Numerical Co-Simulation Using FMI Standard to Enhance Efficiency in Marine Hybrid Propulsion and Onboard Electric Networks

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OPTELAN Project

This presentation is a part of the **OPTELAN** project which is currently in progress at **HTW Berlin** (Berlin University of Applied Sciences) with partnership with the **PSS Company** (Physical Software Solutions GmbH) and supported from **ZIM** (Zentrales Innovationsprogramm Mittelstand) and **Federal Ministry for Economic Affairs and Energy** Germany.

The OPTELAN project aims to develop a simulation-based technical service to support the design of electric/hybrid watercraft, enabling the optimal design of electrical connections and contacts in the on-board power supply system.

Supported by:

Federal Ministry for Economic Affairs and Energy

ZIM Zentrales Innovationsprogramm Mittelstand

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Agenda

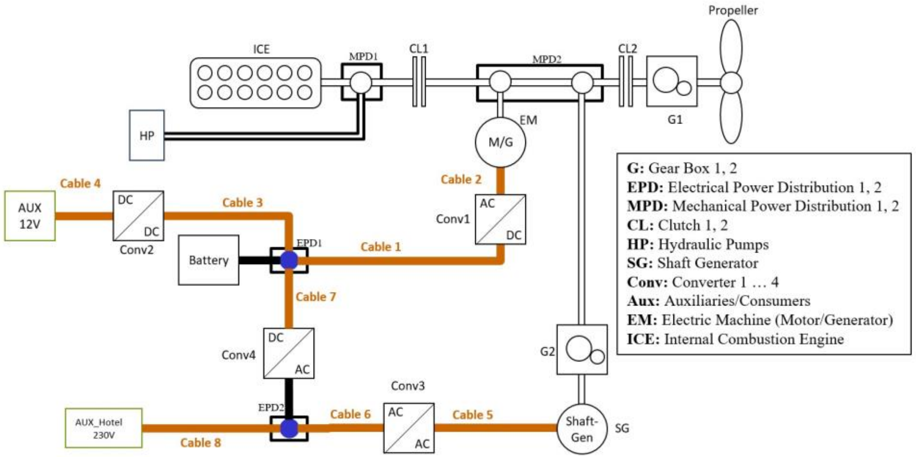
1 Introduction

- **Hybrid propulsion** is a key enabler of CO_2 reduction in the maritime sector, supporting global decarbonization efforts.
- This presentation introduces a **simulation-based** hybrid-boat model developed to optimize onboard electric network design and reduce costs.

- **OPTELAN** Project Requirements:
  - Model should be able to predict current profiles of high-power consumers.
  - Model should support Co-Simulation.
  - Model should allow open and closed loop simulations.
  - Model should allow the users to control vessel operating conditions.
  - Model should be validated and verfified by various types of hybrid-boats.

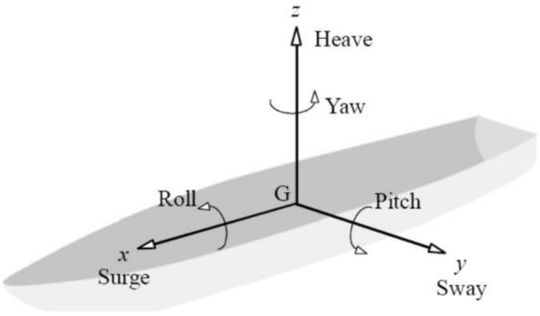
2 Hybrid Boat Model

- **No standardized** configuration applicable to all hybrid watercrafts.
- A **generalized** propulsion system architecture, is proposed for implementation in the model.
- The design adapts to different propulsion and operational modes/scenarios.
  - Full electric drive
  - Full ICE drive
  - Boosting mode ICE & EM in service
  - Battery Charging with ICE drive
  - Recuperation mode

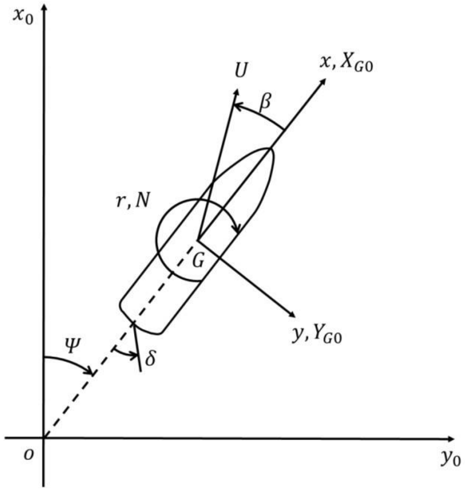


2 Boat’s Hydrodynamic Control

- Vessel motion can be effectively represented using a three-degree-of-freedom (**3-DOF**) model (Ref.1).
- The model simulates vessel dynamics in three DOFs: **surge** (X-axis motion), **sway** (Y-axis motion), and **yaw** (rotation about the Z-axis).



