# Shore connection applications

## Main challenges

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### Executive summary

Many of the world's ports are located near densely-populated areas, and the pollution generated by maritime shipping activities—nitrogen oxides, sulfur oxides, particulate matter, and carbon dioxide—has harmful effects on local populations. Shore connection solutions can substantially reduce emissions as compared to on-ship equipment while effectively responding to the shipping industry's unique constraints: high-voltage operation and handling, varying frequencies, and different types of ships and infrastructures. This white paper offers a comprehensive overview of Shore connection solutions and highlights the main technical issues to address during the engineering, installation, and operation phases.


Schneider Electric

# Shore connection applications

## Main Challenges

# Glossary

| | |
|---|---|
| **ABS** | American Bureau of Shipping |
| **AMP** | Alternative Maritime Power |
| **ANSI** | American National Standards Institute |
| **AVR** | Automatic Voltage Regulator |
| **BV** | Bureau Veritas |
| **CB** | Circuit Breaker |
| **DNV** | Det Norske Veritas |
| **ECA** | Emissions Control Areas |
| **ED** | Electrical Distribution |
| **EMCS** | Energy Management and Control System |
| **EMIS** | Energy Management and Information System |
| **GFC** | Grid Frequency Converter |
| **GOV** | Governor (Speed Regulator) |
| **HFO** | Heavy Fuel Oil |
| **HRE** | High Resistance Earthing |
| **HV** | High Voltage |
| **HVSC** | High Voltage Shore Connection |
| **IMO** | International Maritime Organization |
| **LHV** | Lower Heating Value |
| **LNG** | Liquefied Natural Gas |
| **LRE** | Low Resistance Earthing |
| **LRS** | Lloyds Register |
| **LV** | Low Voltage |
| **MARPOL** | International Convention for the Prevention of Pollution from Ships |
| **MDO** | Marine Diesel Oil |
| **MV** | Medium Voltage |
| **NGR** | Neutral Grounding Resistor |
| **OPS** | Onshore Power Supply |
| **PLC** | Programmable Logic Controller |
| **PLS** | Power Logic SCADA |
| **PM** | Particulate Matter |
| **RMU** | Ring Main Unit |
| **SC** | Shore Connection |
| **SCADA** | Supervisory Control And Data Acquisition |
| **SECA** | Sulfur Emissions Control Areas |
| **SIL** | Safety Integrity Level |
| **WPCI** | World Port Climate Initiative |

# 1 Pollution from maritime shipping in ports and harbors

## 1.1 General considerations

Historically, ports have developed in very close proximity to urban areas. Consequently, in harbor cities, ship emissions are often a dominant source of urban pollution affecting the health of people living and working in these areas.

Indeed, the auxiliary engines of oceangoing vessels contribute substantially to exhaust gas emissions and air pollution. This contribution is particularly significant for cruise ships, which have a constant need for ancillary power to meet lighting and ventilation requirements both at sea and in port.

As a result, pollutant emissions from shipping have continued to rise, while emissions from land-based sources have gradually come down due to dedicated efforts to reduce emissions. For memory, the sulfur content of standard marine fuel is 2,700 times higher than that of conventional diesel for cars. The main air emissions resulting from burning this type of fuel include:

- Particulate matter (PM)
  - PM 10, Particulate Matter with aerodynamic diameters of 10 µm
  - PM 2.5, Particulate Matter with aerodynamic diameters of 2.5 µm
- Nitrogen oxides, $NO_X$ ( NO and $NO_2$ )
- Sulfur oxide, $SO_X$ ($SO_2$)
- Carbon oxide (CO)
- Carbon dioxide ($CO_2$)
- Volatile organic compounds (VOCs): benzene, toluene, ethyl benzene, and xylene, a volatile aromatic compound typically found in gasoline and diesel fuel.

It is now known that maritime transportation contributes significantly to air pollution in ports and coastal areas[2].

Annually, oceangoing vessels are estimated to emit:

- 1.2 million–1.6 million tons of PM 10
- 4.7 million–6.5 million tons of sulfur oxides $SO_X$
- 5 million–6.9 million tons of nitrogen oxides $NO_X$

Studies have estimated around 15% of global $NO_X$ and 5–8% of global $SO_x$ emissions are attributable to oceangoing vessels[2].

The negative effects on local air quality and human health are largely dominated by the presence of PM 2.5 and PM 10, $SO_X$, $NO_X$, and $CO_2$ [1].

## 1.2 Impacts on human health

Ambient PM concentrations have been associated with a wide range of health impacts including asthma, heart attacks, and hospital admissions.
A major PM-related health effect is premature mortality; in particular, an increase in PM 2.5 concentrations has been closely associated with an increase in cardiopulmonary and lung cancer mortalities in exposed populations. According to one study, PM emissions contribute to approximately 60,000 deaths annually worldwide, with impacts concentrated in coastal regions on major trade routes[2].

1,2. See bibliography page 31

NOx can penetrate deeply into sensitive lung tissue and damage it, causing premature death in extreme cases. Inhalation of such particles may cause or worsen respiratory diseases such as emphysema and bronchitis; it may also aggravate existing heart disease.

Current scientific evidence links exposures to $SO_2$ with an array of adverse respiratory effects including bronchoconstriction and increased asthma symptoms. $SO_2$ can react with other compounds in the atmosphere to form small particles. These particles can also penetrate deeply into sensitive parts of the lungs and can cause or worsen respiratory disease, such as emphysema and bronchitis, and can aggravate existing heart disease, leading to increased hospital admissions and premature death.

VOCs contribute to eye, nose, and throat irritation; headaches; loss of coordination; nausea; and damage to the liver, kidneys, and central nervous system. Some are suspected or known to cause cancer in humans.

CO can have significant cardiovascular effects on those who suffer from heart disease. The central nervous system can also be affected. Breathing high levels of CO can result in blurred vision, a reduced ability to work or learn, and reduced manual dexterity[1].

## 1.3 Impacts on the climate

At the global level, carbon dioxide, or $CO_2$, is the most significant contributor to global climate change.

Sulfur ($SO_X$) and nitrogen ($NO_X$) compounds emitted by ships can cause acid deposition detrimental to the natural environment (lakes, rivers, soil, fauna, and flora).

An additional contribution of shipping to climate change is brought about by the darker fraction of the PM emitted, known as black carbon. Its capability to absorb the energy derived from incoming sunlight makes it particularly dangerous in the Arctic and Antarctic, where it plays an important role in the acceleration of the snow and ice melting process.

# 2 Measures to reduce pollution from maritime shipping

The continuous increase of shipping-related pollution and its dramatic effects on human health are now well known and widely documented. Organizations at all levels, from local to international, have issued standards, regulations, and recommendations to reduce pollution.

Currently, there are four main ways to reduce shipping-related pollution:

- Low sulphur fuel
- Shore Connection systems
- LNG as a fuel for ships
- Scrubbers systems

## 2.1 Limiting the sulfur content of the fuel used in oceangoing vessels

Both the International Maritime Organization (IMO) and the European Union (EU) have issued directives that aim to limit the sulfur content of the fuel used in oceangoing vessels.

The International Convention for the Prevention of Pollution from Ships (MARPOL) is the main IMO convention currently in force regarding the protection of the marine environment.

The convention includes six annexes that cover the various sources of pollution from ships; it provides an overarching framework for international objectives. Annex VI sets limits on sulfur oxide, nitrogen oxide, and other emissions from marine vessel operations and prohibits the deliberate emission of ozone-depleting substances into the atmosphere.

**MARPOL Annex VI (Fig. 1):**

- Limits the sulfur content of the fuel used in oceangoing vessels to 3.5% in 2012 (35,000 parts per million or ppm) and 0.5% in 2020. By comparison, highway diesel fuel in the United States is limited to 15 ppm.
- Establishes Sulfur Emission Control Areas (SECA), currently the Baltic Sea, the North Sea, the English Channel and the North American coasts where SOx emissions are limited and where the authorized sulfur content of fuel is reduced to 1% starting in 2010 (10,000 ppm).
- Limits $NO_x$ emissions from new engines and engines that have undergone major conversions to an average of 9.6 grams per kilowatt-hour (g/kWh) in 2012. By comparison, power plants in the eastern United States are limited to 0.45–0.73 g/kWh.
- Limits $CO_2$ emissions by making mandatory the Energy Efficiency Design Index (EEDI) and the Ship Energy Efficiency Management Plan ( SEEMP).

In Europe, Directive 2005/33/EC sets sulphur contents limits (0,1%) for the fuel used by oceangoing vessels staying more than 2 hours in a European port.

Fig. 1 - Maritime shipping air emission reduction targets and implementation dates

<table>
<tr><th rowspan="3">Year</th><th colspan="2">Maximum S in fuel (% m/m)</th><th>Maximum average N in fuel (g/kWh)</th></tr>
<tr><th colspan="2">MARPOL Annex VI EU Directive 2005/33/EC</th><th>MARPOL Annex VI</th></tr>
<tr><th>High sea and berth</th><th>SECA</th><th>High sea and berth</th></tr>
<tr><td>2009</td><td rowspan="4">4.5%</td><td rowspan="2">1.5%</td><td rowspan="3">11.8</td></tr>
<tr><td>2010</td></tr>
<tr><td>2010, June</td><td rowspan="3">1.0%</td></tr>
<tr><td>2011</td><td rowspan="3">9.6</td></tr>
<tr><td>2012</td><td rowspan="3">3.5%</td></tr>
<tr><td>2015</td><td rowspan="3">0.1%</td></tr>
<tr><td>2016</td><td rowspan="2">2.3</td></tr>
<tr><td>2020</td><td>0.5%</td></tr>
</table>

## 2.2 Shore connection solutions

Shore connection solutions consist of an onshore power supply for vessels at berth and a system of procedures and equipments, that provides ships with an alternative to the onboard service electrical power system[7,8 & 9].

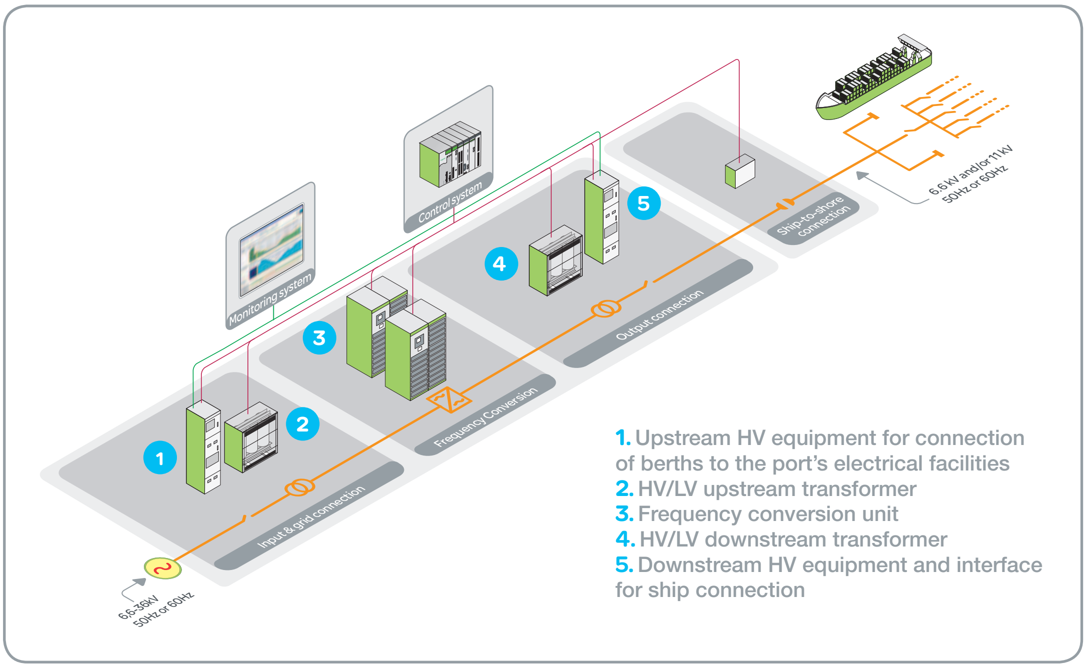
Shore connection solutions for oceangoing vessels at berth appear to be the most cost-effective way to reduce emissions, as these solutions allow the vessels to stop their main and auxiliary engines. Consequently, this technology cuts all emissions(SOx, NOx, PM, CO2), noise and vibrations of ships at berth and make them compliant with Marpol 6 requirements.

