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MECA0527 EV, HEV, and FC vehicles

ENERGY CONSUMPTION

ASSIGNMENT 2

Your second assignment tackles the estimation of the modelling and the computer simulation of the energy consumption performance of a battery electric vehicle. This year, we are going to consider the following vehicle: ***Nissan Leaf II (model 2018)***

Data collected in the references [1,3] give:

ELECTRIC MOTOR

- Pmax = 110 kW @ [3282-10 000] rpm
- Cmax =320 Nm @ [0 ; 3282] rpm
- Nmax = 10300 rpm

BATTERY

- Lithium ion NMC
- Capacity: 40 kWh
- Voltage:
- Internal resistance model (see Ref [1])
- Peukert coefficient: k=1.03

- Power consumption of accessories: 200 W

VEHICLE DATA

- C_X = 0.29
- S = 2.19 m²
- Air density ρ=1,22 kg/m³
- Tire size: 205/55 R 16 91H
- Effective rolling radius R_e: 0,31 [m]

- Tire rolling resistance: $f = 0.0136 + 0.4 \cdot 10^{-7} V^2$ (with V in km/h)

TRANSMISSION

- Transmission to the front wheels
- Single reduction ratio: 7.9377
- Transmission efficiency η: 0.97 (Please validate this estimation given by [1] using the guidelines given in the lectures).

GEOMETRY AND MASS PROPERTIES

- Length/Width/height (mm): 4490/1788/1530
- Wheelbase (mm): 2700
- Curb weight: 1580 -1640 kg (+driver mass 75 kg)
- Weight distribution between front and rear axles: 50/50
- The elevation of the center of gravity as given by h= 20 inches = 508 mm

ELECTRIC MOTOR EFFICIENCY MODEL

Mahmoudi et al [4] have proposed an interesting approach to model the losses of electric machines and then determine an approximated efficiency map. This one assumes that looses are described by a polynomial expression

$$P_{loss} = \Sigma\, k_{mn} (T/T_b)^m (\omega/\omega_b)^n \text{ pu}$$

In Ref [4], the authors propose the following table of coefficients for IPM motors:

T^3	0.339			
T^2	0.103	1.071		
T	0.470	-1.022	0.534	
1	-0.033	0.239	-0.334	0.171
	1	ω	ω^2	ω^3

This model was used by Laitinen in Ref [5,6] to model the Nissan Leaf e-motor for model 2013. It is suggested to revisit the model and to adapt it at best to our new Nissan Leaf model 2018.

The Nissan Leaf E-motor and inverter maps are provided in Appendix 1.

The MATLAB code by Laitinen [5] is also provided.

EXPECTED OUTCOMES OF ASSIGNMENT 2: ENERGY CONSUMPTION

1. Determine an approximation of the energy conversion efficiency map of the electric motor and inverter by revisiting the model of energy losses proposed by Mahmoudi et al [4]
2. Determine a model of the battery using the approach suggested in Ref [1].
3. Compute the energy consumption [kWh/100 km] at constant speed at 30 km/h, 50 km/h, 70 km/h, 90 km/h and 120 km/h
4. Draw the energy consumption [kWh/100km] curves (at constant speed) as a function of the driving speed from 5 km/h to 130 km/h. (The fuel consumption curve should look like a U shape as suggested by Badin et al. 2013 [7]).
5. What is your conclusion on the reduction of speed limits from 50 km/h to 30 km/h in the city considering only the fuel consumption criteria?
6. Estimate the extra energy consumption when driving in winter conditions (-5°c) and in hot and wet summary conditions (+35°C)? Comment your results.
7. Calculate the energy consumption over the driving cycle shown in Figure 2 suggested in Ref. [8].
8. Investigate the effect of a better braking energy recovery efficiency and estimate the improved energy consumption upon the drive cycle of Figure 2 when the coefficient α rises from 0.3 to 0.4 or 0.5.
9. To study the effect of aggressive driving on fuel consumption, consider the cycles in Figure 3 [8]. Compare the increase in energy consumption if the maximum plateau speed varies between 15 m/s, 20 m/s, and 25 m/s.
10. Bonus question: Estimate the energy consumption according to the European driving cycle (NEDC) using your computer code.
    a. What is the fuel consumption for the city driving cycle only?
    b. What is the fuel consumption for the extra urban driving cycle?

