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IEEE VTS Motor Vehicle Challenge 2026

Design of Powertrain and Energy Management Strategy for a Refrigerated Lorry

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Aims and goals of the MVC

- 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!

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
  - Registration: 31st January, 2026
  - Submission: 1st March, 2026
  - Results: 31st March, 2026

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 lorry operating route
- 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!

Previous editions – the challenges

- First edition in 2017
- This year we are celebrating the 10th edition
- Organisation included institutions from North America to Europe and Asia

2017 – Energy Management of a Fuel Cell/Battery Vehicle

2018 – Energy Management of a Range Extender EV

2019 – Energy Management of a Dual-Mode Locomotive

2020 – Energy management of a Fuel cell/ultracapacitor/ battery HEV

2021 – Energy Management of a Dual-Motor All-Wheel Drive EV

2022 – Sizing and energy management of a supercapacitor/ battery commercial EV

2023 – Energy Management of a Fuel Cell/Battery EV with three motors

2024 – Energy and Powertrain Losses Management of an e-Racing Vehicle

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

2026

MVC 2026 - Design of Powertrain and Energy Management Strategy for a Refrigerated Lorry

Context:

A refrigerated electric lorry follows a predefined delivery route and must deliver/pick up goods from customers. The route is shaped by speed profiles, cargo weight, road slope, and wind conditions.

It can rely on high- and low-power charging stations and wireless charging system, to keep its battery powered. An emergency charging option is always available.

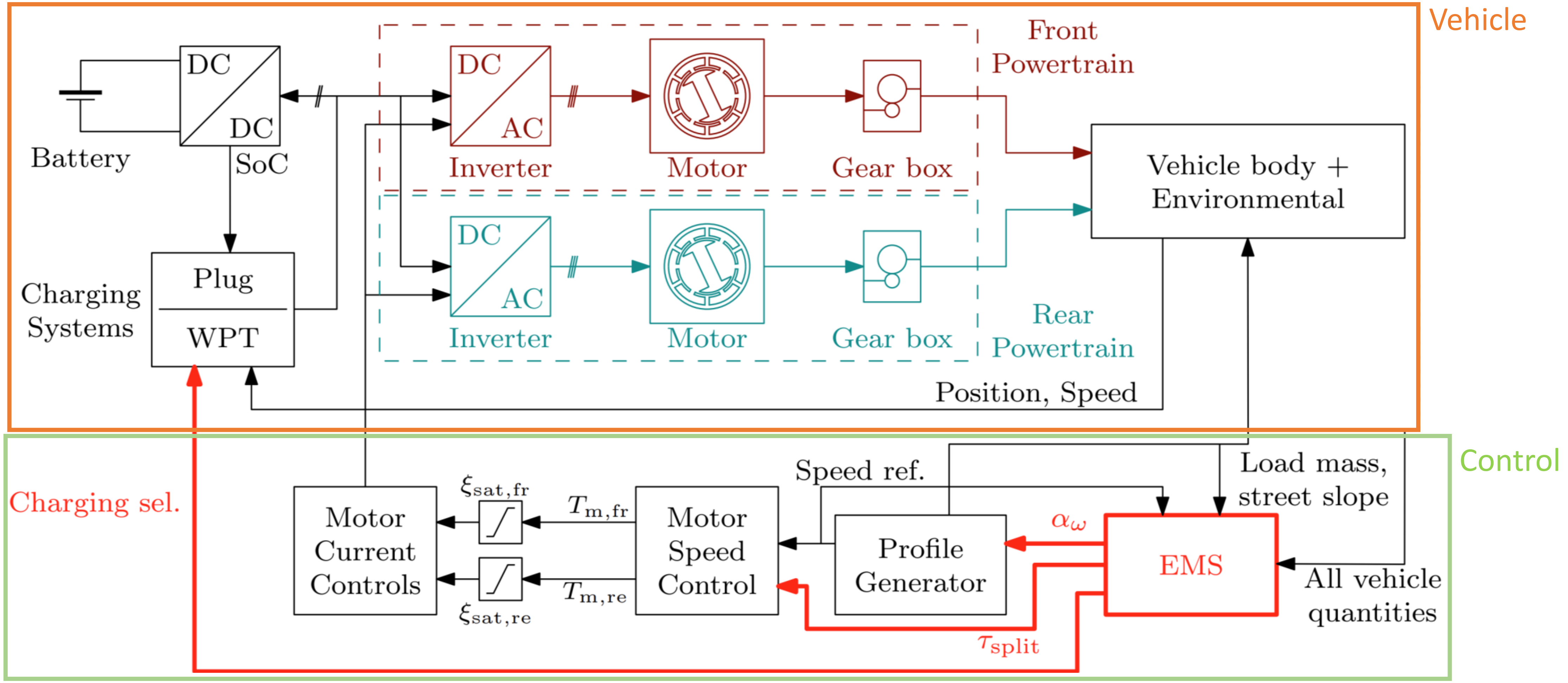
MVC 2026 - Design of Powertrain and Energy Management Strategy for a Refrigerated Lorry

