Exercise – Electrical Vehicle – Simulation model

Course: Electric Propulsion
Exercise: Electric Vehicle – Simulation model

Purpose is to create a Matlab/Simulink model of the EV and to simulate its behaviour under:

- Slow charge
- Fast charge
- Driving session according to NEDC cycles

NEDC: New European Driving Cycle

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EV Battery Cell. Technical data

31 Ah NMC Li-ion cell specifications

- Nominal Capacity = 31 Ah
- Nominal Voltage = 3.7 V
- Voltage range = 3.4 V - 4.2 V
- Nominal energy capacity = 114,7Wh

Operating temperatures
- Charge = 0°C / +40°C
- Discharge = -20°C /+ 60°C

Dimensions
- Thickness = 8.4 mm
- Width = 215 mm
- Length = 220 mm
- Weight 1 kg

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EV Battery Pack. Technical data

Configuration:
100 cells in series, 3 branches in parallel (100S-3P)
Total number of cells: 300

- Nominal Capacity = 93 Ah
- Nominal Voltage = 370 V
- Nominal energy capacity = 34,4kWh

- DC Round trip efficiency RTE = 94%
- Equivalent series resistance = 120 mohm
- Net weight (only cells) = 300kg

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Thermal model of battery pack

A simplified first-order model is adopted, the battery pack weight is approximated by taking the cell weight only.
See thermal equivalent circuit.

Cell specific heat = 800 J/kg °C
Battery thermal capacity Cth = 800 x 300 = 240kJ/°C

Heat transfer: thermal conductance Gth battery-to-ambient has to be calculated
Two cooling methods are possible:
air cooling and liquid cooling (more efficient)
The same heat exchange area is chosen for both cooling methods = 0,5m2

- Air convection coefficient Kth-air = 200 W/m2 °C
- Glycol convection coefficient Kth-glyc = 2000 W/m2 °C

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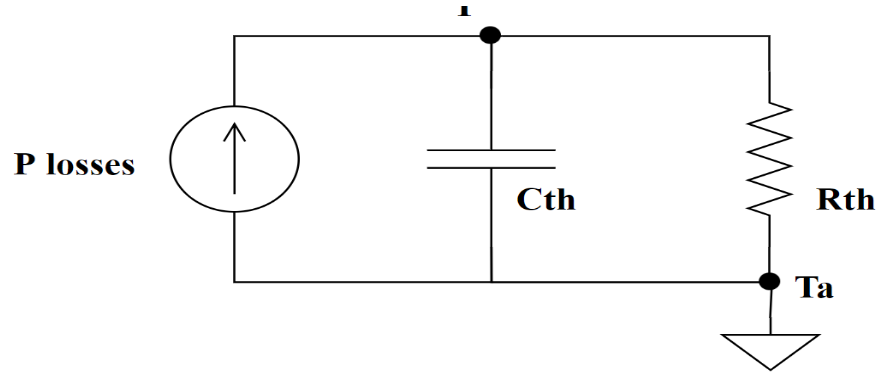

Thermal equivalent circuit

Calculation of the thermal conductance Gth

- Air convection Gth-a = 200 W/m2 °C x 0,5m2 = 100 W/°C
- Glycol convection Gth-g = 2000 W/m2 °C x 0,5m2 = 1000 W/°C

Numerical example: In steady state operating conditions, with a battery loss of 1kW, which corresponds to a charge at 1C, (93A^2x0,12ohm=1kW), the temperature rise of battery cells over ambient will be:

ΔT air = P / Gth-a = 1000W / 100 W/°C = 10°C
ΔT glyc = P / Gth-g = 1000W / 1000 W/°C = 1°C

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Vehicle data

- Average Kerb Weight = 1500 kg
- DC link battery voltage = 370 V
- Tank-to-Wheel efficiency = 80%
- Regenerative braking percentage = 50%
- **Rolling resistance coefficient fv**, tire on road = 0.02 pu
- **Shape coefficient cv** = 0.29 pu
- Vehicle frontal area = 2.38 m2
- Wheel radius = 0,35m

The EV is equipped with a 60kW electric motor. See variable speed characteristics in next slide

The kerb weight refers to the car loaded with all the fluids for its operation plus the weight of an average driver.

The Tank-to-Wheel (T2W) efficiency takes into account the mechanical transmission, the electric motor, the inverters and the battery.

Mechanical transmission has only one gear. Transmission ratio kt = N motor / N wheel = 5

