

Battery operation

Implementation on Sea Challenger

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This project examines the suitability of covering the energy consumption of the A2SEA vessel Sea Challenger with a battery pack, when it is jacked-up and is installing offshore wind turbines.

The purpose of installing a battery pack is to optimize the load on the diesel generators, thus increasing efficiency during periods of sailing, and supplying solely from the battery during installations.

The project concludes that it is not suitable to cover the energy consumption of the vessel during wind turbine installations exclusively by a battery pack, due to the relatively high consumption. A battery pack that is able to supply the needed energy would be too large and too expensive, compared to the space available and the payback period.

Keywords: Energy, consumption, battery pack, optimisation, efficiency

1 Introduction

During our education and practice on board merchant vessels, we have seen plenty of work and studies aimed to optimize and make processes more efficient. On a global scale MARPOL's SEEMP and the upcoming MRV regulation aims to affect the shipping companies and the mariner's behaviour to reduce exhaust fumes and waste impacting the climate¹. On a national scale, companies, universities and the Danish government established Blue INNOship. It is a partnership

¹5 (IMO) 4(DNV GL)

working towards a greater and more flourish marine sector through innovations and energy-efficient solutions².

Inspired by various newbuilding's and projects implementing battery packs in ferries we chose to investigate the possibility of retrofitting MV Sea Challenger with a battery pack. MV Sea Challenger is a purpose-built jack-up vessel designed to install offshore wind turbines. Data from Blue INNOship revealed that the generators of MV Sea Challenger in the jack-up periods were running at one third of the designed capacity.

1.1 Problem statement

Is it suitable to retrofit MV Sea Challenger with batteries to cover the energy consumption, when it is jacked-up installing offshore wind turbines?

Due to the project's timeframe delimitations were necessary. The project aims to cover the aspects of the financial incitements of which it consider the economical difference between a normal jack-up operation versus a possible battery operation. The project focus on the jack-up period and thereby the battery packs impact on the complete operation and voyage will not be considered. The technical solution, integration and costs of implementing the battery pack will not be considered. Calculations are based on a six hours' jack-up operation determined by preliminary interviews³.

1.2 Data processing

Knowledge of the ship and its performance including battery technology was required to approach the problem statement. We were given access to live performance data from MV Sea Challenger in the time frame 8/3- 19/5 2016. MV Sea Challenger was installing 6 MW turbines at Gode Wind 1 & 2, Germany. These performance metrics were chosen:

- 6x Diesel Generators (2880 kW_e)
- 6x Hydraulic Power Units
- 3x Voith Schneider propeller
- Speed (STW)

Furthermore, we gained access to the Integrated Control System of the ship from where we collected the diesel generators efficiency performance. In the given timeframe MV Sea Challenger installed 35 offshore wind turbines.

2 Battery applications

Implementation of a battery pack can be done differently depending on its purpose. *Enhanced Dynamic Performance* is a concept where a sudden increase of load will be absorbed by the battery

²(Blue INNO+) ³(Blue INNOship+)

³6 (Koenemann)

pack. Gradually the load will be distributed to the generator. This application of batteries is suitable for engines with slow regulation like LNG and dual fuel engines⁴.

The concept of *Peak Shaving* is that the engine is running at the best efficiency during high loads while the battery pack is designed to absorb peak loads. This is illustrated on figure 1.

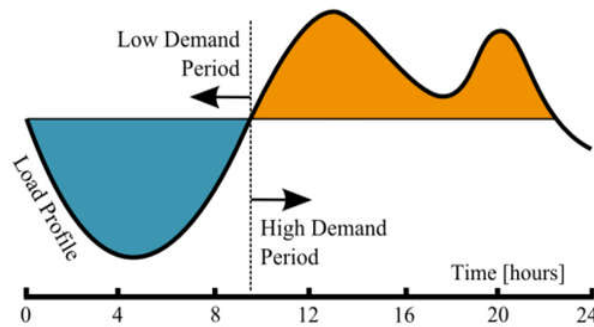


Figure 1 - Peak Shaving

In low demand periods the engine continues to run most efficiently as it charges the battery pack. Peak Shaving aims to produce the most kWh per fuel unit.

