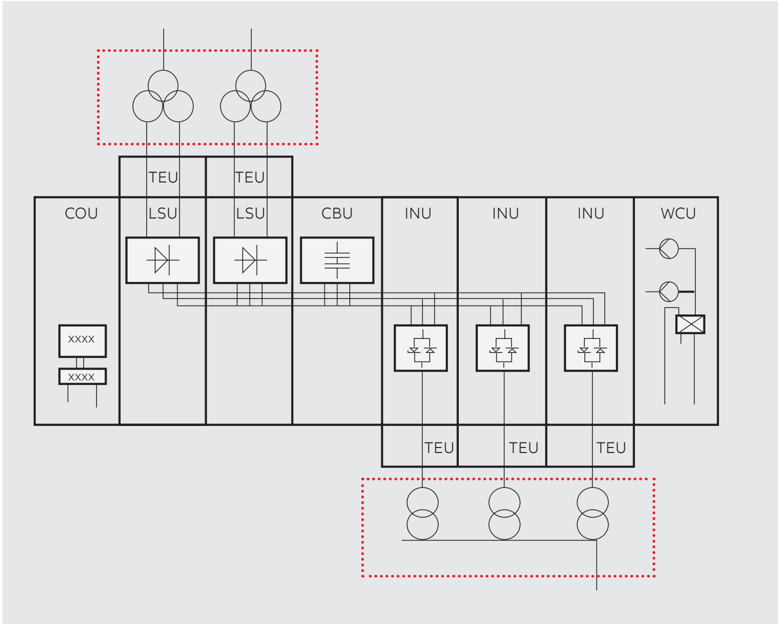

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02 ABB's ACS6000.

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03 Standard ACS6000 SFC configurations.

03a ACS6000 SFC Double (up to 14 MVA).

03b ACS6000 SFC Triple (up to 24 MVA).

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04 Converter system and delivery scope overview.

Several additional ship-specific aspects must be taken into consideration:

- System voltage for the ship supply: 6.6 kV, or 11 kV via a step-up transformer. The transformer requires an off-load tap changer to switch between these two voltage levels.
- Synchronization and load sharing with the on-board diesel generator, particularly during the transition immediately after vessel connection to the shore-to-ship power facility.
- Any reverse power flow from the vessel to shore should be managed through a dedicated braking resistor to avoid power feedback into the port grid as this is not acceptable in some national grid codes.
- Real-time power factor control (active and reactive power management) should be achieved, taking into account the different vessel grids.
- Downstream selectivity when selecting the short-circuit current capability of the converter as well as overloading arising from onboard switching loads.

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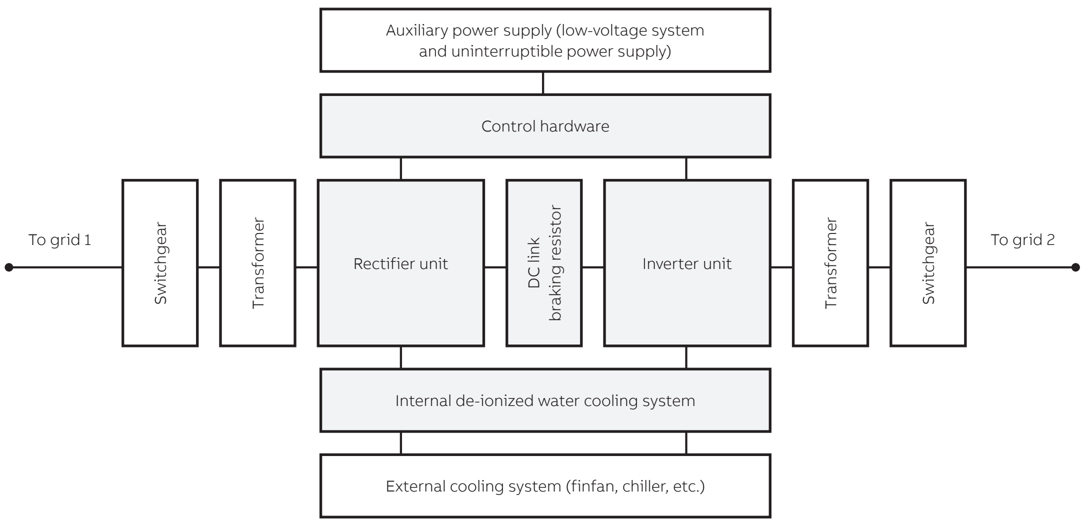
The enhanced ACS6000 SFC platform chosen for this application has 12 variants covering the entire range of power requirements.