EU recommandation 2006/336/EC promotes shore connection solutions as the optimal way to cut costs and reduce pollution.

Shore connection capabilities have been mandatory for all ships at berth in California since 2010, as regulation from CARB. In 2014, vessels without shore connection capabilities will not be allowed to berth in the state's ports. In 2020, at least 80% of berths have to be equipped with shore connection technology.

Fig. 2 gives the principle of the shore connection architecture.

Fig. 2 - **Shore connection system architecture**




7,8 & 9. See bibliography page 31

## 2.3 Liquefied Natural Gas

LNG is being tested in some countries because it is a green and cheaper alternative than the use of fuel.

The main drawbacks of using LNG are the need for tank capacity on board and the reduced Lower Heating Value (LHV) compared to the Marine Diesel Oil. Consequently, it can not suit to every vessel.

If it might play a role in the future, this technology is still in the early stage of development. Indeed, the entire bunkering facilities infrastructure needs to be built and it still faces safety and lack of standardization issues. Moreover, as the retrofits of existing vessels would cost too much to be feasible, this option is mainly considered for new build ships (see Fig. 3).

Fig. 3 - Typical mission factors for a medium speed 4T engine

| | $CO_2$ (g/kWh) | $NO_x$ (g/Kwh) |
|---|---|---|
| MDO | 700 | 17 |
| LNG | 430 | 1.4 |

## 2.4 Treatment of ship emissions: scrubbers

Scrubbers are devices that can be mounted in the ship's funnel to reduce and/or completely eliminate the sulfur emitted by marine fuels. The main types of scrubbers are: seawater scrubbers, freshwater scrubbers, and dry scrubbers. Early experimentation raised concerns as to long-term reliability and disposal of the sulfur residues produced by the scrubbers.

# 3 Shore connection technology

## 3.1 Development and early experimentation

Shore connection systems have been used since the 80s to supply commercial vessels with electricity. Ferries, due to the fact that they always dock in the same position, making connection relatively easy, were the first vessels to be shoreside connected. Military ports, where ships tend to remain at berth for long periods, have also been using shore connection systems for decades. These pioneering shore connection installations were mainly low-voltage. However, amid ships' increasing demand for electricity, several successful high-voltage shore connection (HVSC) experiments have been carried out. In 2000, the Port of Gothenburg was the first port in the world to introduce HVSC. Since then many other ports have followed suit. Other successful shore connection experiments have been carried out under the pressure of the CARB (California Air Resources Board) in the ports of Los Angeles and Long Beach. These and other experiments have proven the huge environmental benefits of HVSC.

Today, ports around the world are starting to provide HVSC capabilities to connect different types of commercial ships—cruise, container, cargo, Ro-Pax and Ro-Ro—to the grid.

## 3.2 The shore connection standard: IEC/ISO/IEEE 80005-1

Shore connection systems must comply with the standard IEC/ISO/IEEE 80005-1 Ed.1: Utility Connections in Port - Part 1: High Voltage Shore Connection (HVSC) Systems[3].

The IEC/ISO/IEEE 80005-1 standard was developed jointly by:
- IEC technical committee TC18: Electrical Installations of Ships and of Mobile and Fixed Offshore Units
- ISO technical committee TC8: Ships and Marine Technology Subcommittee SC 3, Piping and Machinery
- IEEE PCIC Marine Industry Subcommittee

The aim of the standard is to set forth:
- Requirements for shore connection design and construction
- Requirements to guarantee the safety of high-voltage shore connection systems
- Requirements for compatibility between ships and high-voltage shore connection systems

The goal is for the shipping industry and port facilities to cooperate to develop appropriate operating procedures for connecting ships to HVSC systems.

The standard is designed to guarantee standard, straightforward connection, eliminating the need for ships to make adaptations to their equipment at different ports. Ships that do not comply with the standard may find it impossible to connect to compliant shore supplies. This standard is rounded out by IEC 62613-1 & 2, which sets standards for high-voltage plugs, socket-outlets, and ship couplers for HVSC systems[4,5].

**The standard covers:**
- Quality of the power supply
- Electrical requirements
- Environmental and mechanical requirements
- Safety
- Electrical equipment requirements
- Compatibility between ship and shore connection equipment
- Ship-to-shore connection and interface
- Plugs and socket-outlets
- Ship requirements
- Verification and testing

3,4,5. See bibliography page 31

## 3.3 Main requirements for HVSC systems

Shore connection systems must be suitable for all types and sizes of ships, from the medium-sized cargo and container ships up to the largest cruise ships (Fig. 4)[6]. This white paper will discuss only HVSC systems, which are recommended for ship power requirements of 1MW and up.

The main system criteria are determined by:
- Vessel type and required power on board when at berth
- The number and regularity of calls at port per year
- Average duration of every call at port

According to IEC 80005-1 electricity must be supplied to vessels in two frequencies, 50Hz and 60Hz, and in two standardized voltages, 6.6 kV and 11kV.

However, 70% of ships are designed for 60Hz while only 30% of ports supply 50Hz power. Shore connection equipment must therefore be designed for both frequencies (Fig. 5).

**Electrical requirements for shore connection inputs and outputs:**
- **Inputs:**

- From 4.76kV up to 36 kV
- 50Hz and 60Hz
- Up to 25 kA -1s

- **Outputs:**

- 6.6 kV and / or 11 kV, +6%, - 3.5%
- 50Hz and 60Hz, +,- 5%
- Up to 25 kA-1s

Fig. 4 - Necessary power at berth and call time for different ships

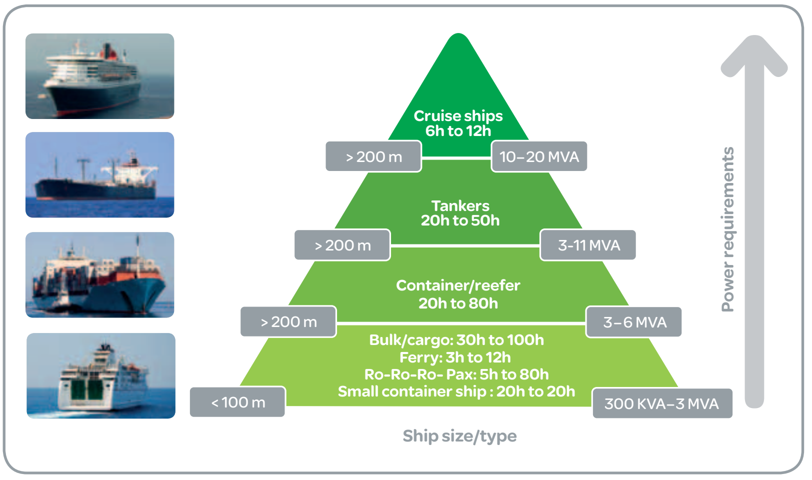



Fig. 5 - Voltages and frequencies for different types of ships[15]

| | LV | HV | 50Hz | 60Hz |
|---|---|---|---|---|
| Container<140m | 100% | 0% | 63% | 37% |
| Container>140m | 88% | 12% | 6% | 94% |
| Ro-Ro | 100% | 0% | 30% | 70% |
| Oil tankers | 100% | 0% | 20% | 80% |
| Cruise ships<200m | 100% | 0% | 36% | 64% |
| Cruise ships>200m | 12% | 88% | 0% | 100% |

6,15. See bibliography page 31

## 3.4 Shore connection system architectures

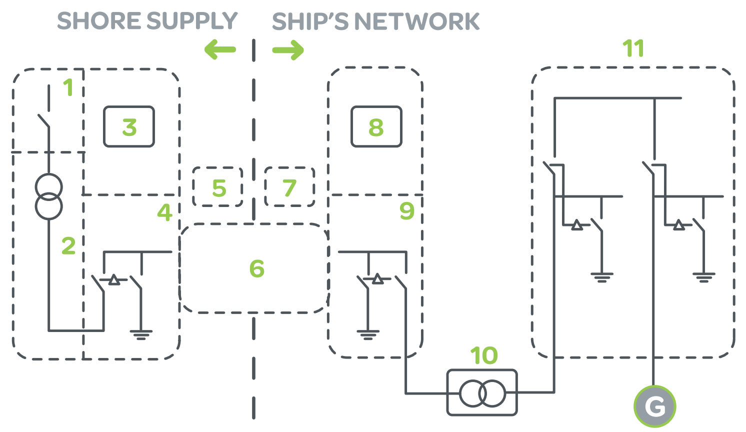
The shore connection electrical architecture covers three main functions (Fig. 6 and Fig. 7).

● **Connection to the port's electrical supply**
- Standard voltages from 4.76kV up to 36 kV as well as the two frequencies 50Hz and 60Hz need to be considered
- The required functions include the HV cubicles for the shoreside connection, either to the port's MV network or to the local grid

● **Shore-to-ship connection system including:**
- Isolation transformer for voltage adaptation
- Main HV circuit breaker cubicle with associated protective relays needed for fault clearing
- Disconnectors and earthing switches required for safety
- System for connection to ships including motorized HV cable reels and HV plugs and sockets with their handling facilities

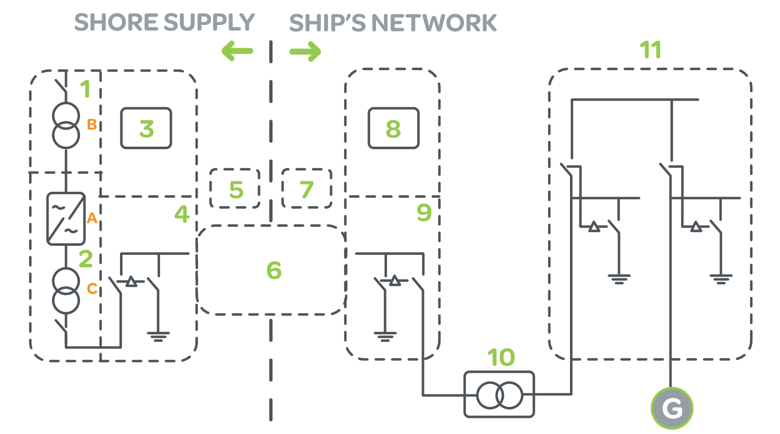
● **Frequency conversion system** to deliver 50Hz and 60 Hz power.
The shore connection system could be equipped with a frequency conversion system or not depending on its use. When needed, frequency conversion systems consist of one or several parallel frequency converter units, depending of the required power. Generally, two power transformers are dedicated to each frequency converter unit: one step-down transformer upstream and one step-up transformer downstream.

