IEEE VPPC 2024
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IEEE VTS Motor Vehicle Challenge 2025

Energy Management and Control of a Marine Electric Propulsion System

Mario Porru, mario.porru@unica.it

Alessandro Serpi, alessandro.serpi@unica.it

Fabio Tinazzi, fabio.tinazzi@unipd.it

Ludovico Ortombina, ludovico.ortombina@unipd.it

IEEE VTS Connecting the Mobile World

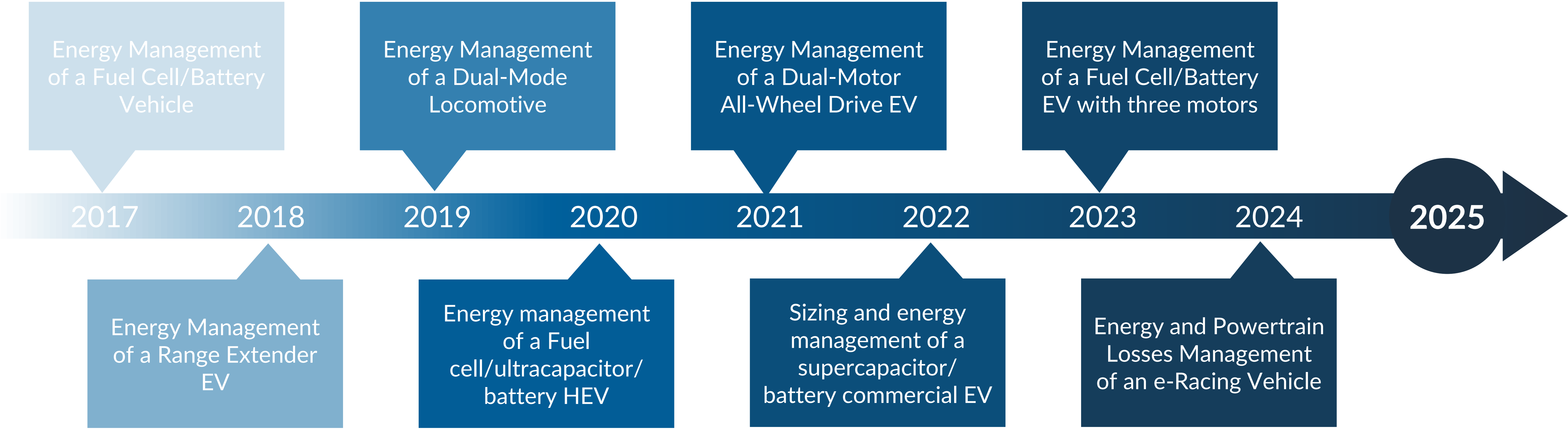
IEEE

Aims and goals of the VMC

- Motor Vehicle Challenge (MVC) is an annual activity to find an appropriate energy management strategy to improve electric vehicles' performance
- The MVC is supported (also financially) by the IEEE Vehicular Technology Society
- The general objective of the Challenge is developing an energy management system to minimize a given cost function
- Participants from both academia and industry are welcome, and students in particular are encouraged to team up and take up the challenge!

Previous editions – the challenges

- First edition in 2017
- Organisation included institutions from North America to Europe and Asia



Previous editions – numbers and figures

- MVC 2023 - Energy Management of a Fuel Cell/Battery EV with three motors
  - organized by German Aerospace Center (DE) and University of California Merced (USA)
  - 40+ teams and 100+ researchers registered for the competition
  - 2 special sessions organized @ VPPC 2023
  - open-access to competition materials available @ github

- MVC 2024 - Energy and Powertrain Losses Management of an e-Racing Vehicle
  - organized by Nottingham University (UK), Hanoi University of Science and Technology (VT), and the University of Cagliari (IT)
  - +32 teams registered and 12 teams submitted their strategies (42 solutions)
  - one special session @ VPPC 2024 (later today at 14:00, room Oceanis B)
  - open-access to competition materials available on the competition website (as that of all previous challenges)

