ONSHORE POWER SYSTEM, CONNECTION TO REDUCE EMISSIONS

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ABSTRACT

The presentation gives information about the actual status of emissions from ships in harbors. It outlines possibilities to reduce these emissions by using onshore power supply to provide ships with electrical power in harbors. Economical and environmental aspects are considered.

ONSHORE POWER SYSTEM

Actual situation

The actual situation of ships in harbors shows that moored ships produce a lot of emissions. One of the main problems is the Sulfur dioxide (SO$_2$) emission which originates to 94% from ships in harbor cities.

SO$_2$ Emissions measured in Luebeck, Germany
Values in t/a

<table>
<thead>
<tr>
<th>Source</th>
<th>Emissions (t/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trucks/Cars</td>
<td>5</td>
</tr>
<tr>
<td>Rail</td>
<td>0.4</td>
</tr>
<tr>
<td>Busses</td>
<td>19</td>
</tr>
<tr>
<td>Heating</td>
<td>0.4</td>
</tr>
<tr>
<td>Ships</td>
<td>393 (94%)</td>
</tr>
</tbody>
</table>

Reference: German meteorological service (DWD) / City of Luebeck, sector environment, 1994

Figure 1: SO$_2$ emissions measured in harbor

The European community predicts that short after 2010 the SO$_2$ emissions of all ships will exceed the SO$_2$ emissions of the complete land based traffic due to more stringent emission regulations in the different countries on the one hand and the increasing ship traffic without regulation on the other hand.

Now it’s time for a change. A change to better environmental conditions and manageable power costs in harbors in the future for the ship owners. A change to a win-win situation for ship owners, utilities, harbors, residents and the environment.

Solution

One possible solution for this is the Onshore Power Supply, an electric feed to the ships from onshore.

4 Steps for onshore power to the ship

Receive it
Convert and/or adapt it.
Separate it.
Supply it
Distribute it (onboard the ship)

Figure 2: 4 steps for onshore power supply

This is no trivial job because the frequency of the shore grid and the frequency of the ships grid are different in most countries. 2/3 of all seagoing vessels have a 60 Hz ship grid. In all European countries these ships can not be connected to the shore grid directly. The frequency must be converted.

A second fundamental topic is that the shore grid and the ships grid must not be connected directly. They must be separated galvanically by means of a transformer because the neutral point treatment of shore and ships grids are completely different.

In the first areas onshore power systems are established, California (USA), Gothenburg (Sweden), Lübeck (Germany). Onshore power became a top topic as everybody can find in the internet. Try using Google with the key words:
- Cold ironing
- AMP (alternative maritime power)
- Onshore power
- Shoreside power
Emission comparison

<table>
<thead>
<tr>
<th>Emission factors from ships engines using</th>
<th>CO₂ (g/kWh)</th>
<th>NO₂ (g/kWh)</th>
<th>SO₂ (g/kWh)</th>
<th>PM (µg/kWh)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2,7% sulphur fuel</td>
<td>0.34</td>
<td>12.47</td>
<td>12.30</td>
<td>0.80</td>
</tr>
<tr>
<td>0,1% sulphur fuel</td>
<td>0.13</td>
<td>11.80</td>
<td>0.46</td>
<td>0.30</td>
</tr>
<tr>
<td>Emission factors from shore power EU average</td>
<td>0.15</td>
<td>0.35</td>
<td>0.46</td>
<td>0.03</td>
</tr>
</tbody>
</table>

Source: Entec UK Ltd, report for European Commission

Figure 3: Emission comparison between ship and shore

The emission comparison between emissions from ships using different fuel and the emissions from shore-side power plants generating the same power show that some emission problems (for example SO₂) can be solved using different fuel but most of the problems can not. The huge amount of Nitrogen oxides (NOₓ) produced on ships is inherent to the system using piston engines. In harbor cities more than ¾ of the NOₓ emissions derive from ships.

NOₓ is the main emission problem nowadays, more severe than sulfur dioxide. NOₓ acts as a fertilizer in the sea and leads to huge algae growth which is a severe problem because it reduces the oxygen in the water and fish motility reaches alarming proportions. Under severe conditions the water can collapse making living impossible. Especially water areas with low fresh water exchange are endangered like the Baltic sea.

And even the CO₂ production is reduced with shore power because the efficiency of big power plants is better than that of relatively small diesel generators. In addition part of the electrical power ashore is produced by water, wind, solar or nuclear plants, which do not generate CO₂.

**Frequently asked questions (FAQ)**

Generally there are some concerns against onshore power and the fact, that ships are not independent any more when laying in harbors. The most commonly asked questions are:

**How long does it take and how complicated is it to connect the vessel?**

Generally it is getting the power cable from or to the ship, plugging in a connector, pushing a button and shutting down the diesel generators. All this is done within a few minutes.

If a testing of the cable connection to the ship is required, this seems to take more time than the connection procedure. But there are possibilities to speed up this procedure also.

**Do all vessels have a lead-in for electrical connection?**

Almost each ship has a lead-in which is used when the ship is docked in the yard for maintenance. These lead-ins are normally dimensioned for lighting and some fans which is not enough for a ship laying in the harbor. But these lead-ins can be improved for the greater amount of power.

**Frequently Asked Questions (FAQ)**

**Is it possible to connect older ships electrically?**

This is entirely possible. What is required on board are a main switch and a transformer. The electrical lead-in can be located anywhere on board, for example near a bunker, hatch or other entrance.