Fig. 6 - Shore connection solution without frequency conversion




1. Connection to the MV port's internal network or to local grid
2. Shoreside isolation transformer: mandatory to prevent circulation of earth fault current between several ships
3. Shoreside protection relays and interlocking system
4. Shoreside CB and earthing switch
5. 6. 7. Shore-to-ship connection, including: HV cables and cable reels, HV plug/socket-outlets with handling facilities, communication and control wires, equipotential bonding cable, etc.
8. Shipside protection relays and interlocking system
9. Shipside CB and earthing switch
10. Where applicable (ship voltage different from shore connection voltage), an onboard transformer is needed to adapt the high voltage supply to the ship's main switchboard voltage; this transformer is preferably located near the main switchboard in a dedicated room
11. Onboard receiving switchboard

Fig. 7 - **Shore connection solution with frequency conversion**




**Power frequency conversion system:**
Power converter (A) unit including
step down power transformer (B)
step-up power transformer (C)
The power frequency converter is either included in each shore connection system
or centralized at port level for large power requirements.

1. Connection to the MV port's electrical network or to the local grid
2. Power frequency conversion system
3. Shoreside protection relays and interlocking system
4. Shoreside CB and earthing switch
5. 6. 7. Shore-to-ship connection, including: HV cables and cable reels, HV plug/socket-outlets with handling facilities, communication and control wires, equipotential bonding cable, etc.
8. Shipside protection relays and interlocking system
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10. Where applicable (ship voltage different from shore connection voltage), an onboard transformer is needed to adapt the high voltage supply to the ship's main switchboard voltage; this transformer is preferably located near the main switchboard in a dedicated room
11. Onboard receiving switchboard

## 3.5 General operating procedures

A shore connection system must include procedures to be followed by port and onboard maintenance staff for:

- MV cable connection and disconnection; safety hazards are managed by automatic and/or key interlocks and safety checks by maintenance operators
- As generally connection and disconnection of the ship's power supply is done without blackout, coupling between the shore substation and onboard generators must be synchronized

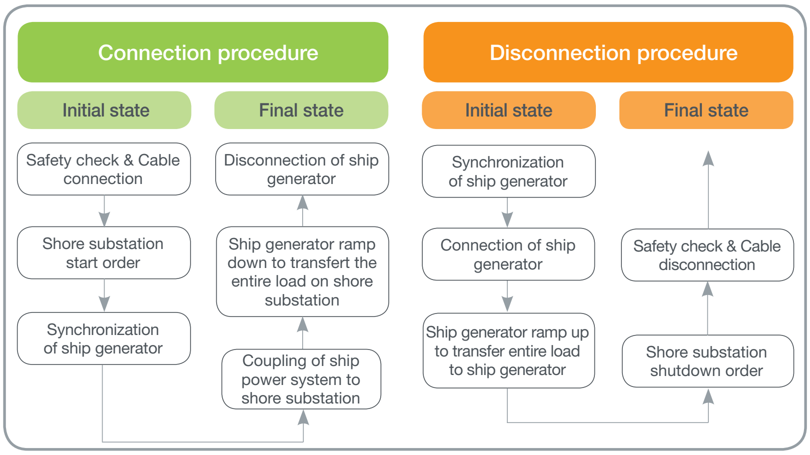
A basic description of main the operations is provided in Fig. 8.

These procedures may depend on the ship type, the shore substation design, and port maintenance requirements:

- Power architecture (cable to connect, switchboard architecture)
- Interlocking systems (automatic interlocking and/or key interlocking)
- Operators involved in the procedure (onboard operators, port authorities, on-shore operators)

The operating configurations for Schneider Electric shore connection solutions for different types of vessels are detailed in section 5.3.

Fig. 8 - **Connection and disconnection procedures**



# 4 Main challenges

## 4.1 Neutral earthing systems

In HV and LV installations, the neutral may or may not be earthed. The commonly used term is **system earthing** (also called **system grounding**), which determines how the neutral point of a transformer or generator and the exposed conductive parts (ECP) of the user's installation are earthed.

There are different solutions for earthing. Selecting the right one is a determining factor in terms of continuity of service, trouble-free operation, and protection against overloads and faults. A poor choice may result in damage to equipment, malfunctions, or hazardous situations. Installations where the type of earthing has been poorly selected or, even worse, poorly implemented, may result in damage and electric shocks—or worse—electrocution.

Each earthing method affects network electrical parameters differently and determines the operating conditions of the installation in the event of a phase-to-earth fault. During an insulation fault or a phase-to-earth fault, fault currents, touch voltages, and overvoltages depend to a large degree on the type of earthing. A directly-earthed neutral helps limit overvoltages, but is characterized by high fault currents. Conversely, an isolated system limits fault currents, but favors high overvoltages.

In all installations, when an insulation fault occurs, continuity of service also depends on the type of earthing. An isolated neutral enhances continuity of service in LV and even HV systems, on the condition that worker safety regulations are observed. On the other hand, a directly earthed or somewhat impedant neutral results in tripping when the first insulation fault occurs.

The type of earthing also determines the degree of damage suffered by certain loads (e.g. rotating AC machines, transformers) when an internal insulation fault occurs. When the neutral is directly earthed, an insulation fault causes severe damage due to the high fault currents. In installations with an isolated or highly impedant neutral, damage is limited, but equipment must have insulation levels compatible with the overvoltages that can occur in this type of system.

The type of earthing significantly influences the type and level of electromagnetic disturbances arising in an installation. Earthing that favors high fault currents and their flow in the metal structures of buildings causes major disturbances. Conversely, earthing that limits fault currents and ensures good equipotentiality does not cause significant disturbances.

For both LV and HV installations the type of earthing depends on the type of installation and type of network. It is also influenced by the types of loads, the need for continuity of service, and limits to disturbances for sensitive equipment.

A review of the different earthing methods and their implementation on ships follows[10,12&13], with recommendations from standards and classification organizations (BV, DNV, LRS, ABS, etc.) as per DNV, G 102[14].

10,12,13,14. See Bibliography page 31

### 4.1.1 Overview of earthing methods and implementation on ships

This section covers the impact of the earthing system on earth fault current, over voltages, and earth fault detection and clearing.

The contribution to the earth fault current of the capacitive leakage current (charging current) of HV cables must be carefully estimated for all ship operating conditions and for all load situations when at berth.

A ship could use different earthing methods on board for different areas (machine rooms, cargo holds, passenger cabins), for example. A comparative overview is presented in Table 1.

#### 4.1.1.1 Solid earthing

- The transformer neutral is directly connected to the earth
- The earth-fault current is comparable to three-phase fault current and is easily detectable even if the fault occurs close to the neutral point of a star winding
- The level of transient overvoltages is low; the increase of the voltage between the earth and the two healthy phases remains low, thus no overinsulation is required
- Tripping is mandatory at the first earth fault
- According to the applicable class standards (BV, DNV, LRS, ABS, etc.) the system allowed for ships in this case is three-phase, three-wire (or four-wire in LV) with neutral directly earthed
- This arrangement is generally not used for ship power plant generation; however, hotel space for cruise ships can use a low-voltage three-phase system with the neutral directly earthed, a TT or TN-S system (5 wires: 3 phase conductors (L1, L2, L3), neutral conductor (N), protective earth (PE).

#### 4.1.1.2 Low-resistance earthing

- The transformer neutral is connected to the earth via a low-resistance, faults being generally limited above 50A
- Like for solid earthing, earth fault detection is performed without any difficulties
- Transient overvoltages are well-controlled; the increase of voltage between the earth and the two healthy phases remains acceptable and does not require any improvement to the insulation of electrical equipment
- Tripping is mandatory at the first earth fault
- According to the applicable class standards (BV, DNV, LRS, ABS, etc.) the system allowed for ships in this case is three-phase, three-wire (or four-wire in LV) with neutral directly earthed through a low-resistance
- This arrangement is generally not used for ship generators

#### 4.1.1.3 High-resistance earthing

- The transformer neutral is connected to the earth via a high-resistance; the maximum single-phase-to-earth fault current is limited to a value in the range of approximately 5A to 25A primary current, depending on the value of capacitive leakage current of the network and the current through resistor
- The charging current (capacitive leakage current) of cables must be estimated for all ship situations, this value is used to determine the maximum earth fault current within the ship; the typical cable charging current for ships with HV systems is 5A to 10A depending on the size of the ship, with the exception of big cruise ships, where the charging current may reach a maximum value of 15A to 20A
- The level of transient over-voltages is linked to the value of the current limited by the neutral earthing resistance; with a primary earthing resistive current of 2 times the cable charging current, the peak value of the transient over voltages will never exceed 240% of the nominal voltage
- Due to the low value of the fault current, tripping at the first insulation fault is not mandatory and the operation of the installation may continue; nevertheless, the measurement of the residual current of each HV feeder allows the fault to be located rapidly for maintenance staff to clear it within a reasonably short time
- When a second fault occurs prior to the first fault clearing, the fault current reaches the value of the phase-to-phase short circuit and requires immediate tripping by the phase-to-phase overcurrent protections

- When a phase-to-earth fault occurs, the voltage between the earth and the two healthy phases reaches a value close to the phase-to-phase voltage, so overinsulation of electrical equipment is required
- According to the applicable class standards (BV, DNV, LRS, ABS, etc.) the system allowed for ships in this case is three-phase, three-wire with a high-resistance earthing
- This method is very widely used on bulk carrier ships, chemical ships, cargo ships, container ships, Ro-Ro ships, reefer ships, tankers, cruise liners, offshore supply ships, recreational vessels, coast guard ships, frigates, destroyers, supply ships, and aircraft carriers.

### 4.1.1.4 Unearthed systems

- No resistance is connected between the transformer neutral and the earth; the earth fault is equal to the cable charging current (2A in LV up to 20A in HV as mentioned above)
- As for high-resistance earthing, in the event of a phase-to-earth fault the voltage between the two healthy phases and the earth reaches the phase-to-phase voltage and requires improvement of the insulation of electrical equipment
- Tripping at the first fault is not mandatory; it becomes mandatory at the second fault, the fault becoming a phase-to-phase fault
- The level of insulation of any unearthed distribution system must be permanently monitored by an appropriate device (IMD, Insulation Monitoring Device) providing an audible or visual alarm when an unacceptable level of network insulation is detected (for HV systems the alarm must be both audible and visual (IACS E11 2); the fault must be located and eliminated by a maintenance team within a reasonably short time
- According to the applicable class standards (BV, DNV, LRS, ABS, etc.) the system allowed for ships in this case is three-phase, three-wire neutral-insulated system; for small LV ships like recreational and sailing ships, it is a single-phase two-wire neutral-insulated system
- As per high-resistance earthing systems, widely used on ships, unearthed systems are also found on a wide range of ship types.

