An energy management concept with a load-prediction engine to improve the fuel economy of a hybrid maritime propulsion system

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Abstract

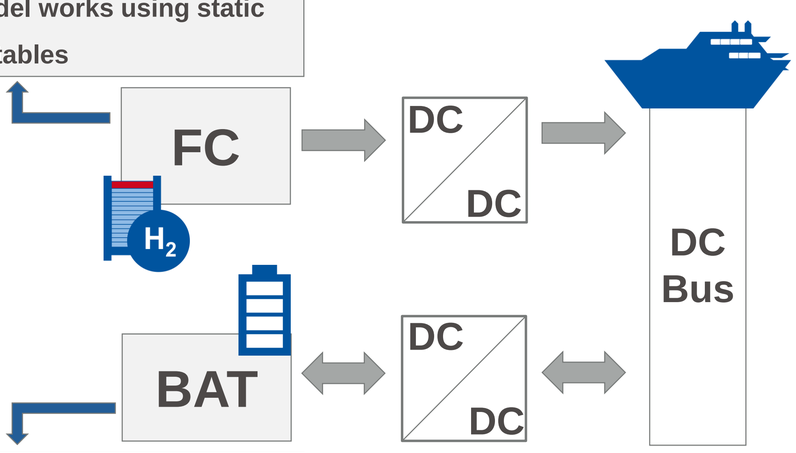
To reduce anthropogenic greenhouse gas emissions, novel and clean propulsion technologies are being developed in the maritime sector. Hybrid powertrains consisting of batteries and fuel cells represent a good alternative to conventional propulsion systems. By employing prediction algorithms, intelligent energy management can enhance fuel efficiency. A load-prediction engine based on machine learning is proposed to improve the fuel efficiency of a cruise ship's hybrid propulsion system consisting of a high-voltage lithium-ion battery and a high-temperature solid oxide fuel cell (SOFC).

Conclusion

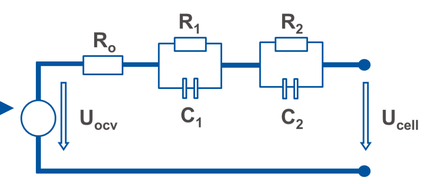
- Different machine learning (ML) algorithms were used in a training phase and implemented in the energy management system (EMS) of a large maritime propulsion system to predict load patterns online.
- By using the prediction algorithms, the fuel costs of a cruise could be reduced by up to 5.7 %.

Hybrid propulsion Concept

- Parametrized using literature-based data
- The model works using static lookup tables

