Diesel-electric propulsion concepts – How to match environmental and economical challenges?

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Electrical installations are present in any ship, from powering of communication and navigation equipment, alarm and monitoring system, running of motors for pumps, fans or winches, to high power installation for electric propulsion. Electric propulsion is an emerging area where various fields of competence meet. Successful solutions for vessels with electric propulsion are found in environments where naval architects, hydrodynamic and propulsion engineers, and electrical engineers cooperate under design, operational, and economical considerations. An optimized design can only be achieved with a common concept language and mutual understanding of the different subjects.
This lecture gives an introduction how to match environmental and economical challenges by means of diesel-electric propulsion systems. At present, electric propulsion is applied mainly in the following types of ships: Cruise vessels, ferries, DP drilling vessels, thruster assisted moored floating production facilities, shuttle tankers, cable layers, pipe layers, icebreakers and other ice going vessels, supply vessels, and war ships. There is also significant research of using electric propulsion in new vessel designs for existing and new application areas.
Some simplified considerations of power flow and power efficiency at full load and part load conditions are shown. This shows clearly the advantages of a diesel-electric propulsion system during part load conditions in comparison to a diesel-mechanical configuration. The diesel-electric propulsion system exhibits only a small difference in efficiency between full load and part load conditions.
The consideration of the power demand characteristic shows the constraints of diesel-electric propulsion systems. If part load conditions occur rather seldom, a diesel-mechanical configuration has economical benefits.
Some selected examples show that these general statements on efficiency of different propulsions concepts are tailored to concrete numbers by methods of model based design. The simulation tool Matlab/Simulink is used for this purpose.
The following characteristics summarize the main advantages of diesel-electric propulsion:

- Improved life cycle cost by reduced fuel consumption and maintenance – if there is a large variation in load demand
- Reduced vulnerability to single failure in the propulsion system and possibility to optimize loading of prime movers
- Application of light high- or medium-speed diesel engines
- Less propulsion noise and vibrations inside the power train since the propulsion torque is smoother
- Prime movers are running on fixed speed and inside an optimal load range

These advantages should be weighted up against the present penalties, such as:

- Increased investment costs
- Additional components (electrical equipment – generators, transformers, drives and motors/machines) between prime mover and propeller increase the transmission losses at full load

It is furthermore important to consider the total system of both the electric power generation and the power train. To increase the overall efficiency it is necessary to include waste heat consumers. The development of future power plants with combined systems consisting of diesel engines, gas turbines with high efficiency and fuel cells is an additional challenge. Finally, model-based design and simulation is an important factor towards technological innovation.

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