European Commission

INEA

Innovation and Networks Executive Agency

Cluster GV-04-2017

Michal KLIMA

Senior Project Manager

EU Commission – INEA

Joint webinar European Mobility Week

18 September 2020

Innovation and Networks Executive Agency

Policy context

Featured projects are Part of the Green Vehicle Initiative PPP, created with the aim to:

- Create more energy efficient vehicles using alternative powertrains, strengthening the future competitiveness of the automotive industry

- Help to reach the ambitious targets set by the European Union (EU) for transport, energy and climate protection

- Match the transport needs within the EU with highly efficient and more flexible mobility products / services

Call - 2016-2017 Green Vehicles

Topic GV-04-2017: Next generation electric drivetrains for fully electric vehicles, focusing on high efficiency and low cost.

The scope of the topic is to optimise drivetrain components for fully electric vehicles in terms of efficient use and recovery of energy taking into account design for manufacturing, low weight and material cost

Call - 2016-2017 Green Vehicles

Topic GV-04-2017: Expected impacts from actions should be demonstrated on full size working prototypes as follows:

- An incremental reduction in total motor and power electronics system costs through optimised design for manufacture
- A 30% increase in specific torque and specific power of electric motors with a 50% increase in maximum operating speed whilst halving motor losses.
- A 50% increase in the power density of motor power electronics, a 50% reduction in losses and the ability to operate with the same cooling liquids and temperatures used for the combustion engine in hybrid configurations.

For more information

inea@ec.europa.eu

http://ec.europa.eu/inea

@inea_eu

Look for INEA!

Thank you!

DRIVEMODE

Integrated Modular Distributed Drivetrain
for Electric & Hybrid Vehicles

DRIVEMODE Project

Mehrnaz Farzam Far, VTT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769989

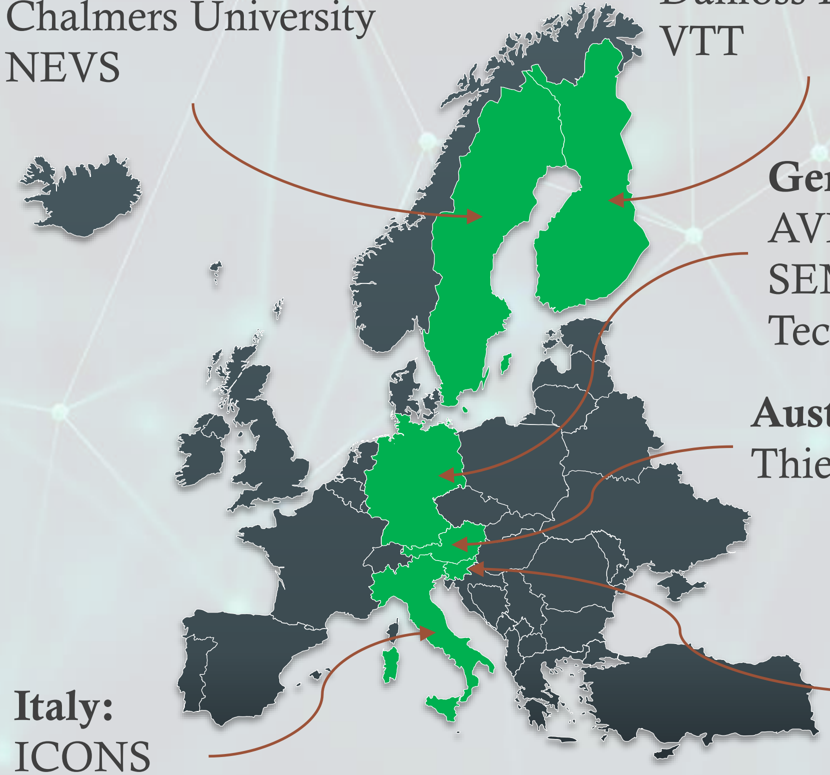
Consortium

Sweden:
BorgWarner
Chalmers University
NEVS

Finland:
Danfoss Editron
VTT

Germany:
AVL
SEMIKRON
Technical University Ilmenau

Austria:
Thien eDrives



Slovenia:
University of Ljubljana

Italy:
ICONS
S.C.I.R.E

- **HORIZON 2020**
- **2017 – 2021**
- **Budget ~9,5 mil €**
- **12 Partners**
- **6 countries**

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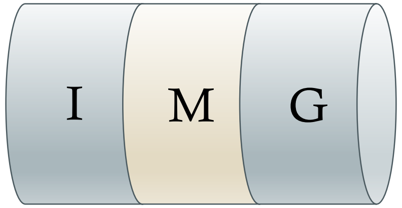
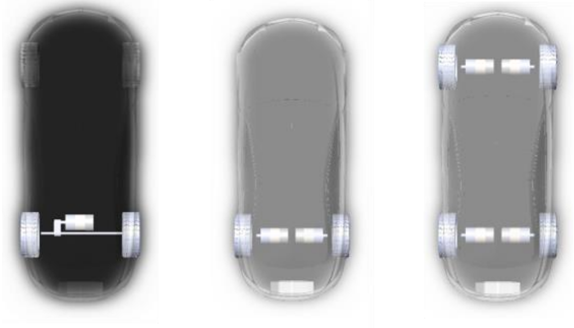
Objectives

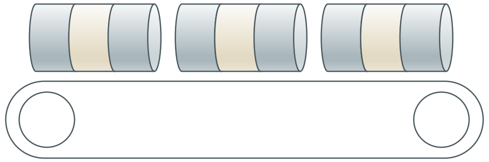
Developing efficient and cost-effective drivetrain modules for distributed drive concept



Integrated drivetrain module (IDM)



Distributed drive



Mass production

Target Values

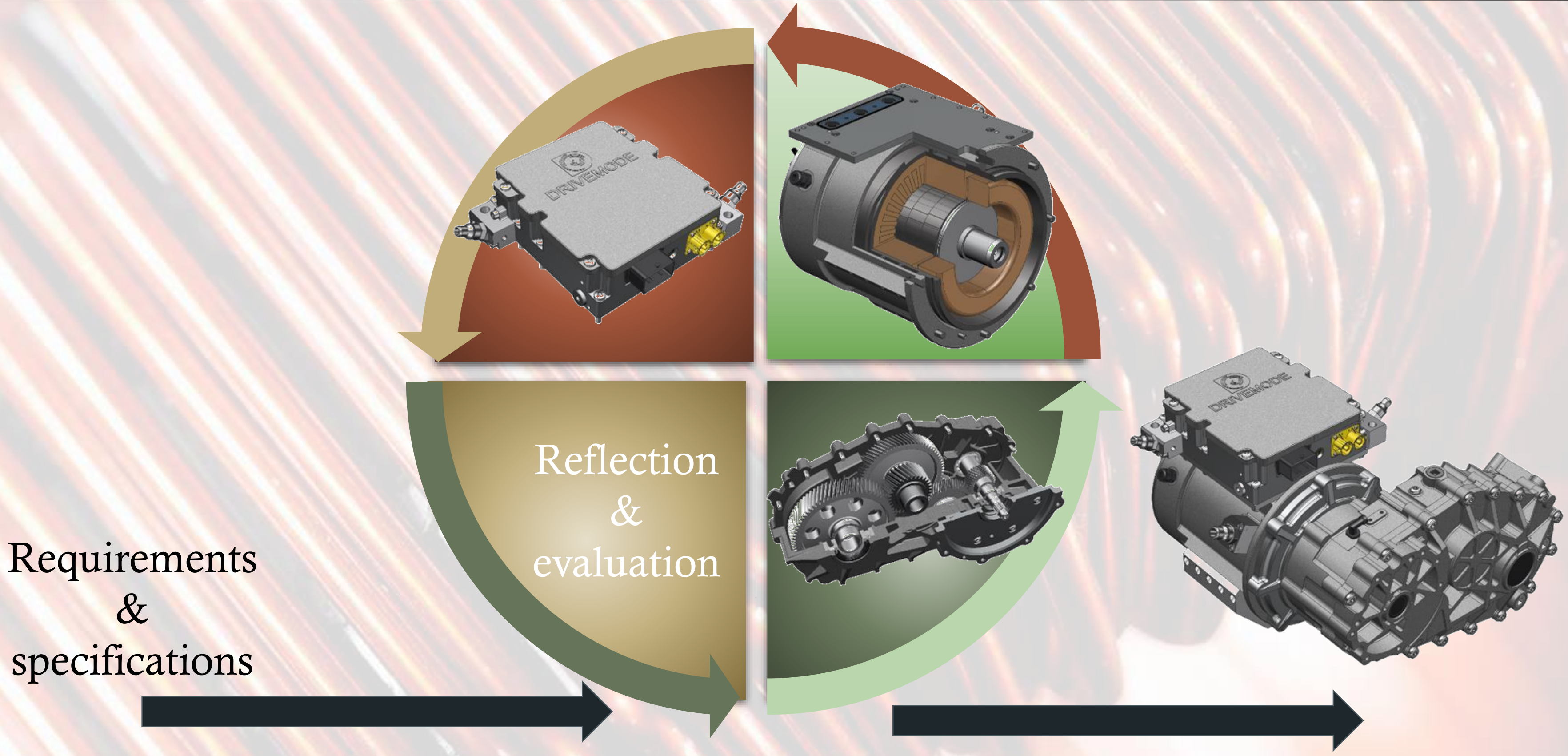
50% increase in e-motor speed

800V voltage for material reduction and fast charging

30% increase in specific torque & power

50% reduction in losses

Design Approach



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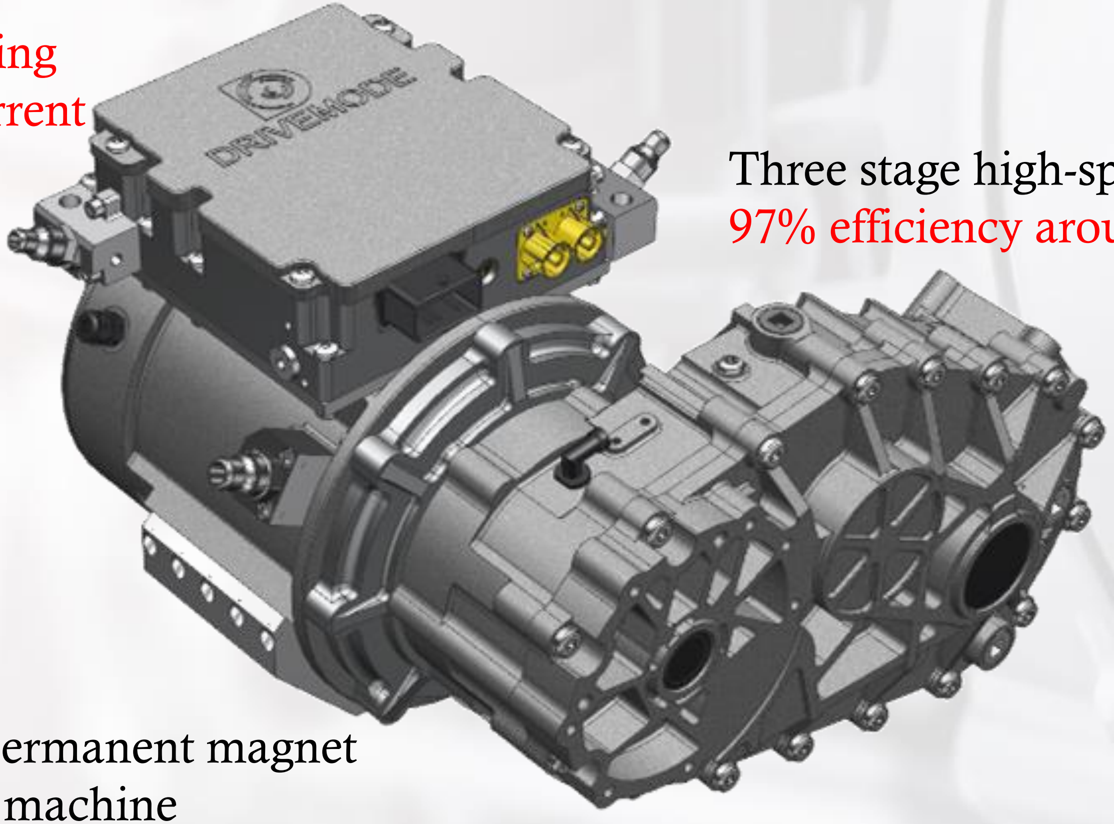
DRIVEMODE IDM