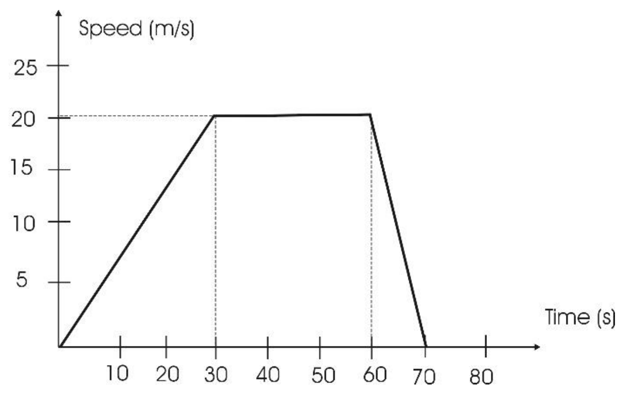

Figure 2 : Driving cycle 1

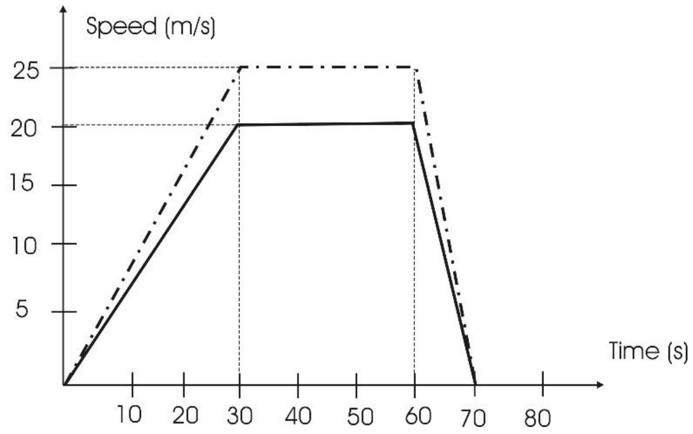

Figure 3 : Driving cycle 2

Terms of Duty:

The work will be in a group of two students. Each group will submit a report of a maximum of 30 pages. Reports are preferably submitted under pdf format. The report will include a description of the hypotheses made, the equations used, the complete results (possibly in appendix), a critical analysis of the results, a copy of the calculation codes used (possibly in appendix).

The report will be submitted by email to p.duysinx@uliege.be by Thursday, December 23, 2021 at 23:59 (Brussels time).

References:

[1] Paolo Iora and Laura Tribioli. *Effect of Ambient Temperature on Electric Vehicles' Energy Consumption and Range: Model Definition and Sensitivity Analysis Based on Nissan Leaf Data*. World Electric Vehicle Journal. 2019, 10, 2. doi:10.3390/wevj10010002.

[2] Li Gang and Yang Zhi. *Energy saving control based on motor efficiency map for electric vehicles with four-wheel independently driven in-wheel motor*s. Advances in Mechanical Engineering. 2018, Vol. 10(8) 1–18. DOI: 10.1177/1687814018793064

[3] https://en.wikipedia.org/wiki/Nissan_Leaf , visited on October 20, 2021.

[4] A. Mahmoudi, W. L. Soong, G. Pellegrino and E. Armando, "*Efficiency maps of electrical machines*," 2015 IEEE Energy Conversion Congress and Exposition (ECCE), 2015, pp. 2791-2799, doi: 10.1109/ECCE.2015.7310051.

[5] H. Laitinen. *Improving electric vehicle energy efficiency with two-speed gearbox*. Master Thesis. Aalto University, Finlay. May 2017.

[6] H. Laitinen, A. Lajunen and K. Tammi, "Improving Electric Vehicle Energy Efficiency with Two-Speed Gearbox," 2017 IEEE Vehicle Power and Propulsion Conference (VPPC), 2017, pp. 1-5, doi: 10.1109/VPPC.2017.8330889.