Partecipants has to:

- Design the dual-motor powertrain (offline)
- Choose the battery capacity (offline)
- Develop a motors current strategy (offline)

- Choose the instantaneous torque split (online)
- Develop the energy management strategy to ensure the completion of the required activity (online)

Simulation schematics



Simulation details

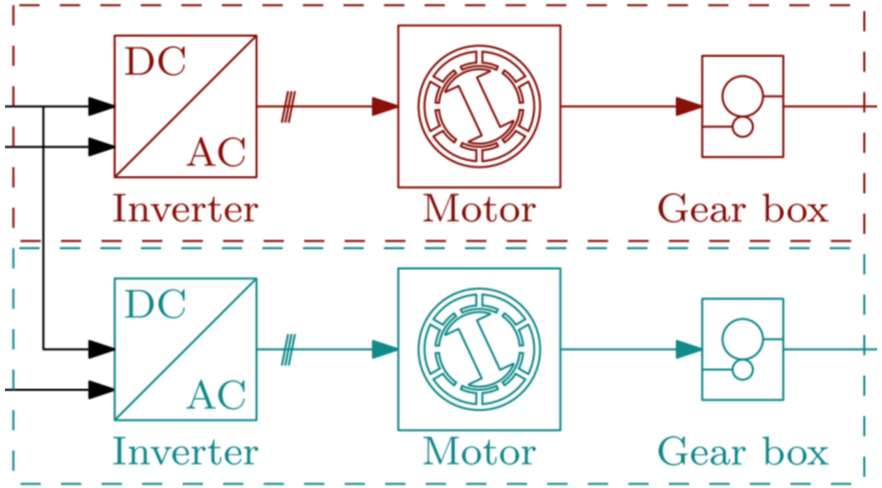
- The Simulation has been developed in MATLAB/Simulink environment
- Version and Toolbox requirements:
    - MATLAB/Simulink 2023b Update 10
    - Simscape (ver. 23.2)
        - Simscape Battery
        - Simscape Driveline
        - Simscape Electrical
    - Optimization Toolbox (ver 23.2)
    - Control System Toolbox

We would like to thank MathWorks Italy for the support in improving the Simulation files.

Powertrain design

Front and **rear motor power** must be selected

- Front power <= 250kW
- Rear power <= 450kW
- Nominal speed and parameters are given
- Weight proportional to motor torque

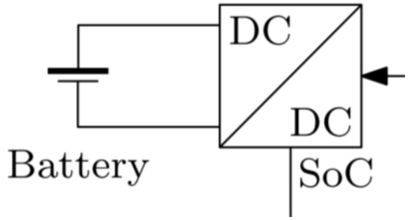


Current control strategy must be developed

- Direct- and quadrature-current trajectory vs torque

Battery capacity must be chosen

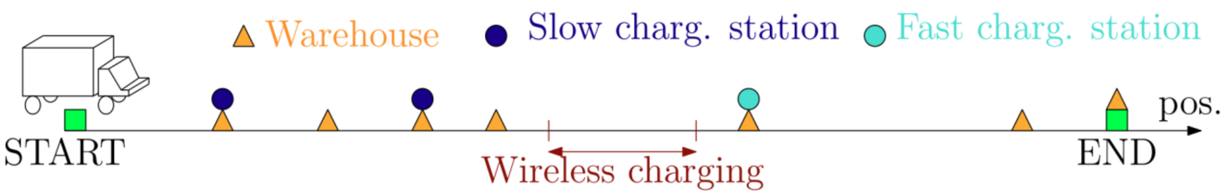
- Four possibilities are provided (7.5, 10, 12.5, 15 kWh)
- Initial provided energy is constant
- Battery weight changes