Spinning Reserve is a concept of which the battery pack is operated as a standby energy supplier meant to substitute the generators for a specific period. Furthermore, it can be used as a back-up supply in the case of loss of power. This project covers the aspect of a spinning reserve solution.

3 Operational pattern

MV Sea Challenger has several operation conditions. The analysis of the operational pattern is centred at the specific Jacked-up Installation Work period. The analysis is conducted to clarify the duration, the consumption and the peak loads to determine the particulars of the battery pack.

Figure 2 visualizes the data of one trip. Between port and platform, the vessel operates in *Transit* where the load is high and all generators are running. The vessel is operated in *Site Manoeuvring DP* mode when approaching the platform. This is followed by the *Jacking Operation*. These modes are illustrated with the upper part of the figure. The single blue line on the right represents one generator supplying the ship in the installation period.

⁴1 (ABB)

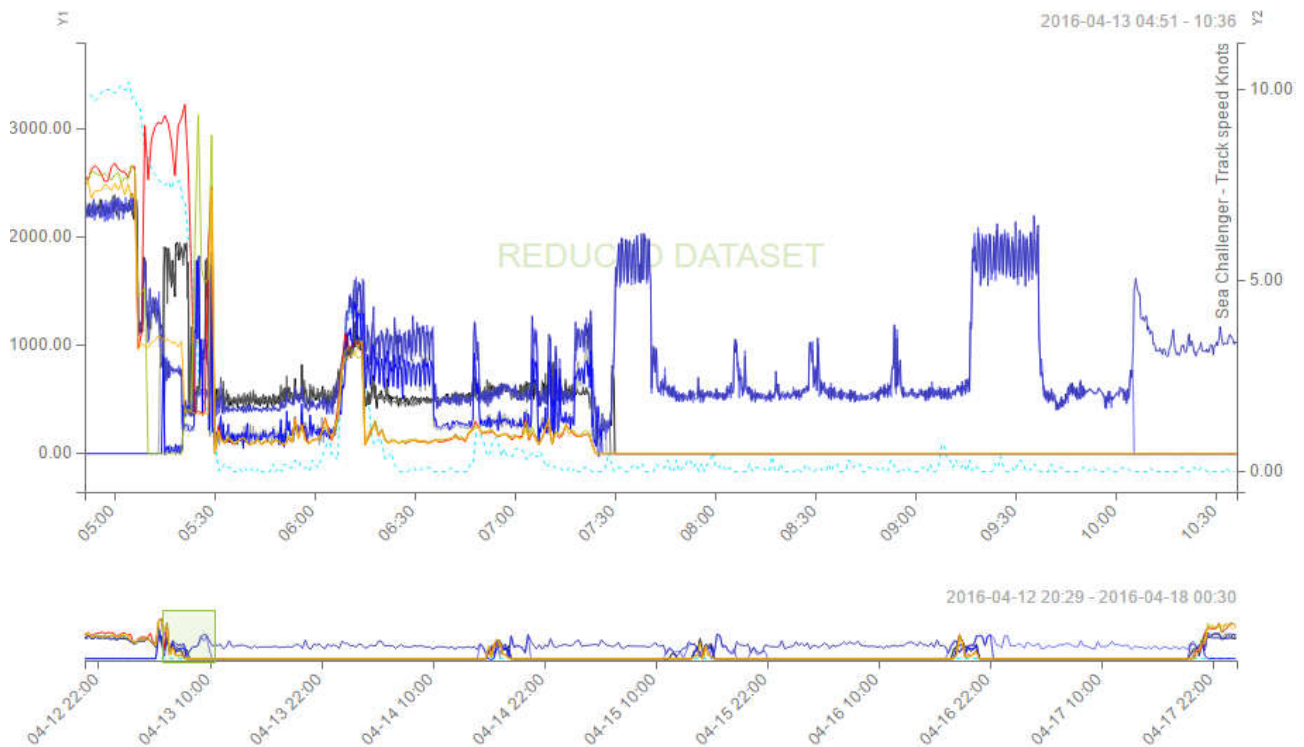


Figure 2 - ALDAQ, Manoeuvring

A greater view of the trip from port to port is shown at the bottom. During the trip, four wind turbines are installed which shows as similar periods on the graph. Throughout the jacked-up installations one generator is running with a steady load. The energy consumption was calculated for every 35 installations in the specific period. By average the ship then consumed 1015 kWh. Given the preliminary conditions of a six-hour long installation the battery pack should delivery 6090 kWh. The time spent on wind turbine installations represents 49.8 % of a typical trip whereof the following calculations are based on.