Table 1 - Different earthing systems for ships

| Earthing system | Earth fault current | Damage | Transient overvoltages | Phase-to-earth overvoltage healthy phase | Tripping at the first fault |
|---|---|---|---|---|---|
| Solide earthing | High, 3-phase fault current | Very high | Low | Very low | Mandatory |
| Low-resistance earthing | Medium, above 50A | High | Controlled | Low | Mandatory |
| High-resistance earthing | Low, up to 25A Charging current increase the current limited by the resistance | Low | Limited if the current limited by the resistance is higher than 2 times the charging current | The phase-to-earth voltage is close to the phase-to-phase voltage; Insulation level needs to be improved | Not Mandatory Location and elimination of the fault are mandatory |
| Unearthed | Equal to the charging current | Low | High | The phase-to-earth voltage is close to the phase-to-phase voltage; Insulation level needs to be improved | Not Mandatory Location and elimination of the fault are mandatory |

## 4.1.2 IEC/ISO/IEEE 80005-1 requirements

For HVSC systems, the IEC/ISO/IEEE 80005-1 standard specifies both voltage and neutral earthing systems for different kinds of ships (Ro-Ro, cruise, container, LNG carriers, tankers). These systems are presented below.

### 4.1.2.1 General requirements

According to IEC80005, the shore connection earthing system is similar to a low-resistance earthing system, with tripping at the first phase-to-earth fault. Hence, the neutral point of the HVSC system transformer must be earthed:

- through a neutral earthing resistor; or
- where frequency conversion of the shore supply is required, either through a neutral earthing resistor (or Neutral Grounding Resistor: NGR) or through an earthing transformer with resistor on the primary side that provides an equivalent earth fault impedance.

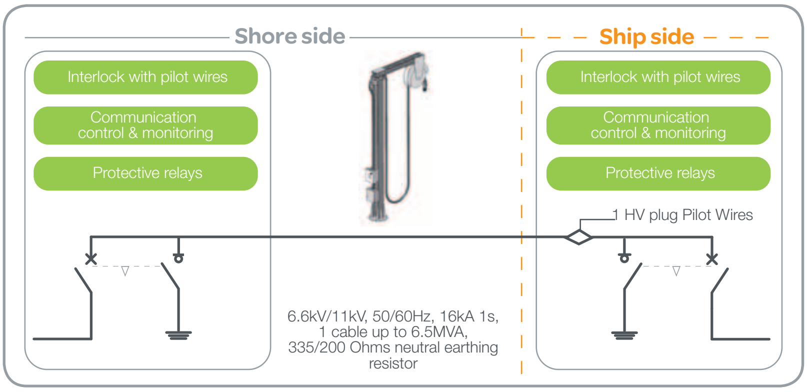
The neutral earthing resistor rating in amperes must not be less 1.25 times the preliminary system charging current. The rated current of the resistor must be sized to a minimum of 25A continuous.
The continuity of the neutral earthing resistor must be continuously monitored. In the event of loss of continuity the shoreside circuit breaker must be tripped.

An earth fault must not create a step or touch voltage exceeding 30 V at any location in the shore-to-ship power system. An equipotential bonding cable between shore and ship is required, the earth conductor being distributed from shore-to-ship.

### 4.1.2.2 Ro-Ro cargo ships and Ro-Ro passenger ships

- Shore connection nominal voltage: 11kV, accepted 6.6kV for waterborne transportation services
- Shore connection earthing system: LRE with 335/200 Ohms NGR
- Number of cables to feed the vessel: 1
- Location of the cable management system: berth
- Most frequently used earthing system on ship: high-resistance earthing

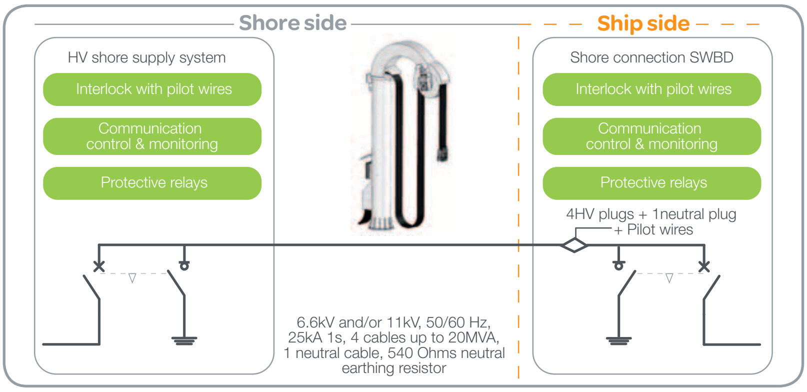
Fig. 9 -Shore connection solution for Ro-Ro-Ro-Pax ship.



### 4.1.2.3 Cruise ships

- Shore connection nominal voltage: 11kV and/or 6.6kV
- Shore connection earthing system: LRE with 540 Ohms NGR
- Number of cables to feed the vessel: 4 power cables, neutral distributed to ship
- Location of the cable management system: berth
- Most frequently used earthing system on ship: high-resistance earthing

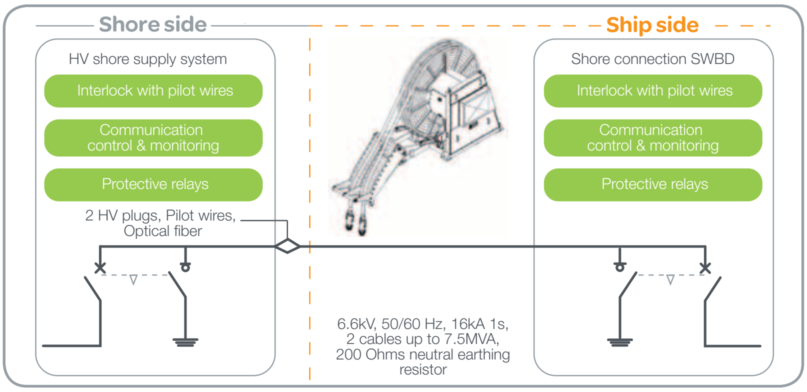
Fig. 10 - **Shore connection solution for cruise ship**




### 4.1.2.4 Container ships

- Shore connection nominal voltage: 6.6kV
- Shore connection earthing system: LRE with 200 Ohms NGR
- Number of cables to feed the vessel: 2
- Location of the cable management system: on ship
- Most frequently used earthing system on ship: high-resistance earthing

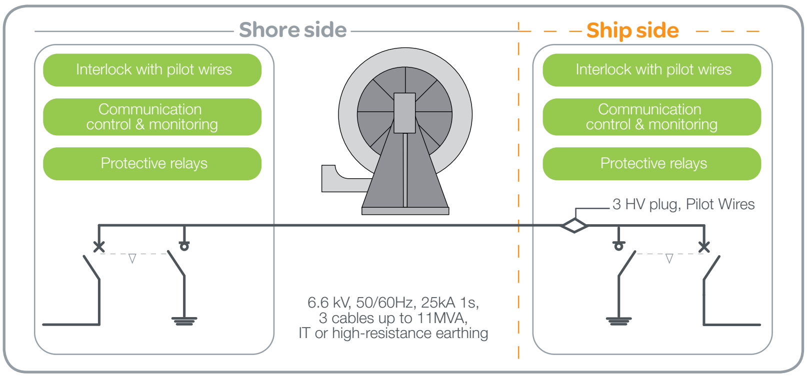
Fig.11 - **Shore connection solution for container ship**




### 4.1.2.5 LNG carriers and tankers

- Shore connection nominal voltage: 6.6kV
- Shore connection earthing system: unearthed
- Number of cables to feed the vessel: 3
- Location of the cable management system: berth
- Most frequently used earthing system on ship: unearthed or high-resistance earthing

Fig. 12 - **Shore connection solution for LNG carriers and tanker ship**



## 4.2 Shore connection protection system

### 4.2.1 Protection plan

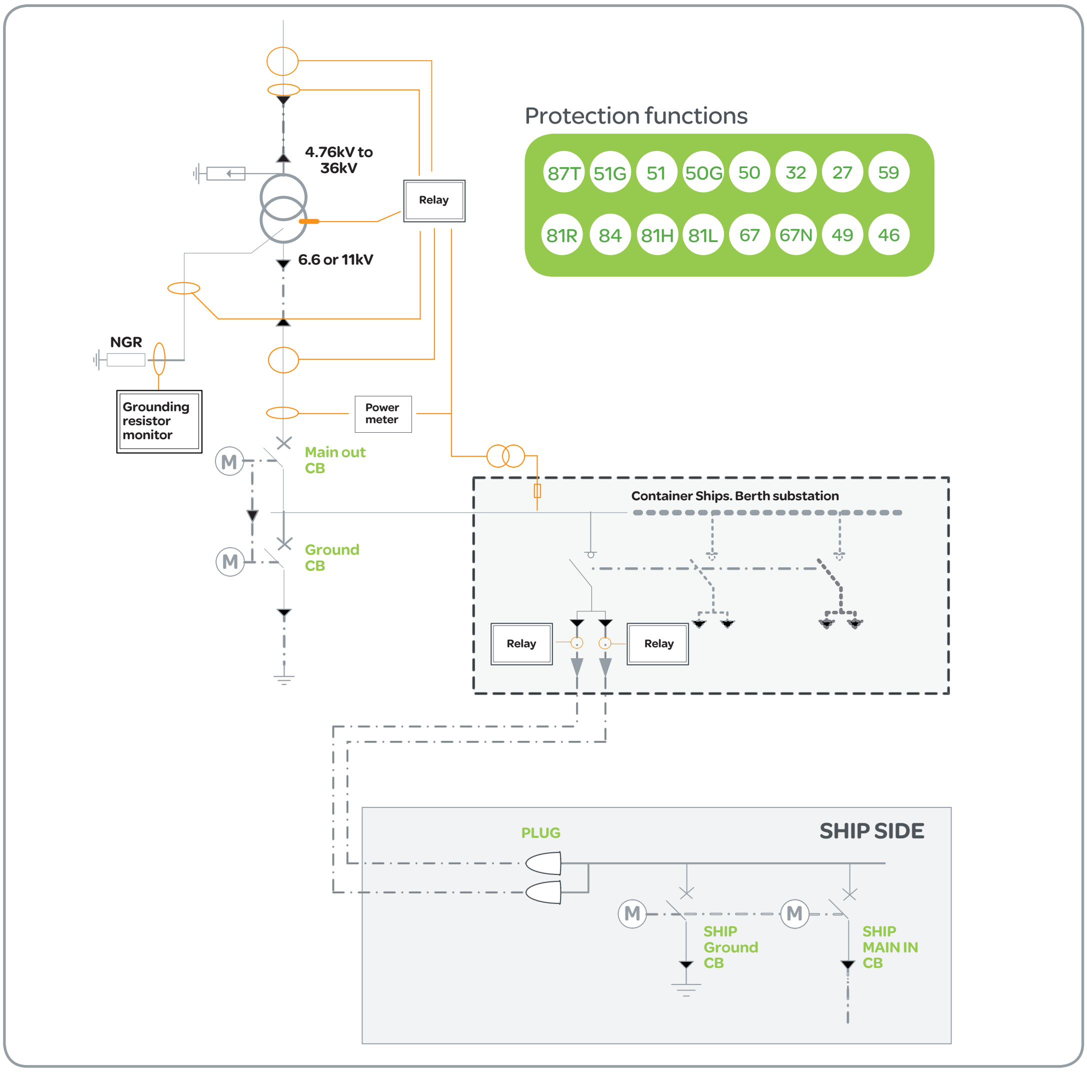
Shore connection substations must be able to cope with a complex electrical power system:

- Multiple sources (utility delivery substation and onboard generators)
- Power conversion for frequency conversion
- Mobile equipment (MV cable and plug) for shore-to-ship electrical connection, which can be used several times a day

Considering the complexity of the installation, additional risks must be managed by implementing adequate protections. As example, this section will provide an overview of the protections that must be set in the main output MV switchboard, for container ship applications.