- The boat’s dimensions, as well as the propeller and rudder coefficients, can be inserted and controlled through an **initialization** file of the model.
- The motion equations will be inserted as non-dimensional equations with **hydrodynamic derivative coefficients**, in the model (Ref.2).



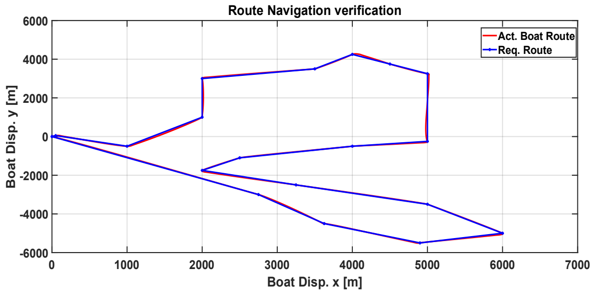
2 Boat's Navigation Control

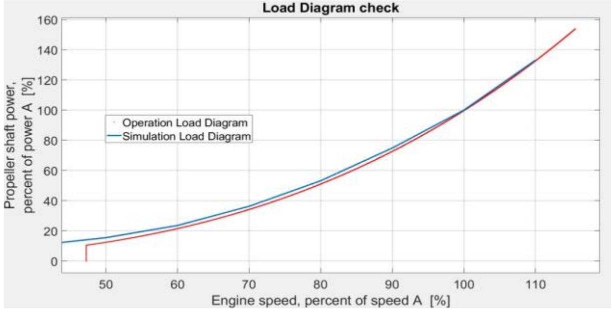
- The simulation model includes a control block that allows the navigation of the vessel under various predefined **courses**.
- A user-defined **velocity** and **rudder** cycle reproduces realistic vessel behavior.
- For medium- and large-sized marine vessels, the model also offers an (x, y) waypoint tracking mode.

Control Cycle	*Use*	*Time-Related*
Longitudinal-Speed	Model Test	Yes
Speed-Rudder Angle	Small-Size Boats	Yes
Points-Tracking	Medium-Large-Boats	No
Water-Current-Speed	Recuperation	Yes

3 Model Verification and Validation

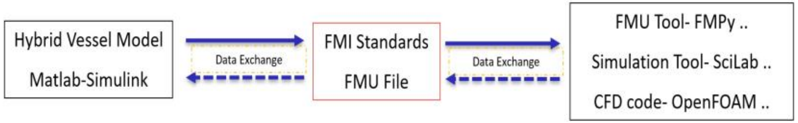
- Verifying compliance with the principles of power and energy **conservation** under a wide range of operating cycles and scenarios.
- The **point-tracking** cycle is being tested using different types of route point configurations to ensure accurate and flexible vessel movement.
- A complete set of operational data from an actual vessel **Nord-Traveller** into the model was integrated.
- ICE parameters are processed to generate corresponding vessel operations.



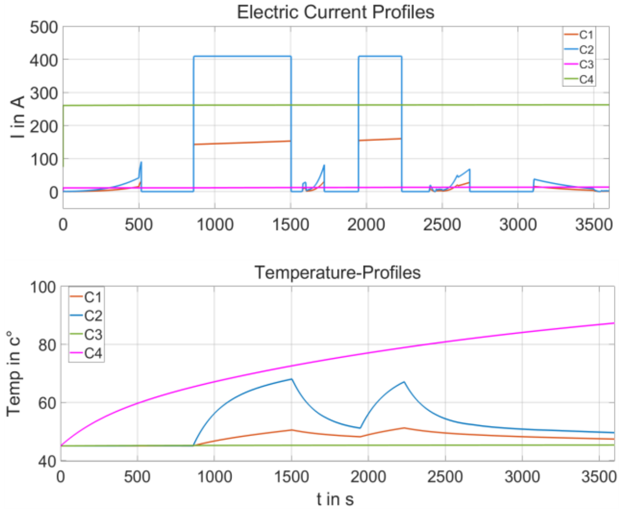


4 Model Co-Simulation Procedure

- Running the model in Co-Simulation mode using a Functional Mockup Unit (**FMU**) is a key objective.



- The first Co-Simulation direction involves generating an FMU-model and use it directly in external FMU-compatible tools/framework.