4 Processing data: Efficiency

The purpose of installing a battery pack is based on the fuel savings achieved by running the diesel generators at a more optimal load. The fuel savings are calculated from data on g/kWh. By comparing the efficiency (g/kWh) at low load with the efficiency at a higher load due to charging of the batteries, the fuel savings are observed.

4.1 Data – g/kWh

By comparing efficiency with the energy consumption, a trendline can describe the connection between efficiency and consumption and different loads.

Data on efficiency from the period: 16.05.2016 00:01 to 19.05.2016 23:59 (DD.MM.YEAR HR:MIN) exported from the vessels ICS was paired with data on energy consumption. In this period the diesel generators were sharing the load equally.

5 Trendline

To be able to determine the efficiency at any given load, the correlation between efficiency and load is described with a trendline. The following section describes and evaluates the selected trendline.

By plotting the matching data in a coordinate system with the load as the ordinate and the efficiency as the abscissa the trendline, Figure 3, shows that the correlation matches the data from the manufacturer, although measured values in all are higher than stated on the engines data sheets.

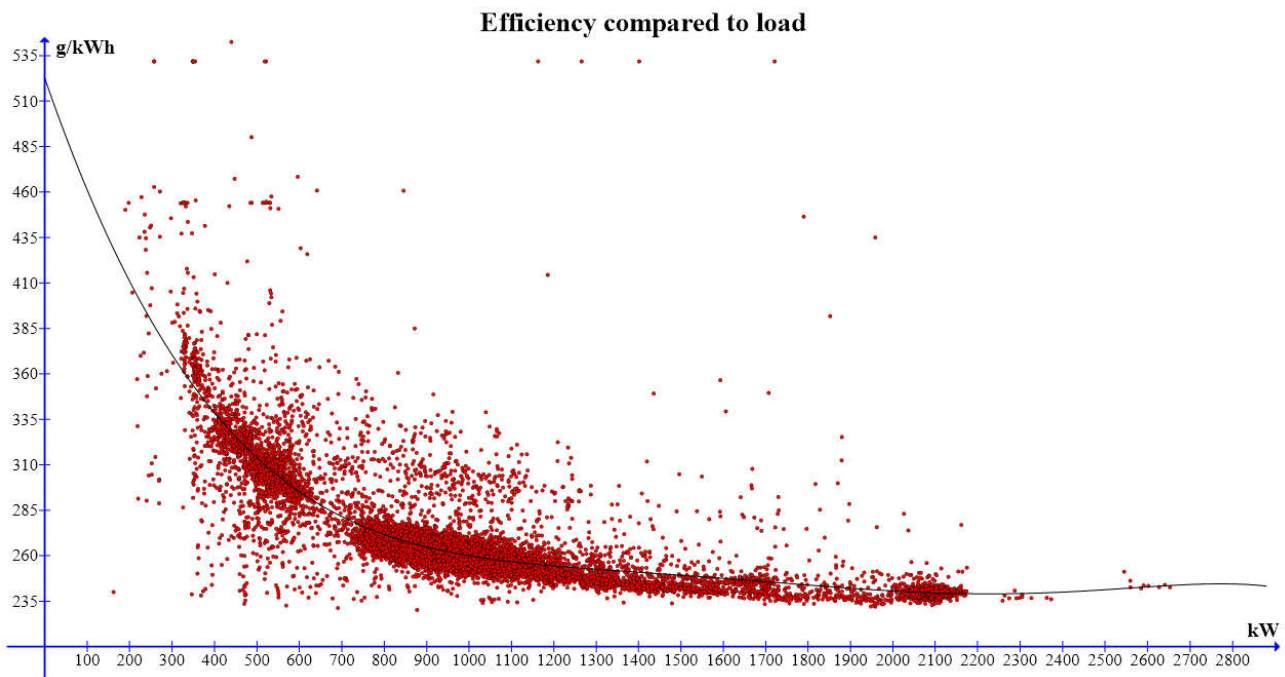


Figure 3

The trendline shows that the engines are working at the highest efficiency at loads between 2000 and 2500 kW, and that loads below 1000 kW cause a significantly worse efficiency.