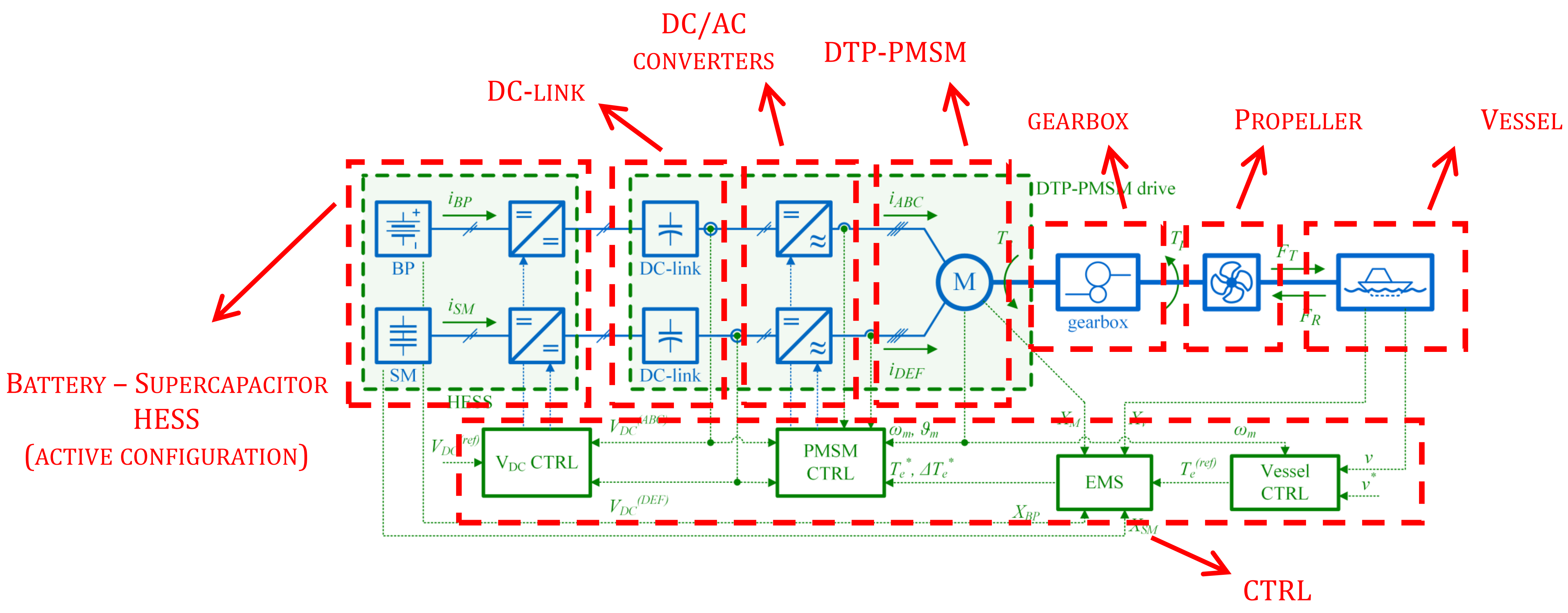
VMC 2025 – Energy Management and Control of a Marine Electric Propulsion System

Energy Management and Control of a Marine Electric Propulsion System *

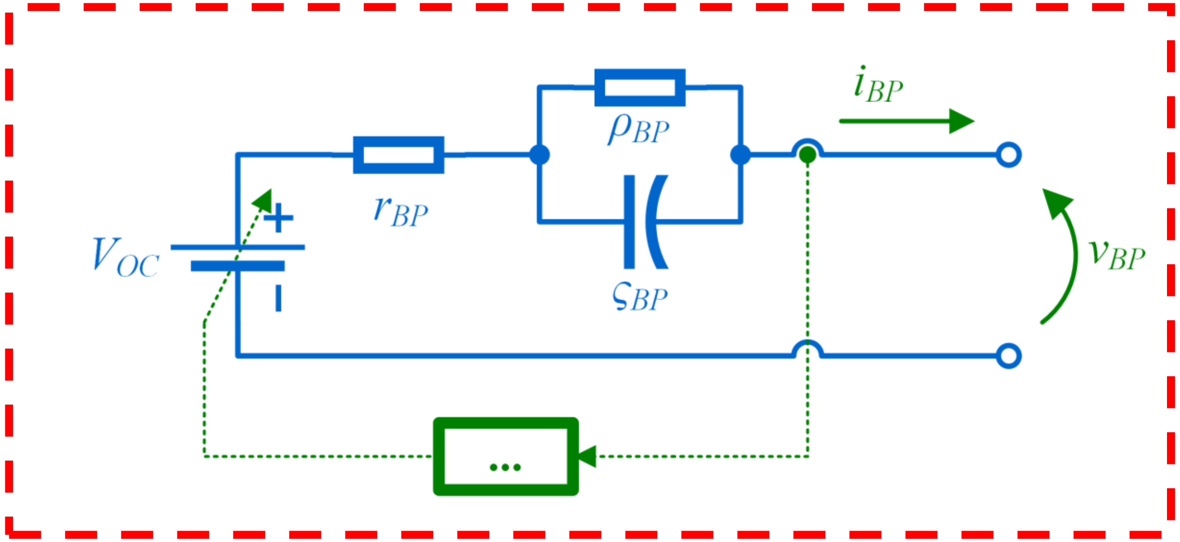
- Battery – Supercapacitor Hybrid Energy Storage System (HESS)
- Dual Three-Phase Permanent Magnet Synchronous Machine (DTP-PMSM)
- Marine propeller
- Vessel
- Case study: electric tugboat

* developed within an Italian national project NEPTUNE (Highly-iNtegrated all-Electric Propulsion-charging system on zero-emissions TUgboats for NExt-generation harbours) - https://prin.unica.it/neptune/