SiC Inverter
20kHz switching
140 A rms current



Three stage high-speed gearbox
97% efficiency around nominal points

High-speed permanent magnet synchronous machine
75kW, 100Nm, >20,000 rpm

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DRIVEMODE

Integrated Modular Distributed Drivetrain
for Electric & Hybrid Vehicles

DRIVEMODE Project

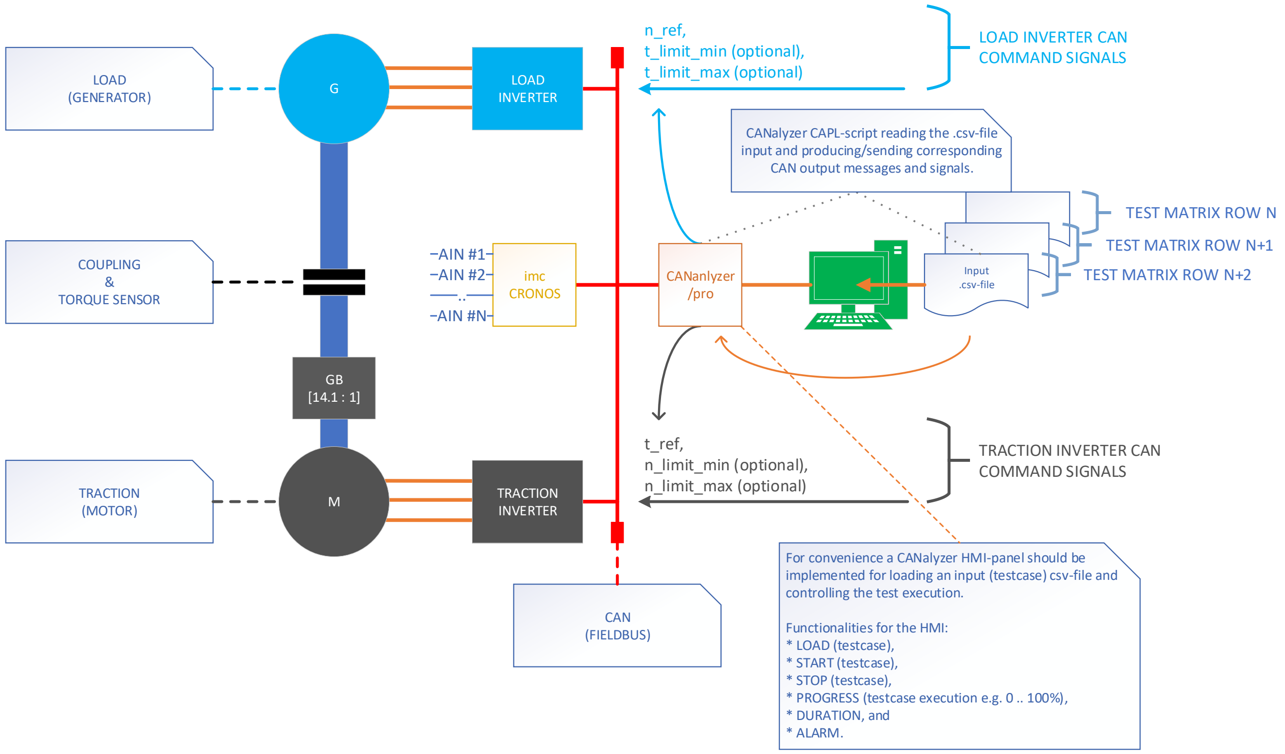
Tommi Kankaanranta, Danfoss

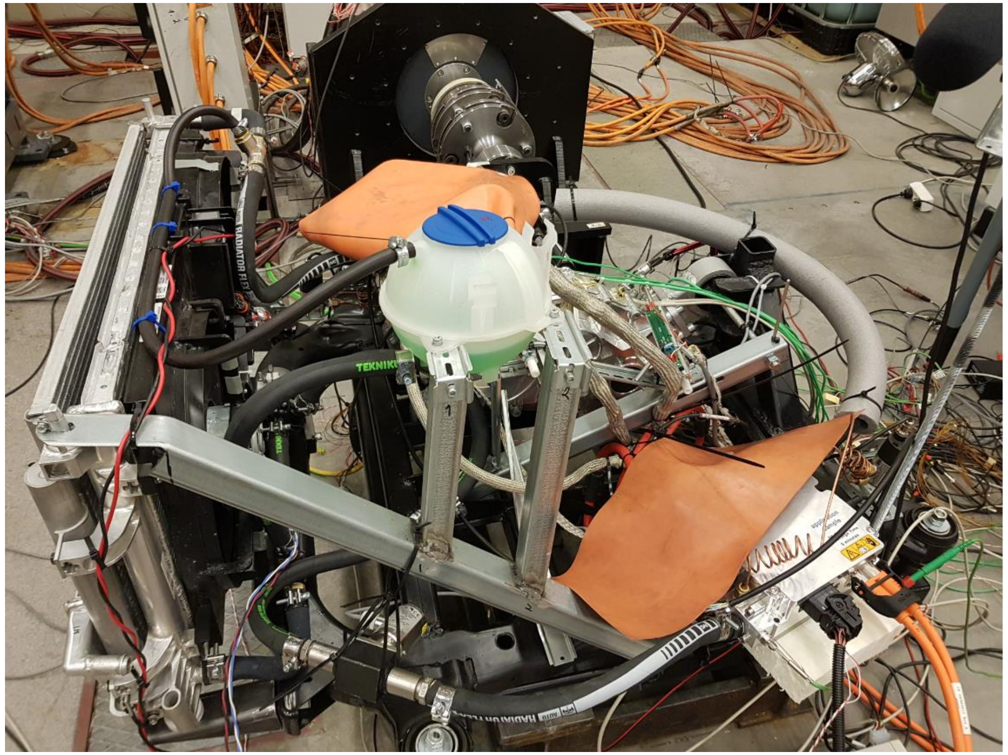
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769989

IDM Test Objectives

- Validation of the system performance requirements (D2.1)
  - 0-100 km/h acceleration in seconds
  - Top speed on flat road (km/h)
  - Top speed on 4% gradient (km/h)
  - Top speed on 6% gradient (km/h)
  - Continuous torque/power
  - Peak torque/power
- Validation of the efficiency over the operational range (four quadrant operation)
  - Motoring
  - Generating

IDM Test Setup (concept)





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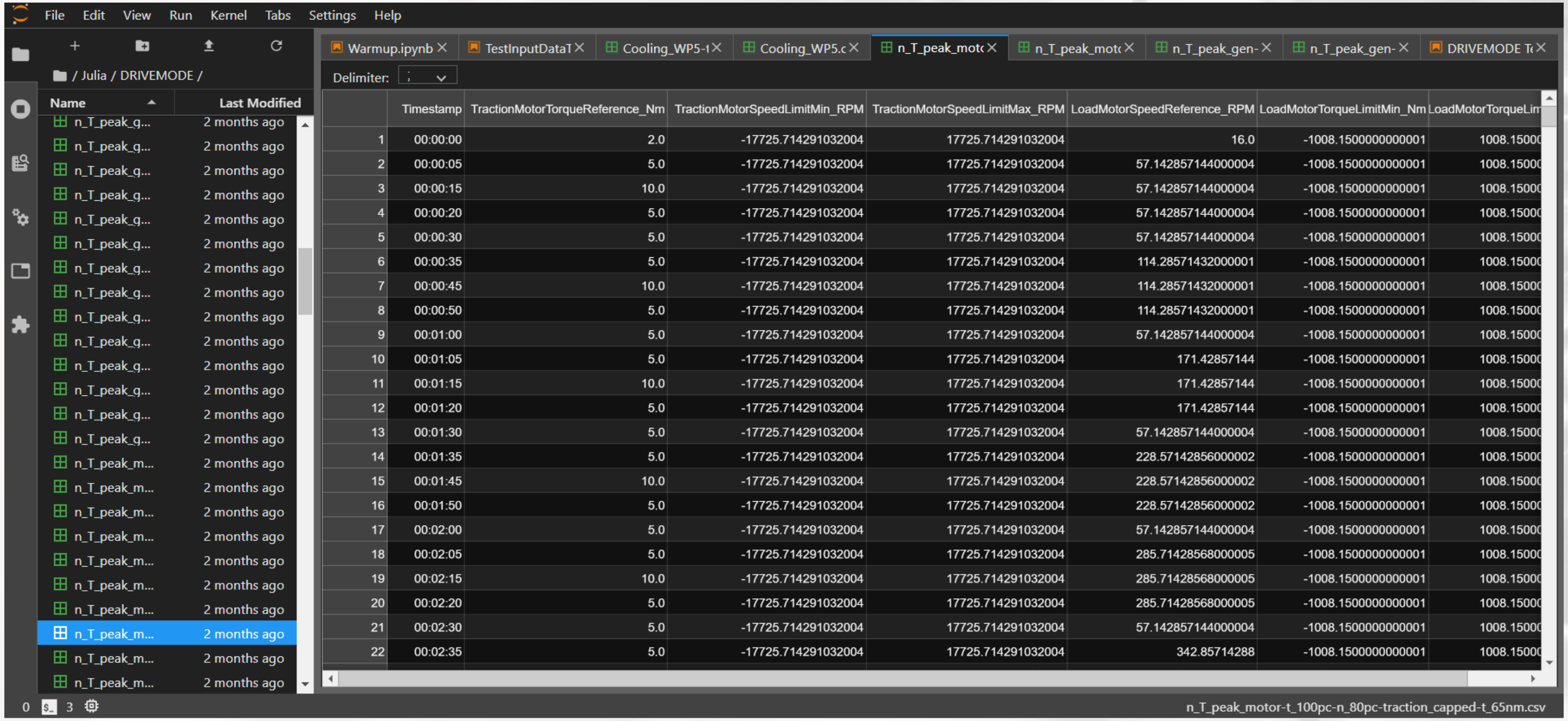
IDM Test Setup (components)

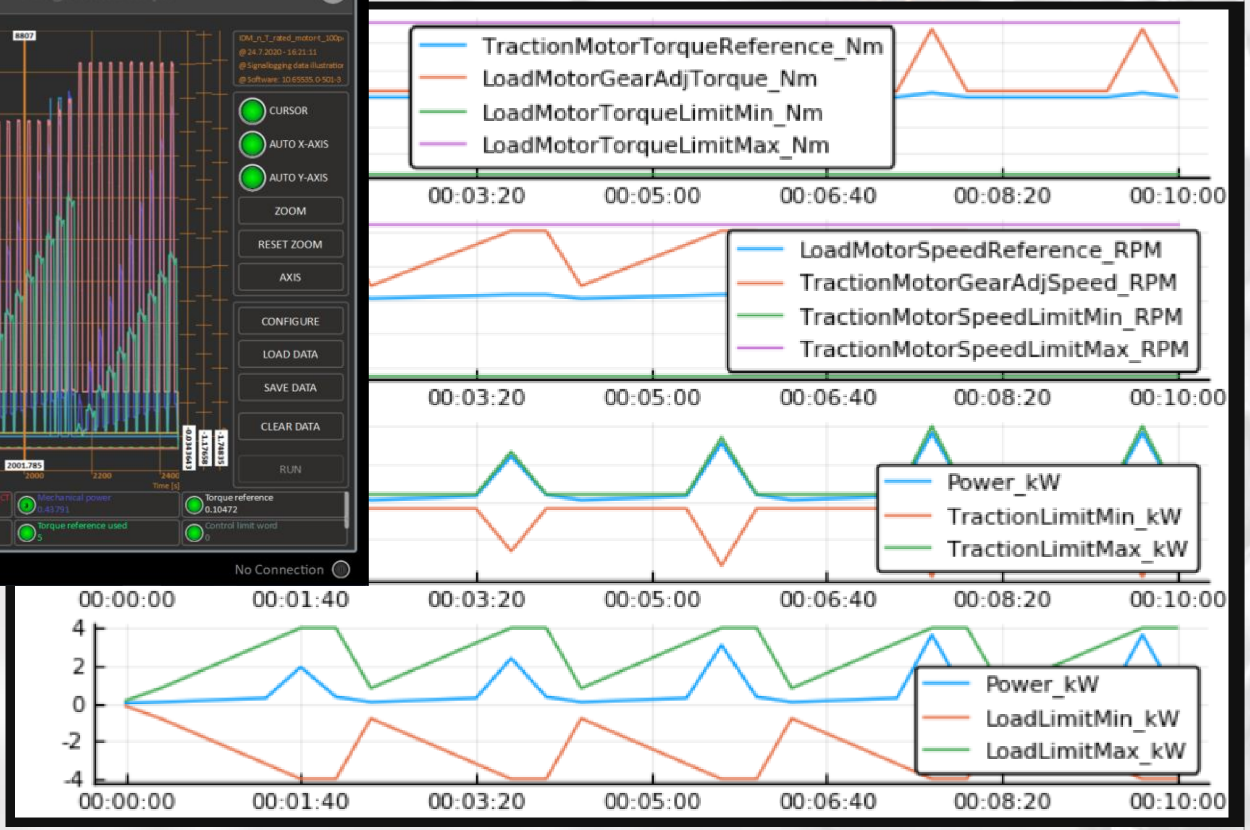
- Imc CRONOS DAQ (VTT)
  - Analog and digital measurement system storing the data for detailed analysis later
- CANalyzer /PRO automation (Danfoss)
  - Test automation for sequencing of test vectors and input data
- IDM components (AVL, BW, Danfoss, NEVS, SCiRE, Semikron, TeD, VTT)
  - IDM assembly running in a closed cooling circuit with integrated and extensive sensoring (temperature, current, voltage, vibration, noise, etc.)
- Load Motor and Inverter (Danfoss, Semikron)
  - Speed controlled load inverter with high current rating e-motor