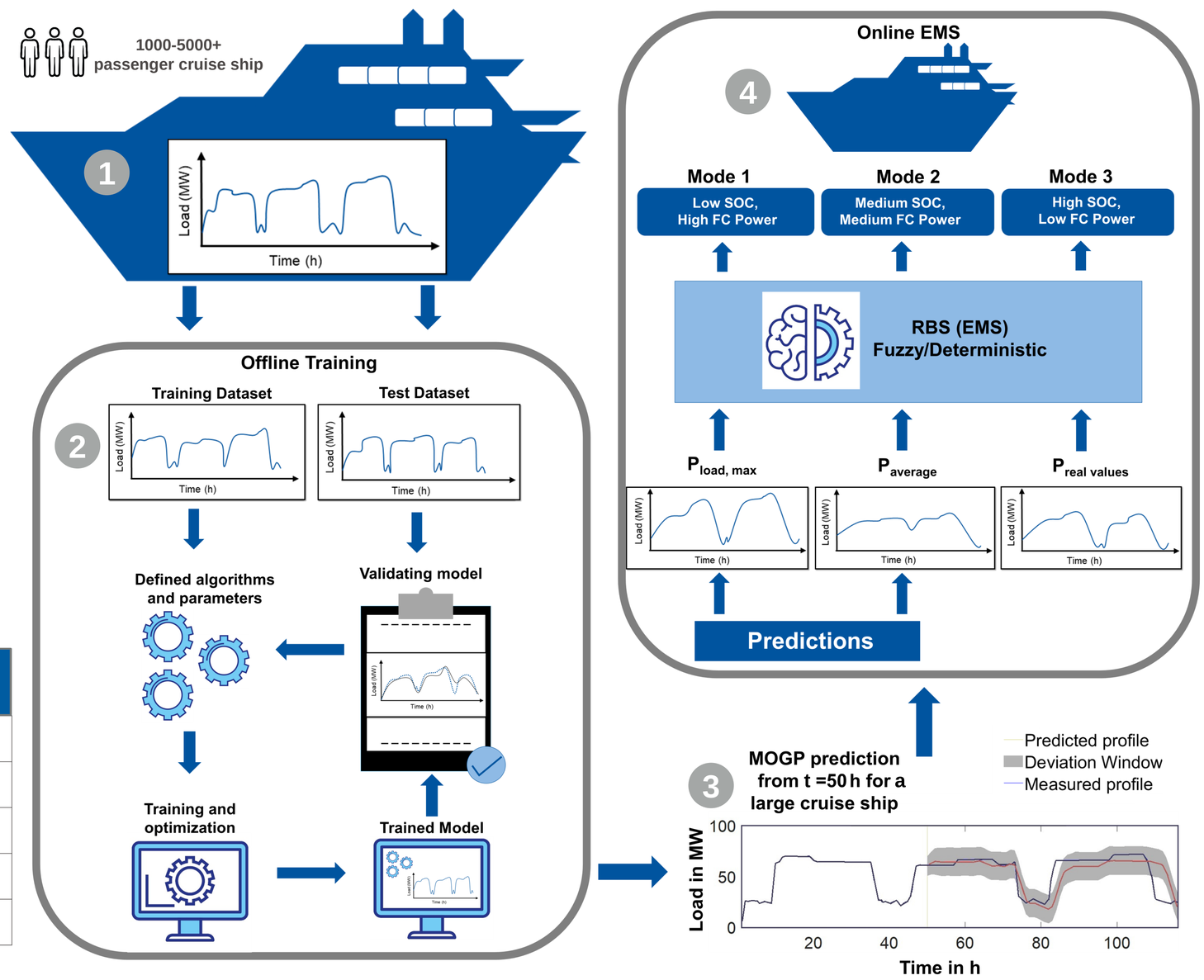


- Parametrized with actual measurement data
- 2-RC circuit battery model



ML-based Energy Management

1 Data Analysis
2 Training Phase
3 Predictions
4 Implementation into EMS



Comparison of ML algorithms

Algorithms	RMSE (MW)	Feasibility
Gaussian process regression	21.69	★
Multiple-Output GPR	17.59	★ ★
Long short-term memory	16.71	★ ★ ★
Recursive LSTM	16.15	★ ★ ★
Acceleration analysis	17.53	★ ★ ½

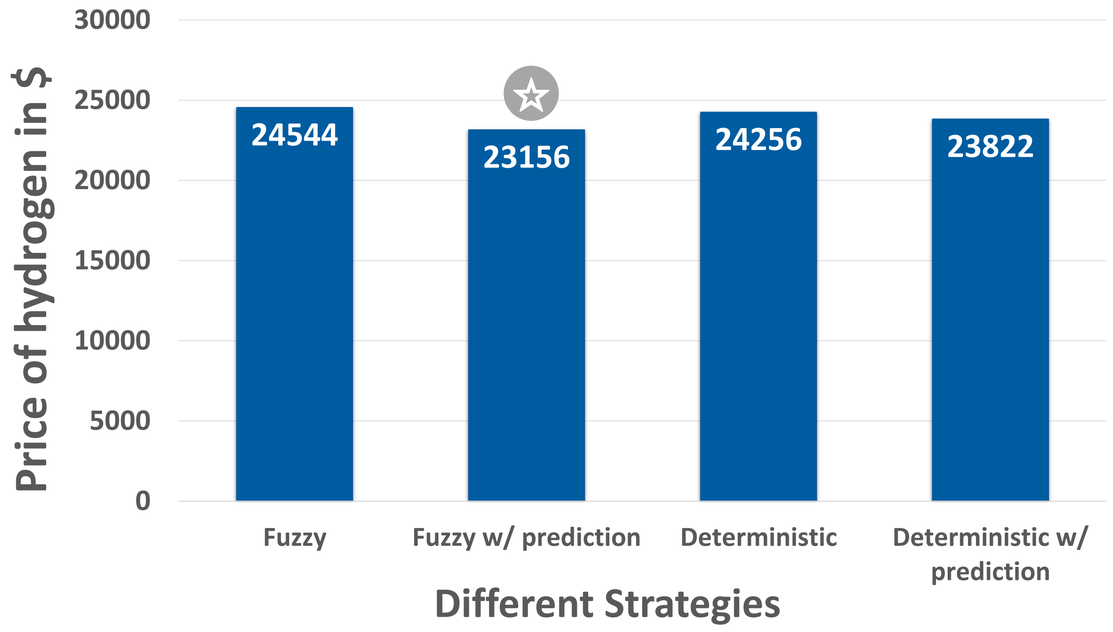
! High root mean square error because of gradual horizontal shift.

Results of Energy Management System

Various energy management methods were benchmarked for the drive cycle costs.

- ➔ Recursive LSTM delivered the best results in terms of fuel cost reductions since it has the lowest RMSE.
- ➔ Hydrogen fuel price: 5 $/kg
- ➔ The hydrogen cost by using actual global average power in both fuzzy and deterministic RBS is lower than the predicted global average power.

☆ Fuzzy RBS including the prediction parameters achieves the best fuel consumption and a cost improvement of 5.7 % is achieved.



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