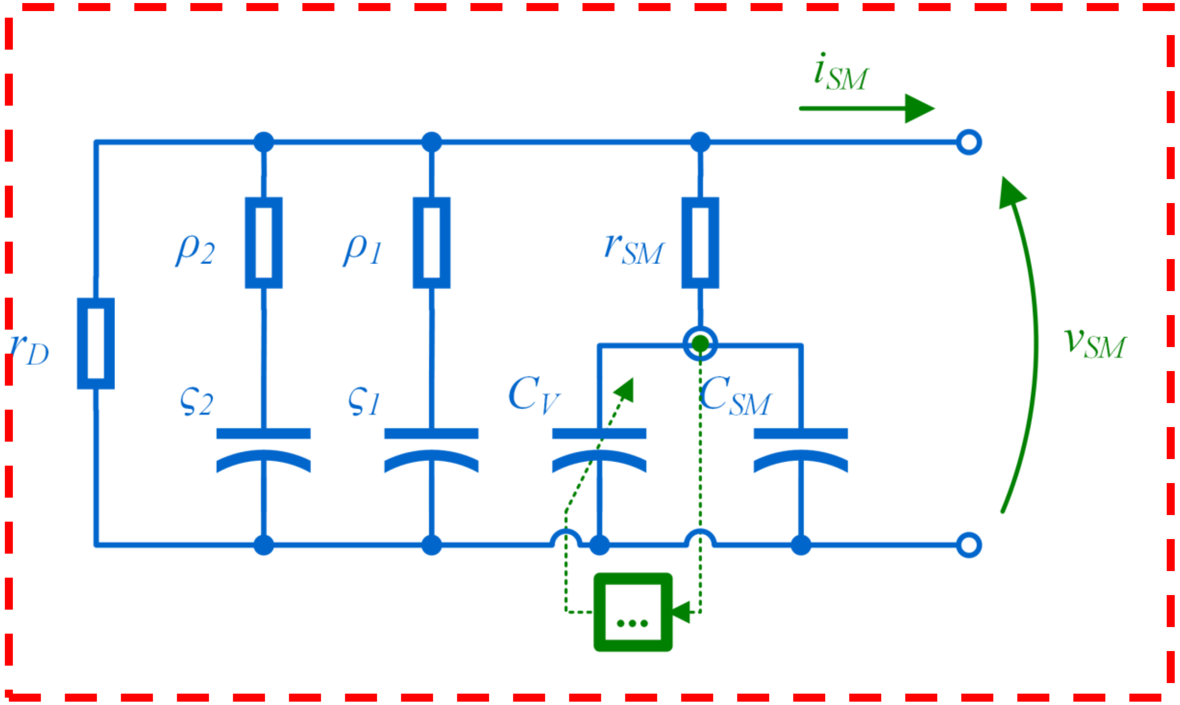
EPS CONFIGURATION – System Overview



EPS MODEL – Energy storage systems



BATTERY EQUIVALENT CIRCUIT MODEL



SUPERCAPACITOR EQUIVALENT CIRCUIT MODEL

EPS MODEL – DTP-PMSM

$$v_{dq+} = (r + j\omega L_s) i_{dq+} + L_s \frac{di_{dq+}}{dt} + 2j\omega\Lambda$$

$$v_{dq-} = (r - j\omega L_0) i_{dq-} + L_0 \frac{di_{dq-}}{dt}, \quad v_{0z} = r\, i_{0z} + L_0 \frac{di_{0z}}{dt}$$

$$T_e = \frac{3}{2} p\Lambda i_{q+}, \quad \Delta T_e = \frac{3}{2} p\Lambda i_{q-}$$

$$T_e = J \frac{d\omega_m}{dt} + D\omega_m + T_L$$

DTP-PMSM
MATHEMATICAL MODEL

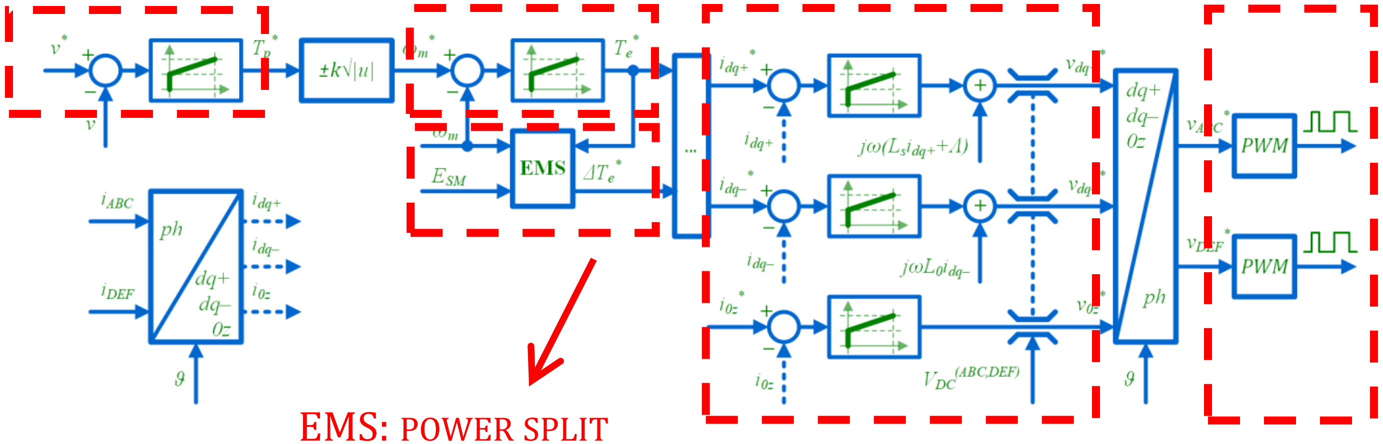
A. Serpi, M. Porru, A. Turno, F. Tinazzi, M. Pastura, and M. Zigliotto, 'Asymetric Supply of a Double Three-Phase PMSM through a Hybrid Energy Storage System in Marine Electric Propulsion Systems', in To be presented at the IEEE Vehicle Power and Propulsion Conference 2024 (VPPC 2024), Washington DC (USA), Oct. 2024. doi: NA