[7] Badin F., Le Berr F., Briki H., Dabadie J.-C., Petit M., Magand S., and Condemine E. *Evaluation of EVs energy consumption influencing factors, driving conditions, auxiliaries use, driver's aggressiveness*. 2013 World Electric Vehicle Symposium and Exhibition (EVS27), Barcelona, Spain, 17-20.11.2013. IEEE p. 1-12

[8] B. Mashadi and D. Crolla. Vehicle Powertrain Systems. J. Wiley and Sons. 2012.

Appendix 1: Nissan Leaf electric machine maps

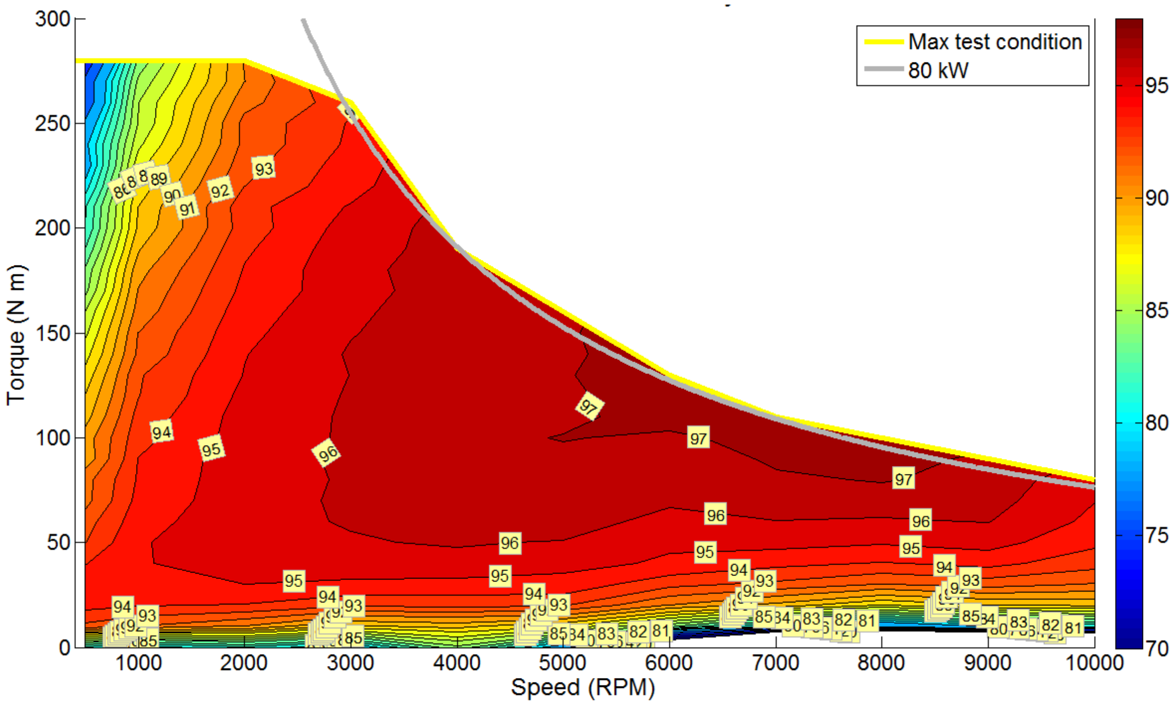

Figure 1 Efficiency map for the Nissan Leaf electric (model 2012) machine 80 kW

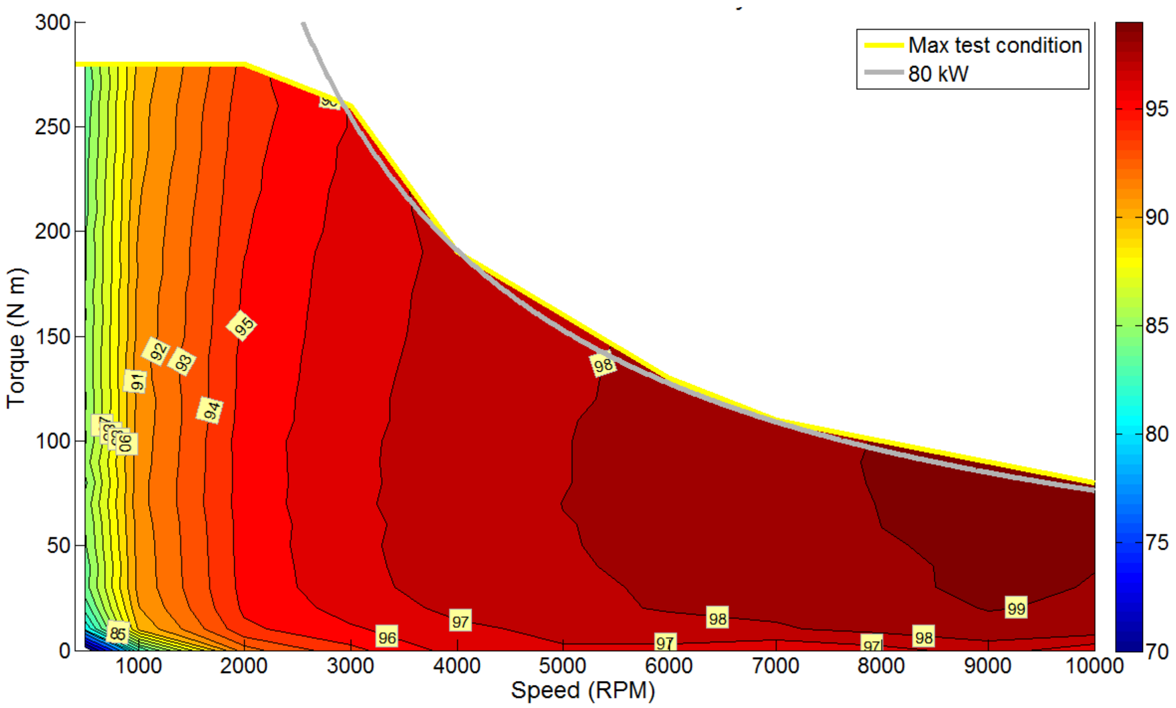

Figure 2 Efficiency map for the Nissan Leaf inverter (model 2012) 80 kW

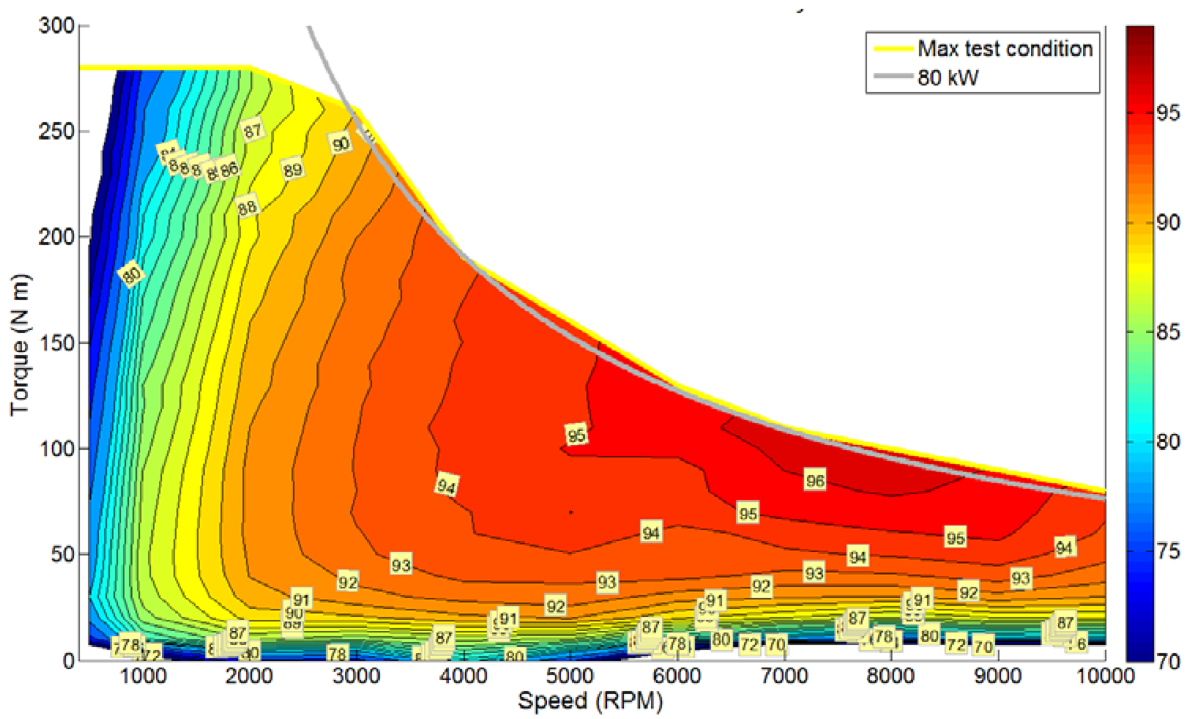

Figure 3 Efficiency map for the Nissan Leaf e-motor + inverter (model 2012) 80 kW