IDM Test Setup Input Data (Chalmers, VTT and Danfoss)

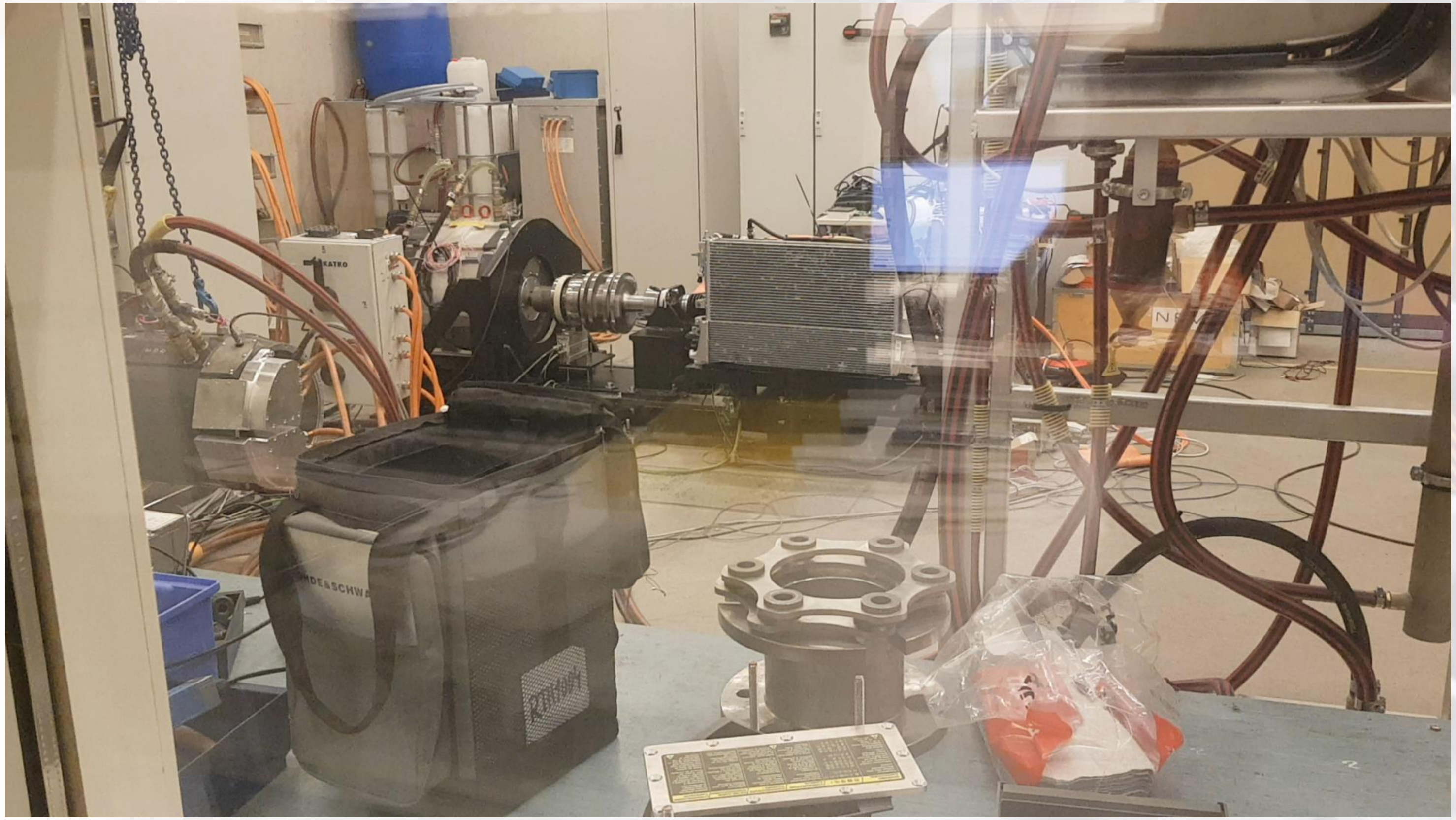


	Timestamp	TractionMotorTorqueReference_Nm	TractionMotorSpeedLimitMin_RPM	TractionMotorSpeedLimitMax_RPM	LoadMotorSpeedReference_RPM	LoadMotorTorqueLimitMin_Nm	LoadMotorTorqueLim
1	00:00:00	2.0	-17725.714291032004	17725.714291032004	16.0	-1008.1500000000001	1008.1500
2	00:00:05	5.0	-17725.714291032004	17725.714291032004	57.142857144000004	-1008.1500000000001	1008.1500
3	00:00:15	10.0	-17725.714291032004	17725.714291032004	57.142857144000004	-1008.1500000000001	1008.1500
4	00:00:20	5.0	-17725.714291032004	17725.714291032004	57.142857144000004	-1008.1500000000001	1008.1500
5	00:00:30	5.0	-17725.714291032004	17725.714291032004	57.142857144000004	-1008.1500000000001	1008.1500
6	00:00:35	5.0	-17725.714291032004	17725.714291032004	114.28571432000001	-1008.1500000000001	1008.1500
7	00:00:45	10.0	-17725.714291032004	17725.714291032004	114.28571432000001	-1008.1500000000001	1008.1500
8	00:00:50	5.0	-17725.714291032004	17725.714291032004	114.28571432000001	-1008.1500000000001	1008.1500
9	00:01:00	5.0	-17725.714291032004	17725.714291032004	57.142857144000004	-1008.1500000000001	1008.1500
10	00:01:05	5.0	-17725.714291032004	17725.714291032004	171.42857144	-1008.1500000000001	1008.1500
11	00:01:15	10.0	-17725.714291032004	17725.714291032004	171.42857144	-1008.1500000000001	1008.1500
12	00:01:20	5.0	-17725.714291032004	17725.714291032004	171.42857144	-1008.1500000000001	1008.1500
13	00:01:30	5.0	-17725.714291032004	17725.714291032004	57.142857144000004	-1008.1500000000001	1008.1500
14	00:01:35	5.0	-17725.714291032004	17725.714291032004	228.57142856000002	-1008.1500000000001	1008.1500
15	00:01:45	10.0	-17725.714291032004	17725.714291032004	228.57142856000002	-1008.1500000000001	1008.1500
16	00:01:50	5.0	-17725.714291032004	17725.714291032004	228.57142856000002	-1008.1500000000001	1008.1500
17	00:02:00	5.0	-17725.714291032004	17725.714291032004	57.142857144000004	-1008.1500000000001	1008.1500
18	00:02:05	5.0	-17725.714291032004	17725.714291032004	285.71428568000005	-1008.1500000000001	1008.1500
19	00:02:15	10.0	-17725.714291032004	17725.714291032004	285.71428568000005	-1008.1500000000001	1008.1500
20	00:02:20	5.0	-17725.714291032004	17725.714291032004	285.71428568000005	-1008.1500000000001	1008.1500
21	00:02:30	5.0	-17725.714291032004	17725.714291032004	57.142857144000004	-1008.1500000000001	1008.1500
22	00:02:35	5.0	-17725.714291032004	17725.714291032004	342.85714288	-1008.1500000000001	1008.1500

IDM Test Execution (Danfoss)



IDM Test Setup (running)



DRIVEMODE

DRIVEMODE

Integrated Modular Distributed Drivetrain
for Electric & Hybrid Vehicles

Assembly, Testing and Demonstration

Deepak Singh, NEVS

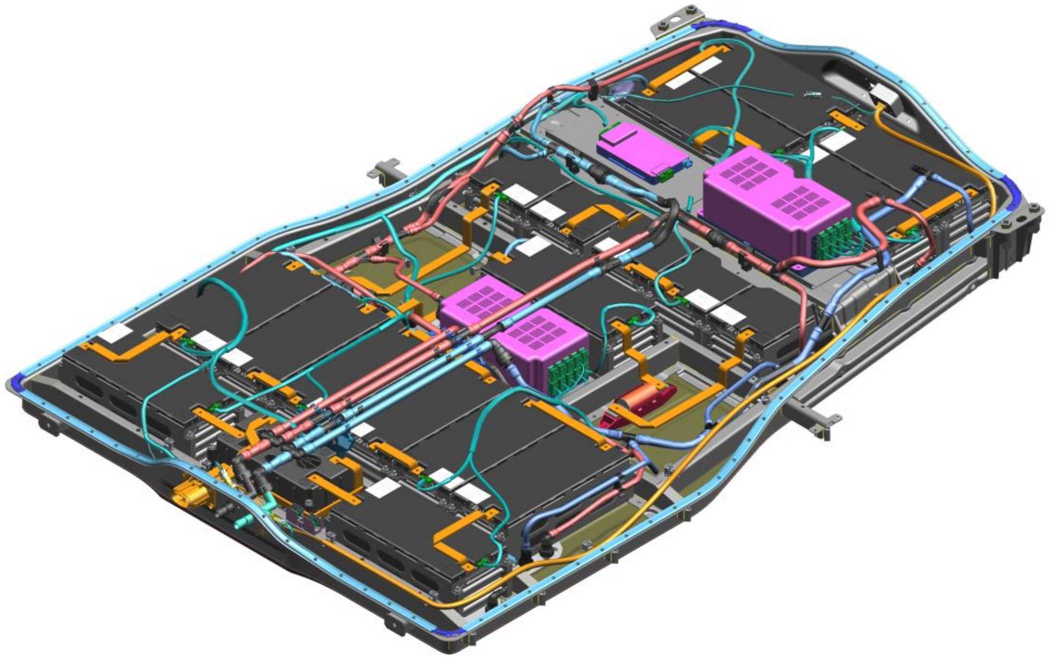
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 769989

Assembly of Demonstration Vehicle

- 800V DC Battery Pack
- Mechanical Integration
- Electrical Integration
  - HV Architecture
  - LV Architecture
- Thermal Integration
- SW Integration

