Thermo-magnetic FEM simulation of a PM synchronous motor with input data from telemetry driving cycles

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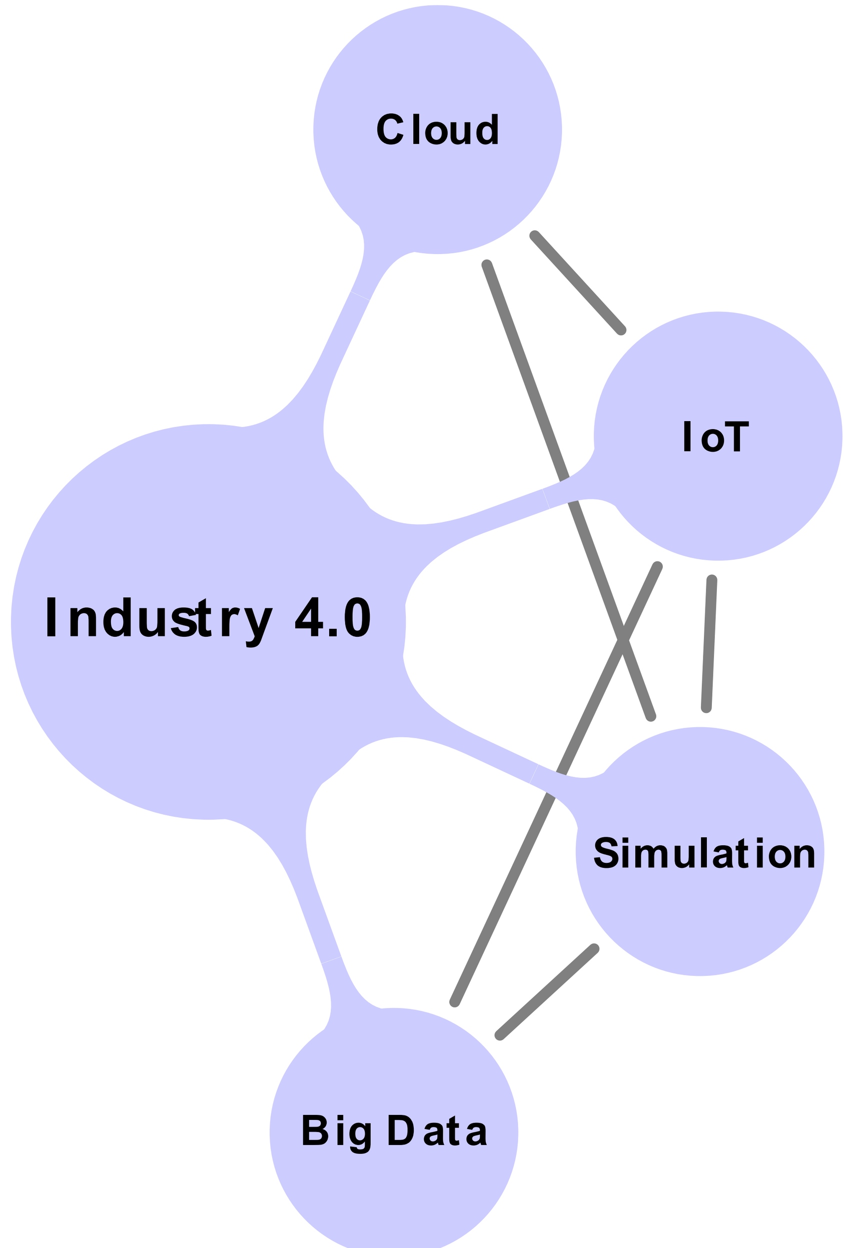
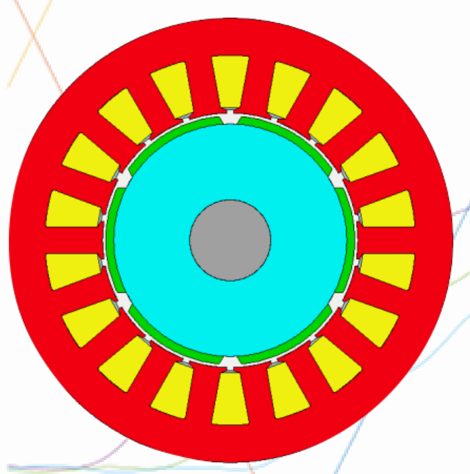