- Full electrical control and protection of the vessel and converter should be provided through the arrangement of load-side and ship-side switchgear.



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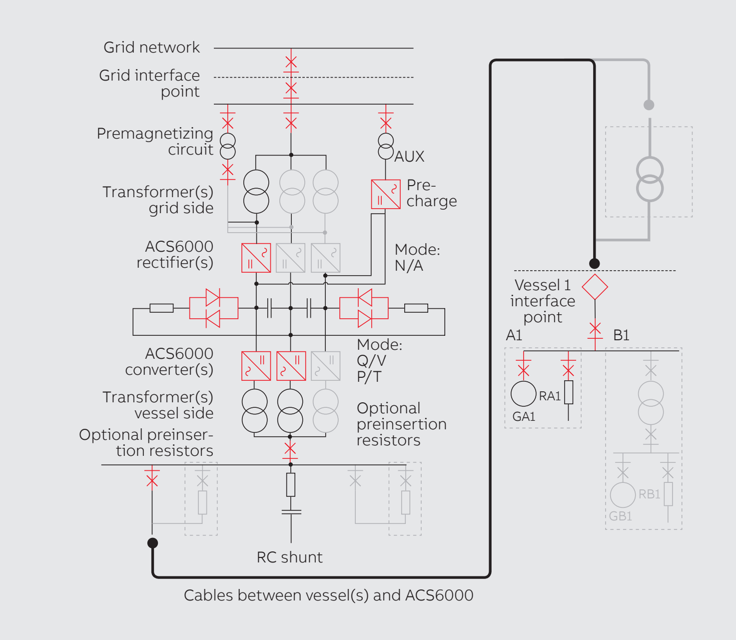

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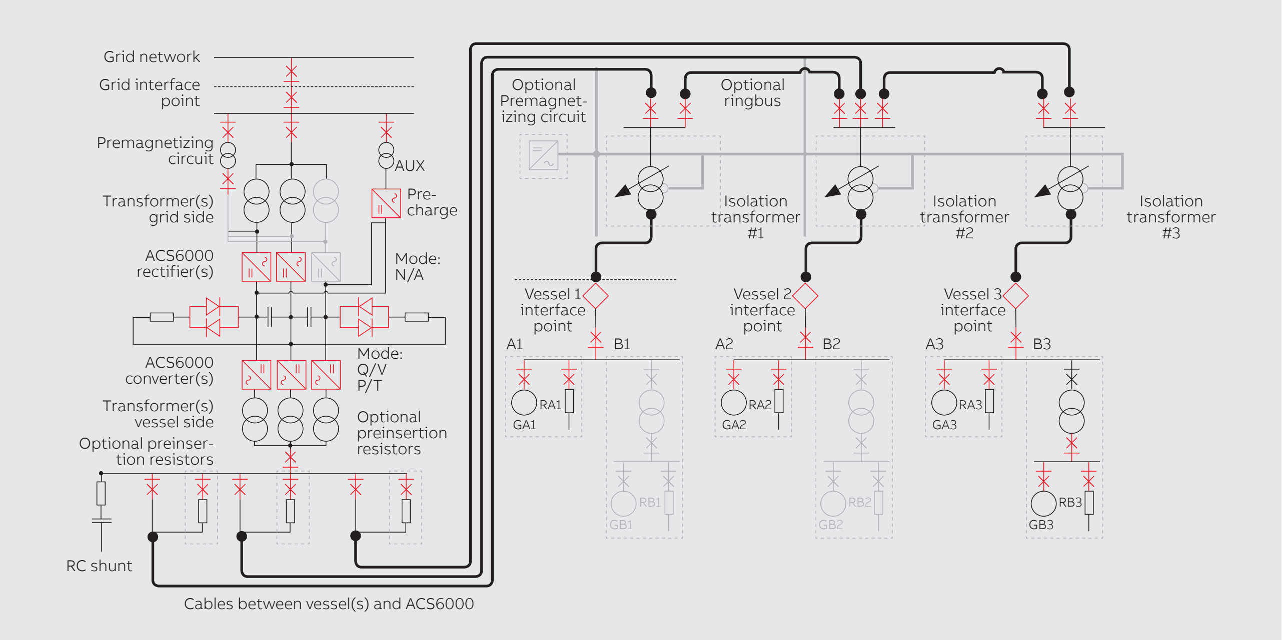