Fig.13 illustrates the overall architecture of the main output MV switchboard for container ship applications, including the protection functions embedded in each relay.

Fig. 13 - Protection plan for a shore connection system without frequency conversion




#### 4.2.1.1 Protection against shore substation internal faults

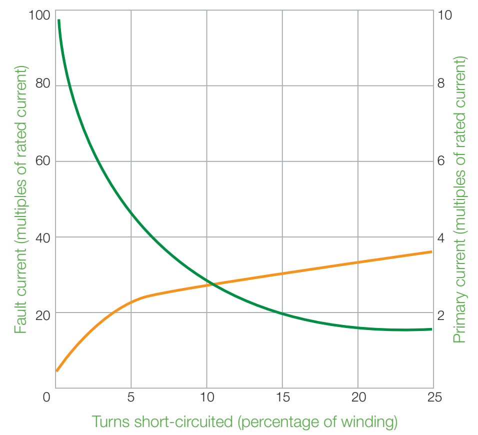
Protection against an internal fault (earth or phase-to-phase faults) is provided by maximum overcurrent protections (ANSI 50/51 and 50/51 N), which are set to trip both input and output circuit breakers.

Particular attention must be paid to internal faults within the shore system. Transformer internal faults such as inter-turn faults may be difficult to detect due to the low level of the corresponding line current (Fig. 14). On the other hand, with frequency power conversion the limited value of the short-circuit current, with possible shutdown time generally between 0.5s to 1s, must be taken into account.

Consequently, for transformers, the use of two winding differential relays (ANSI 87T protection) and restrained earth fault protection  are a reliable solution for internal faults. To secure the system, additional protections such as thermal overload (ANSI 49T) should also be installed.

In the event of a utility voltage interruption or collapse of frequency conversion units, an undervoltage protection (ANSI 59) trips the shore main output CB and then allows the ship to restart its own generators without any risk of inadvertent coupling with the shore substation.

Fig. 14 - **Transformer inter-turn faults current/number of turns short circuited**




A short circuit of a few turns of the winding will give rise to heavy fault current in the short-circuited loop, but the terminal currents will be very small, because of the high ratio of transformation between the whole winding and the short-circuited turns.

### 4.2.1.2 Shore output protections

For earthing and phase-to-phase fault detection downstream of the shore installation, output maximum overcurrent protections (ANSI 50/51 and 50/51 N) are set to trip the output circuit breaker.

As the system can be supplied by both shore and ship side, directional protections (ANSI 67 and 67N) are set to trip on reverse overcurrent, coordinating protection and facilitating fault troubleshooting.

As the neutral earthing resistor could experience failures like connection resistance deviations or connection breakdowns, a specific relay is set to provide monitoring, detect possible failures, and guarantee that the installation will operate with the right neutral earthing system.

### 4.2.1.3 Parallel operation

During the shore start sequence, there is a risk that shore substation will close its main output breaker once the ship has already energized the connection cable. To prevent the shore from being connected to a ship without synchronization, a dead bus verification (ANSI 84) is set up on the main output breaker. This protection enables the closing of the main output breaker only if no voltage is detected downstream.

During the parallel operation of the shore substation with ship generators, a reverse power protection (ANSI 32P) is placed on the main output breaker of the shore substation to prevent the ship from providing power to the grid.

To guarantee the acceptable voltage tolerance to ship loads, under/overvoltage protection (ANSI 27 and 59) and under/overfrequency protection (ANSI 81U/O) are also set up on the main shore output breaker.

### 4.2.1.4 Connection cable continuity monitoring

In the event of a breakdown or high impedance (poor contact) of the shore-to-ship earthing conductor, the bonding potential between the shore and the ship could exceed 30V during an earth fault and present a danger to operators (Fig. 15). As the shore-to-ship cable is handled many times for each ship connection, this risk is not minor. Hence, an earthing check system is installed between the shore and ship to detect an earthing conductor failure (Fig. 16). A current is injected into an additional pilot wire and passes through the earthing conductor; if a failure occurs on the earthing conductor, the earthing check system will trip the main circuit breakers on both sides.

There is also the potential risk of a power connector resistance deviation (due to poor contact) that could result in plug arcing phenomena. To detect this kind of failure, a negative sequence overcurrent protection (ANSI 46) is placed on the shoreside main output relay.

Fig. 15 - Earthing conductor failure

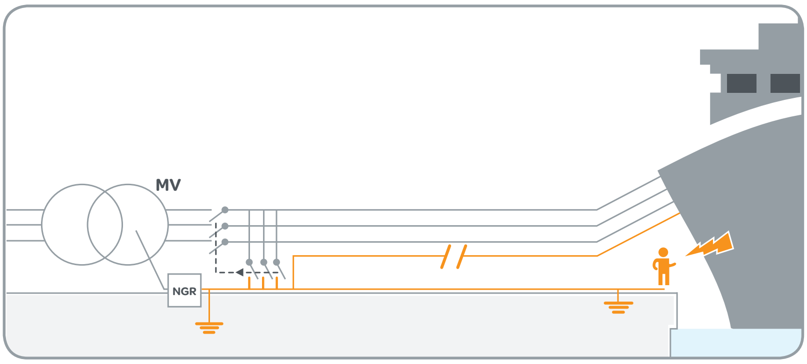
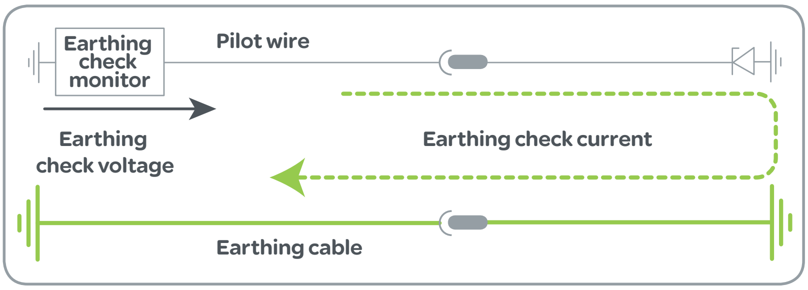



Fig. 16 - Earthing check system



## 4.2.2 Protection coordination

### 4.2.2.1 Earth fault coordination

The IEC/ISO/IEEE 80005-1 standard requires a galvanic separation between the shore connection and the onboard electrical network. A shoreside delta-star power transformer is used to meet this requirement. The star point of the transformer needs to be earthed through a resistance or remains isolated as defined above for each type of vessel.

As the voltages of the shore connection system are 6.6kV or 11kV, the system could require a delta-star transformer installed on board for ship voltage adaptation; in this case we would be dealing with two separate systems regarding earth faults. The shoreside earth fault protections do not need to be coordinated with those of the ship, which may maintain their existing settings.

Without an onboard transformer earthing protection must be coordinated. The difficulty lies in knowing the settings of the earth fault protection installed onboard. The best policy would be to set the shore earth fault protection below the minimum realistic earth fault current, taking into account resistive earth faults, and with a long time lapse exceeding the maximum time lapse met on board. Hence, any fault not cleared by the onboard earth fault system will be detected and cleared by the onshore system. This solution does not reduce the availability of the loading/unloading operation, and the 80005-1 standard allows restoring ship power as specified by SOLAS CH II-1/D Reg. 42 or 43 after a blackout.

With the above solution, if the onboard earth fault relay does not trip, the shore earth-fault relay will trip as a back-up relay (Fig. 17).

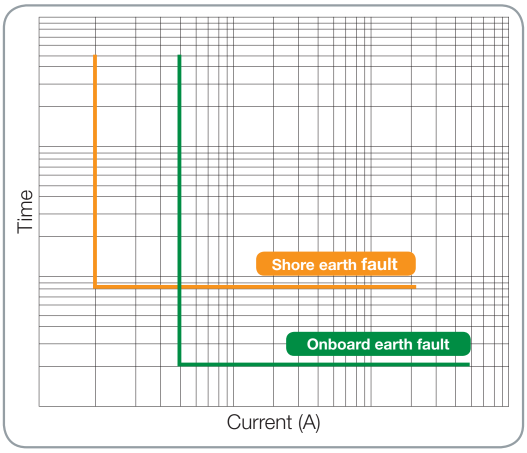



Fig. 17 - Earth fault coordination in a shore connection system.

#### 4.2.2.2 Phase-to-phase fault coordination

The major concern relative to the detection and clearing of phase-to-phase faults is the level of the expected short-circuit current. Currently, on the ship side, the expected short-circuit currents are very high due to the presence of several gensets on the main busbars; the protection system sets in accordance with these currents.
With power frequency conversion, the short-circuit current can be low and may collapse rapidly (depending on the frequency converter technology with LV or MV conversion; for MV conversion no overload capacity is available).
In such situations, the coordination of shore protection with the onboard protection system becomes sensitive, and practically unachievable.
In addition, when the ship is connected to the shore, onboard protections may not work properly because their settings are adjusted according to the minimum short-circuit current of the power generator and the largest onboard load.

Standard 80005-1 requires shore substations to provide enough short-circuit current to trip the protection relay of the biggest load on the ship, in the case of a ship-side short circuit. Particular attention has to be paid to ANSI 50/51 protection coordination requirements, considering the limited level of short-circuit currents provided by the static frequency converters and the requirement that a shore protection system be set according to each ship.
Whatever fault occurs onboard, the solutions generally consist of:
- Providing enough short-circuit current for enough time by using proper frequency converter technology or over-sizing the installation to ensure the selectivity of the largest onboard load as required by IEC/ISO/IEEE 80005-1
- Ensuring that setting time and current of the shoreside CB are coordinated with the frequency converters' total current time limitation; there is a general on-shore trip, followed by a shore connection system blackout, and, finally, onboard ship power is restored.

## 4.3 Safety

### 4.3.1 Safety during shore connection and disconnection

There are electrical hazards inherent to the handling, connection, and disconnection of MV plugs. As shown in Fig. 18, when performing a connection/disconnection, the operator has access to power connectors and can be exposed to a shock hazard if the power connectors are not disconnected and earthed.