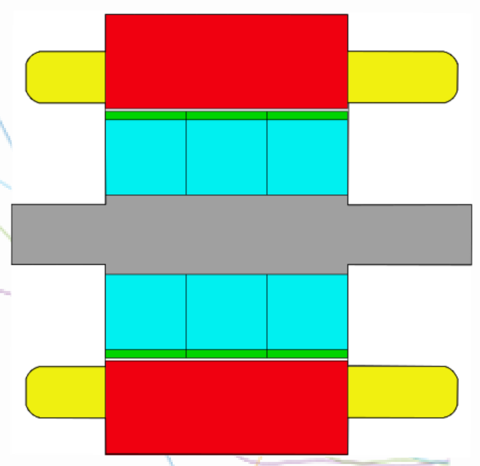
Introduction

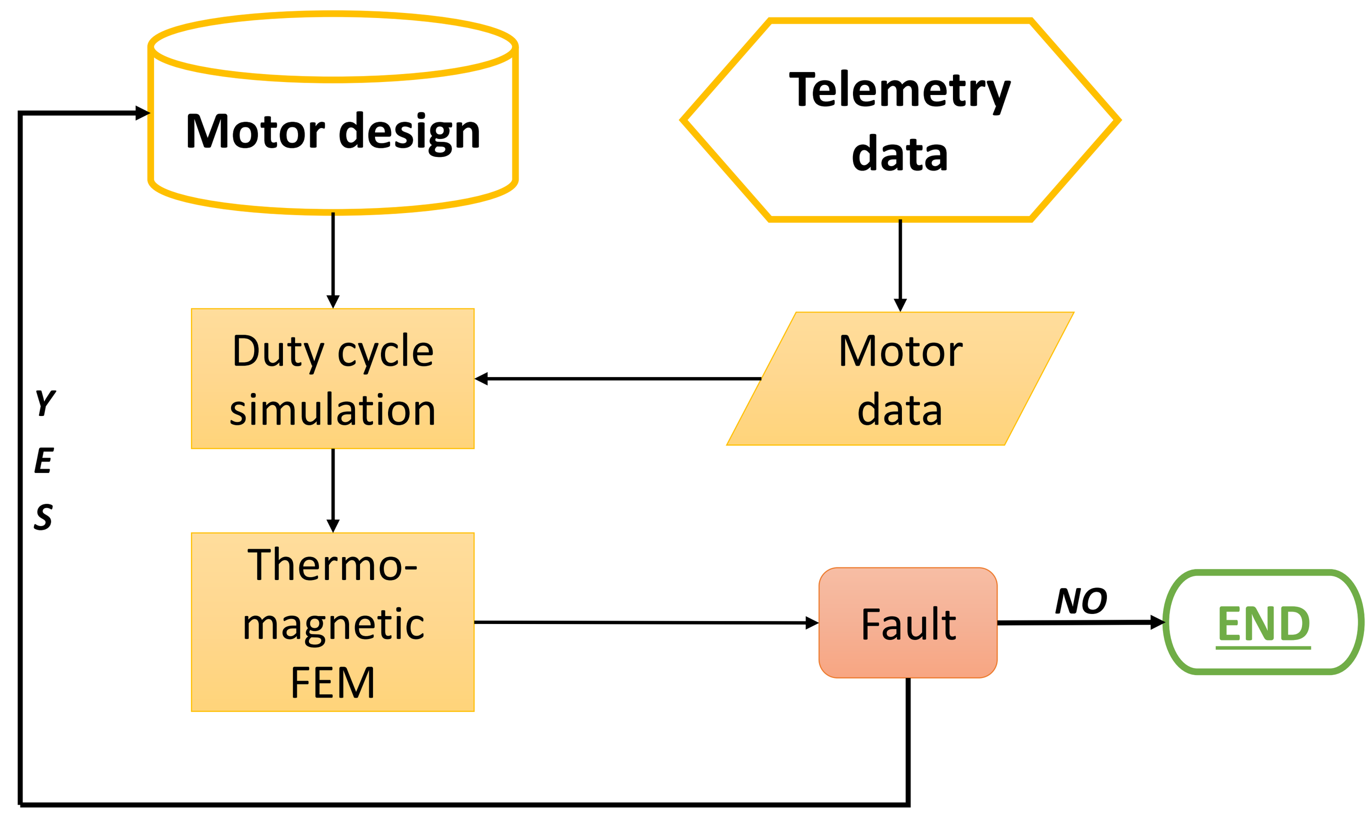
Earth's changing climate has several impacts on the individual mobility, logistics and agriculture. Research in magnetic materials has led to use of rare-earth magnets that enhances the motor power, but at the same time they are prone to demagnetize under thermal stress. In the context of the Industry 4.0, which has been representing the fourth industrial revolution, referring to the digital integration of machines in the network, in a way to prevent faults before they happen, by scheduling predictive maintenance using operational reports. This work points out a method for a continuous monitoring of a full electric vehicle prototype, equipped with a permanent magnets synchronous motor. By acquiring data with an electronic Arduino-based platform connected to the vehicle CAN-bus and by using them as inputs for a reverse engineered motor, designed starting from manufacturer's overall characteristics, the entire system health, including motor, batteries and power electronics are analysed, by paying attention on demagnetization in the worst-loaded points of the cycle.

