Connecting low power consumption vessels to shore-to-ship power facilities

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Shore-to-ship power and shore charging

In 2018, International Maritime Organization (IMO) has adopted ambitious targets to reduce greenhouse gas (GHG) emissions from maritime shipping, requiring shipping companies to perform a 50% cut of their GHG emissions by 2050, taking 2008 levels as the starting point.

To achieve the given decarbonization goals, a revolution must happen in shipping sector from a technology perspective, starting from the use of bio-fuels to vessel hybridization with battery energy storage systems or electrification with fuel cells generation on board, just to name a few options.

As a readily available solution that allows to achieve zero emission operation during their stay at berth, shore-to-ship power is now definitely taking pace. By means of shore-to-ship power solutions, vessel can turn down their engines and get the required power from the port electrical grid.

In addition to the well-known environmental benefits of shore power solutions, such as reduction in polluting emissions and noise in port areas, electric and hybrid vessels will also need battery charging facilities in ports, thus requiring a re-design of shore-to-ship power facilities to cope with those additional needs.
Different vessel types: specific needs

Any ship could potentially be connected to shore-to-ship power, but technical solutions vary substantially from one vessel type to another. There are many ways to categorize shore-to-ship power applications, but the three most popular ones are vessel type, on board voltage and power requirements.

### Table 1. Vessel voltages and power requirements

<table>
<thead>
<tr>
<th>Category</th>
<th>Power Requirements</th>
<th>On-Board Voltage</th>
<th>Applicable Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>LVSC</td>
<td>Low Power Consumption</td>
<td>≤ 1 MVA Low Voltage Vessel</td>
<td>440, 440, 690 V</td>
</tr>
<tr>
<td>HVSC – Low Power</td>
<td>Low Power Consumption</td>
<td>≤ 5 MVA High Voltage Vessel</td>
<td>6.6 - 11 kV</td>
</tr>
<tr>
<td>HVSC – High Power</td>
<td>High Power Consumption</td>
<td>≥ 5 MVA High Voltage Vessel</td>
<td>6.6 - 11 kV</td>
</tr>
</tbody>
</table>

This paper will further describe the various options for shore-to-ship power supply to low power consumption vessels (LVSC and HVSC-Low Power).
Low voltage shore connection (LVSC)

The traditional shore-to-ship power low voltage solution can easily be compared with a home-based e-vehicle charging facility. After berthing (parking), the vessel (car) is connected to the electrical grid by means of a static frequency converter with dedicated and fixed plugs. Main electrical components of a low voltage shore-to-ship power system are shown in figure below.

![Diagram of low voltage shore connection](image)

**Figure 4. Low voltage shore connection (LVSC) conceptual single line diagram**

Low voltage shore connection solutions must be compliant with IEC80005-3 standard. Depending on vessel power demand and on-board voltage, a different number of plugs will have to be used for shore power connection.

<table>
<thead>
<tr>
<th>POWER DEMAND</th>
<th>VOLTAGE ON BOARD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>400 Vac</td>
</tr>
<tr>
<td>up to 250 kVA</td>
<td>2</td>
</tr>
<tr>
<td>251 - 500 kVA</td>
<td>3</td>
</tr>
<tr>
<td>501 - 750 kVA</td>
<td>4</td>
</tr>
<tr>
<td>751 - 1000 kVA</td>
<td>5</td>
</tr>
</tbody>
</table>

*Table 2. Low Voltage Shore Connection – Number of Plugs*
Due to high number of high voltage cables/plugs required, for power demands higher than 1 MVA shore-to-ship power connection usually shift to high voltage.

**High voltage shore connection (HVSC) – low power**

Typical solution for a single high voltage shore connection is shown below.

![Diagram](image)

Typical rating of a low power high voltage shore connection is 1 to 5 MVA.
High voltage shore connection (HVSC) – energy storage option

Some customers might have additional site-specific application requirements such as:

- Immunity to voltage sags
- Continuity of operation during temporary loss of grid power supply
- Peak shaving/power boost in case of weak port grid

In all the above cases an additional energy storage system would be required, the type of storage and its dimensioning being defined on a case-by-case basis.