EPS CTRL – System Overview

MOTOR SPEED LOOP

MOTOR CURRENT LOOP

PWM



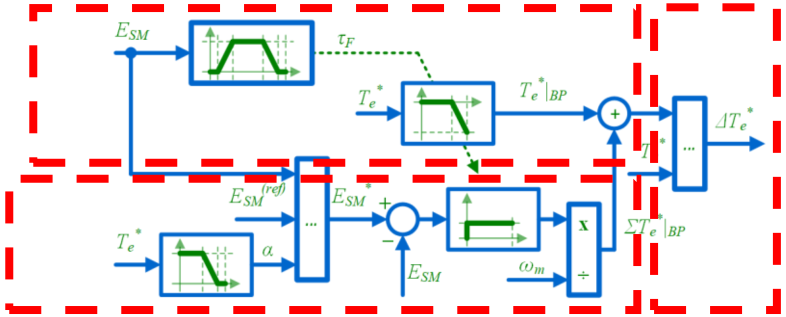
VESSEL SPEED LOOP (OUTPUT PROPELLER REFERENCE TORQUE)

EMS: POWER SPLIT THROUGH TORQUE/POWER IMBALANCE BETWEEN THE THREE-PHASE SYSTEMS OF THE DTP-PMSM

EPS CTRL – Reference EMS

MVC PARTICIPANTS MUST DEVELOP A NEW EMS TO MINIMISE A GIVEN COST FUNCTION

LPF: LOW FREQUENCY CONTENT TO BE HANDLED BY THE BATTERY



TORQUE/POWER IMBALANCE

SUPERCAPACITOR ENERGY LOOP

MVC 2025 – Cost function

$$\Phi = k_{BP}\phi_{BP} + k_E\phi_E + k_{SPM}\phi_{SPM} + k_w\phi_w$$

- BP current fluctuations penalization (especially at high time rates)

$$\phi_{BP} = \frac{1}{T}\int_T \left(\frac{di_{BP}}{dt}\right)^2 dt$$

- overall energy usage

$$\phi_E = \left(E_{BP} + E_{SM}\right)\Big|_T^0$$

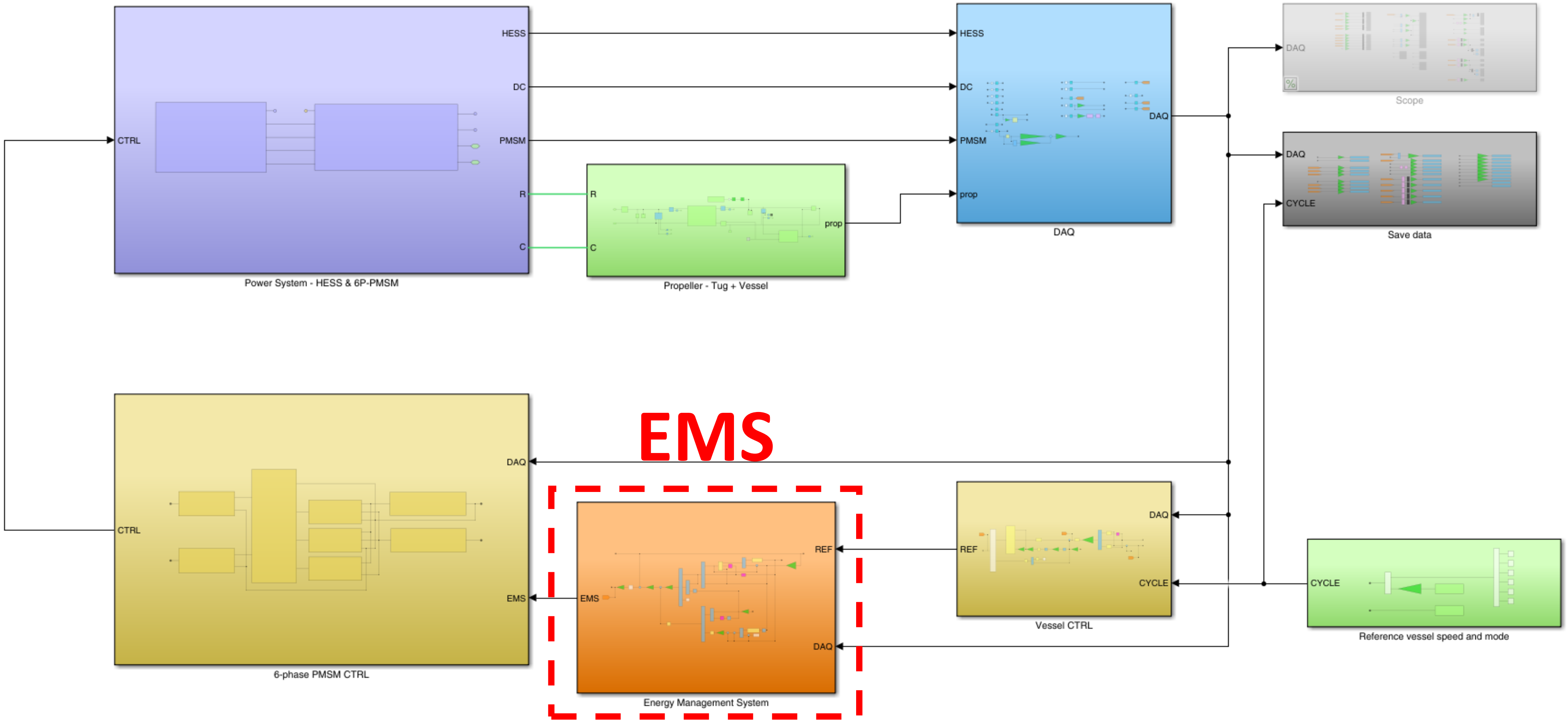
- power threshold overcome penalization (each winding can handle up to 80% of the DTP-PMSM rated power safely)