**Why go for medium voltage?**

Medium Voltage connection

Low Voltage connection

*Gothenburg*  
*Los Angeles*

Figure 4: Frequently asked questions

**Is it possible to connect even older ships electrically?**

Even older ships can be refitted to onshore power supply. If the lead-in for the yard is not used there will be some other opening which is accessible. If the owner does not want a hole in the hull of the ship, it is possible to bring the cable up to the main deck where you will find a lot of entrance possibilities for the cable with the plug.

**Why use medium voltage, when the ships mains is low voltage?**

The first onshore power supply systems in USA started with low voltage plugs. The cable connection ended up with 12 plugs which needed some time to be connected and were hard to monitor. In Gothenburg only one single medium voltage cable is used which is easy to monitor.

**Basic conditions**

**Basic preconditions for a High Voltage Onshore Power System**

Simple plug-in connection from the shore side with interlocking to prevent the plug-in connection from being opened during operation.

Personal safety is guaranteed by a safe interlocking system.

Connection is automated, so that people without special training can operate it safely. Mooring personal must be able to make the connection.

Automatic start-up of the on-shore power supply released by the ship when the plug-in connection is ready.

The ship keeps the command over the shore side power supply. It controls start and stop and synchronisation.

Control of different frequencies from the shore side to the ship side (50 – 60 Hz) for different kinds of ships.

Figure 5: Basic conditions for HV-OPS
The basic preconditions for a shore-to-ship connection are:
The connection must be simple with an interlocking, so that it cannot be unplugged when energized. Mechanical interlocks prevent the access to the energized plug and socket connection. In addition pilot contacts switch off the power as soon as the plug and socket connection is opened.

It must be safe for the people who operate it. This can be achieved by the interlocking in the automation systems on board and ashore.

The interlocking prevents that the plug moved is under voltage. The plug is only accessible, when it is solidly earthed. The automation systems onboard and ashore only release the earthing when the plug is safely connected and mechanically secured. No manual switching is necessary ashore.

The start-up must be automatic under control of the ships engineer. So the ships engineer must not be trained especially to make the connections. The intelligence for the start-up is stored in the automation systems.

The automation systems are designed in that way, that all necessary actions are coming from the ships control room. The shore system is remote controlled from the ship system.

The shore-to-ship connection must be able to provide 50 AND 60 Hz to the ship. About 2/3 of the ships worldwide are 60 Hz ships, the others are 50 Hz ones. The harbor must be prepared to serve all ships coming in.

The plug which is able to transmit 6 MVA at a voltage of 11 kV is only 53 cm long and weighs about 10 kg. It can be handled by one person. The most part of the weight comes from the cable connected to the plug.

The industrial used plug and socket system is proven since years for different applications in different areas for example mining or tunnel drilling which are very harsh environments. So it’s the right choice for this application.

The block diagram shows, what is necessary for an onshore power supply. At the top the medium voltage distribution can be seen. This is available in harbors and can be adapted to the additional needs of the ships.

At the bottom of the drawing two ships are shown, on the left a big one which needs more power than 5 MVA, on the right a smaller vessel which needs up to 5 MVA.

In between the converter is shown which changes the frequency according to the ships needs. It is water cooled and the heat exchange can be done with water as shown in the middle of the picture or with air as shown left. Both possibilities can be used according to the local conditions.

The simple line from the converter is not that simple as drawing a line in a block diagram. There are different designs and ideas to solve this challenge. This must be discussed in close contact with the port operator according to the specific needs of the harbor or the quay.

### Economic and environmental prospects

**Economic Background**

- Theoretically, one kg of MDO generates about 5, practically 3.5 kWh.

- At an MDO price with a sulphur content < 1% of about 46 US ct, each kWh generated on board costs about 11 € ct.

- According to the present market prices for electrical power, the on shore kWh prices are up to 50 % lower, depending on day/night power.

- The calculation for kWh generated on-board out of MDO also have to consider losses for ancillary components as cooling pumps, fans, fuel heating, fuel pumps, etc. and maintenance for diesels.

- The use of heavy bunker reduces the output to 2.9 – 3.1 kWh due to losses for fuel heating.

**Figure 8: Economic background**
The economic background dated Dec. 2008 shows that each kWh produced costs about 10 € cent. 4 months earlier each kWh produced onboard was double the price. Basis of this calculation is the fact that from 2010 onwards only low sulfur fuel is allowed in European harbors. So the price for this fuel is used in the calculation. Prices for electrical power have been reported between 4 € cent (4,5 $ cent port of Los Angeles) and 6 € cent (port of Rotterdam), which is very much lower than the prices for power produced onboard.

Environmental Background

Figure 9: Environmental background

For the environmental background a container vessel using 3 MVA of electrical power is used as a calculation model. This is the size of a medium container vessel. The calculation shows the amount of emissions which can be saved when the vessel is supplied from the shore, although the production of power onshore also produces emissions.

To produce the power of 3 MVA for 24 hours the vessel would need 16,5 t of fuel. It would produce 36,5 t of CO₂. The same amount of power produced onshore would only emit 23,9 t of CO₂ which leaves a difference of 12,6 t of CO₂ saved.

The adequate savings for NOₓ are 700 kg, for SOₓ 680 kg and particulate matter 44 kg. The above mentioned values are savings which happen EACH DAY for EACH VESSEL.

The savings multiplied with the number of berths in the harbor and the days in use gives the huge amount of possible savings on emissions made possible with onshore power supply.