Reverse engineering motor design



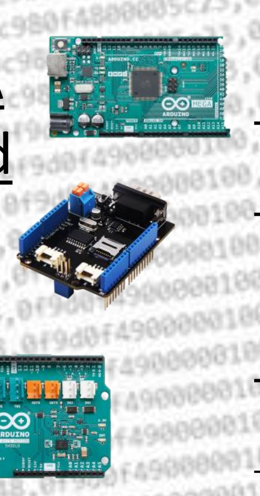
Power	43 kW
Torque	48 Nm
Current	150 A_{RMS}
BackEMF	180 V_{RMS}
Efficiency	96%





Telemetry system & Electric Vehicle data

- Arduino MEGA
- CAN-Bus shield
- IMU 9-axis motion
- GPS shield

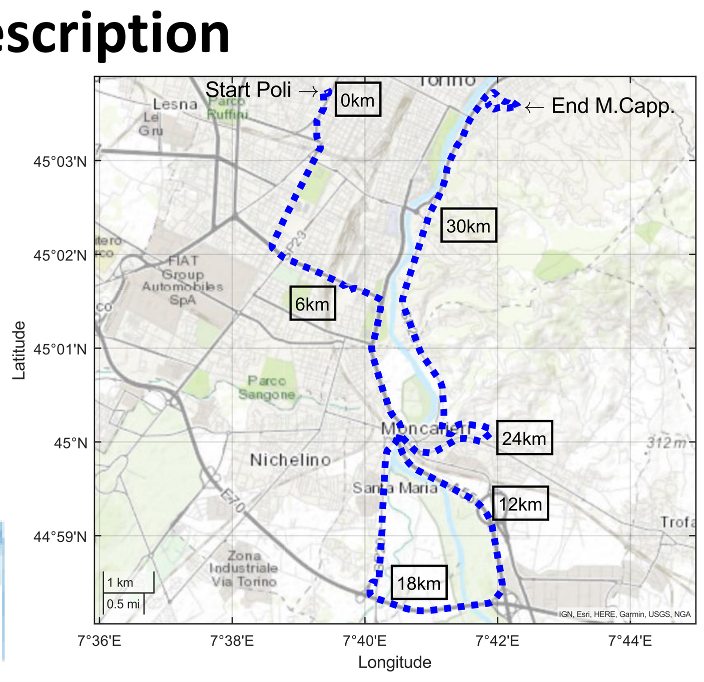


Battery	16 kWh
Voltage	640 V
Max speed	120 km/h
Range	150 km

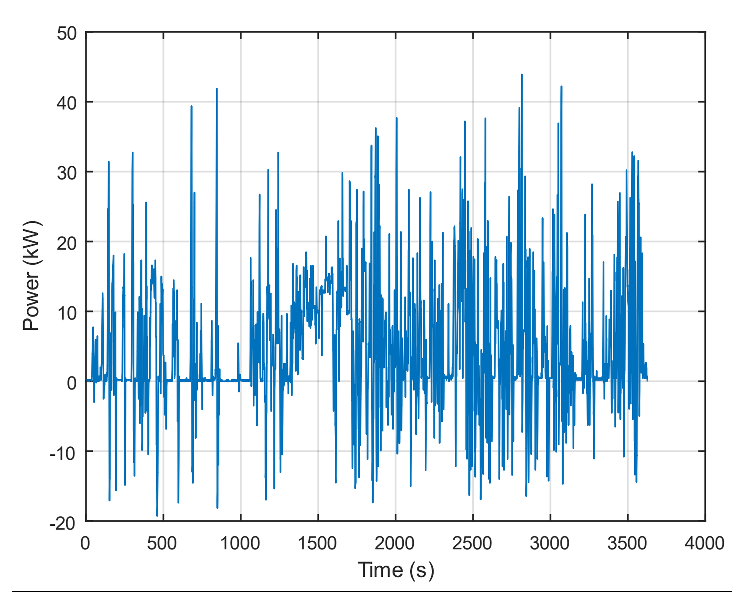
Duty cycle description

- Mixed Urban-Highway-Uphill path

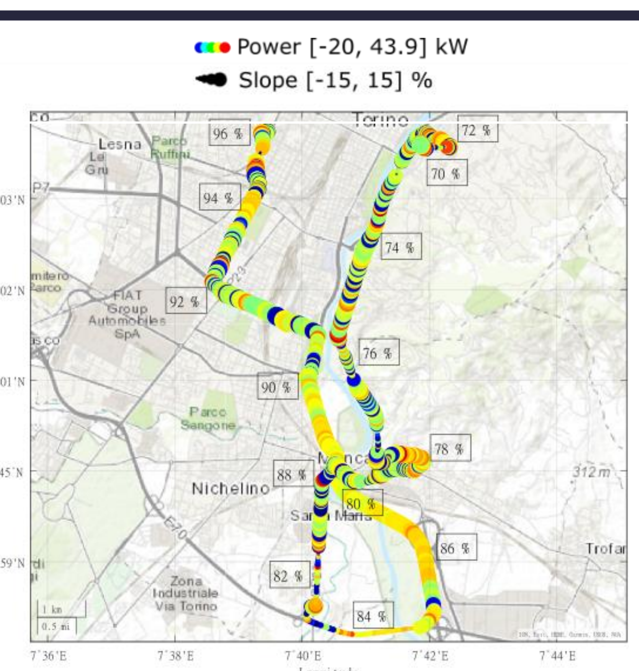
Distance	34 km
Av. Speed	36 km/h
Time	60 min
ΔElevation	60 m