The chosen trendline is decreasing at loads higher than 2772 kW. This is inaccurate, as efficiency is expected to drop at maximum loads. It is caused by the fact that no data is collected at loads higher than 2650 kW, and thereby no data is present to affect the trendline in the highest loads.

6 Economic perspective

To be able to evaluate the fuel savings from implementing a battery pack, the fuel cost of charging the batteries must be calculated. The intention is to charge the battery pack as the vessel moves between two installations. To estimate added fuel consumption from charging the batteries, a representative period of sailing from one installation to the next is evaluated.

6.1 Cost of charging

The calculations show that the charging time is 3.04 hours. The total consumption without charging is 2457.8 kg fuel. With charging the consumption is 3783.5 kg fuel. Charging leads to an added fuel consumption in comparison to normal operations of:

$$3783.5 \text{ ton} - 2457.8 \text{ ton} = 1326 \text{ ton}$$

The vessel is running on MGO 0.1 % only. Per Dan Bunkering A/S the price for this fuel type is 3202 DKK per ton. Charging of the battery package will have a fuel cost of:

$$1326 \text{ ton} \cdot 3202 \text{ DKK} = 4245 \text{ DKK}$$

6.2 Savings during battery supply

In the periods where the ship is supplied from battery, no diesel generator will be running. The fuel that would have been used is the equivalent of 5059 DKK. By comparing the price of charging the battery to the cost of fuel saved, the gain of every battery cycle is:

$$5049 \text{ DKK} - 4245 \text{ DKK} = 804 \text{ DKK} \approx 130 \text{ USD}$$

This saving comes from running the diesel generators at a more efficient load at manoeuvring while charging, compared to the load at installations.

At 97 installations per year, given that the battery covers 6 hours of energy consumption the fuel cost savings per year are: $804 \text{ DKK} \cdot 97 = 77988 \text{ DKK} \approx 12,500 \text{ USD}$

Interviews with represents of 3 different manufacturers give an indication of the price of a battery package needed: $56,345,853 \text{ DKK} \approx 9 \text{ million USD}$

Compared to the yearly economic savings, the payback period is:

$$\frac{56,345,853 \text{ DKK}}{77988 \frac{\text{DKK}}{\text{year}}} = 723 \text{ years}$$

The payback period is dependent on the price of the battery and the savings by running on battery. The price on batteries is decreasing. The savings by running on battery is a combination of fuel price and amount of fuel saved. Fuel prices are constantly changing. The amount of fuel saved can be further increased by continuously matching the number of running diesel generators to the load, taken charging load into consideration.

7 Conclusion

The purpose of the project is to examine whether it is suitable for MV Sea Challenger to use a battery pack as a spinning reserve during the installation period.

The operational pattern and energy demand has been analysed through quantitative data. The single cost and size of the battery has been estimated through interviews with leading authorities in the field including knowledge of preceding projects and battery technology.

Based on collected and analysed data we conclude it is not suitable for MV Sea Challenger to implement a battery pack as a spinning reserve.

The analysis revealed that the vessel is in jack-operation longer than initially considered. This will require a larger battery pack. The consumption on 1 MWh will require a larger battery pack which will increase the physical size as well as the price. This will increase the payback period, which already surpasses the lifetime of the battery pack and ship. It is estimated that errors and uncertainties of the data is negligible considering the physical size and payback period.

8 Perspectives

Besides the economic benefits of installing a battery pack, running on batteries can improve work environment due to less noise and vibrations including zero emissions. Especially zero emission operations with a spinning reserve installation could be relevant when berthed in future ports.

The duration of the installation period combined with the consumption of 1 MWh does not fit a spinning reserve solution. On the other hand, the generators will run ineffectively with 1/3 of their capacity. To solve the problem a new study should be made to examine implementation of a smaller generator combined with a battery pack operating as Peak Shaving.

The development of big scale battery technology is currently driven by companies developing GridStorage units to accumulate energy from wind turbine, solar farms etc. As this sector develops, the maritime sector will gain from the increased research and development in large battery packs.

9 References

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