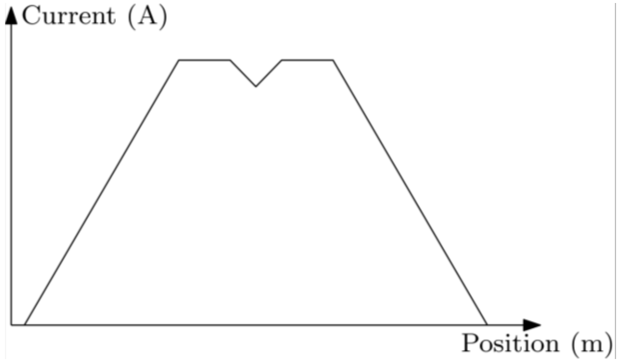


Charging infrastructure

In each lorry route, there are

- A high-power station
  - Charging current 200 A
  - Position range 99-101 m
  - Max approach speed 0.1 m/s
- Two low-power stations
  - Charging current 100 A
  - Position range 450-452 m & 1300-1302m
  - Max approach speed 0.1 m/s
- A wireless power transfer system
  - Max charging current 125 A
  - Position range 500-900 m
  - Max operating speed 15 m/s
  - Transferred power depends on position and speed

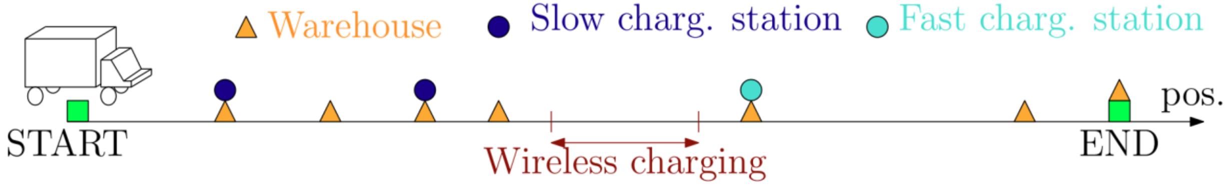




Energy management strategy

The charging source can be selected by a flag

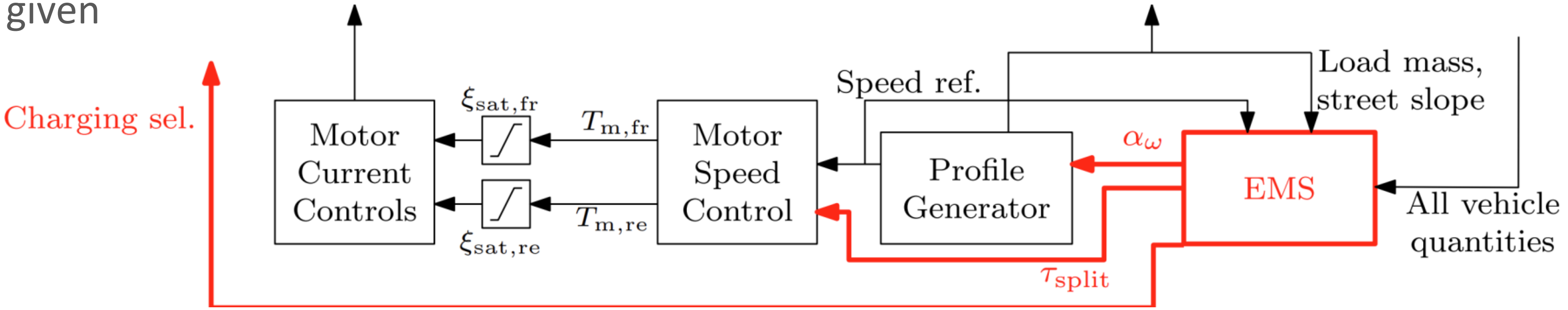
- 0 -> No charging
- 1 -> Plug
- 2 -> WPT



Lorry speed reference can be adjusted by the parameter α_ω

$$\omega^*_{\mathrm{m}}(t) = \frac{d}{dt}\vartheta^*_{\mathrm{profile}}(\tau) \quad \text{with} \quad \tau = \int_0^T \alpha_\omega dt$$

With $\alpha_\omega \in [0,1]$ and $\vartheta^*_{\mathrm{profile}}$ given



Energy management strategy

Torque split between electrical motors

$T_{\text{m,rear}}(t) = (1 - \tau_{\text{split}}(t))T_{\text{tot}}(t)$

$T_{\text{m,front}}(t) = \tau_{\text{split}}(t)T_{\text{tot}}(t)$

- $T_{\text{tot}}(t)$ is the obtained by the speed loop
- Both signal are saturated to the nominal motor torque

