New Generation Power And Energy Management System For Autonomous Vessel Propulsion System

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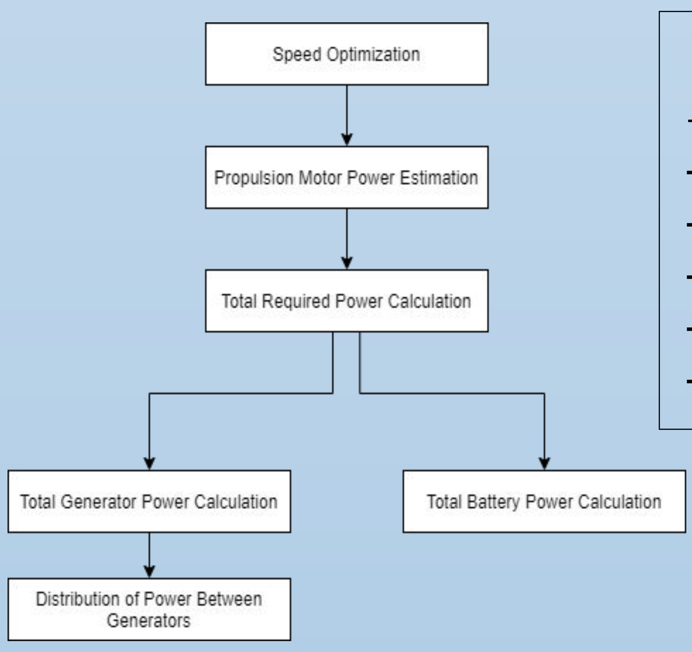
ABSTRACT

The project aimed to implement a new generation power and energy management system for autonomous vessel propulsion systems. The power and energy system was supposed to be developed for hybrid ships which could use battery powers along with the energy generated by the generators and process real-time input parameters. This system, unlike any other developed so far, will take into account real-time values for power generation organs, physical and weather conditions of the sea, load condition, and battery status of the ship to suggest the most optimal values for a set of parameters in order to reduce the total cost, and CO2 emission. The set of parameters for which the optimal values are calculated includes generator power, motor power, battery usage, and speed. The system's core has been implemented using Deep Learning Algorithms which take into account real-time conditions and then suggests optimal values for the preset parameters to the ship's captain. To predict these values as accurately as possible, the system has been trained with real-life data provided by ELKON with all required input parameters. The output is displayed using a user-friendly interface, which is easy to read and interact with. In conclusion, we were able to set up a system that meets all the requirements set up by ELKON for their new generation power and energy system.

OBJECTIVES

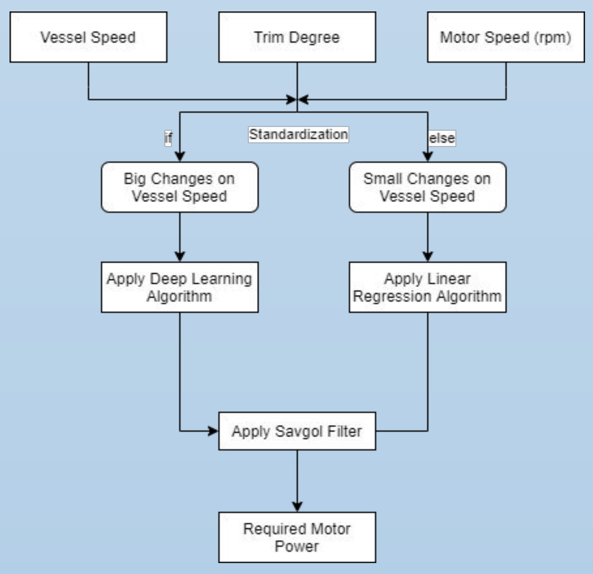
2.1.1. Research ELKON and ship systems
2.1.2. Understand autonomous shipping systems
2.1.3. Understand the power and energy management of the hybrid ship system
2.1.4. Understand and analyze the input parameters
2.1.5. Determine the relationship between data received from ELKON and power management systems
2.1.6. Visualize the data and find dependencies between input parameters 2.1.7. Implement a series of different Artificial Intelligence, Machine Learning, and Deep Learning models
2.1.8. Test all models and fine-tune the model with the most accuracy
2.1.9. Use the model to train the system with available data and predict the state of output parameters
2.1.10. Understand the cost function of the model and shipping system concerning input and output parameters
2.1.11. Test the model in a simulated environment and find the cost reduction
2.1.12. Design a Graphical User Interface for the ship's captain
2.1.13. Implement a dynamic version of the GUI which takes into account real-time values and suggests values of output parameters