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Given the above, particular attention is paid to the selection of the converter dimensioning, transformer (input and output) specification, cooling system, and protection and control devices →4.

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Important design considerations were to minimize the impact of grid-side harmonics and maximize the vessel-side power quality.

The integration of the ACS6000 SFC into a pre-engineered solution allows a smooth execution for any project configuration.

As an example, a single-berth/single-vessel solution is characterized by the selection of an ACS6000 SFC that not only complies with the vessel's nominal power requirement but that also accommodates the overload arising from the startup of large direct-on-line motors and the energization of onboard transformers, as well the selectivity necessary to isolate faults on the vessel's electrical network →5a. Specific attention is given to the premagnetization of the grid-side transformer in order to minimize potential voltage drops in the port grid.

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05 Pre-engineered solutions allow smooth execution.

05a Single-berth configuration.

05b Multi-berth configuration.

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06 Smart ports need a lean and efficient grid integration that successfully balances supply and demand.

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Reference
[1] "ESPO / EcoPorts Port Environmental Review 2016 – Insight on port environmental performance and its evolution over time," April 2016. Available: http://www.espo.be/media/news/ESPO_EcoPorts%20Port%20Environmental%20Review%202016.pdf

A multi-berth installation can have a lower overall OPEX since a single frequency conversion substation can be used to supply several vessels at the same time →5b. An additional assessment of the specific load presented by a single vessel should be performed to make sure that the substation capabilities match the overall load, taking into account the premagnetization needs of the onshore transformer that ensures the galvanic isolation between the vessels.

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When selecting the SFC, high importance was given to its efficiency in order to minimize end-user OPEX.

Port electrification – a holistic view
Due to the complexity of the solution and related constraints, a shore-to-ship power installation in a port grid requires an engineering perspective that extends beyond the shore-to-ship system itself to cover the port electrification as a whole. The port grid should be seen as a dynamic environment into which new electricity consumers or producers can enter at any time. For this reason, a strong port grid is a critical ingredient: To maintain a successful balance between demand and supply, the port grid must be robust all the way from the incoming high-voltage (HV) substation down to the low-voltage user →6. An HV substation upgrade or port grid repowering can accommodate the introduction into the port area of e-mobility consumers both on the blue side (electric or hybrid ferries) and on the land side (electric vehicles) and facilitate the integration of renewable power sources such as wind farms or photovoltaic plants.

In a nutshell, shore-to-ship power and port electrification promote ports in their role as vital regional economic engines – in a traditional way, as transit hubs for people and goods, and in a modern way, as sustainable business entities wholly integrated with the surrounding community. Clean energy provision and elimination of diesel emissions and noise will improve the working, transit and living environment in and around ports. Electrification is the only cost-effective way to reduce on-site emissions by almost 100 percent and ensure long-term port growth. ●

Power & Automation for ...	Overview	Benefits
Shore-to-ship power	• Infrastructure to power ships with electricity from shore when staying at berth	• Eliminate 98% of emissions and all noise and vibration • Improve quality of life near port
Port electrification	• HV substation • MV/LV electrification • Power transformers	• ABB as a single interface for whole port electrification • High reliability HV products
Port grid integration	• Port distribution grid automation • Renewables integration • Communication networks	• Improved reliability of supply • Self-sufficient port microgrid • Secure/powerful communication
E-mobility solutions	• Battery-hybrid ferries charging infrastructure • EV-chargers	• Zero emission port calls • Integrated transportation (from railway to e-vehicles)
Service/ retrofit	• Consulting for optimal solution • Retrofit of existing installation • Maintenance contracts/spares	• Major improvement in reliability, safety and performance • Extended system life cycle

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