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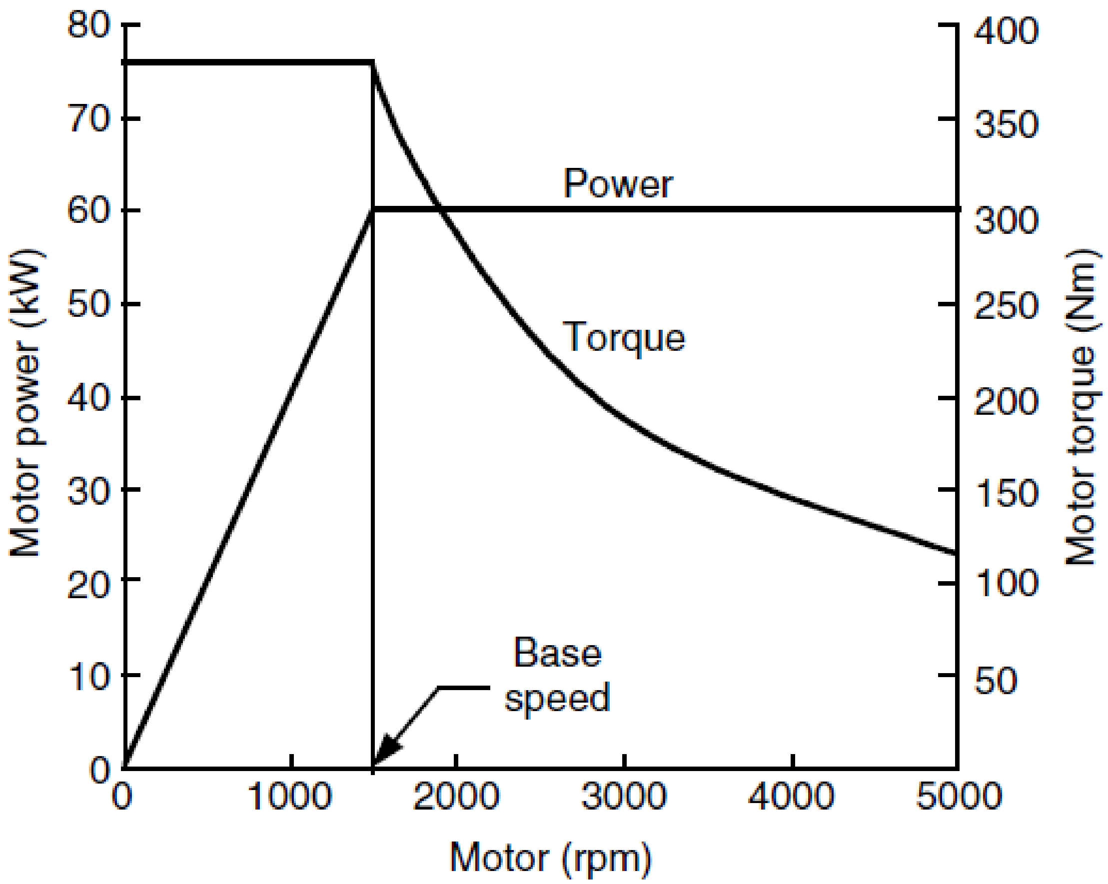
Variable speed characteristics of 60kW electric motor



Base speed = 1500 rpm
Max speed = 6000 rpm

X = max/base speed = 4

Base angular speed = 157 rad/s

Torque @ base speed = 382 Nm

Power = 382Nm x 157 rad/s = 60kW

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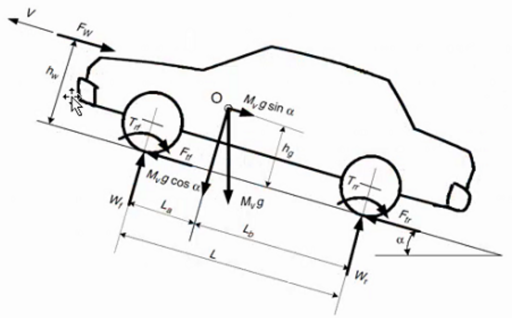
Calculation of electric power Pe

Forces acting on vehicle

In this exercise the grading resistance is neglected, assuming alfa=0



Calculation of electric power Pe

Forces acting on vehicle

In this exercise the grading resistance is neglected, assuming alfa=0

$$R_{rolling} = f_v \cdot m \cdot g$$

$$R_{aerodynamic} = \frac{1}{2} \cdot \rho_{air} \cdot A_{vehicle} \cdot v^2 \cdot c_v$$

$$P_m = F_T \cdot v = (R_{rolling} + R_{aerodynamic} + m_e a) \cdot v$$

$$P_e = P_m / \eta_{T2W}$$

An additional constant load of 800W has to be added to account for the power of the auxiliaries, such as heater or air conditioning

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Simulation:

<u>Slow charge</u>
A 7,2kW single phase rectifier (OBC = on board battery charger) charge the battery at approximately C4, with a current equal to one quarter of capacity, up to a SoC = 90%

<u>Fast charge</u>
A 50kW three phase rectifier (converter located in the external charger, EVSE = EV Supply Equipment) charge the battery at approximately 1,5C for 20minutes, starting from SoC = 20%

Assuming an AC RTE (Round Trip Efficiency) = 90%, the power losses in the battery chargers are equal to about 2,15%
AC RTE = 0,9 = RTE bat x (1-charger losses)^2 -> 0,9/0,94 = (1-charger losses)^2 -> charger losses = 2,15%

<u>Driving session, two NEDC cycles</u>

Calculate and draw the curves vs time of:

- Energy consumption
- Battery temperature
- SoC

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NEDC = New European Driving Cycle

NEDC represents the typical usage of a car in Europe.
It consists of four repeated ECE-15 urban driving cycles (UDC) and one Extra-Urban driving cycle (EUDC).