The possible risks are:
- Failure to disconnect from the shore substation
- Failure to disconnect from ship power system
- Failure to discharge the MV cable[11]

Shoreside connection and disconnection can be performed by non-electricians. Consequently, all basic operations must be simple and secure. Shore connection and disconnection safety is achieved by adhering to two basic concepts:
- Operating instructions and procedures
- Automatic interlocks managed by a safety system (Fig.19)

IEC/ISO/IEEE 80005-1 sets forth specific measures to prevent the risks presented previously. The recommended measures are classified as follows in the standard:
- Emergency shutdown
- Conditions for the shore connection start sequence (conditions for main breaker closing and earthing switch opening)
- Conditions for plug handling during plugging and unplugging (opening the disconnector and closing the earthing switch on both sides)

The purpose of automatic interlocks is to prevent all the risks intrinsic to MV plug handling during plugging and unplugging. The main safety requirements are:

- While not connected, on shoreside (ship side for container ships case):
  - Allow access to and handling of the plug only when the shore circuit breaker is locked opened and when the earthing switch is locked in closed position

- While not connected, on ship side (shoreside for container ship case) can be:
  - Prevent access to the MV socket while not earthed

- For disconnection:
  - Allow plug disconnection only if the MV plug & socket are isolated from the sources (shore and ship circuit breakers open) then the earthing switch of the shore side is locked in the closed position to discharge the MV cable and the earthing switch of the ship side is locked in the closed position

Fig. 18 - Electrical hazards during connection/ disconnection

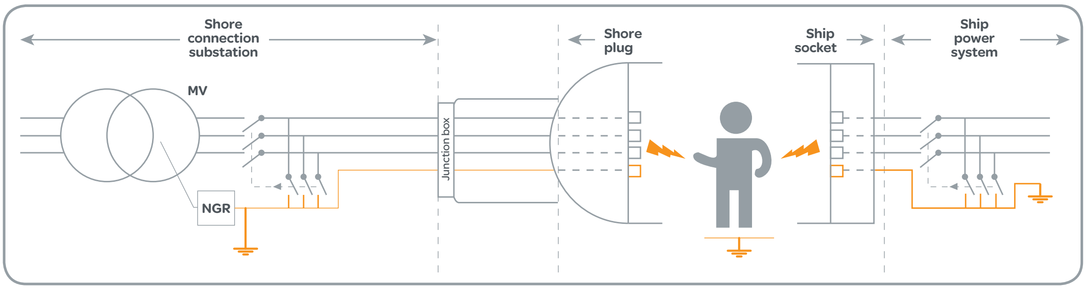
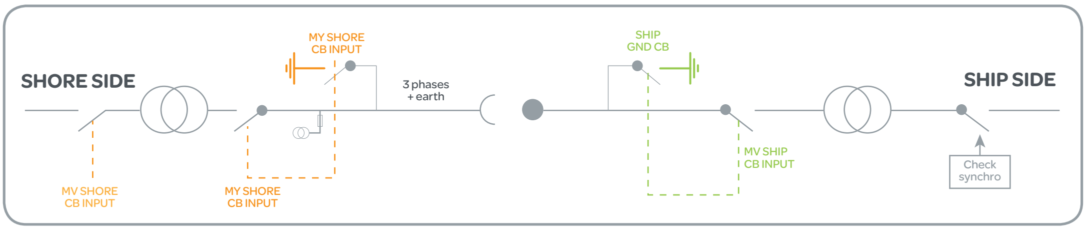



Fig. 19 - MV shore-to-ship connection architecture




## 4.3.2 Safety during maintenance

Protecting personnel from direct and indirect electrical shocks and internal arcing requires appropriate standardized measures such as envelopes, barriers, equipotential bonding, interlocks, and safety instructions. In addition, high-voltage equipment must be internal-arc type.

## 4.4 Reliability and availability

A high level of availability is also a key point in reducing OpEx and, consequently, for the success of the shore connection system.

The shore connection system must be:

- Reliable
- Maintainable
- Available

To achieve these requirements, the engineering and design by the solution must follow the process below (Fig. 20).

- Proper equipment selection
- Proper design and integration of the solution
- Reliability assessment and improvement
- Availability assessment and improvement

Fig. 20 - Reliability and availability criteria to be used in shore connection solution design and operation

| | |
|---|---|
| **Equipment selection** | ● Equipment inclued in the shore connection system is well-tested and compliant with IEC standards.<br>● Weather and environmental conditions, safety of persons operating the system, simplicity of operation, and reduction of maintenance are the main criteria for the selection of electrical equipment. |
| **Design and Integration** | ● Electrical equipment and HVAC housings are designed for extrem conditions (temperature, salt, rain, humidity, dust, wind, snow, ice, earthquakes) and for all phases of system's lifecycle (running, standby and hibernating phases)<br>● Electromagnetic compatibility is perfectly controlled and resolved.<br>Particular attention must be paid to the installation of electrical equipment and cabling.<br>No equipment (power equipment, control system, protection system) is subject to electromagnetic disturbances higher than is immunity level.<br>● Fault detection system is designed to detect and clear all types of faults with full discrimination. |
| **Reliability evaluation and improvement** | Equipment<br>● The shore connection system is based on well-tested equipment subject to continuous improvement and offering high reliabilty.<br><br>Solution<br>● For frequency conversion, the modularity of frequency converters is a key point. It means that cost-effective redundancy can been achieved when high reliability is required.<br>● Compared to one large single conversion unit several frequency converters working in parallel increases power availability; a failure of one converter does not lead to a complete shutdown of the installation but rather to a reduction of the available power.<br>● Reliability is optimized thanks to reliability analysis; unreliable equipment is redundant.<br>● Adequate preventive maintenance services are provided to ensure reliability and prevent premature equipment aging. |
| **Availability assessment and improvement** | Reduced mean downtime<br>● Monitoring system to significantly reduce fault detection and analysis times<br>● Shore connection solution uses proven equipment; spare parts are easily available.<br>● A spare parts procedure to reduce downtime.<br>● Maintenance operations are reduced and do not require highly-qualified personnel or special tools or equipment.<br>● Technical facilities have been designed to permit handling and replacement of the equipment. |

## 4.5 Environment and installation

The shore connection system must be designed and built to be installed in environmental conditions that are generally harsh (at berth).

The following environmental and mechanical constraints must be taken account for the design of the solution and selection of electrical equipment: temperature, humidity, salt, rain, dust, wind, snow, ice, shocks, and earthquakes.

Concerning the handling, transportation, and installation of the shore connection system, limits need to be determined for its dimensions and weight.

Some of the values and recommendations listed here should be considered the minimum requirements for all the above parameters:

- Temperature conditions:
  - 3K6/3Z6 according IEC 60721-3-3
  - -25°C /+45°C, Maximum daily average 25°C
  - 95 %, Relative humidity at -25°C et +45°C
- Salt and chemicals:
  - 3C 3 according IEC 60721-3-3. For the forced-air ventilation version, filters must be used to protect the equipment against salt mist
  - Paint and coatings must be suitable for expected exposure to salt and chemicals
- Degree of protection according IEC 60529:
  - Transformer rooms: IP34
  - Frequency converter room IP33, IP44 with filters
  - HV room IP 34
  - During maintenance: IP 01
- Accessibility and maintainability:
  - Security perimeter around the substation with access control
  - Easy to maintain design to keep the system operable during maintenance
- Installation:
  - The shore connection system must not disrupt port activity during installation and operation
  - No special lifting equipment is required other than that usually available at the port.

## 4.6 CapEx and OpEx

As presented in the sections above, to comply with shipping-related pollution regulations, both shipowners and ports need to invest in new technologies. And several technologies are available. Nevertheless, shore connection systems are probably the most attractive solution from both a technical and an economic standpoint.

To remain competitive, and invest in green technology, ports must reduce both CapEx and OpEx to a minimum. The recommendations and guidelines presented above are designed to help ports reduce these costs. Moreover, amid economic uncertainty and the trend toward larger ships, port traffic is likely to change over time, and the number and type of vessels berthing at port likely to evolve. Therefore, ports need a modular, upgradeable shore connection solution.

# 5 Shore connection solution by Schneider Electric

## 5.1 Typical shore connection architectures

### 5.1.1 Architecture without frequency conversion

Suitable for North America (60Hz to 60Hz) and some European and Asian waterborne transportation ships (50Hz to 50Hz).

The shore connection system installed at berth may be supplied either:

- Directly by the local utility (Fig. 21).
- By one or several HV internal port substations, depending on their location and the configuration of the port's electrical network. One feeder may be dedicated to each shore connection. The shore connection may also be included in a electrical distribution loop (Fig. 22).

Fig.21 - Shore connection system without frequency conversion installed at berth

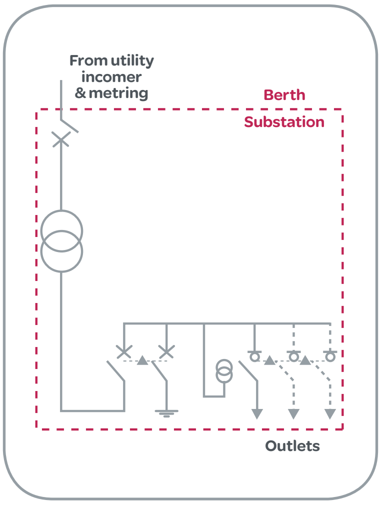
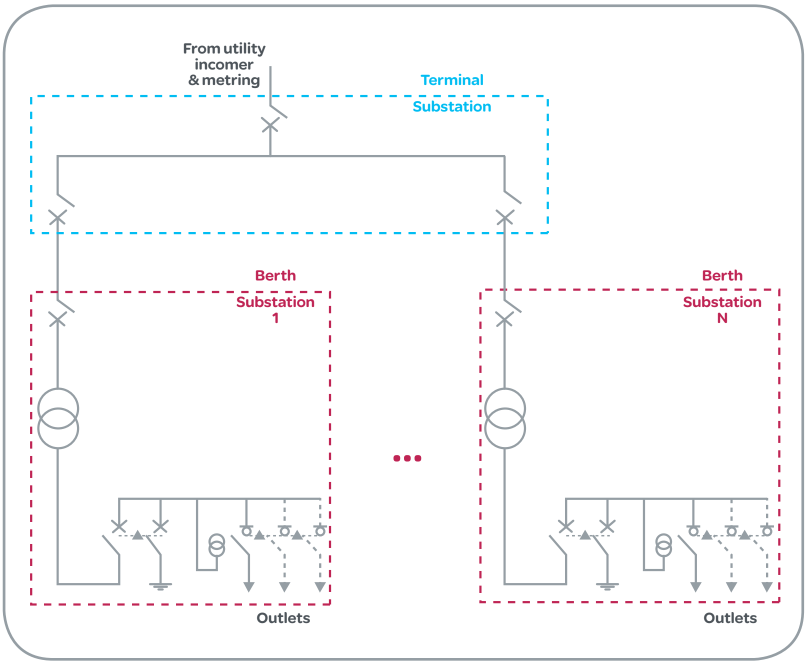



Fig.22 - Shore connection system without frequency conversion installed at terminal level



## 5.1.2 Architecture with frequency conversion

This architecture is not applicable in North America (as all ocean going vessels are 60 Hz).

**Solution I:**
Each shore connection system includes its own frequency converter and is dedicated to the supply of one ship only. The shore connection system is supplied as above, either by the local utility or port substations (Fig. 23).

The principle is applicable to shore connection systems equipped with a single power converter unit as well as ones with several power converter units in parallel.

**Solution II:**
One central frequency conversion substation supplies one or several shore connection systems. Each shore connection system includes its own power transformer required for galvanic isolation (Fig. 24).