*Figure 6. High voltage shore connection (HVSC) with energy storage system (ESS)*
To achieve immunity to voltage sags that have usually a duration spanning from tenth of microseconds to a few seconds, an ultracapacitor energy storage system would be integrated on the static frequency converter DC bus by means of an additional DC/DC converter.

On the other hand, continuity of operation during power outages would require a battery energy storage system that shall be properly dimensioned according to the expected maximum time of such power outages.

Finally, a system study shall be carried out to determine the best dimensioning of an energy storage system for peak shaving or power boost, as this option would be applied whenever a shore-to-ship power supply or electric/hybrid vessel charging occurs in ports having a weak grid.

Some key factors to be taken into consideration in this case are:

- Vessel nominal and peak power requirements
- Power available by the port electrical grid
- Time available for on-shore power battery charging process when vessel is not connected

System dimensioning shall be therefore performed with the aim to make sure that the sum of port grid available power and battery energy storage available power covers the overall vessel consumption requirements for the whole time of its stay at port (dimensioning criteria: peak power requirement). In addition to that, a sufficient quantity of batteries shall be envisaged to ensure that the re-charge cycle can take place when vessel is not connected, thus allowing the required energy to be stored in batteries (dimensioning criteria: energy requirement).

**Low power consumption S2SP solution – centralized concept**

When a relatively high number of low power vessels shall be connected to a shore-to-ship power facility, the option to use a centralized solution shall be taken into consideration as this will allow significant benefits:

- Lower CAPEX, as a single shore-to-ship power system can be used to feed multiple vessels
- Lower OPEX, as the number of items composing the system is optimized (reduced maintenance costs) and the efficiency of the system is increased (only the inverters/transformers connected to one vessel are active)
- Smaller Footprint, enabled by compact and pre-engineered solution that can be installed in standard ISO containers
This design is possible thanks to the intrinsic modularity of the low voltage frequency conversion platform.

Two possible options can be considered for a centralized solution:

- Single rectifier with full power and one inverter/transformer pair per vessel
- One rectifier/inverter/transformer group per vessel

Both configurations ensure full flexibility of simultaneous connection of 50 and 60 Hz vessels at different output voltages (both low voltage or high voltage).

In the first case, an additional CAPEX saving is granted by the use of one rectifier device that will be activated once the first vessel is connected while each inverter/transformer pair is energized on demand.

The second option allows full flexibility of operation, allowing higher efficiency since each rectifier/inverter/transformer group is energized on demand.
Low power consumption S2SP solution – multiple connections

Multiple vessels can be connected independently by paralleling static frequency conversion devices. In this case, each vessel has an independent shore-to-ship supply rated at full power.

With the installation of a bus-tie-breaker, additional flexibility of operation can be easily achieved, as this design also allows one shore-to-ship power system to be connected alternatively to any of the two vessels in case maintenance is being performed on the twin system.

Figure 8. Low power consumption S2SP – multiple connections
This configuration could also be potentially used to enable an optional high power consumption shore-to-ship power system where, under certain conditions, a double power vessel can be supplied.

This configuration allows flexibility of operation in ports where two small low power consumption vessels or one high power consumption vessel can be alternatively berthed in a certain area of the terminal.

To enable this functionality, the rating of the vessel side interface components shall be dimensioned for double power (and current) flow. Moreover, control and protection system shall be customized to allow the re-configuration of the shore-to-ship power facility for one or two vessel operation, allowing full operator safety.
Conclusions

Shore-to-ship power solutions help ports to reduce their environmental footprint enabling clean energy provision to vessel and consequently eliminating diesel emissions, noise and vibration caused by on-board auxiliary generators.

As a result, working, transit and living environment in and around ports are significantly improved, as well as relationship with surrounding communities.

However, the large deployment and success of shore-to-ship power requires a design and implementation of cost-effective solutions that can serve different vessels segments and local requirements.

The role of the technology supplier is to make available state-of-the-art, modular and flexible solutions that allow achieving the best compromise between capital expenditures and operational costs for any vessel segment and port customer.
ABB Power Grids is a pioneer in shore-to-ship power solutions and smart ports, providing fully integrated systems and a broad range of services. In 2000, ABB Power Grids delivered the world’s first shore-to-ship power system to the Swedish port of Gothenburg. Today ABB Power Grids offers a single interface for complete port electrification and grid integration, in line with global specifications and standards.