An emergency charging system is implemented

- Charging current 100 A
- Starting SoC 5%
- Ending SoC 50%
- It starts automatically and forces vehicle in standstill condition

A constant power consumption is implemented to emulate the refrigeration system

MVC 2026 – Cost function

$$\Phi_{\text{tot}} = \omega_{\text{E}}\Phi_{\text{E}} + \omega_{\text{cost}}\Phi_{\text{cost}} + \omega_{\text{tau}}\Phi_{\text{tau}} + \omega_{\text{time}}\Phi_{\text{time}} + \omega_{\text{batt}}\Phi_{\text{batt}}$$

- Overall energy usage (provided by battery and charging systems)

$$\Phi_{\text{E}} = \int_0^T P_{\text{batt}}\, dt + \int_0^T P_{\text{charging}}\, dt$$

- Energy cost

$$\Phi_{\text{cost}} = [E_{\text{fast}}, E_{\text{slow}}, E_{\text{WPT}}, E_{\text{emer}}]^T$$

- Motors overloading

$$\Phi_{\text{tau}} = \int_0^T (\xi_{\text{sat,front}} + \xi_{\text{sat,rear}})dt \qquad \xi_{\text{sat},x} = \begin{cases} 1 & \text{if } |T_{\text{m},x}| = T_{\text{r},x} \\ 0 & \text{otherwise} \end{cases}$$