METHODOLOGY



Techniques

- Linear Regression
- Deep Learning
- SavGol Filter
- Standardization
- Normalization
- PyQt



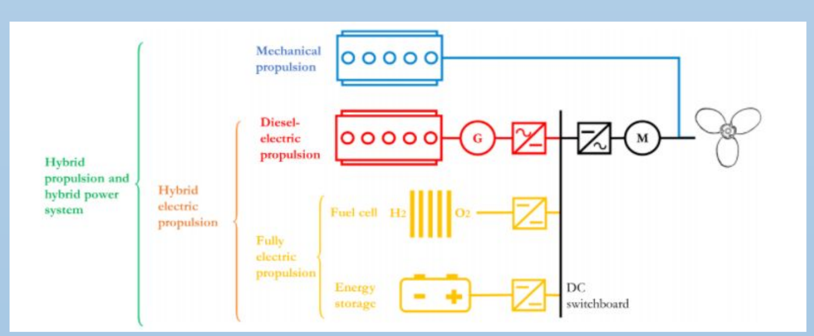


Figure 2: Propulsion system based on Geertsma et al. (2017)

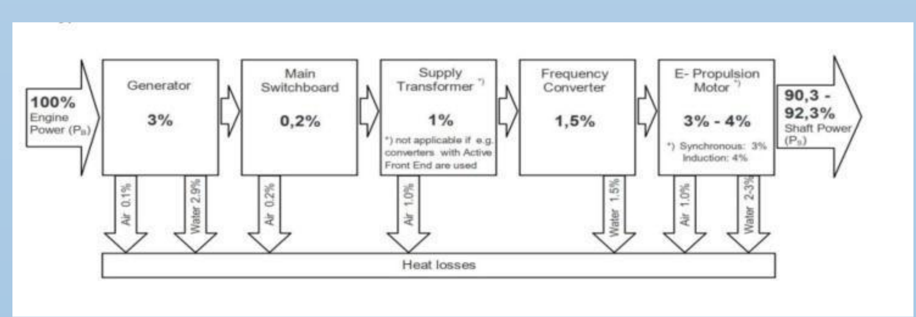


Figure 1: Energy flow on board for propulsion

$$C_{total,eqv} = \sum_{i=1}^{n} C_{eng,i} + C_{batt,eqv,off} + C_{batt,on} \quad (1)$$

$$C_{eng,i} = SFOC\left(P_{eng,i}\right) \times P_{eng,i} \times \Delta t \quad (2)$$

$$1\ gj = 12,322\ \$ \quad (4)$$

$$C_{batt,eqv.off} = s \times FC \times P_{batt} \times \Delta t$$

$$C_{batt,eqv,off} = s \times SFOC\left(P_{batt}\right) \times P_{batt} \times \Delta t \quad (5)$$

$$C_{batt,on} = \left(SOC_{start} - SOC_{end}\right) \times P_{batt,max} \times C_{on-shore} \times \Delta t$$

$$C_{batt,on} = \Delta SOC \times P_{batt,max} \times C_{on-shore} \times \Delta t \quad (6)$$

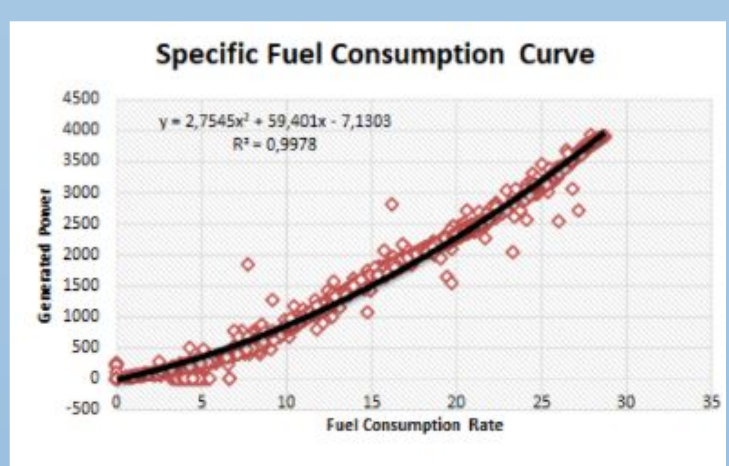


Figure 3: SFOC curve

RESULTS

Propulsion Motor Power Estimation:

