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Master Thesis in Marine Systems Design

Factors Influencing Machinery System Selection for Complex Operational Profiles

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Introduction

New stricter requirements to emissions to air lie in the near future. The International Maritime Organization (IMO) have announced that by 2015 the regulations known as "Tier III" will take effect in the emission controlled areas (ECA) and globally by the year 2020. This has a great impact for the shipping industries, which is a large contributor to global emissions of green house gasses (GHG). The shipping sector must adapt to these new regulations and has to reduce the emissions. Inspired, or pushed by this, new and more energy efficient equipment and solutions enters the marked.

There are many benefits in installing a modern hybrid diesel electric propulsion system with energy storage capacity instead of a more traditionally diesel mechanic system. The most important factor for the ship operator is the cost. Both the investment cost and operating costs. The biggest contributor to the latter is the fuel cost. Even if the investment cost is larger for a diesel electric system it will pay off in the end, especially if the fuel price rises. However, not all ships will benefit equally from this system configuration, and the advantages will to a large extent be determined by the static and dynamic power requirements related to the vessel´s operating profile.

The overall objective of this thesis is to identify the cutting point between selecting hybrid power systems which combines energy production with energy storage capacity and diesel mechanic systems based on operational profiles and external influences such as cost, route, distance, weather conditions, maneuvering and type of operations.

Scope of Work

1. Provide an overview of state of the art hybrid power systems and diesel electric machinery configurations and trends for the future.
2. What are the limitations for the power systems
3. Identify todays decision criteria's and the influencing factors for the two machinery systems
4. Develop a set of possible operational profiles and cases for a PSV
5. Evaluate the selection of machinery system based on the operational profile and influencing factors.
6. What types of vessels and operations are best suited for the modern hybrid power system?
7. Discuss the results and conclude

Influencing Factors

Operational Modes

During a period of time an Offshore Support Vessel may experience several different and varying load demands due to the many different types of operations and conditions they may handle. Usually the supply vessels have a total installed power between 6 and 10 MW. Large construction and anchor handling vessels may have installed up to 20 MW of power. An example of an engine operating profile for a typical OSV is given in Figure 1 below. As it can be seen, the engines operate below 50% load for almost 75% of the time (1).

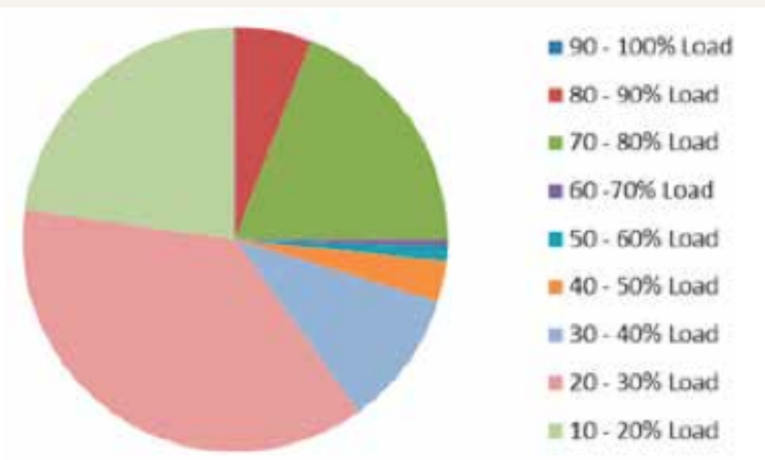

Figure 1 Example of Engine Operating Profile for typical OSV (1)

DP guidelines and requirements to redundancy

Reliable and robust methods of positioning of vessels are required for safe supply vessel operations at offshore installations. To a large extent, offshore supply vessels are now being fitted with dynamic positioning systems. The growth in use of DP over the last decades has been accompanied by the development of internationally recognized rules and standards against which DP vessels are designed, constructed and operated. These include IMO MSC Circ.645, "Guidelines for Vessels with Dynamic Positioning Systems", DP rules of the main classification societies and IMCA M 103, "Guidelines for the Design and Operation of Dynamically Positioned Vessels". The rules and guidelines are focused principally on design, construction and operation of DP vessels and, in particular, apply the principles of redundancy and creating a hierarchy of DP equipment classes.