$$\phi_{SPM} = \frac{1}{T}\int_T \sum_h \left(P_{m,h}^2 - 0.64P_{m,nom}^2\right)\Big\rangle_0^{+\infty} dt$$

- weak DTP-PMSM windings exploitation penalization (weighted by reference torque)

$$\phi_w = \frac{1}{T}\int_T \left(1\big|_{\|i_{ABC}\|=0} + 1\big|_{\|i_{DEF}\|=0}\right)\tau_e^* dt\ , \quad \tau_e^* = \frac{\left|T_e^*\right|}{T_{e,nom}}$$

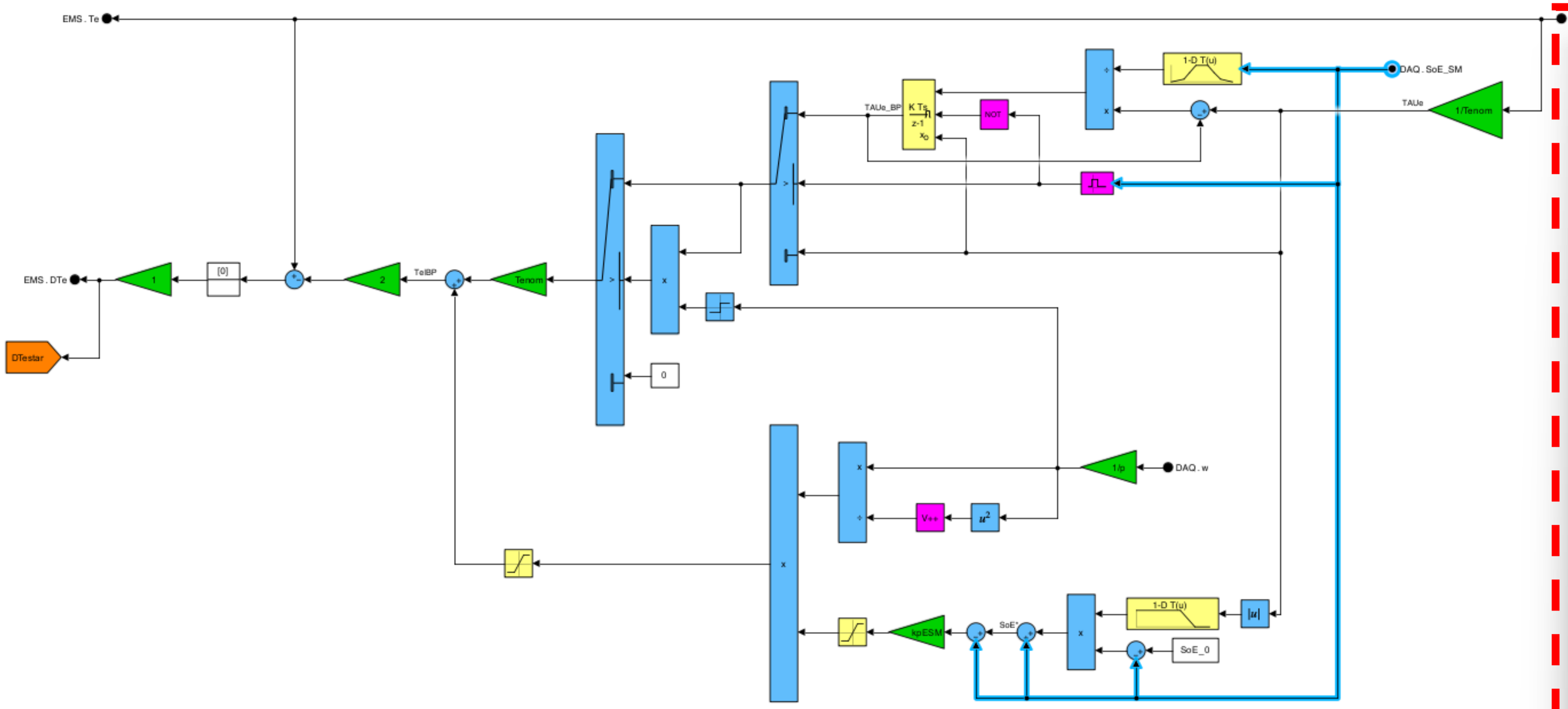
SIMULATION SETUP – OVERVIEW

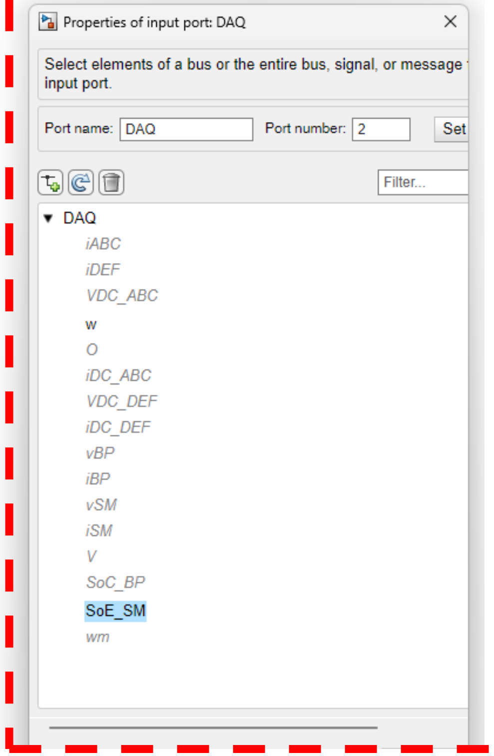


SIMULATION SETUP – Reference EMS

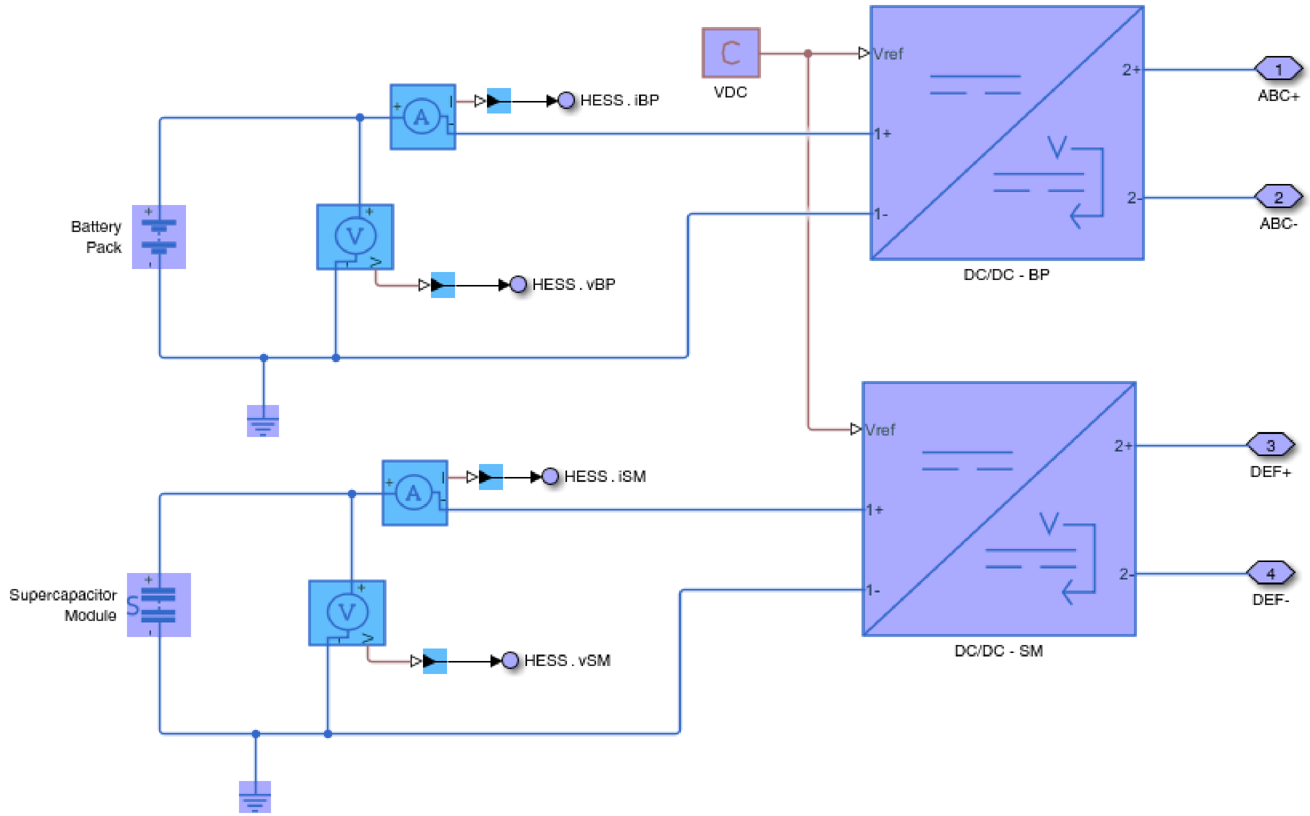
TO BE REPLACED. ONLY THE EMS SUBSYSTEM CAN BE MODIFIED, BUT ALL OTHER SUBSYSTEMS ARE ACCESSIBLE