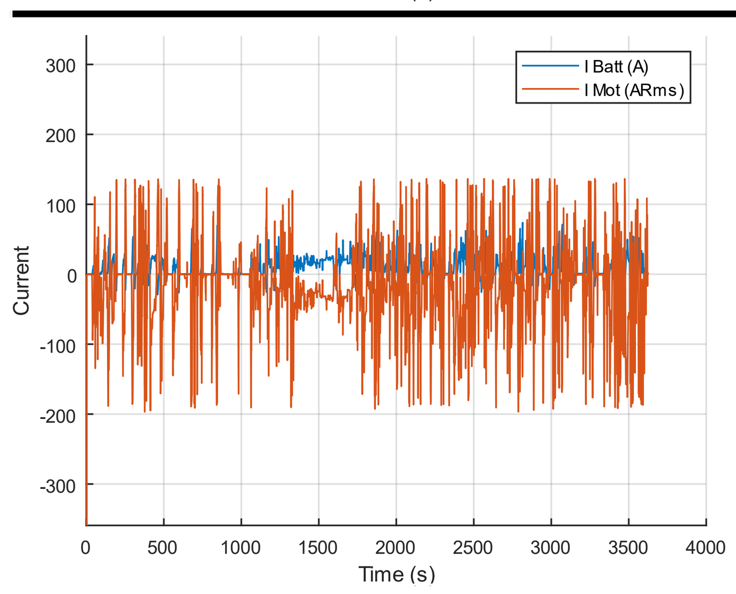


Results

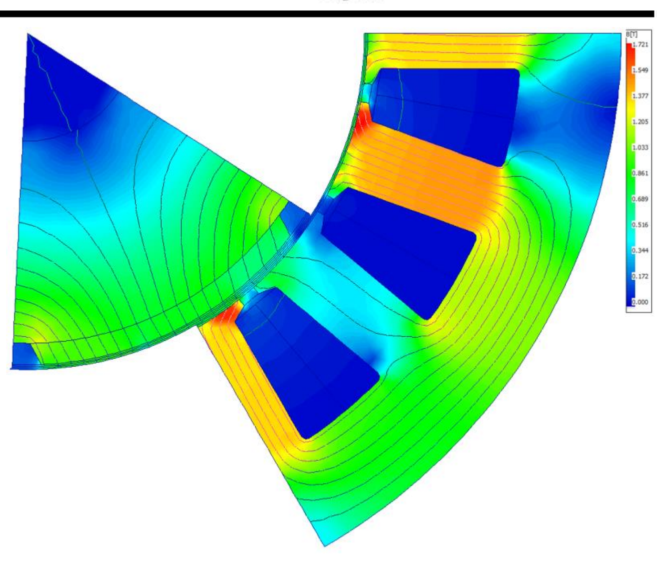


VEHICLE





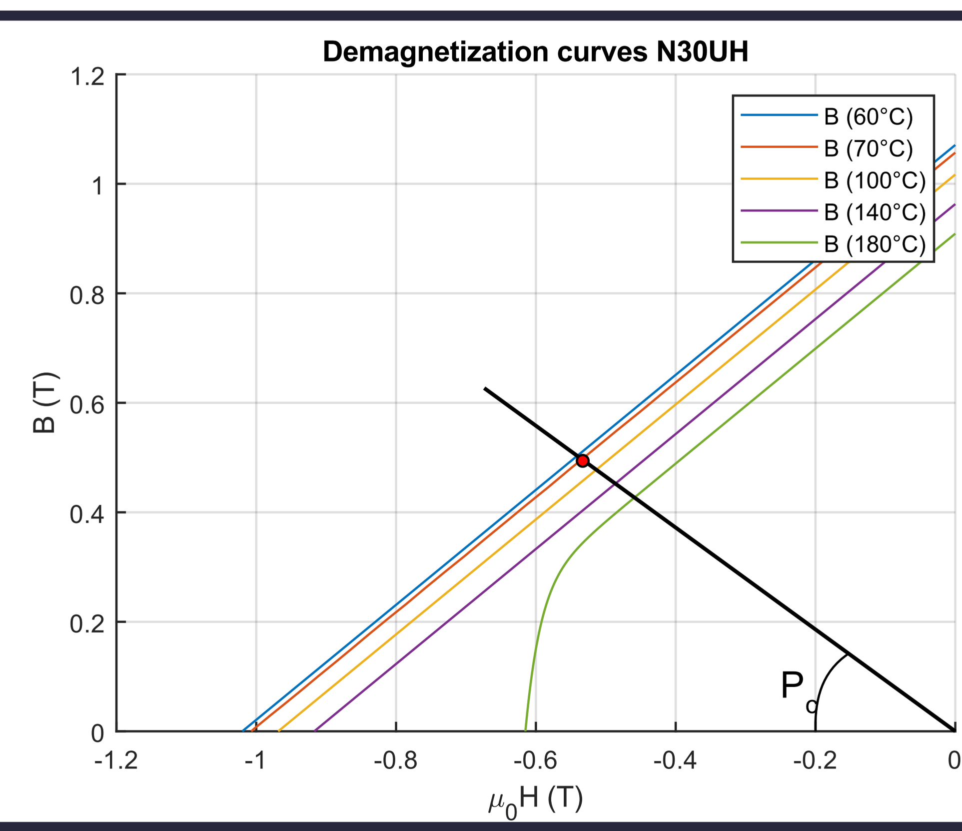
MOTOR



- *Sample time of 50 ms*
- *Coupled **thermal** & **electromagnetic** FEM simulations using MotorCad*

- ✓ *Finding the hottest and the most currents **loaded point** along the working cycle*
- ✓ *Perform **thermo-magnetic** simulation*
- ✓ *Compute **B-H** on magnets region*
- ✓ *Calculate P_c and the working point on demagnetization curves*
- ✓ *Find Safety coefficient against H_{knee}*

$$Cs = \frac{H}{H_{knee}} = 3.2$$



References

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- Mocera F., Somà A., «Working Cycle requirements for an electrified architecture of a vertical feed mixer vehicle»
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