Appendix 2: Nissan Leaf electric machine maps using polynomial model [5,6]

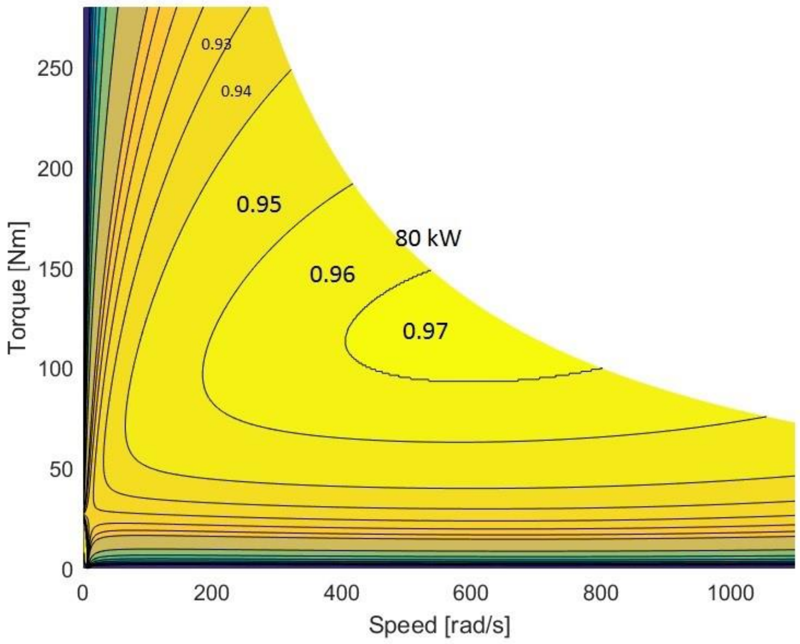

Figure 4 Efficiency map for the Nissan Leaf electric (model 2012) machine 80 kW [5]

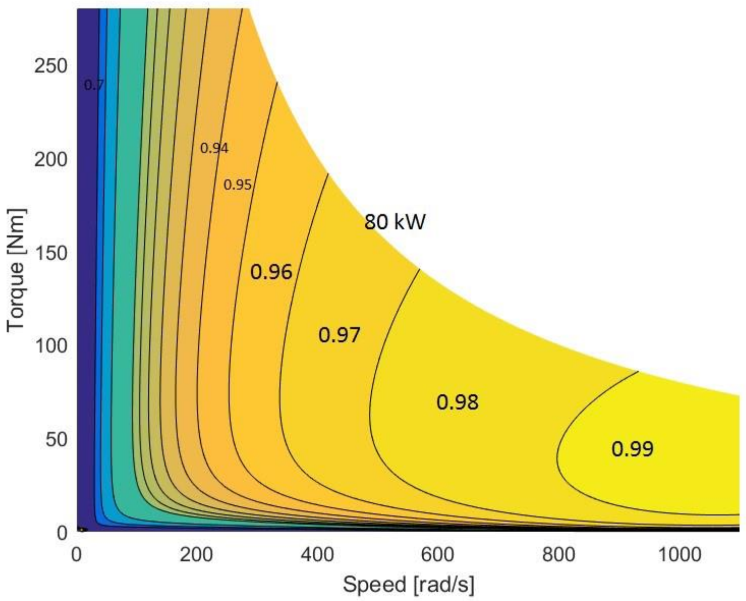

Figure 5 Efficiency map for the Nissan Leaf inverter (model 2012) 80 kW [5]