AVAILABLE SIGNALS TO DEVELOP THE OPTIMAL EMS

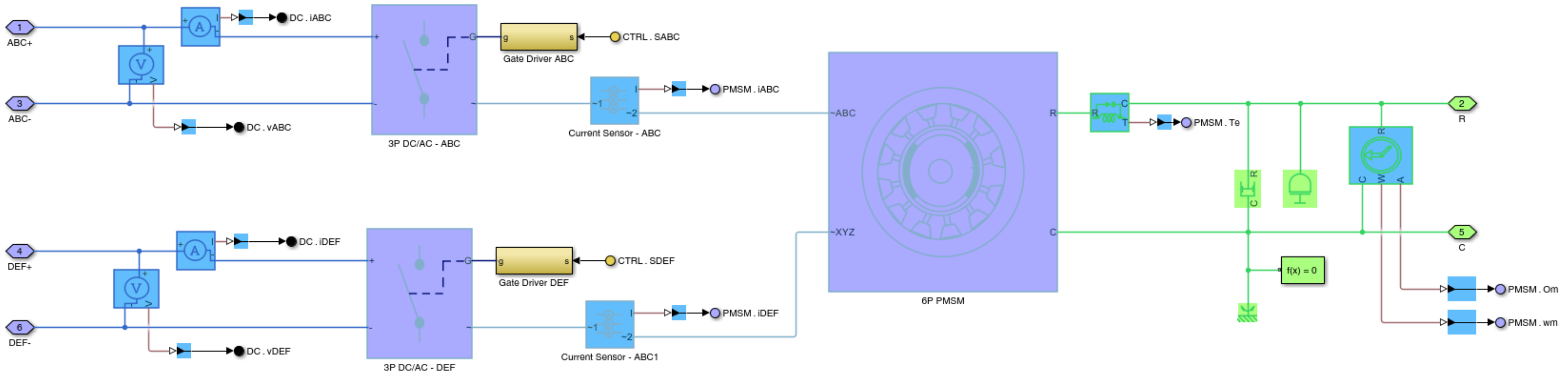




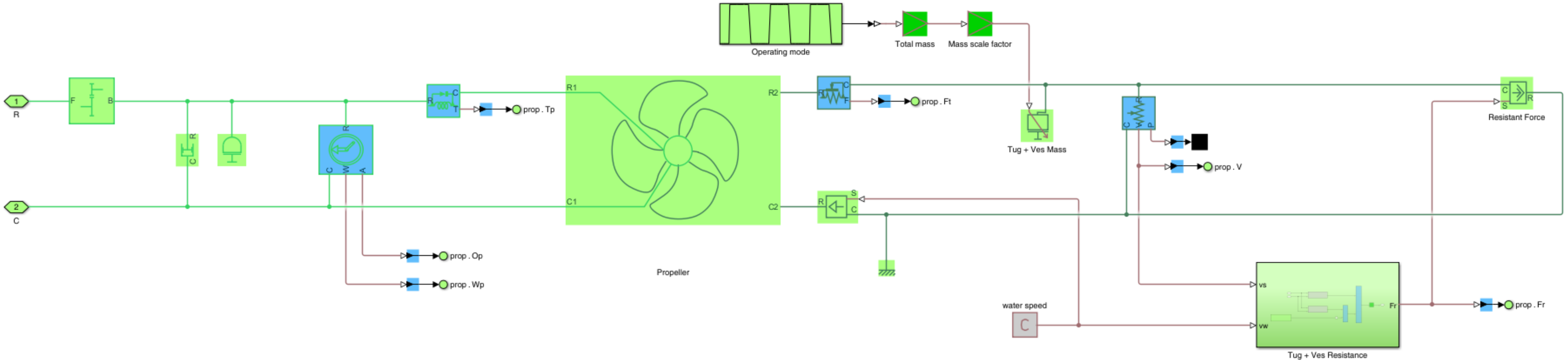
SIMULATION SETUP – HESS



SIMULATION SETUP – DTP PMSM

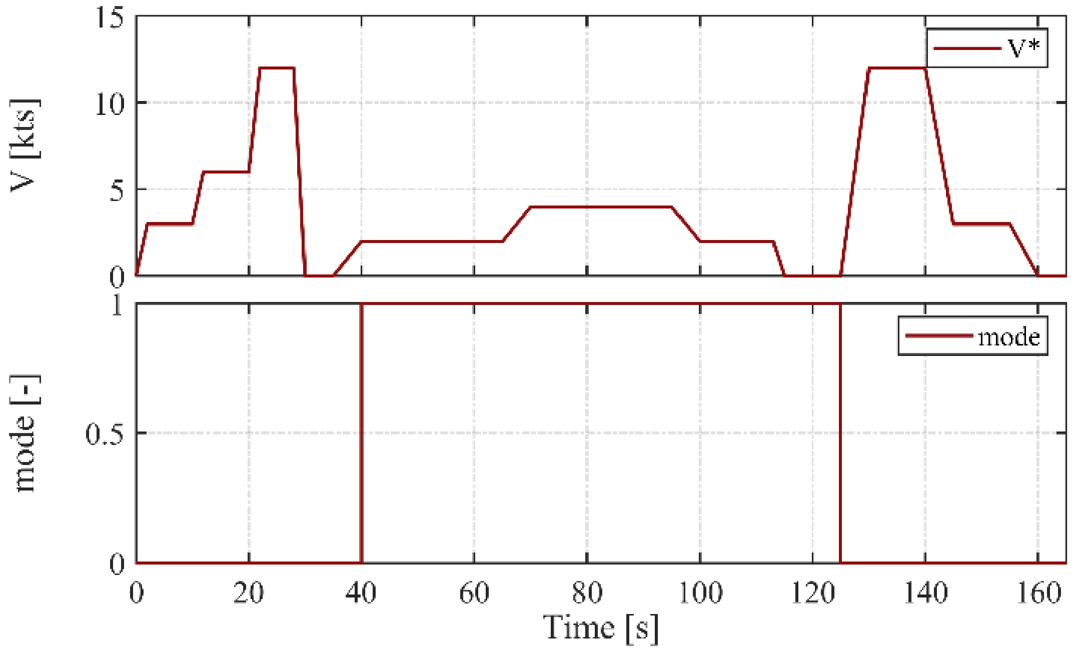


SIMULATION SETUP – Propeller + Tug + Vessel

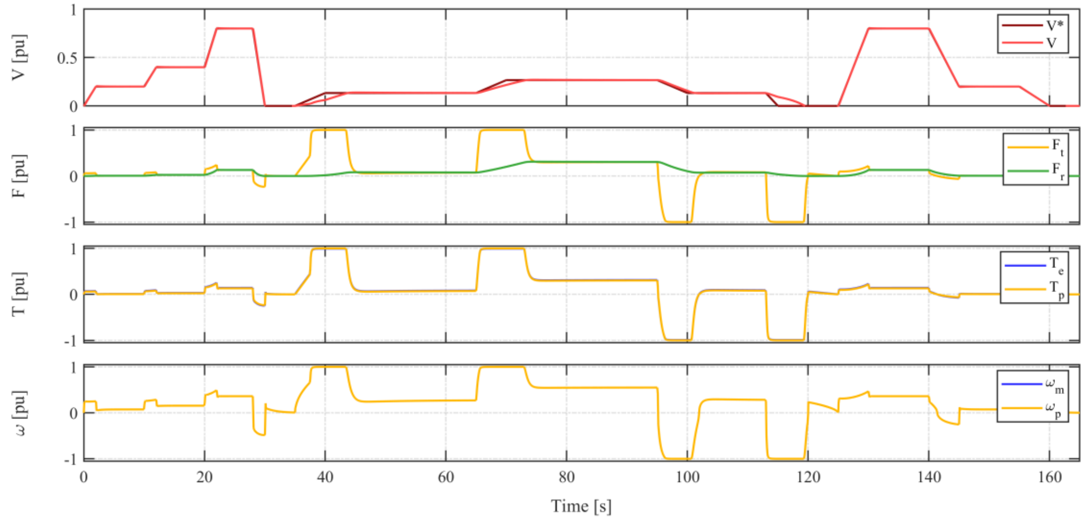


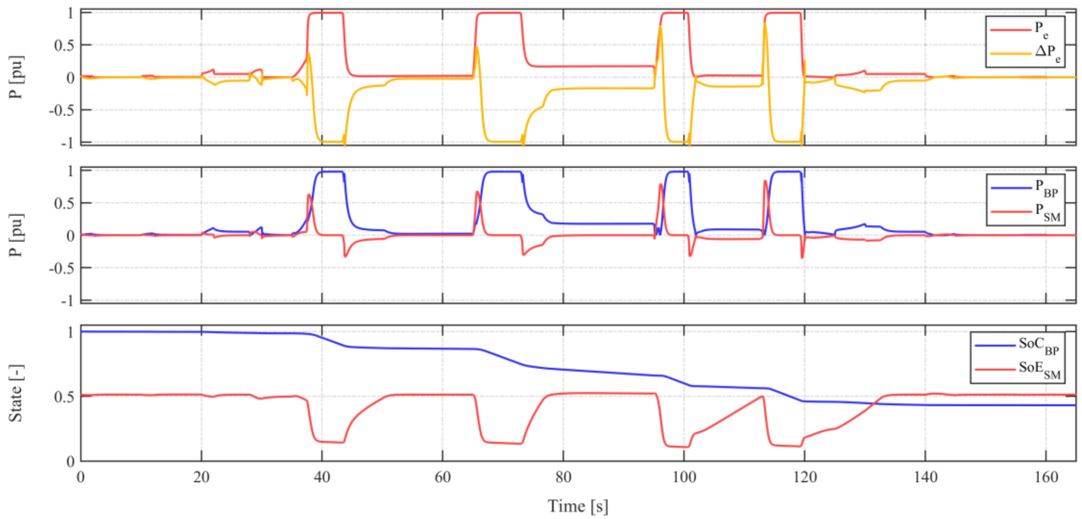
CASE STUDY

- Electric tugboat
- Two operating mode: towing any vessel (m = 1) or not (m = 0)
- All parameters are provided in a dedicated MATLAB script



VMC 2025 – Case study results





Score and awards

- The winner is the team that
  - Submits the legal solutions that
  - Achieves the best score (i.e., the smallest cost function value among all the participants) that will result from weighted average scores achieved with some unknown tugboat speed and operating profiles
- Prizes for the **top two** teams
  - First prize: Up to a limit of 3500 US$
  - Second prize: Up to a limit of 1500 US$
- Note: Only VTS members are eligible to receive the grants. Join us!

General information

- Registration to the competition is **totally free**, but to eventually receive the award VTS subscription is mandatory (strongly suggested anyway)
- One team can submit **several** solutions (more chances to win!)
- All participants will receive
  - Certificate of participation to the competition and
  - Invitation to submit paper for the next VPPC edition (conference deadlines)
- Deadlines (orientative)
  - Registration: end of December, 2024
  - Submission: end of February, 2025
  - Results: end of March, 2025