A study on the stochastic modelling of load balances and the auxiliary power demand of superyachts in an early design phase

Summary

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In order to create an accurate electric power load analysis (EPLA), or more commonly load balance, for a vessel in an early design phase, a tool has been developed in this research. The analysis is based on gathered data of operational vessels in a stochastic big data approach. The tool is widely applicable to all vessel types and establishes the opportunity to perform a solid generator selection and assess the impact of energy-saving measures on the power demand of a vessel. The methods developed in this research are applied to analyse the auxiliary power demand of a superyacht in an early design phase, based on the gathered data of operational superyachts.

The developed tool allows for the designer of a superyacht to collect valuable electrical design information and is also beneficial to the design of other vessel types. The tool is developed with the following aim:

- To create a quick and accurate assessment of the auxiliary power demand of a prospective or future yacht. An experienced designer requires approximately 1 week to perform an assessment with the tool.
- To select and size a combination of generator sets for a future yacht. A solid selection leads to an efficient use of the generator sets, reduced 'time between overhaul', potential space reductions and a general reduction of costs.
- To assess the impact of design choices on the auxiliary power demand of a future yacht.
- To study the impact of applying energy-saving measures, such as: peak-shaving, waste heat recovery and the smart use of HVAC (Heating, Ventilation & Air-conditioning) zones. These measures lead to an overall reduction of green-house gas emissions and improved fuel consumption.
- To develop an updatable and flexible tool directly applicable to a future yacht. Gathered data from yachts and other vessel types can be inserted into the tool to continuously improve the estimation of the power demand of a future vessel.

Traditionally, a load factor analysis is used to calculate the auxiliary power demand. This type of analysis calculates an average power demand value for each piece of equipment and for the system as a whole. However, the methods and the created tool in this research use the entire power demand range that is extrapolated from the gathered data of operational vessels. Such a power demand range gives a solid basis on which a selection of generator sets and energy-saving measures can be made, in addition to an accurate overall assessment of the auxiliary power demand. The stochastic approach, integrated in the tool is well-suited for the developed aim of the research.

The loads on board a vessel are separated in two types of loads, non-HVAC- and HVAC loads. In this research, the non-HVAC loads are estimated based on gathered data from a selection of reference yachts and the HVAC loads are estimated through an HVAC time-domain simulation. An HVAC simulation is necessary, because the HVAC loads depend strongly on external factors, such as temperatures and humidity levels. The tool integrates the created estimations for both types of loads through a Monte Carlo-simulation and produces auxiliary power demand information for a future yacht. The tool is characterized by its flexibility. Gathered data from operational yachts is added to the tool once it becomes available. A selection of reference yachts is made to base the estimation for the non-HVAC loads on. Flexibility is also present in the HVAC simulation itself, because variables such as outdoor air temperatures, required indoor air temperatures and thermal properties of the constructions of a vessel are quickly altered and simulated. A tailor-made HVAC simulation is performed in 4 to 5 days.

The developed method in this research is based on literature describing the advantages of stochastic modelling of electrical loads. The theoretical background is described in DDS 310-1 REV 1 (NAVSEA, 2012). The tool is a design tool that builds and expands on the existing knowledge by directly using the gathered data of operational vessels to estimate the power demand of an entirely new vessel. An assessment of the power demand is quickly created, including an accurate and tailor-made HVAC simulation for a vessel. The designer decides whether

the power demand estimation is based on the data of a large amount of reference vessels to create a broad estimation of the power demand or a more specific selection of reference vessels to create a more accurate power demand range. The selection of reference vessels also depends on the information available at the stage for a vessel in an early design phase.

The power demand estimation for both non-HVAC- and HVAC loads is verified by comparing the estimated values to actual gathered power demand information of operational yachts. The created estimations describe the overall power demand range well, including extreme minimum- and peak power demand values. Reference yachts are selected as basis of the stochastic analysis and a case study is set up for a future yacht for which traditional load factor analysis power demand results are available. When both traditional- and stochastic method results are compared, the stochastic estimation results in a lower range of estimated power demand values. In figure 1, the values of the auxiliary power demand for the traditional- and stochastic estimations are compared to the measured data for an example yacht in this research. The stochastic estimation matches the measured data well, whereas the traditional estimation leads to an overestimation of the power demand.

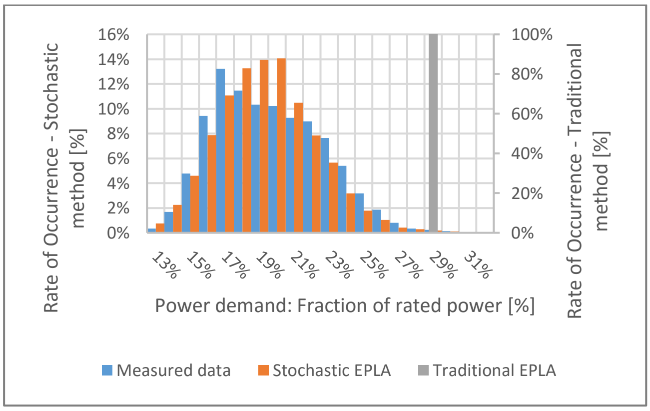

Figure 1: Comparison of the estimated values of the total auxiliary power demand as fraction of the rated power of the electrical loads for the traditional- and stochastic EPLAs as compared to measured operational data for an example yacht

In general, the traditional load factor analysis method can be accurate in estimating the average value of the power demand, when accurate load factors are used, but it does not take peak values, minimum values and the time spent at these conditions into account.

The developed method and tool are applicable to all vessel types and types of equipment. The only requirement is that gathered data for the specific equipment to be installed on board the vessel is available. Ideally, a collection of power demand data for many different equipment items with varying power ratings is desired for an accurate estimation. The main challenge for a designer is the selection of reference vessels that are used to create the electric load list and the non-HVAC power demand information.

References

NAVSEA, 2012. Design data sheets: Electric Power Load Analysis (EPLA) for Surface Ships DDS 310-1 Rev. 1. Naval Sea Systems Command, Department of the Navy, Washington Navy Yard, Washington DC.