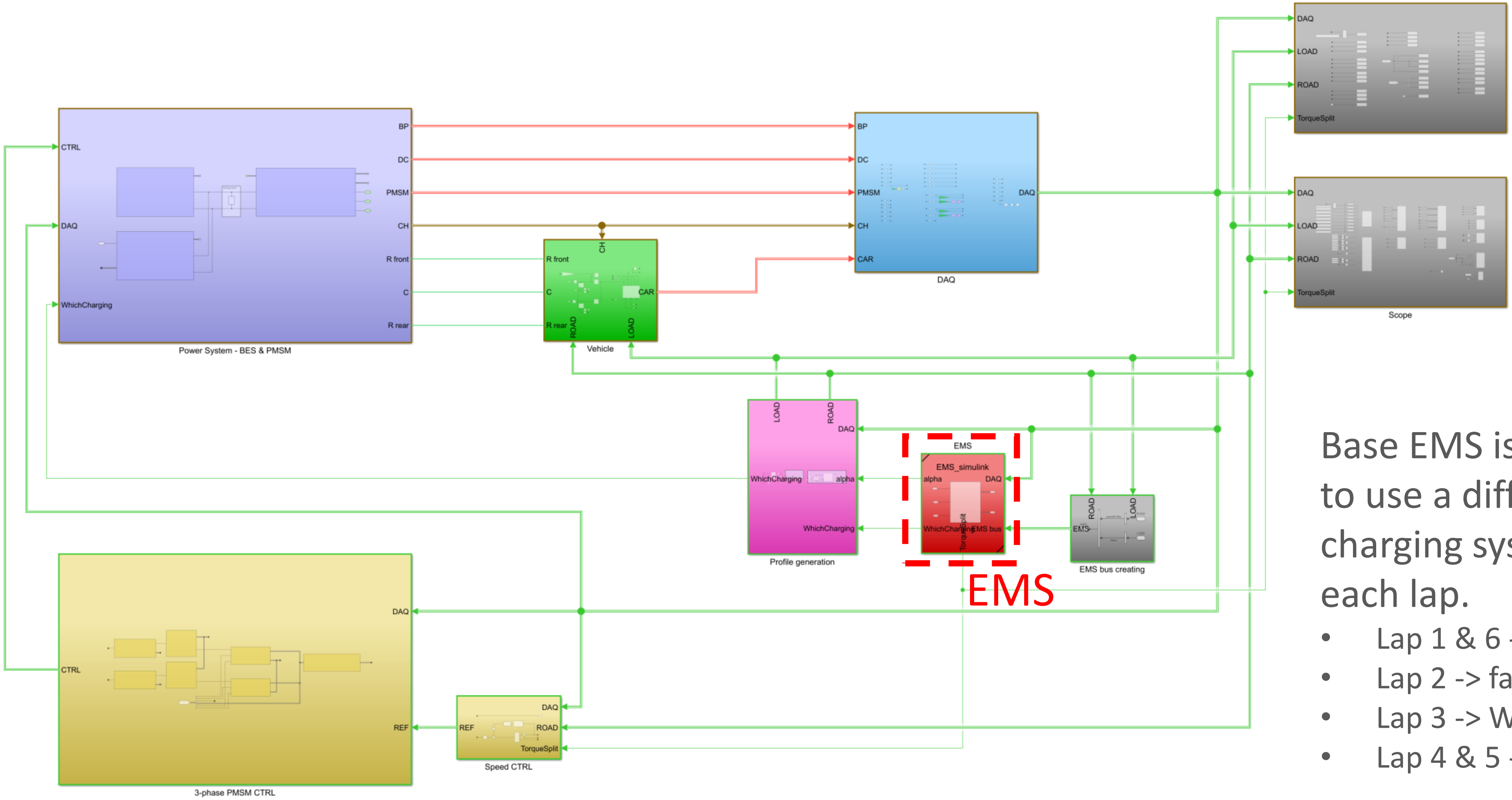
- Time to complete the mission

$$\Phi_{\text{time}} = T$$

- Battery current fluctuations

$$\Phi_{\text{batt}}^2 = \frac{1}{T}\int_0^T \left(\frac{dI_{\text{batt}}}{dt}\right)^2 dt$$

SIMULATION SETUP – OVERVIEW



Base EMS is designed to use a different charging system for each lap.

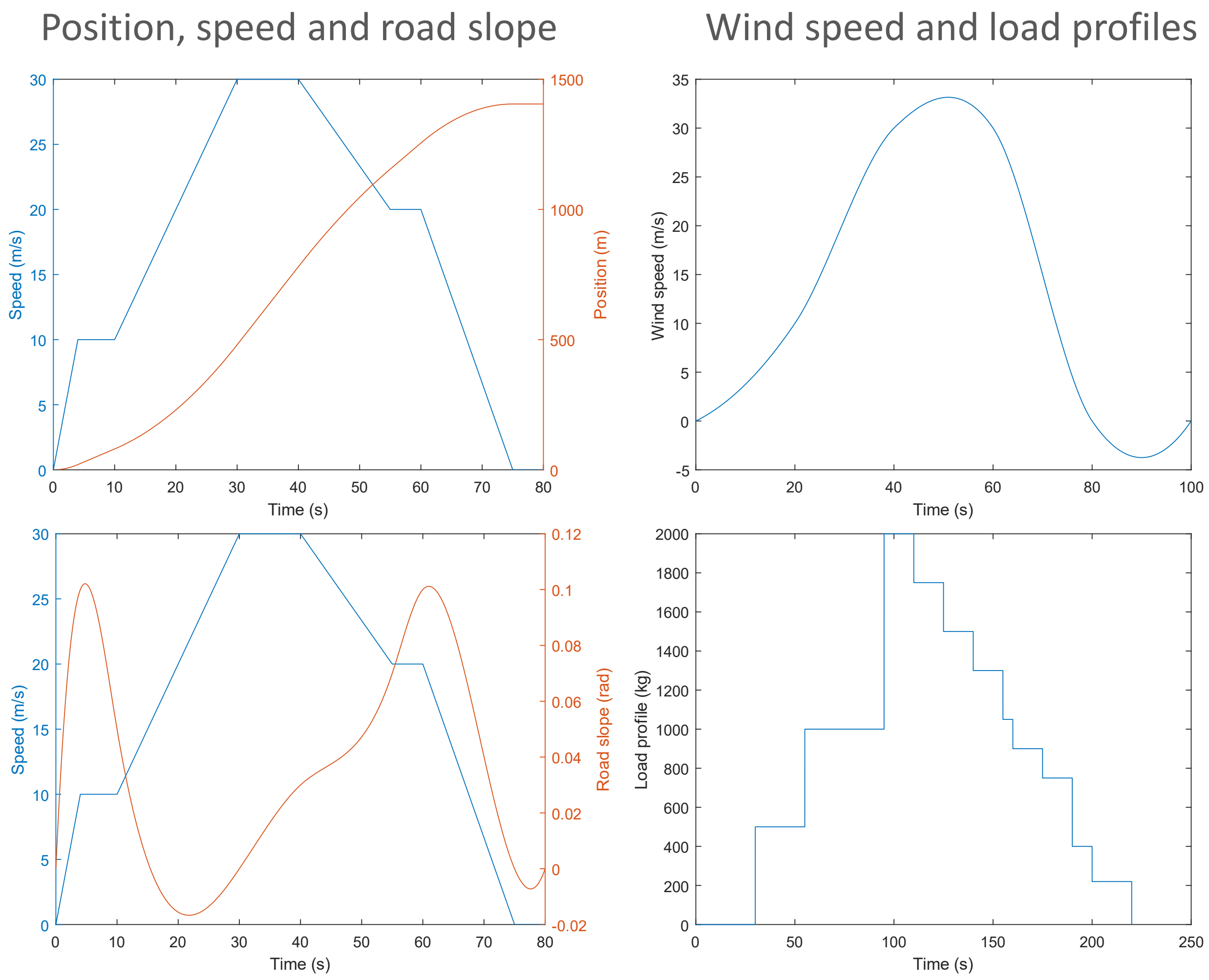
- Lap 1 & 6 -> no charging
- Lap 2 -> fast plug
- Lap 3 -> WPT
- Lap 4 & 5 -> slow plug