DRIVEMODE

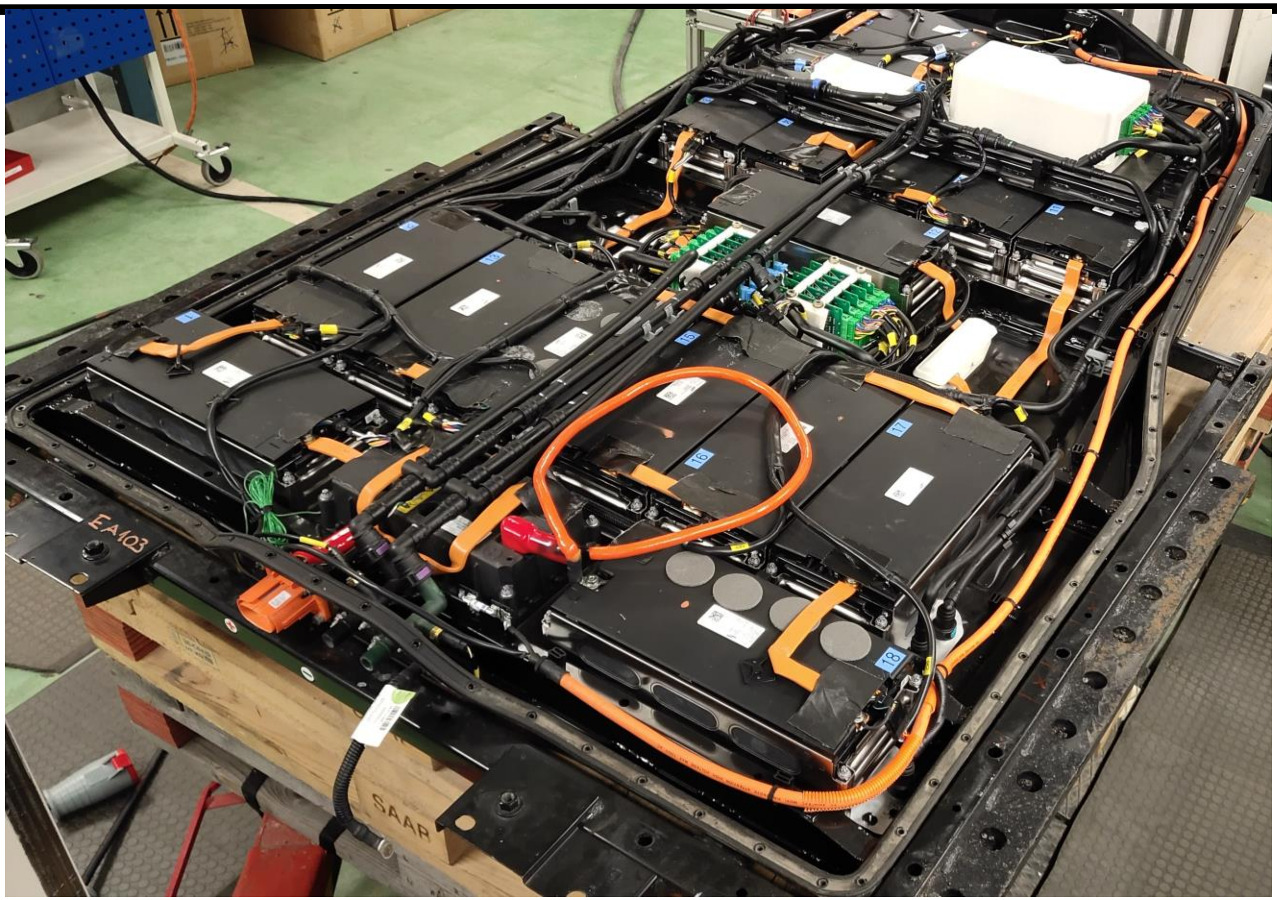
800V DC Battery



Specifications

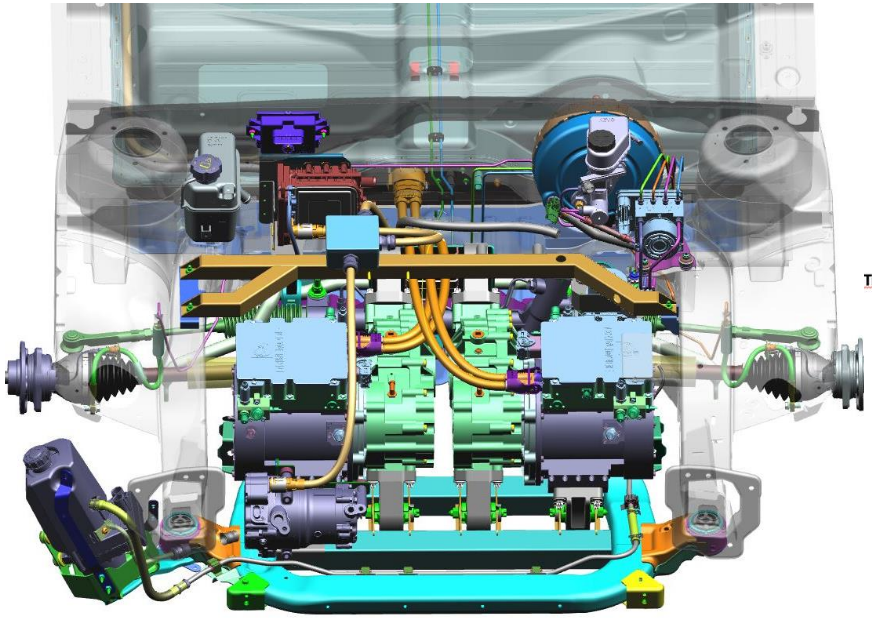
- Cell type
  - Prismatic cell PHEV2 - VDA
  - Dimension: 148x26.5x91
- 18 modules→ 1p12s→ 216 cells
- Pack voltage: ~800Vdc (700-900Vdc)
- Energy: ~40kWh
- Main fuse: 200A
- Aux fuse: 30A
- Weight: ~300kg
- Cooling: Liquid

800V DC Battery

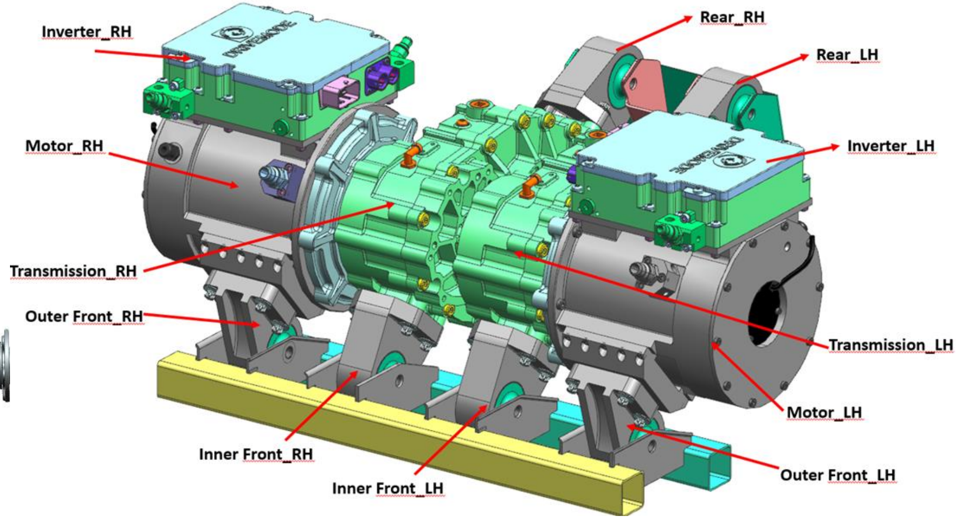


Battery Pack including Battery Management System (BMS) and Battery Disconnect Unit (BDU)