The differences between estimated and real parameters were calculated by comparing the estimation results with the values in the test data and these values were visualized in Figure 7 with time-dependent graphs. The calculation of the total values was found by calculating the total area under the Power-Time graphs, and the difference in the power used by the motors was calculated from here. While 469150.0 kW motor power was used in the actual data, the estimated value with the model was recorded as 425725.0 kW and the difference was calculated as 43425 kW.

Required Generator Power Calculation:

After the total energy is found, the distribution of this energy to the two energy sources on the ship is calculated. This calculation is made using the instantaneous LNG (Liquid Natural Gas) consumption values used by energy sources for a certain power value and is found SFOC - Specific Fuel Oil Curve-. As a result, the energy distribution that should be used for each value in the 0 - 8640 kWh energy range that can be created by using two energy sources was found. The total gas consumption was calculated by evaluating these energy distribution values together with the "LNG consumption rate" values. When the optimal values found are compared with real user data, a significant energy saving of around 13% has been achieved.

Battery Usage:

The differences between estimated and real parameters were calculated by comparing the estimation results with the values in the test data and these values were visualized in Figure 7 with time-dependent graphs. The calculation of the total values was found by calculating the total area under the Power-Time graphs, and the difference in the power used by the motors was calculated from here. While 469150.0 kW motor power was used in the actual data, the estimated value with the model was recorded as 425725.0 kW and the difference was calculated as 43425 kW.

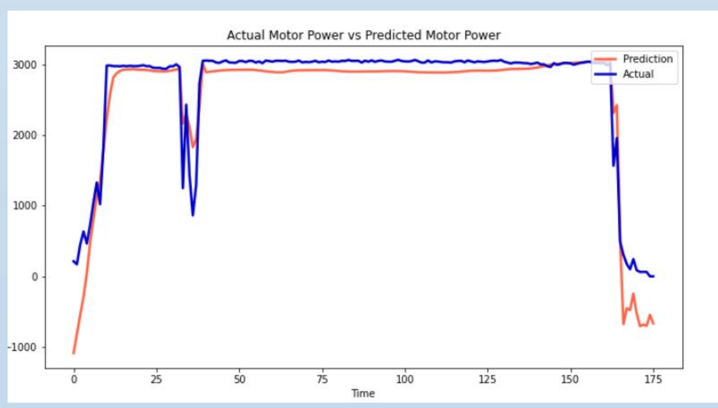


Figure 7: Result of the Estimation of the Motor Power

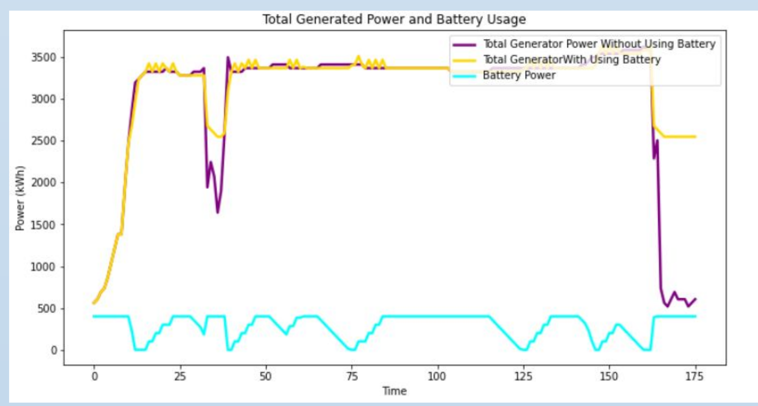


Figure 9:Battery Usage throughout the Trip

Total Cost Calculation:

While calculating the total cost, the amount of fuel used during the cruise is calculated. In this calculation made for each minute, the amount of fuel consumed per minute is multiplied by the unit price. In this equation, the unit price of LNG is accepted as $ 12,322. When the prices are compared, it is calculated as $ 918.99 the total price that the platform spent during a cruise, and this price was reduced to $ 854.69 with optimization and battery usage. The difference is $ 64.3 between the actual values and the optimization values.

Figure 10: A Demonstration from GUI

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