CYCLE EXAMPLE

Position, speed and road slope are jointly defined

Load profile and wind speed have a different time scale so each lap is different with respect the previous one

Decreasing vehicle speed by coeff. α_ω, wind speed is unaffected

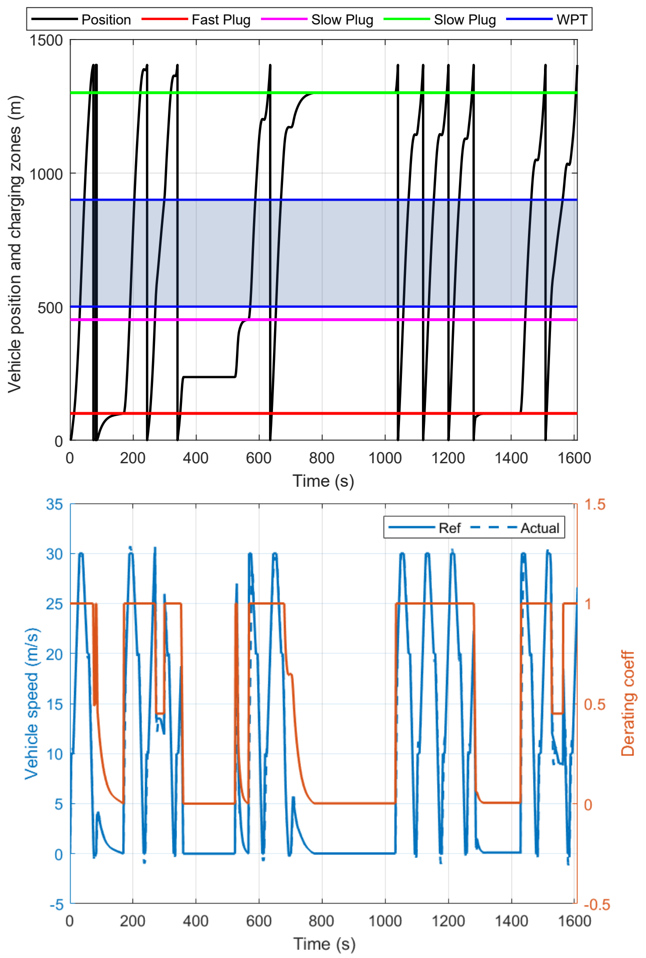


CYCLE EXAMPLE - RESULTS

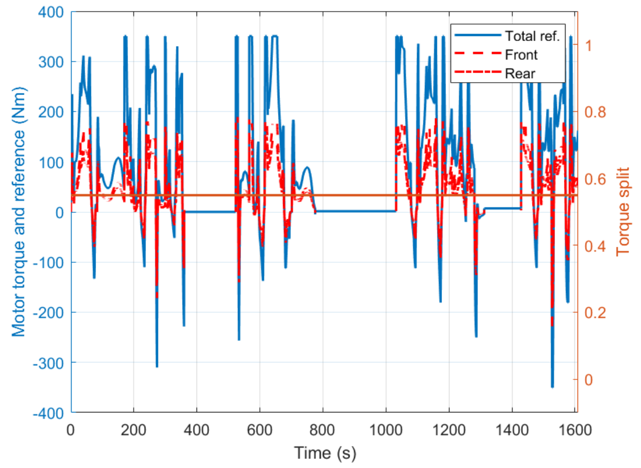
Vehicle speed is different to its reference