Mechanical Integration → Front

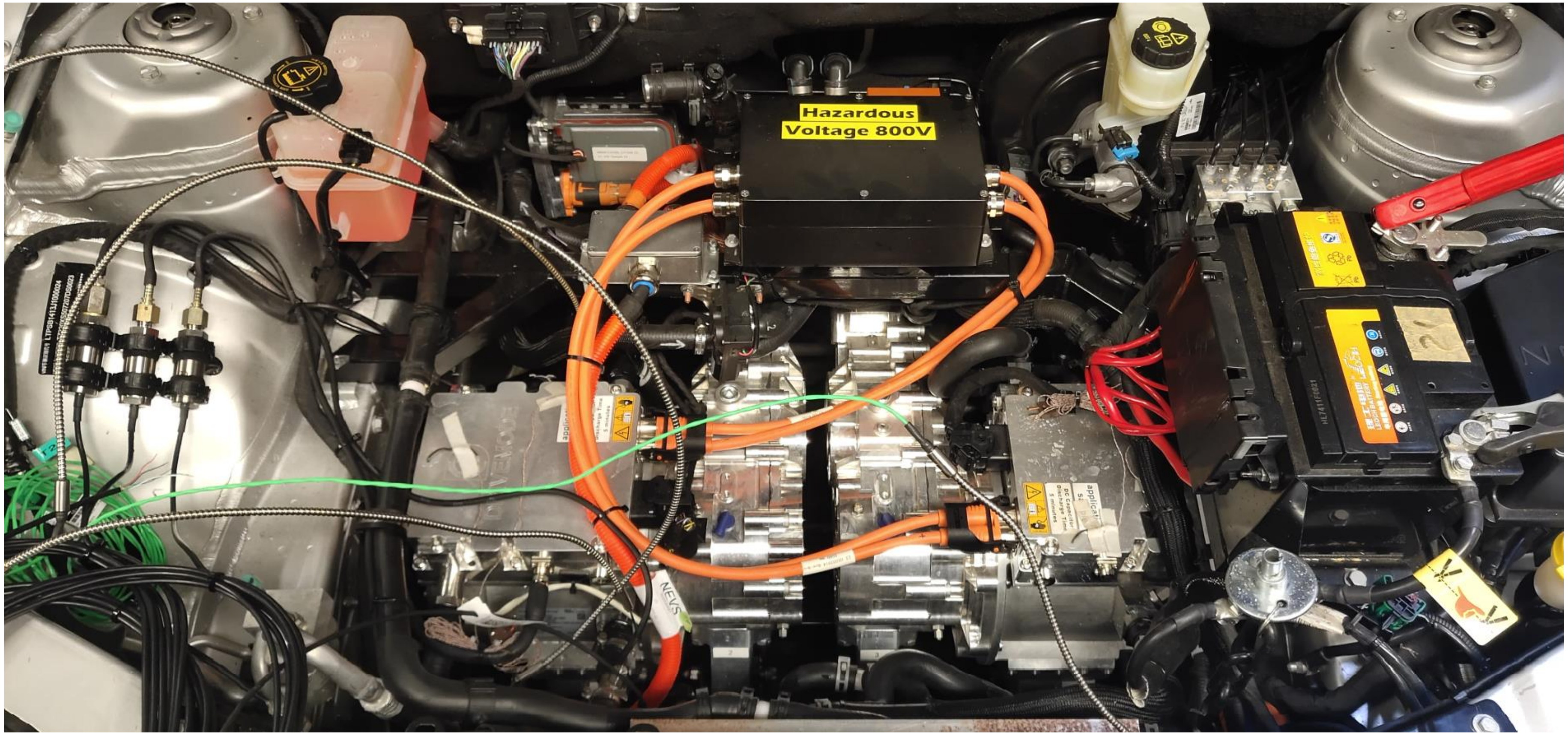


Front end (Engine Bay) Packaging



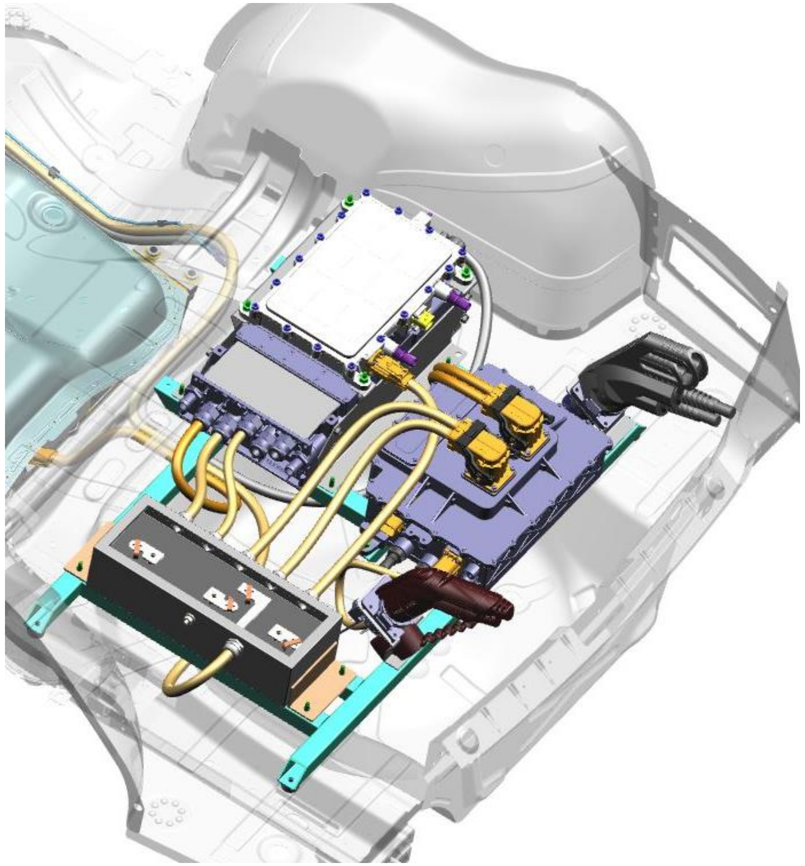
Drive Units Mounting to Sub-frame

Mech. Int. → Front



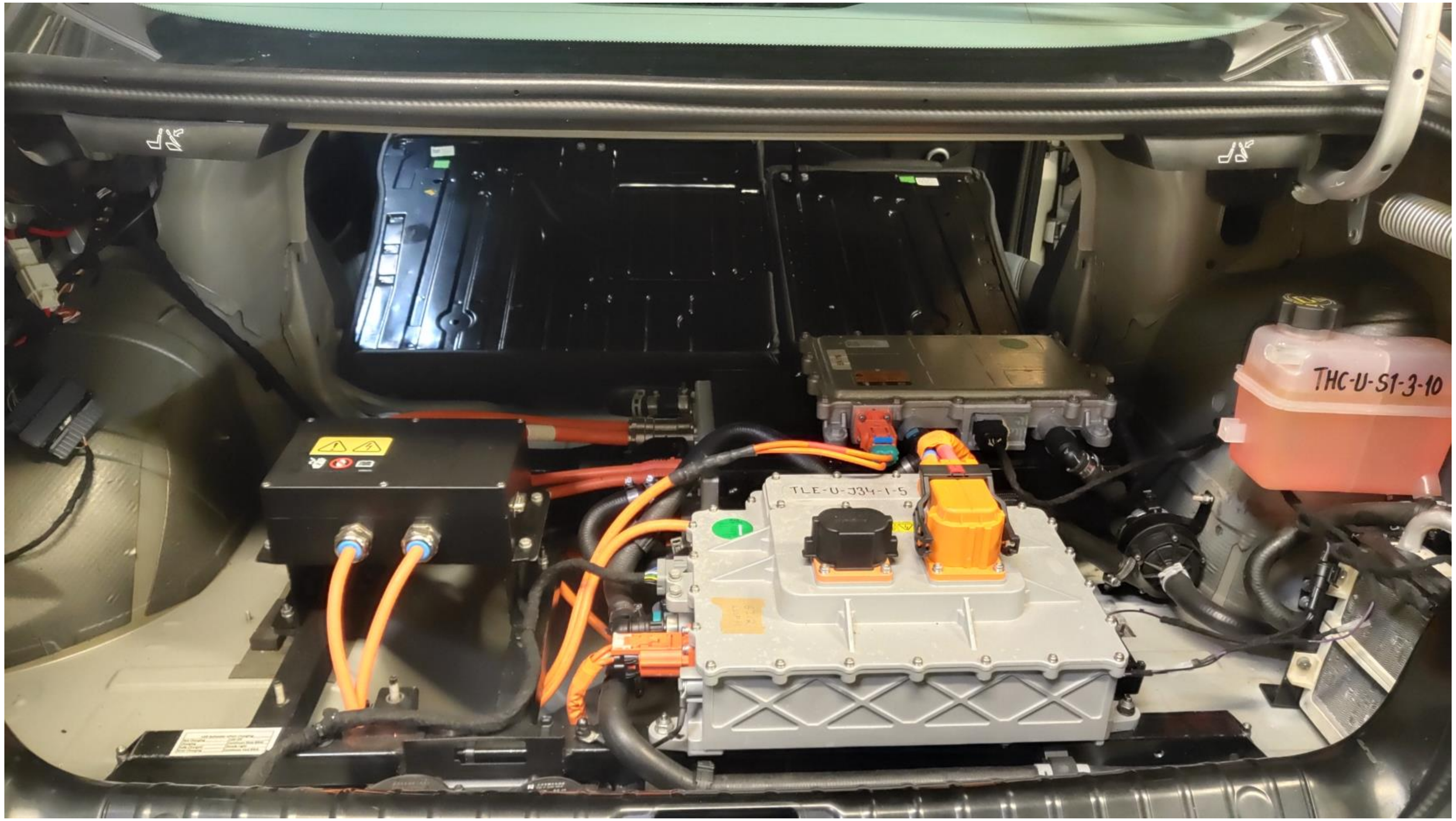
DRIVEMODE

Mech. Int. → Rear



- Components in the trunk:
  - 800/400V DCDC
  - 400/12V DCDC
  - On Board Charger
  - Charging ports
- Separate cooling loop (pump and radiator)
- Frame and brackets

Mech. Int. → Rear

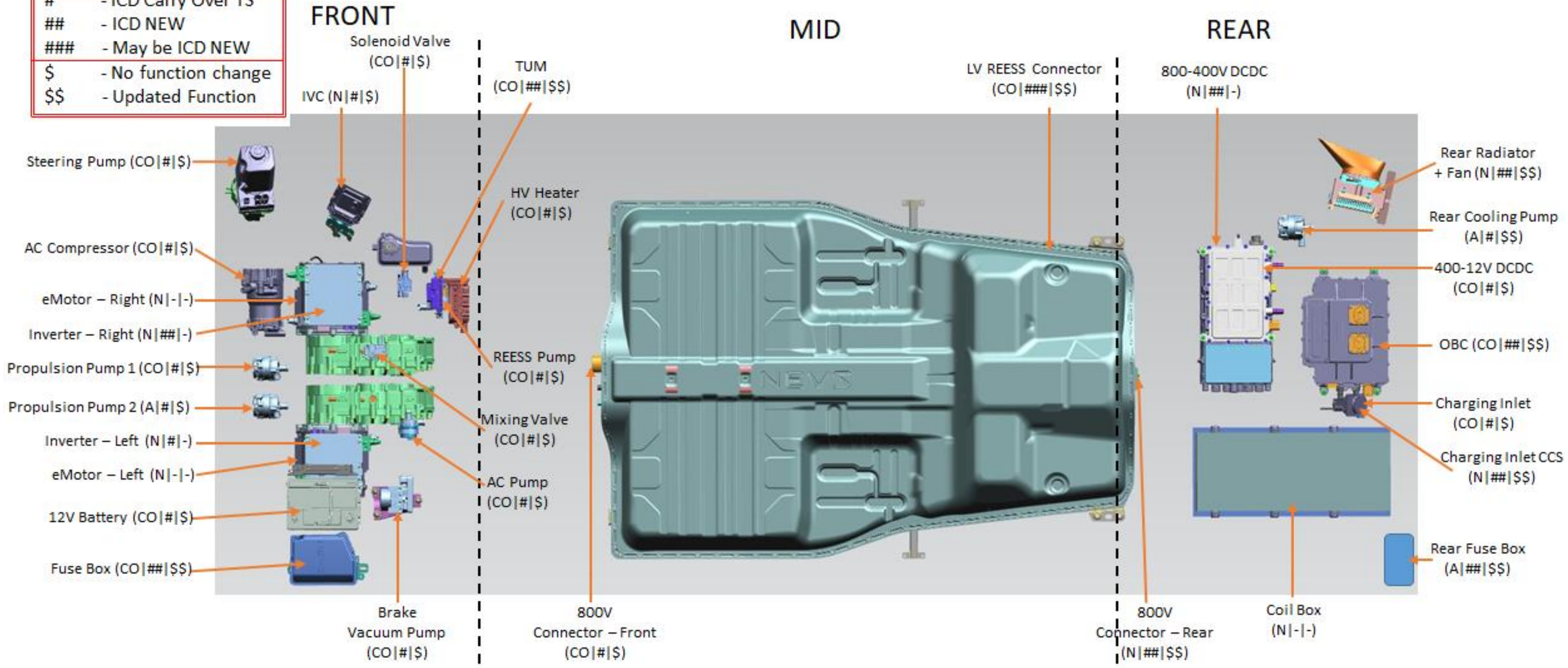


DRIVEMODE

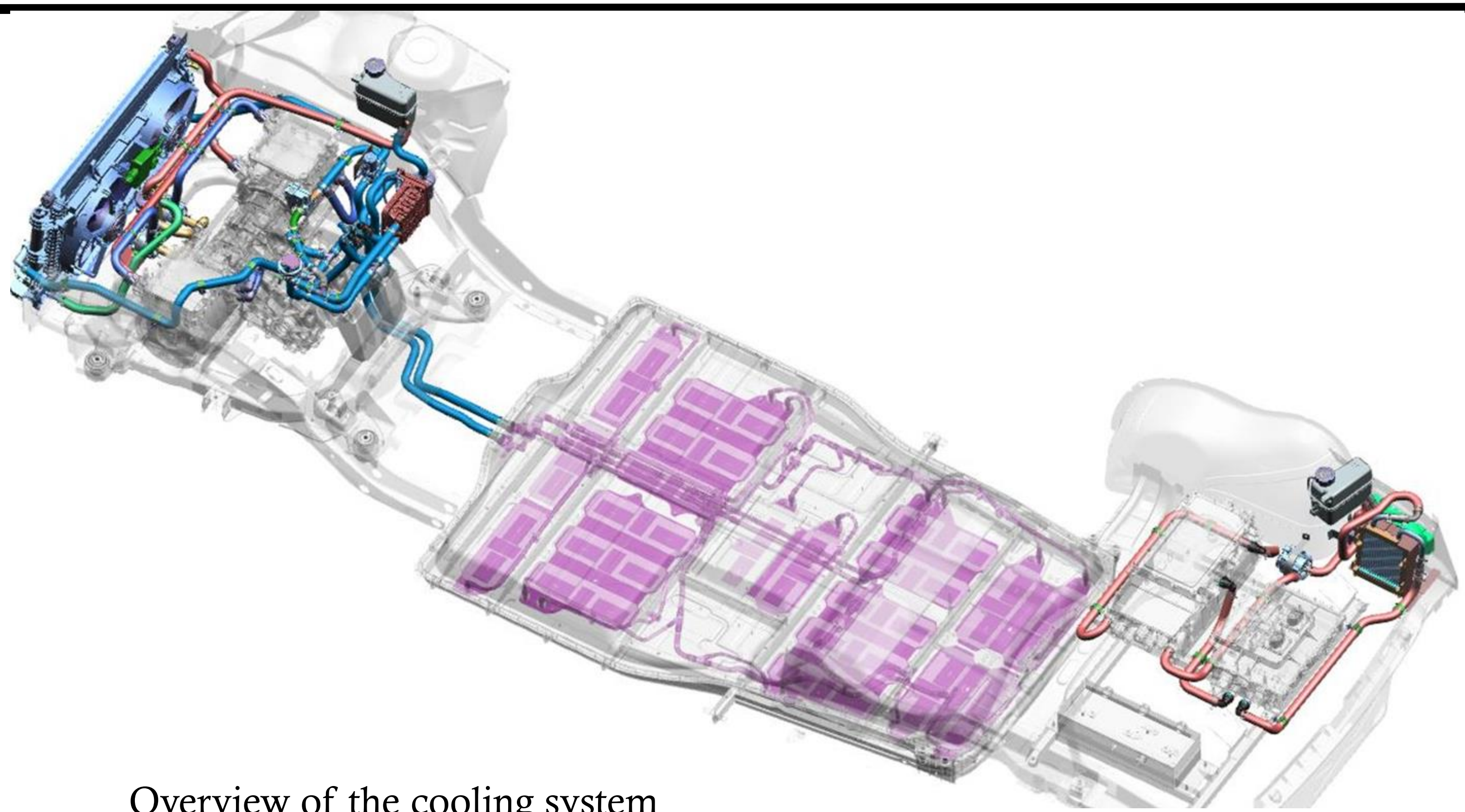
Electrical Architecture

Remark:

CO	– Carry Over TS
N	– New Component
A	- Additional CO
#	- ICD Carry Over TS
##	- ICD NEW
###	- May be ICD NEW
$	- No function change
$$	- Updated Function



Thermal Integration



Overview of the cooling system
(Battery, IDM, HV components and Climate Control)

DRIVEMODE

SW Integration →
Vehicle Control Unit (VCU)

- In-house SW development for vehicle motion control
- VUC coordinates the overall vehicle states and controls many of the core vehicle functionalities such as torque target control, power distribution etc
- Fully Functional Vehicle:
  - Vehicle Functionalities
  - CAN Communication
  - Safety
  - Fault Detection and Management

Vehicle Assembly (support)

- 800V DC Battery Pack
  - In-house development based on consortium's requirements
- Mechanical Integration
  - VTT, BW, AVL, SEMIKRON, DANFOSS, TeD and SCIRE
- Electrical Integration
  - AVL,SEMIKRON and DANFOSS
- Thermal Integration
  - SCIRE, AVL and SEMIKRON
- SW Integration
  - VTT and DANFOSS

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Demo Vehicle → Livery

Demo Vehicle

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Testing

- Vehicle testing @ NEVS
  - Dyno test
  - Track test
- Vehicle testing @ VTT
  - Dyno test