Influencing Factors

Redundancy

The requirements to redundancy, in the power system when operating on DP, are maybe the main reason for low loads on the prime movers. In the Norwegian sector of the North Sea, rules and regulations from the government prohibits the operators to run all switch boards connected. This is done to prevent a total blackout of the whole system. With a split system a worst-case failure will be a partially blackout and the system can continue to operate. To ensure enough power to operate after a single fault most of the engines must be running at all time, even though the power demand is not necessarily very high.

Operational Profile

When a costumer, ship owner or operator wants to order a new vessel he or she has a set of requirements and specifications related to type of ship and operation of the ship. In the process of designing the optimal machinery with the right performance features corresponding to the owners requirements an as accurate as possible operational profile is necessary. In what area will the ship operate, what are the conditions and regulations there, what is the itinerary, what are the specific operations to be performed and for how long time?

Moreover, if we take a closer look at a specific operating profile for a PSV, different types of variations will appear. Some are very high lasting for seconds only, i.e. propeller appears above the surface of the water due to waves. Others may last for longer periods as for example sudden need of thrust for small changes in position when in DP-mode caused by wind, current or other factors. This will have a great influence on the selection of the best-suited machinery system for the specific operational profile and needs to be analyzed thoroughly.

Environmental Effects

There is an increasing focus on the emissions of green house gasses from the shipping industry. CO_2 emissions from maritime transport represent a significant part of the total global green house gas emissions and have a severe negative effect on global warming. According to IMO the emissions from the maritime industry represents over three per cent of the world's total CO_2 emission. If actions are not taken and business goes on as usual it is expected that the emissions are going to increase by as much as 150-250%. IMO is currently considering and debating both technical and marked based measures for reducing the emissions of green house gasses from shipping.

Weather Conditions

The weather conditions in the area of operation will affect the dynamic loading picture of the vessel. Weather characteristics and statistics are given for many of the operation areas such as the North Sea and the Gulf of Mexico. This will give an indication on dynamic power demands needed for the vessel when e.g. operating in dynamic positioning mode, and must be taken into consideration when evaluating the best suited machinery system.

Model

In order to evaluate the best suited machinery configuration based on the operational profile a simple model has been made. In this model, three steps are taken to evaluate the operating profile of a vessel to evaluate the influencing factors as a decision support to select the best suited machinery system. A simple calculation and comparison on fuel consumption and lifetime costs is done in the end to see whether there is an economical benefit in the long run.

Step One

By analyzing the power demand as a function of time in an operational profile one can get an impression of if it is a profile with a varying power demand or a more constant profile where the engines most of the time may run at a constant speed. The idea behind this is that a vessel which has a wide spread of average power demands during a cycle of operation, i.e. 20% of installed power is required for one type of operation over a time period (DP) and 70% for another period (transit) etc. Operating profiles that experience frequent changes in the power demand will have a higher variation from the mean value than vessels with more constant power demand during an operation cycle. This can be measured up against the ratio between the amounts of time spent in dynamic positioning, which leads to low load and a high amount of transients on the engines, and the time spent in transit mode, which normally allows the engines to operate at more constant loads. The result will give an impression on what kind of power system that might be suitable as seen in Figure 2.

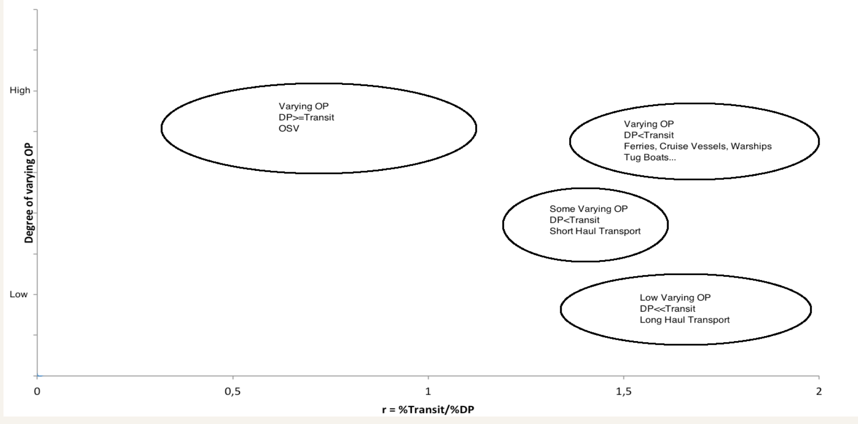

Figure 2 Variation in OP vs. Transit/DP

Model

Step Two

The next step will be to look at the relationship between static and dynamic loads and disturbances on the generators caused by the different consumers in the power system. It is important to determine, or give a good estimation, of the dynamic disturbances and separate them from the static power disturbances. The weather characteristics in the area of operations and what type of operation that is supposed to be performed have a great impact on the estimations of the dynamic power level.