Speed reference is proportional to derating coeff

Position, speed and derating coeff



Ref and measured motors torque



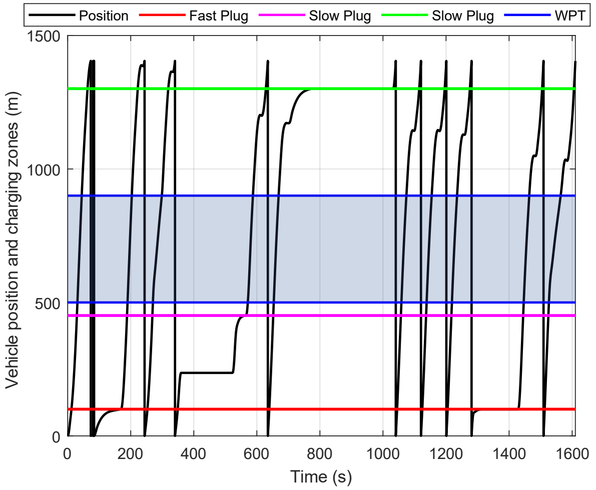
CYCLE EXAMPLE - RESULTS

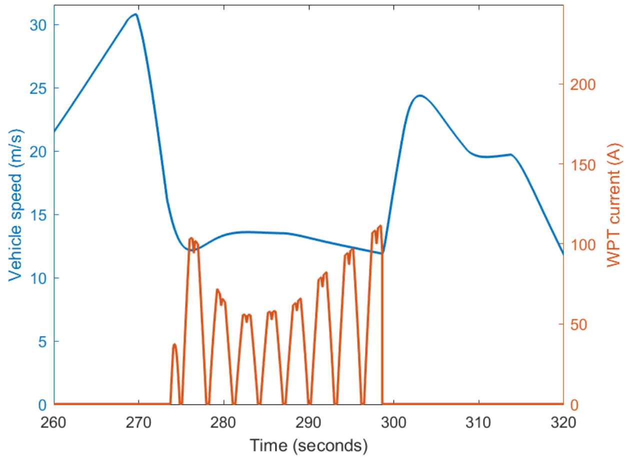
The lorry stops to charge from a power outlet

WPT current depends on position and vehicle speed

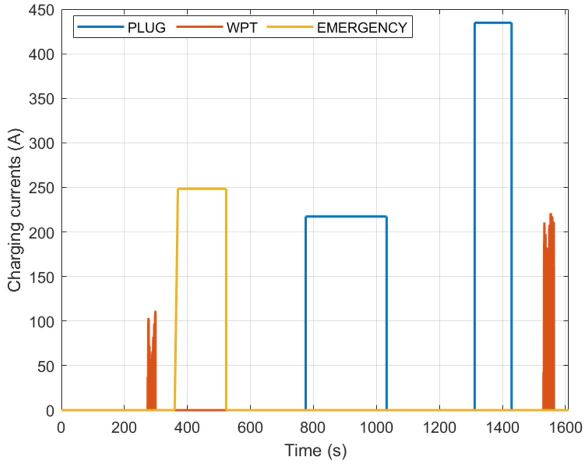
Emergency charging start @5% of SoC and vehicle is in standstill condition

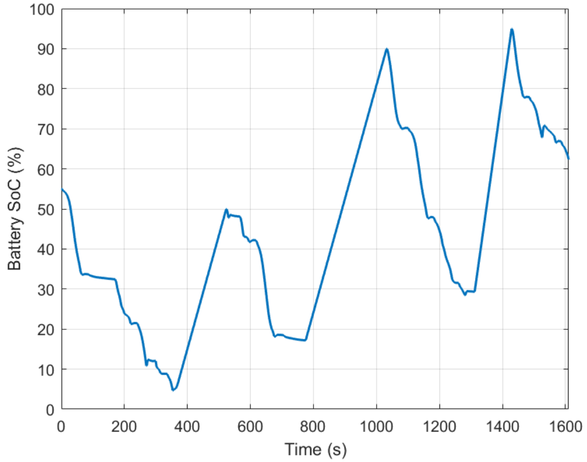
Position and charging zones





Charging currents and SoC





ENJOY THE CHALLENGE
AND MAY THE BEST WIN