DRIVEMODE

Integrated Modular Distributed Drivetrain for Electric & Hybrid Vehicles

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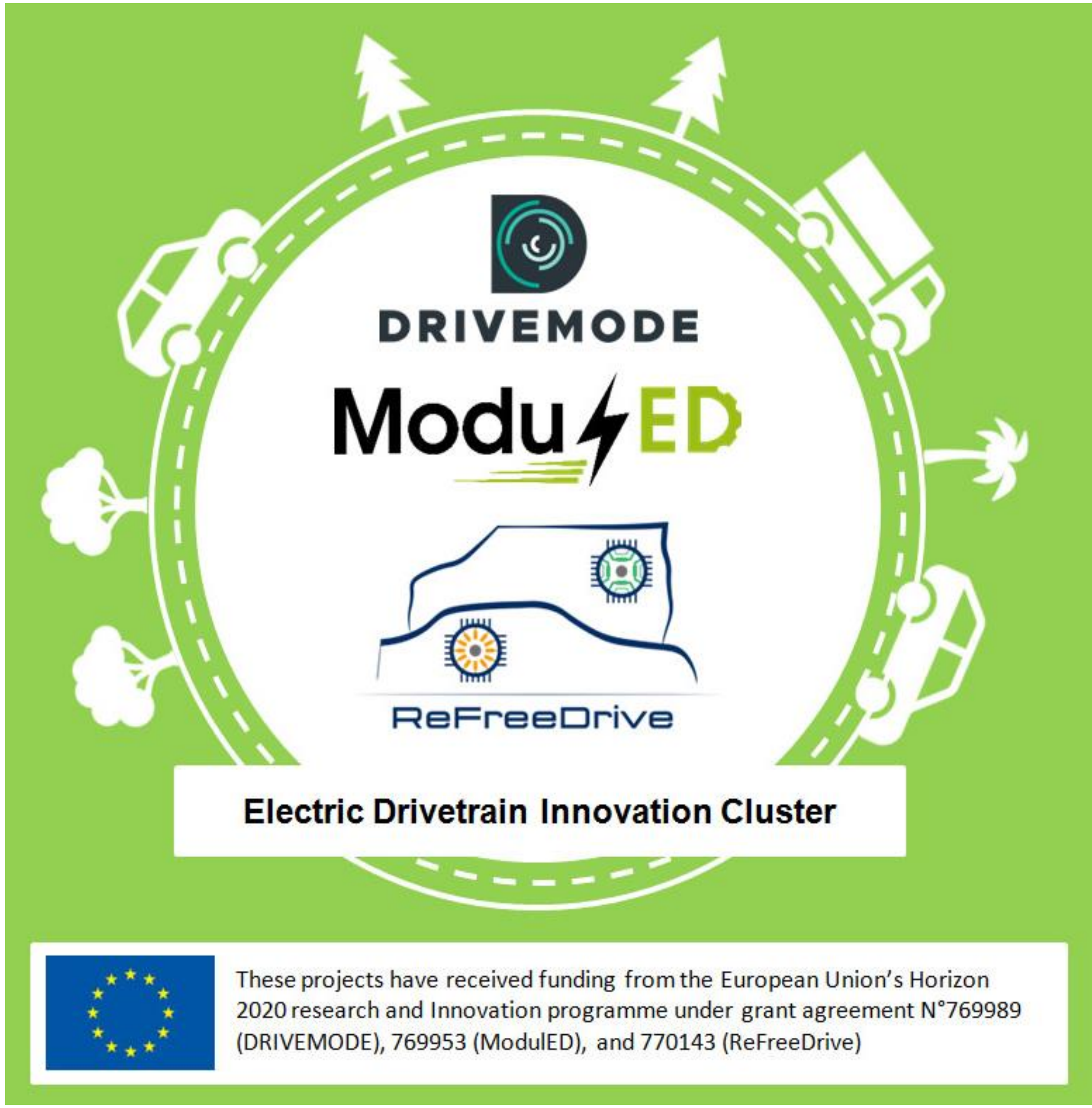
Thank you very much



ReFreeDrive

Driving the future of electromobility through innovative rare-earth free motor technologies

Javier Romo, Fundación CIDAUT

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770143

ReFreeDrive Project Overview

General Figures

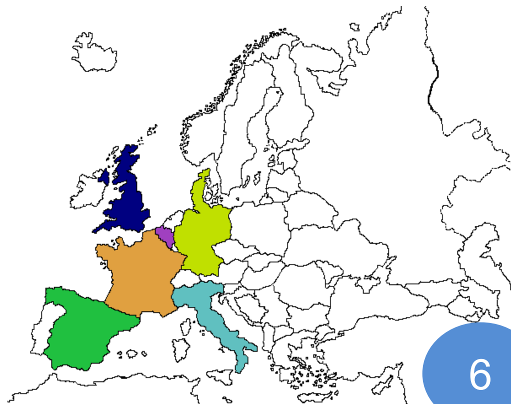
Title: Rare earth free e-Drives featuring low cost manufacturing

Grant Agreement No: 770143

Topic: GV-04-2017

Project Total Costs: 5,999,131.25€

Total EU Contribution: 5,999,131.25€



3 UNITED KINGDOM
European Copper Institute
Motor Design Limited
Jaguar Land Rover

1 BELGIUM
Aurubis

1 FRANCE
IFP Energies Nouvelles

6 ITALY
Universitá degli studi dell'Aquila
Centro Sviluppo Materiali
Tecnomatic
Mavel
R13 Technology
Privé

1 GERMANY
MetallGiesserei
Breuckman

1 SPAIN
Fundación Cidaut

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770143

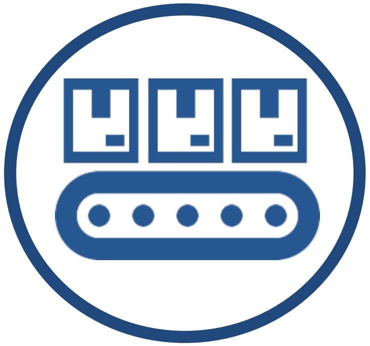
ReFreeDrive Project Overview

Project Objectives

- The main aim of this project is to develop **rare earth-free traction technologies**

LOWER COSTS

INDUSTRIAL FEASIBILITY



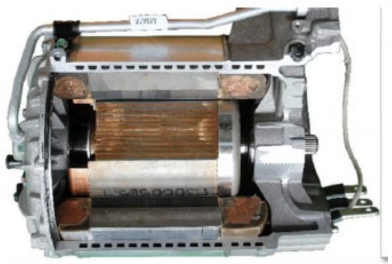
MASS PRODUCTION

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770143

ReFreeDrive Project Overview

Target figures

Benchmark Tesla S60



INCREASE SPECIFIC TORQUE BY 30%

REDUCE MOTOR ENERGY LOSSES BY 50%

15% COST REDUCTION AGAINST SIMILAR SOLUTIONS

INCREASE POWER DENSITY IN POWER ELECTRONICS BY 50%

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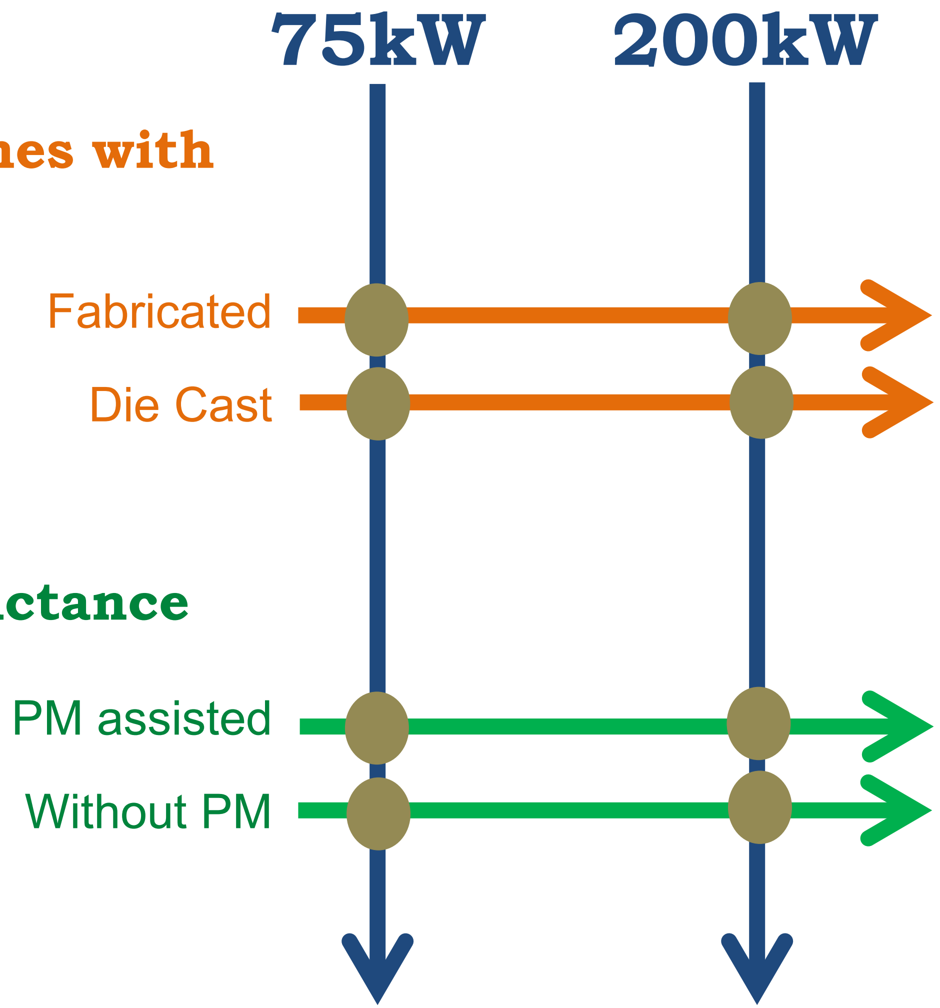
ReFreeDrive Project Overview

Project Technologies

Induction machines with copper rotor

Synchronous reluctance machines



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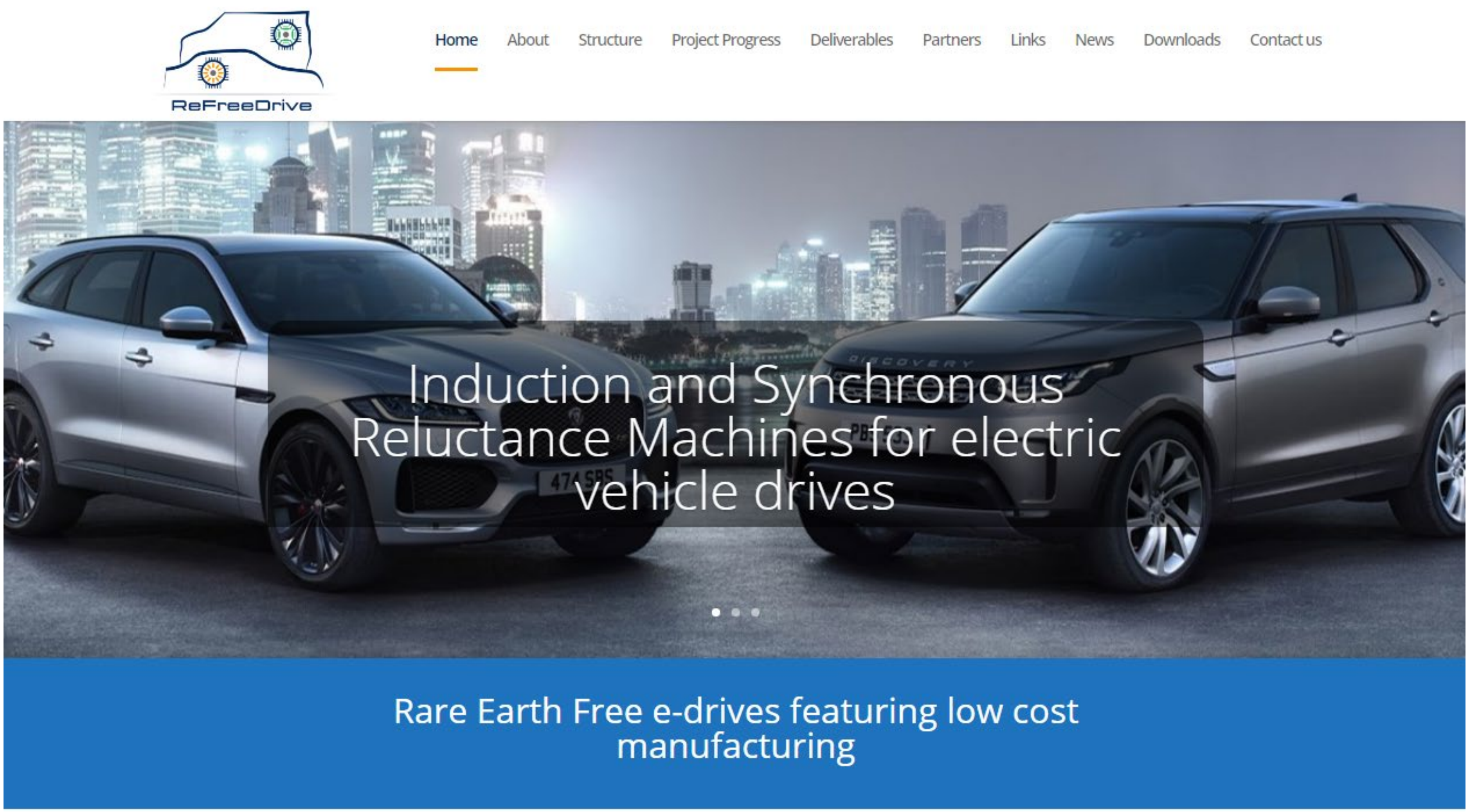
ReFreeDrive Project Overview

https://www.refreedrive.eu



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ReFreeDrive Project Overview

https://www.linkedin.com/company/electric-drivetrain-innovation-cluster/

Contact us

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Fundación cidaut Investigación y Desarrollo en Transporte y Energía