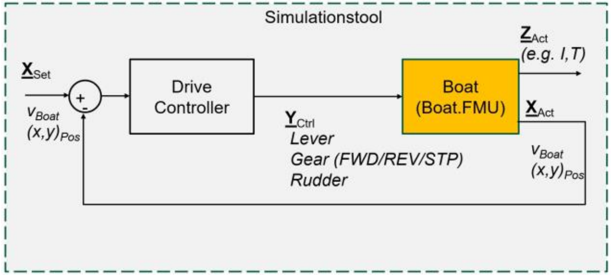
- Focus is on the first direction:
  - FMU model validation and running in Simulink.
  - FMU model verification and performing in SciLab open source platform.
  - FMU model validation and test in **FMPy-Python** open source platform.

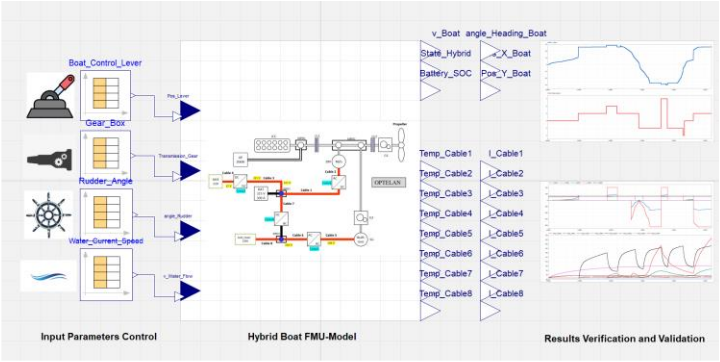
4 Open-Loop Co-Simulation Model

- An **Open-Loop** structure is being developed to integrate the FMU model and control it.

- This design enables interactive use of the FMU model within different tools.

- Open-Loop FMU model provides the output signals
  - Current and Temperature profiles of the electric cables.
  - Velocity and displacement profiles of the marine vessel.
  - Battery status and parameters.
  - Hybrid propulsion modes of the boat.





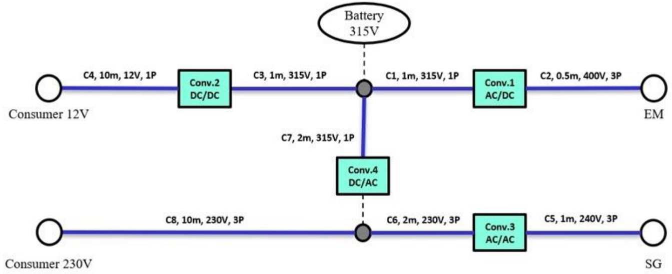
5 Real Time Simulator

- Co-Simulation of the hybrid boat model with **Python** offers the opportunity to develop a real-time simulation tool.
- This tool can support decision-making and design.
- **No** running or modifying the original model.

- The simulator displays real-time current and temperature profiles of the electrical cables, alongside navigation parameters of the boat.
- In cases of **overheating** or **overload**, the onboard electrical network can be modified/re-designed

6 Practical Case Study

- Dimensions and specifications of a 35 m, 312 t hybrid boat have been used for optimization.
- The electric current profiles of the cables have been delivered to **PSS company**.



- Cable costs are estimated in the **PSS tool** using cross-section, weight, material, and insulation factors.
- The PSS tool considers multiple factors, including **temperature class**, cable **aging**, environment, **voltage drop** and worst-case scenarios.

	Design C-S	*Optimized C-S*	*CostSaving*
	mm²	*mm²*	*€*
C1:	150	50	25.06
C2:	3×200	3×70	46.88
C3:	2	1	00.38
C4:	95	70	328.37
C5:	3×100	3×50	61.25
C6:	3×12	3×6	16.78
C7:	35	25	18.61
C8:	3×12	3×6	95.02

Implementation of a **Full-Electric** boat (in Progress).

Implementation of a **Diesel-Electric** (series hybrid system) Boat.

Execute the second Co-Simulation stage, linking **CFD** analysis with the hybrid boat model (FMI compliant).

Create full technical documentation and an **open-source FMU** with supporting scripts and models.

Engage with marine vessel designers and builders to identify and develop potential **cooperation** opportunities.

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Thank you.

Vielen Dank.

Tusen takk.

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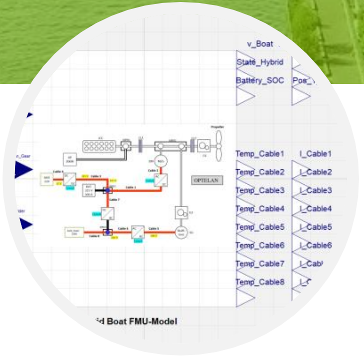

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