Step Three

The implementation of a hybrid power system has many advantages. Most of them are totally dependent on the operational profile of the engines. If the areas of benefit are systemized and measured up against the operating profile of a type of vessel it will be easier to get an overview of which ship types that will suit the hybridization. By giving a score for each ship type and the areas of benefit, the best-suited vessels can be found. The score can be given a value of 1 to 5, where a score of 1 means that the benefit area is not applicable for that vessel and a score of 5 is given to vessels where the benefit is very relevant.

Results

A calculation of the differences in the annual costs of operating the ship with diesel electric and hybrid configuration over a period of 30 years has been performed. Only the capital and operational costs in form of installation cost, fuel costs and emission taxes are considered. Other costs as building costs, maintenance costs, etc. are not considered, because they are assumed equal for the vessel with both machinery systems.

Two scenarios have been evaluated. One with constant fuel and battery prices over a 30 year period and another with rising fuel prices and reduced price of the battery package over the same period of time.

In the case with increased fuel prices and reduced cost for reinstalling the battery pack 3 the potential benefits are higher. The payback time for the hybrid system is about the same as in the constant price scenario, just below five years, and it will remain profitable for the rest of the period, even after the replacement of the battery pack. After 15 years of operation the potential benefit in cost savings will be approximately 7% and after 25 years it will be almost 10%.

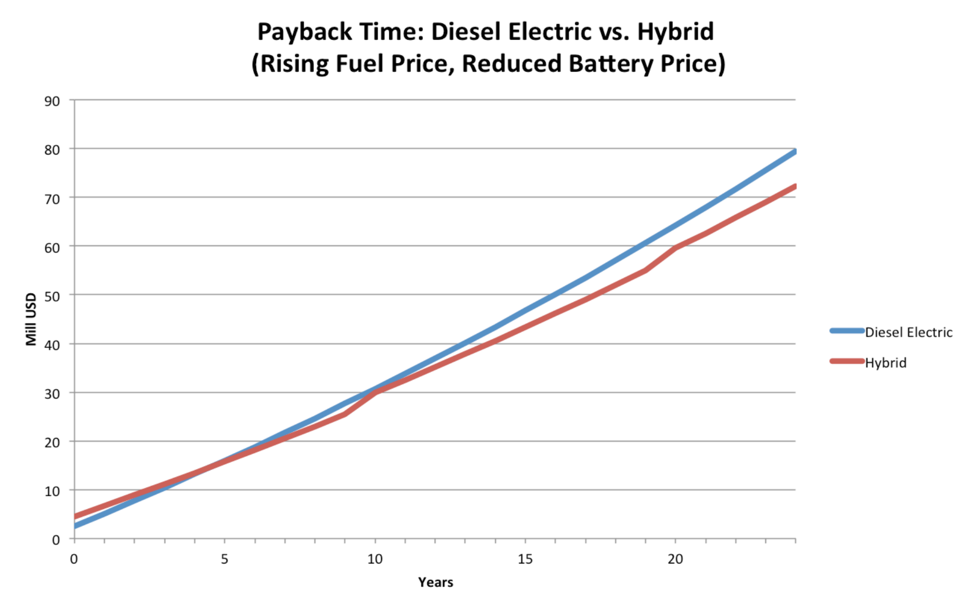

Figure 3 Payback Time Diesel Electric vs. Hybrid with Changing Prices

Conclusions

The results in this work shows that for complex operational profiles with a high degree of varying load demands various forms of diesel electric machinery configurations or hybrids are the best suited systems. For complex operational profiles with a high degree of dynamic loads, transients and low loading situations the introduction of an energy storage unit such as batteries or supercapacitors the performance of the system may be further improved. Even though the investment costs are higher for a hybrid system the savings in fuel consumption will make it profitable within few years. The reduced fuel consumption also leads to lower emissions and thus lower costs in form of taxes due to operations in emission controlled areas (ECA). The maintenance costs in the machinery system may also be reduced due to the lower amounts of low loading and a higher amount of time operating close to the optimal operating point.

References

(1) Vartdal BJ. Hybrid Ships. DNV, Research & Innovation; 2013.