Diesel and turbine electric propulsion of ships

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Introduction
Diesel or turbine electric propulsion of ships is of current interest for several types of ships that are important for norwegian shipping. This also includes platform supply vessels, which are chosen as an example here.

When designing a platform supply vessel a choice has to be made between two different fundamental concepts regarding propulsion; a conventional, straight diesel drive and diesel electric propulsion. For both concepts, the electrical installations are very compact with short distances from generators to consumers. This gives several consequences that are particular for these installations. Common to most platform supply vessels is high generating power, often about 6 - 7 MW, due to large electric thrustermotors. Such a solution also implies high load currents and large fault currents.

Propulsion system for a platform supply vessel
For the analyses two different vessels already in operation are selected as examples. These are considered to be typical examples of the two concepts above.

The vessel with conventional propulsion is powered by two medium speed main engines, each rated 3235 kW and connected to 2600 kVA shaft generators and controllable pitch propellers. There are also two auxiliary diesel generator sets, each rated 450 kVA. The total installed generator power is about 6100 kVA, the main bus voltage is 440 V. There are three tunnelthrusters and one azimuththruster, all powered by asynchronous motors and with controllable pitch propellers.

The diesel electric vessel is powered by four identical medium speed diesel generator sets, each diesel engine with a rating of 1470 kW. The total installed generator power is about 7100 kVA, the main bus voltage is 690 V. There are three azimuththrusters (two of them also used for propulsion) and one tunnel thruster, all fed by frequency converters. All propellers are fixed pitch.

Electric propulsion systems usually mean higher investments. However there are possibilities of reduced fuel costs and often improved total economy. For this type of vessel the figures indicate that the diesel electric concept implies 70-100% increased investment costs of the power generating and propulsion system, representing 5-10% of the total investments of the vessel. Investigation of the operation costs give a payback period of the higher investments of 1 to 5 years, depending on how the ship is operated.

The availability of diesel electric propulsion systems may be designed to be high compared with straight diesel drives, mostly because of the modular design with several units in parallel and the reduced number of moving parts. Calculation of MTBF numbers indicate results as given in table 1 for the selected examples.

Simulation of maritime power systems
A part of the work is definition of suitable computer models for the electric power system, including the prime movers and generators with regulators, as well as the main motordrives etc. Both static and dynamic models must be established. The static models must cover analyses of load flow for different modes of operation, short circuit
calculations and harmonic analyses. The dynamic models must cover stability studies e.g. conditions during motor start-up, generator tripping and temporary short circuit situations.

When the short period with both shaft generators in parallel for the conventional vessel is taken into account, the short circuit levels are quite similar for the two vessels. In this case the short circuit level for the diesel electric vessel is a little lower than for the conventional vessel, due to the higher voltage level and the fact that asynchronous motors connected to the power system via pulse width modulated converters do not contribute to the short circuit current. The results are summarized in table 2.

Calculations of harmonic distortion to current and voltage has been performed by the American computer program EDSA. The measurements and calculations show that harmonic distortion of the bus voltages is not a problem for the conventional vessel, while the rules from Det norske Veritas are partly exceeded for the diesel electric vessel, see table 2 for maximum values. The system works satisfactory despite of this.

The transient analyses have been performed by the computer program SIMPOW developed by ABB Power System AB in Sweden. SIMPOW contains a library of models quite suitable for offshore analyses. For ships, however, the models for the diesel engine, speed governor and voltage regulator must be made from scratch. Models for static converters are also missing. As a part of this work full scale measurements have been made onboard the two example vessels. Some of the results are presented in table 2 and figure 1.

### Table 1: Comparison of availability

<table>
<thead>
<tr>
<th>Scaled MTBF</th>
<th>Conventional</th>
<th>Diesel electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Normal propulsion”</td>
<td>1</td>
<td>50 - 100</td>
</tr>
<tr>
<td>“Take me home”</td>
<td>2</td>
<td>&gt;&gt; 1000</td>
</tr>
</tbody>
</table>

### Table 2: Comparison of dimensioning criteria

<table>
<thead>
<tr>
<th></th>
<th>Conventional</th>
<th>Diesel electric</th>
</tr>
</thead>
<tbody>
<tr>
<td>Trans. voltage drop</td>
<td>-14.6/-16.1%</td>
<td>-7.5/-8.3%</td>
</tr>
<tr>
<td>Voltage overshoot</td>
<td>+13.0/+23.0%</td>
<td>+2.9/+4.5%</td>
</tr>
<tr>
<td>Trans. speed dev.</td>
<td>+4.17/+3.8%</td>
<td>-3.0/-1.3%</td>
</tr>
<tr>
<td>Sc current</td>
<td>-/49.9kA</td>
<td>-/45.3kA</td>
</tr>
<tr>
<td>THD</td>
<td>0.5/-%</td>
<td>14.56/15.3%</td>
</tr>
</tbody>
</table>

**Figure 1:** Measured and simulated line voltages during a direct start up of an asynchronous machine.

### Further work

The first step is to refine the models for the diesel engines and governors. Then all necessary analyses when designing different types of vessels will be described, and simulations carried out for the examples. From the results, guidelines for designing ship power systems will be made.

### References