Fig.23 - Shore connection system with frequency conversion installed at berth

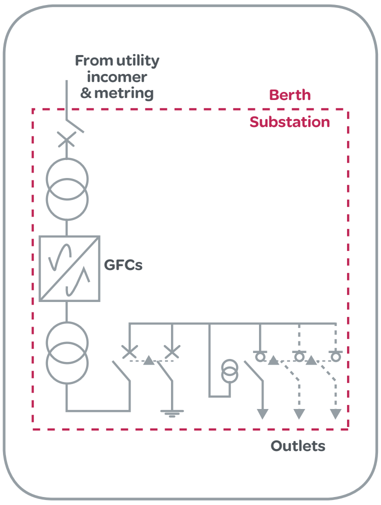
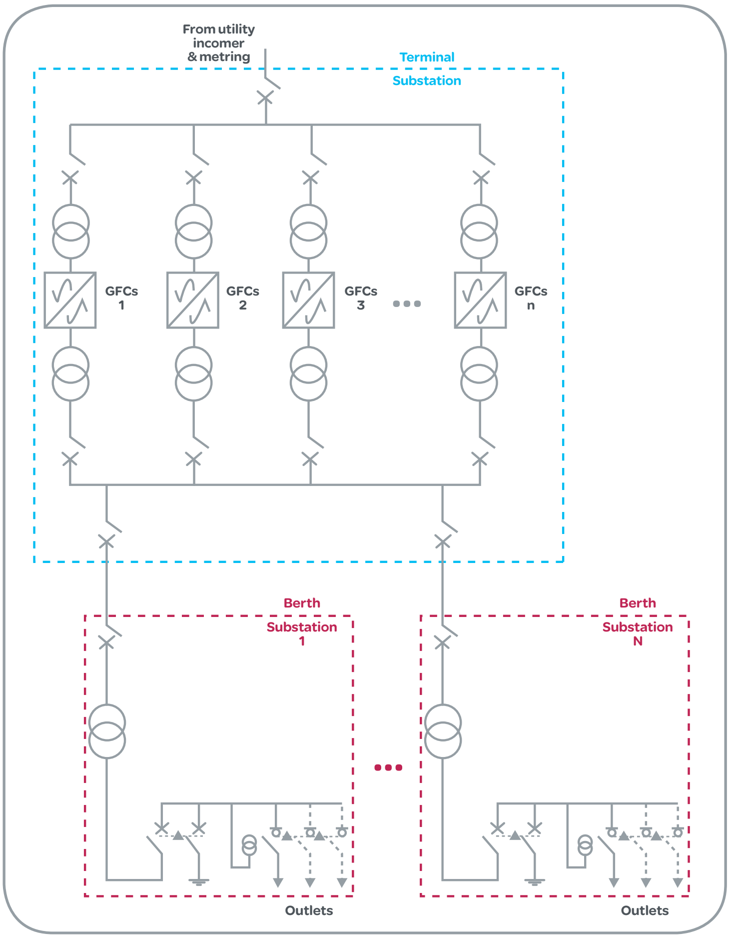



Fig.24 - Shore connection system with central frequency conversion substation installed at terminal level



## 5.2 ShoreBoX™

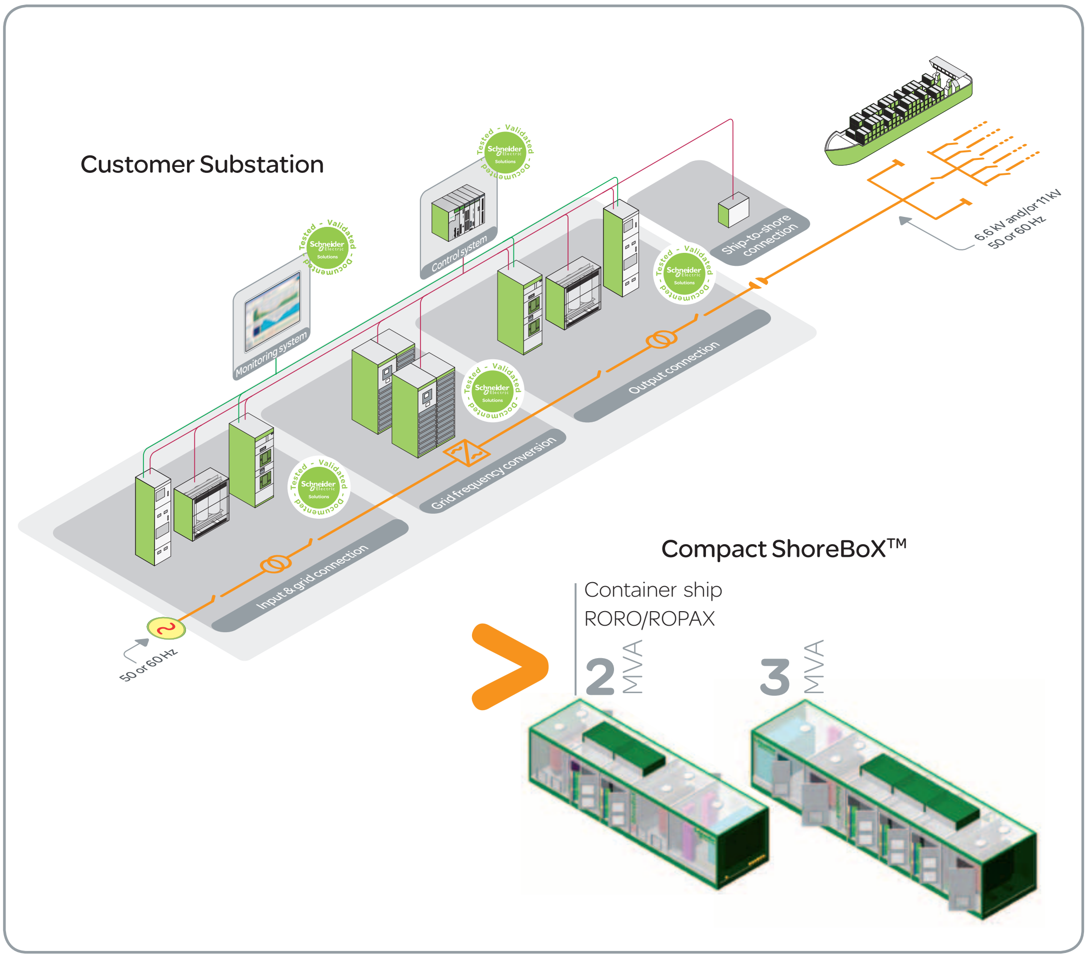
To make shore connection technology sustainable over the long term, both for ports and ships, Schneider Electric has developed an innovative solution called ShoreBoX™ (Fig. 25), designed to reduce CapEx, OpEx, and lead times.

### Optimized footprint & flexible solution

The ShoreBoX™ solution consists of a range of standard components. All shore connection modules include tested, validated, and documented architectures, while guaranteeing system reliability. Fully packaged in a single metal enclosure, ShoreBoX™ was designed with the utmost concern for space and cost optimization. When making complex investments of this scope, ports require support throughout the design, execution, and post-sales service phases. ShoreBoX™ includes support by dedicated local staff.

Ports are constantly-shifting environments. Berth conditions and ships' electrical power demand often change. ShoreBoX™ is designed to accommodate the needs of ships in tomorrow's ports and can be implemented and operated without disrupting port activities. ShoreBoX™ can also be adapted to suit different ships' power needs and electrical frequencies and to a variety of port infrastructures.

Fig. 25 - ShoreBoX™



## Safety

The main safety concerns are the protection of shore connection equipment operators and other people working or moving around in the vicinity of the installation.

Particular attention shall be given to ensuring safety during operation and maintenance phases:

- From direct and indirect electrical shocks by means of appropriate measures such as envelopes, barriers, equipotential bonding, interlocks, and safety instructions
- From internal arcs on the HV and LV switchboards
- During handling, plugging, and unplugging HV plug/socket-outlets by means of appropriate electrical and mechanical interlocks

All these features come standard with ShoreBoX™, and are tested and validated during the design phase.

## Energy management system

ShoreBoX™ includes an energy management and control system that enables ports to optimize their electricity consumption and thereby reduce operating costs. The system could track and report all data in real time, giving ports insight into energy-source selection, forecasts, simulation, metering, and billing. The system also could supply data on port environmental indicators to make a shore connection investment as green and efficient as possible.

## Efficiency

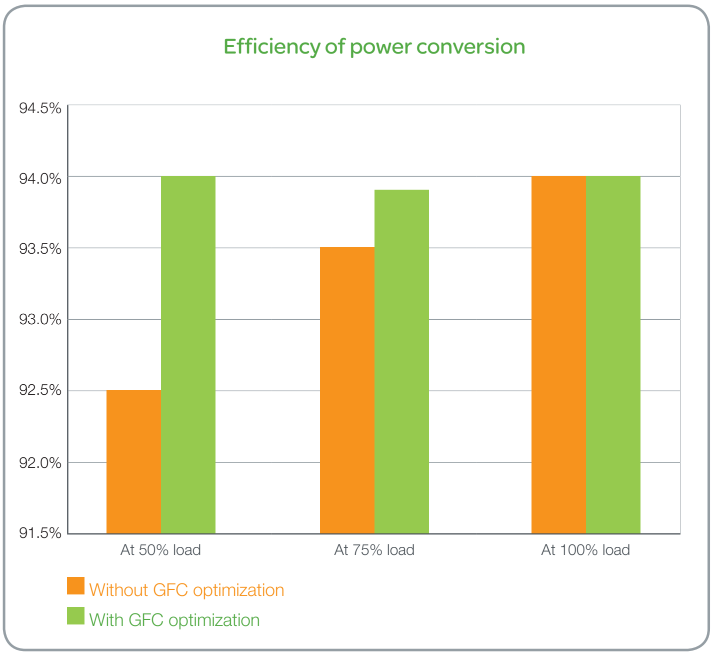
Efficiency is always one of the key points affecting the OpEx of any kind of installation. Generally at low loads, the efficiency of an electrical power system is reduced. The proposed shore connection solution offers a high level of efficiency across the entire range of operation.

One key device affecting the efficiency of shore connection systems is the frequency converter. High performance GFCs offer an interesting solution; an efficiency booster mode makes it possible to adjust the number of GFCs in operation according to the load required. Each GFC operates at close to its rated power with a high level of efficiency.

In addition, the number of fans and AC units running is controlled by internal and external temperature sensors to identify the system's point of maximum efficiency.

Fig. 26 gives the shore connection system targeted efficiency curve.

Fig.26 - **Targeted efficiency curve**



## 5.3 Operating instructions

A specific connection-disconnection procedure is required for each type of vessel (ferry, Ro-Ro, cruise and container). The main procedure is described in Fig. 27 and its application to different kind of ships in Fig. 28.