Fundación cidaut Investigación y Desarrollo en Transporte y Energía

Cu European Copper Institute Copper Alliance

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770143

ReFreeDrive

Induction motors

Mircea Popescu, Motor Design LTD

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 770143

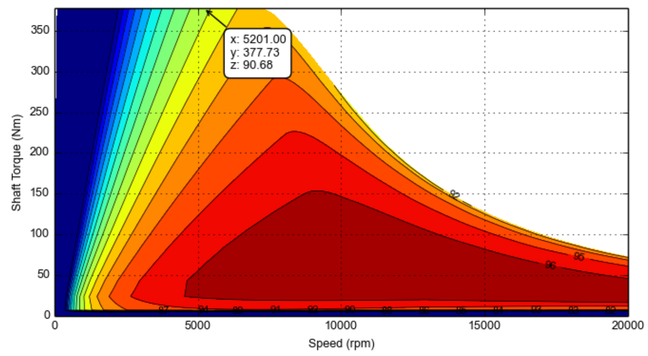
ReFreeDrive Project Overview

Induction Motors

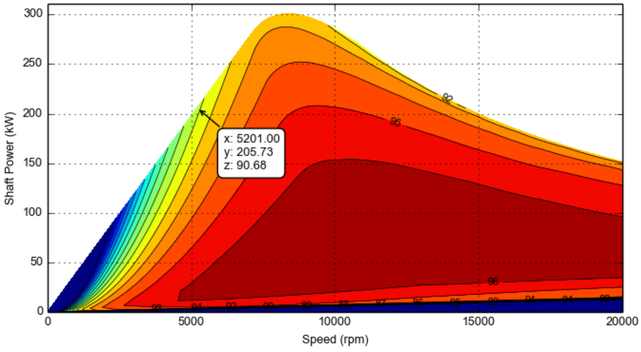
Electromagnetic Design

- Machine topology:
  - 4-pole, 36-slot, 50-bar
- Geometry:
  - OD = 190mm
  - L = 161mm
- Materials
  - M235-35A steel (rotor & stator)
  - CuAg0.04 (fabricated rotor cage)
  - Cu-ETP (die-casted rotor cage)
- Stator winding:
  - Turns / Phase = 12
  - Packing factor (%) = 73
- Power supply:
  - DC Voltage = 350V/720V
  - Current = 350Arms/500Arms

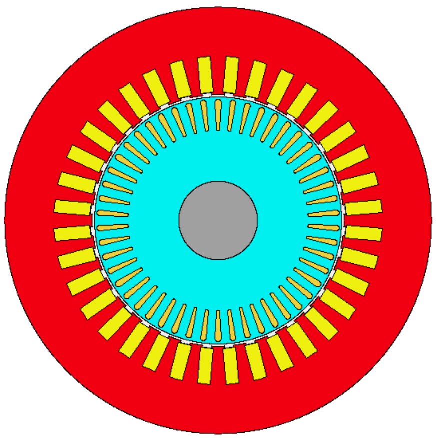
Torque-Efficiency Map



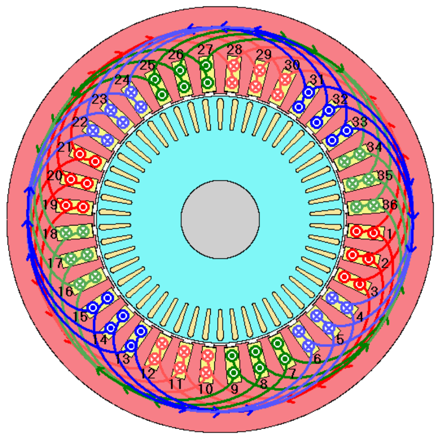
Power-Efficiency Map



Radial Geometry



Winding pattern



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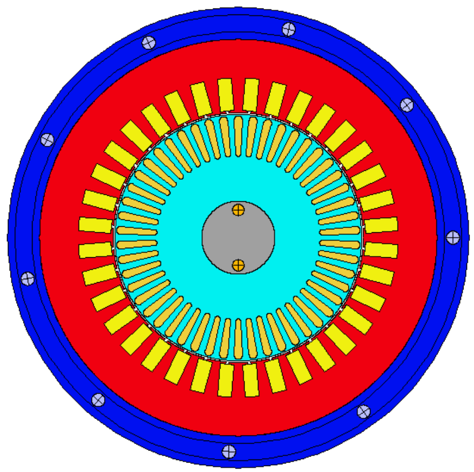
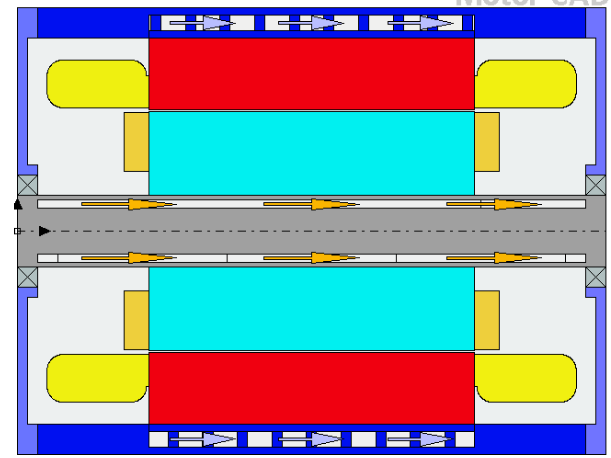
ReFreeDrive Project Overview

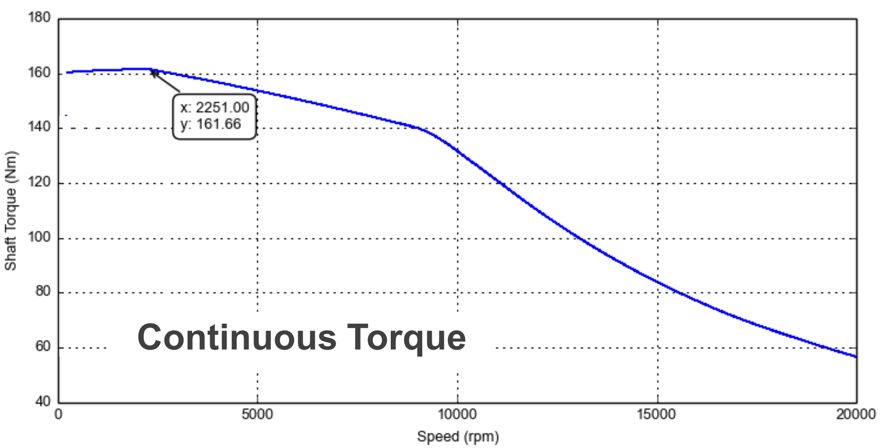
Induction Motors

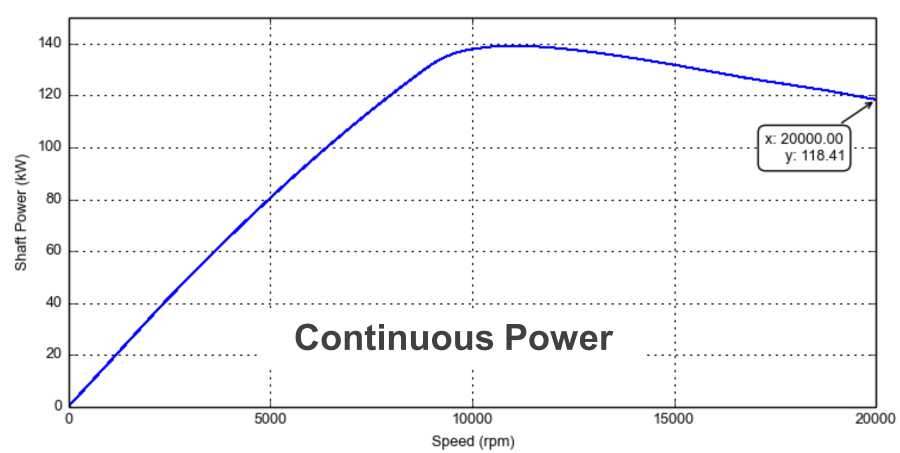
Thermal Design

- Series Cooling system:
- Stator jacket
- Rotor groove
- EWG 50/50
- Flow rate 10 l/min









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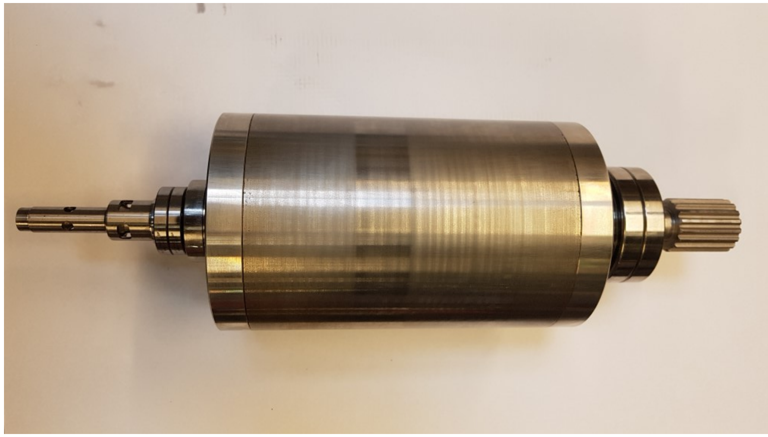
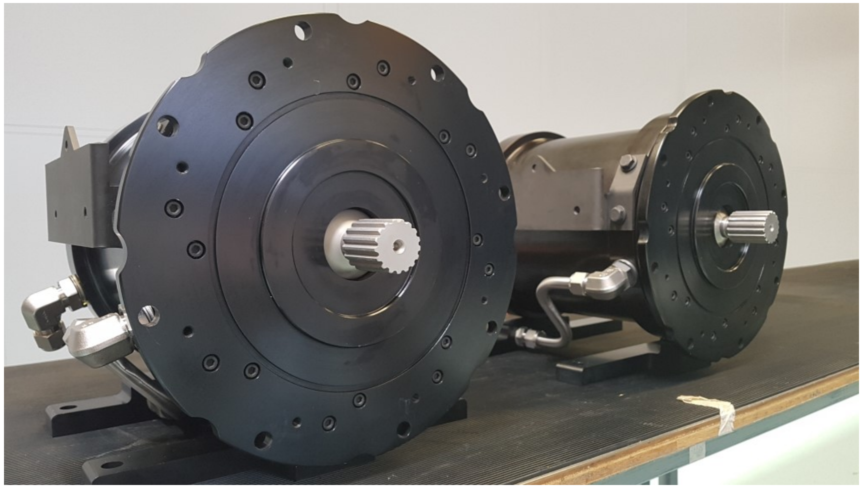
ReFreeDrive Project Overview

Induction Motors

Prototype

Rotor Assembly





Assembled Motors

Stator Assembly

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770143

ReFreeDrive

Pure SynRel motors

Giuseppe Fabri, University of L’Aquila

This project has received funding from the European Union’s Horizon 2020 research and innovation programme under grant agreement No 770143

ReFreeDrive Project Overview

Pure SynRel motors

Motor Design

- Pros:
  - Simple stator (close to IM)
  - cost effective rotor solution,
  - no magnets no copper in the rotor
  - No cooling issues in the rotor
  - High Efficiency
- Cons:
  - Very challenging design for high speed
  - Poor power factor
  - Torque ripple
- Machine topology:
  - 6-pole, 54- stator slot
  - Round wire windings
- Geometry:
  - OD = 220mm
  - L = 200mm
- Materials
  - M235-35A steel (rotor & stator)
- Power supply:
  - DC Voltage = 350V/720V
  - Current = 350Arms/635Arms