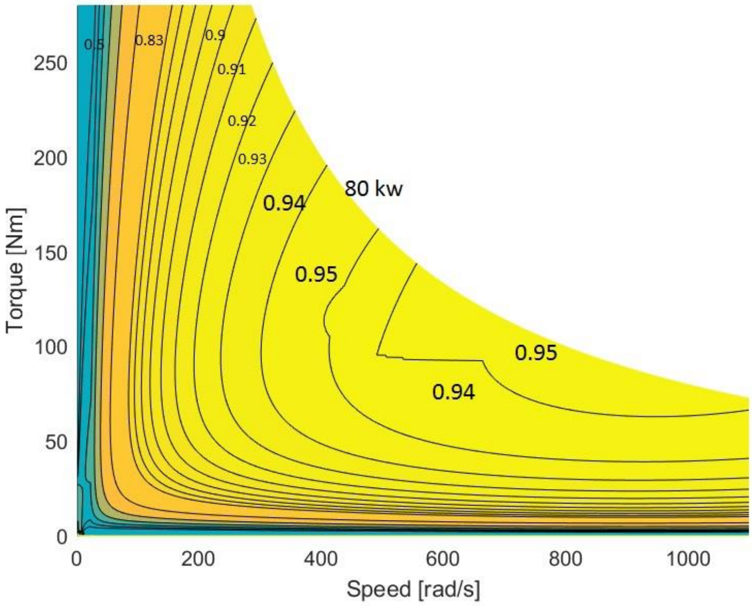

Figure 6 Efficiency map for the Nissan Leaf e-motor + inverter (model 2012) 80 kW

Appendix 3: Nissan Leaf battery curves

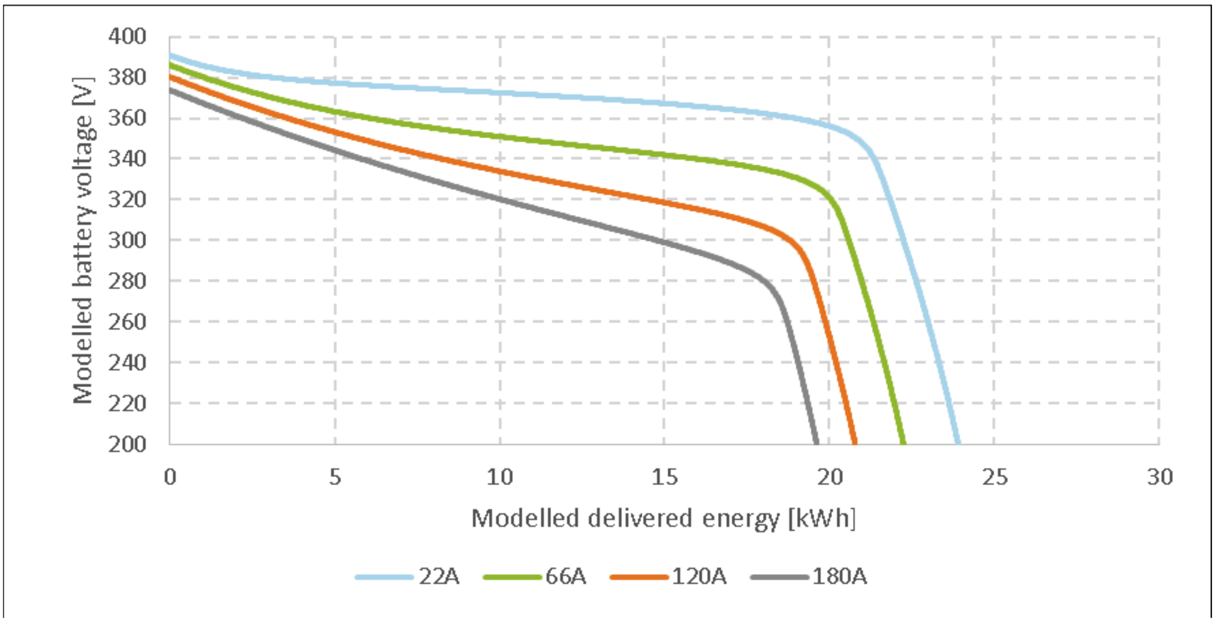

Figure 7: Discharge performance shown in energy, for Nissan Leaf