Fig. 27 - Shore connection system connection sequence

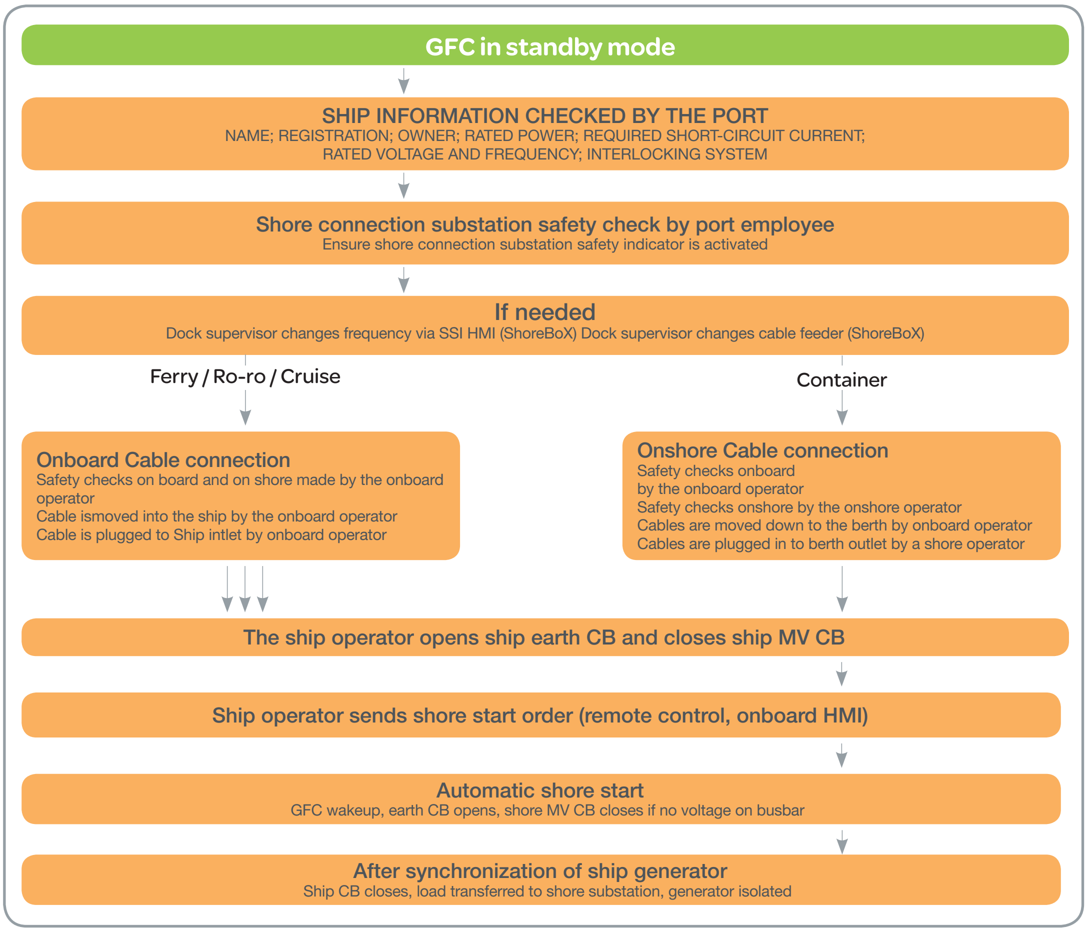
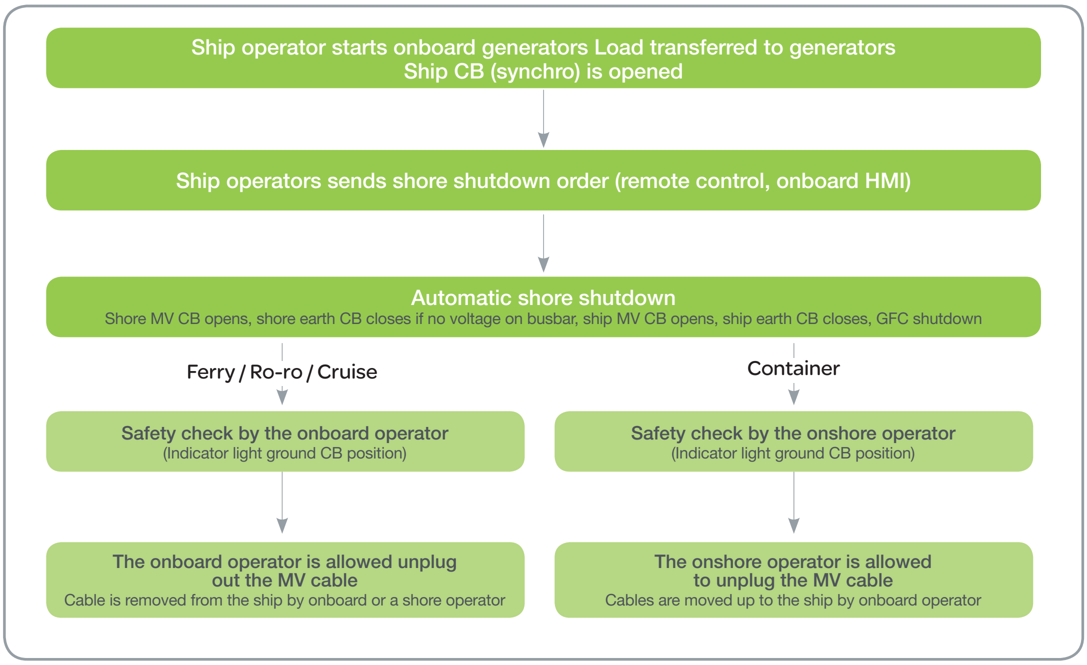


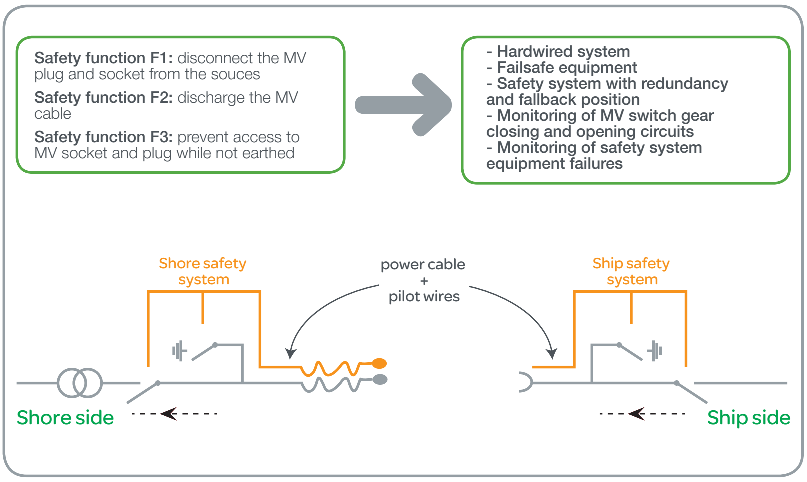

Fig. 28 - Shore connection system disconnection sequence



## 5.4 Safety system

Depending on the risks of handling and plugging/unplugging the MV plug, the safety system has to ensure the safety functions defined in section 4.3.1 with sufficient reliability to meet applicable safety standards (Fig.29).

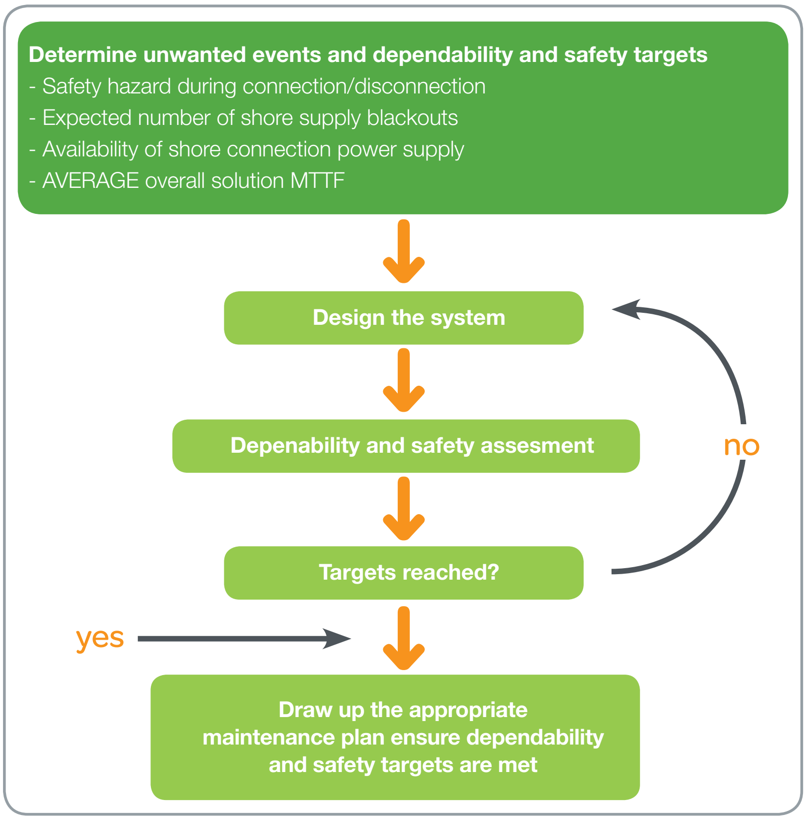
Fig. 29 - Safety system




## 5.5 Dependability

Shore connection systems are designed using dependability and safety assessments to optimize the system architecture, select the right equipment, and draw up the maintenance plan (Fig. 30).

Fig. 30 - Dependability and safety assessments



# 6 Conclusions

Environmental regulations are forcing the entire maritime industry to look for greener technologies. This white paper outlines some of the technical specificities of ship-to-shore electrical distribution systems, connection to these systems, and best practices. It also covers the main design and implementation challenges.

ShoreBoX is a new shore connection system that provides a cost-effective, efficient solution capable of handling high power levels via paralleling and that meets the needs of different types of ships.
ShoreBoX is a Schneider Electric Tested, Validated, and Documented solution.

Compliance with anti-pollution regulations is often viewed as a constraint. And yet, by choosing the right technology, it can open the door to new opportunities. Shore connection systems can generate fuel, energy, and cost savings from which the entire maritime industry can benefit.

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# Notes

## About the author

**Daniel Radu** received his Ph.D. degree in Electrical Engineering, in 2004, from the University “POLITEHNICA” of Bucharest, Romania. From 1998 to 2002 he has been assistant professor of Electrical Engineering in the same University. Follow this was involved in research and teaching activity with Power Engineering Laboratory of Grenoble – LEG, France. He is currently with Schneider Electric, France, since 2006. His interests include shore connection systems, low voltage power systems transient analysis, power systems modelling, LV and MV equipments and system design.
He participates as technical expert to TC18 & TC23 committees of IEC and is IEEE member since 2006. From 2012 he is convener of the IEC/ISO/IEEE JWG 28 Utility connections in port, a group of 30 international experts mandated to develop the Shore Connection Standards.

**Jean Paul Sorrel** graduated from the National Polytechnic Institute of Grenoble (INPG), he is qualified as electrical engineer. He worked for large engineering projects where he was mainly involved in power system and automation. He joined Merlin Gerin (Group Schneider) in 1983 as technical project manager for turn-key project prior to move to the marine activities where he was in charge of electrical propulsion system including power distribution, protection and control for surface ships or submarines. He is now in charge of anticipation, development and expertise for both industrial and marine activities.
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**Robert Jeannot** started his career in 1967. Joined Schneider Electric in 1972 and was graduated from the Conservatoire National des Arts et Métiers of Paris in 1978.
During 43 years he mainly dedicated his activities to the electrical engineering, designing large installations such as power plants, high voltage substations, chemical plants, hospitals, data centers etc...
Within Schneider Electric he held all the main technical positions from technical project manager up to the manager of the technical department.
Beside his main activities he took responsibilities in several organizations:
Quality: Definition of the process of Project Management,
Standardization: From 2000 up to 2010, Chairman of the commission CEF UTE 99 dedicated to high voltage installations,
University Joseph Fourier and ENSE3 of Grenoble : Courses on network protection systems and electrical engineering of industrial plants.

**Malik Megdiche** received his Master of Science degree and his PhD in Electrical Engineering from the National Polytechnic Institute of Grenoble (INPG) in 2001 and 2004. He is presently a power system engineer and reliability expert in Schneider Electric company. His main fields of interest are power system design, simulation and reliability and safety assessment in various applications like critical buildings, industrial plants and shore connection substations.

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