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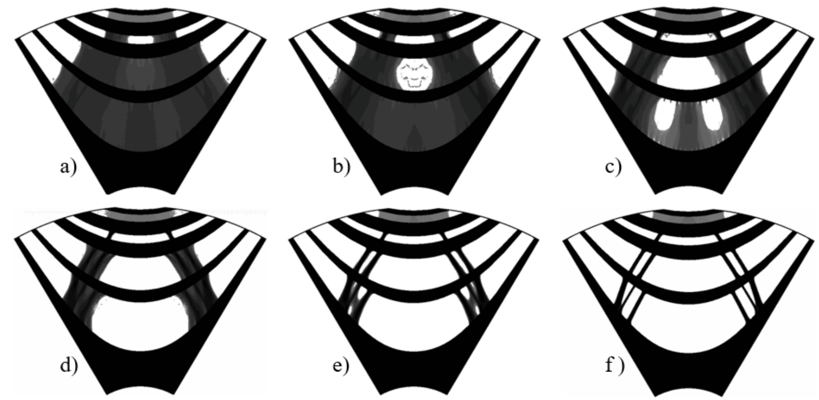
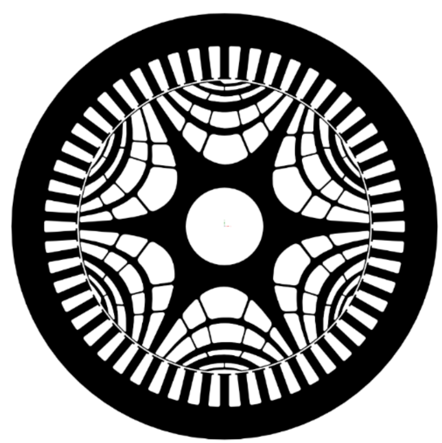
Rotor design aided by topology optimization



A. Credo, G. Fabri, M. Villani and M. Popescu, "Adopting the topology optimization in the design of high-speed synchronous reluctance motors for electric vehicles," ***IEEE Transactions on Industry Applications***

www.refreedrive.eu



Optimized for:
- low torque ripple,
- acceptable power factor
- High efficiency
- High speed

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ReFreeDrive Project Overview

Pure SynRel motors

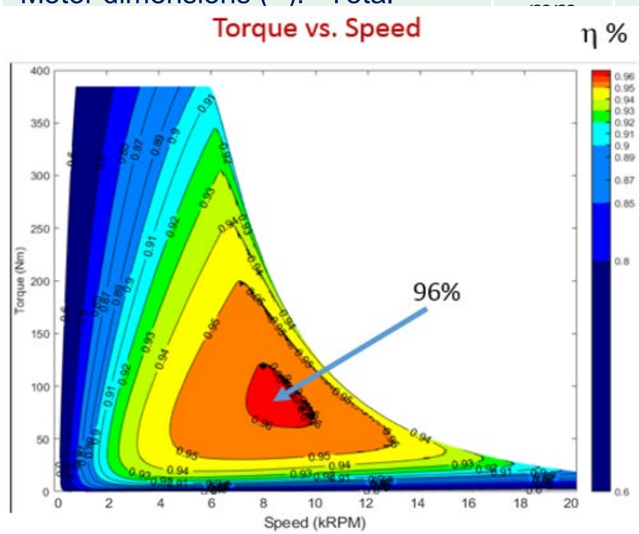
Performance

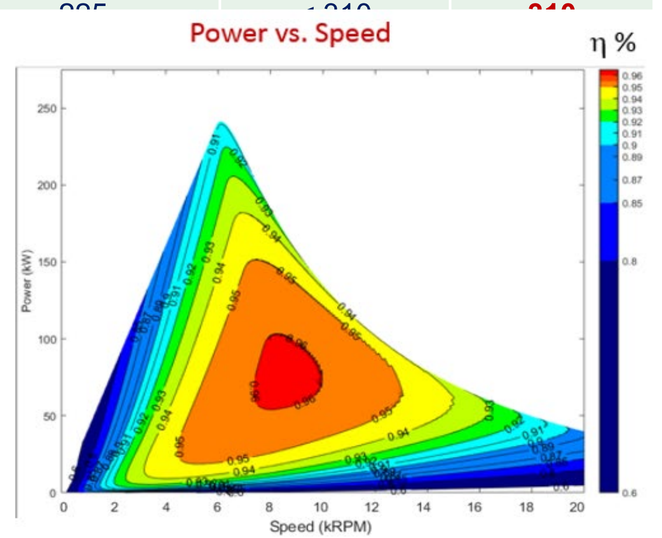
The design matches the challenging requirements

- Very wide speed range;
- High peak efficiency, good efficiency at low speed;
- Acceptable power factor;
- Interesting EV motor technology for less demanding application.

And the research continues…

Parameter	unit	Tesla Model S	RFD Goals	SynRel design
Motor type		Induction Motor		**SynRM**
Cooling		Liquid		**Liquid**
Specific Peak Power (*)	kW/kg	3.3	> 4.3	**5.3**
Specific Peak Torque	Nm/kg	6.32	> 8.2	**8.4**
Maximum speed	krpm	14500	15000 ÷ 18000	**18000**
Peak efficiency	%	92	> 96	**96**
Active parts weight	kg	68	< 47	**46**
Motor dimensions (+): Total				





* active parts only

\+ housing included

\# efficiency maps include mechanical losses

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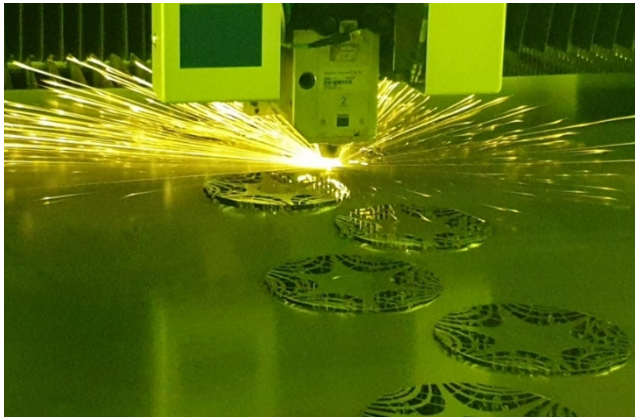
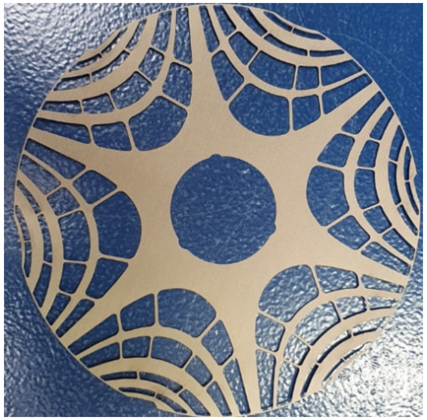
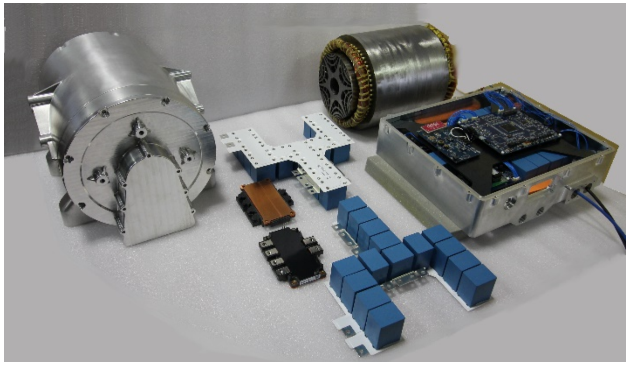
ReFreeDrive Project Overview

Pure SynRel motors

Prototyping


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770143

ReFreeDrive

PMa SynRel motors

Adrien Gilson, IFP Energies Nouvelles

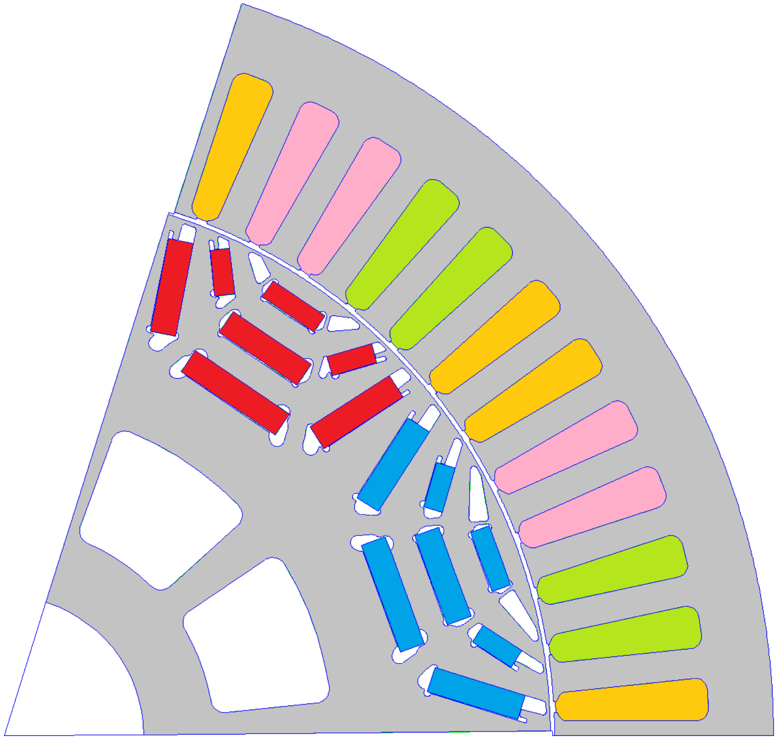
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770143

Design of 75 kW and 200 kW PMaSynRel Motor using rare earth free ferrites

Stator and rotor design

- Machaon rotor design
- 5 pole pairs
- SPP = 2
- 7 ferrite magnets per pole
- AG = 0.6 mm

Designation	Material
Lamination	M235-35A
Magnet	Ferrite
Copper wire	G2 H class



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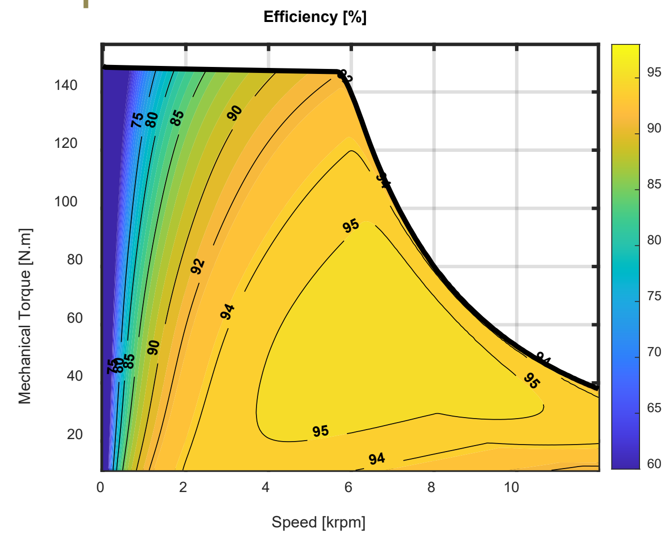
Design of 75 kW and 200 kW PMaSynRel Motor using rare earth free ferrites

Simulated electromagnetics performances

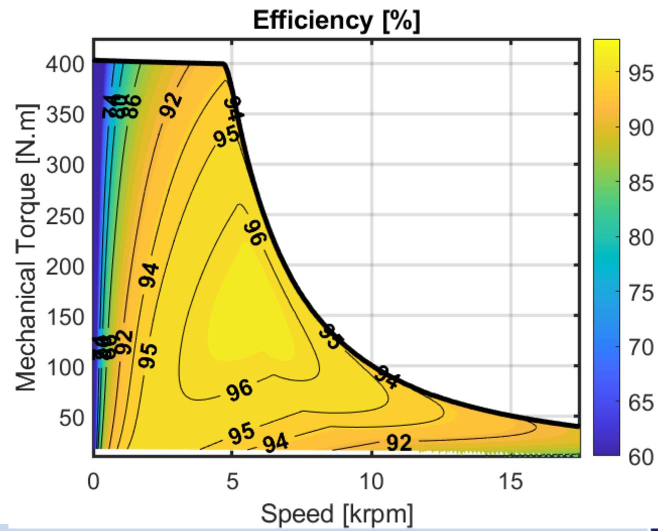
75 kW

- Max torque = 148 N.m
- Peak Power = 88 kW (350 V_{DC})
- Maximum efficiency = 95 %
- Weight = 19 kg (Active Part)



200 kW

- Max torque = 405 N.m
- Peak Power = 206 kW (750 V_{DC})
- Maximum efficiency = 96 %
- Weight = 46.1 kg (Active Part)



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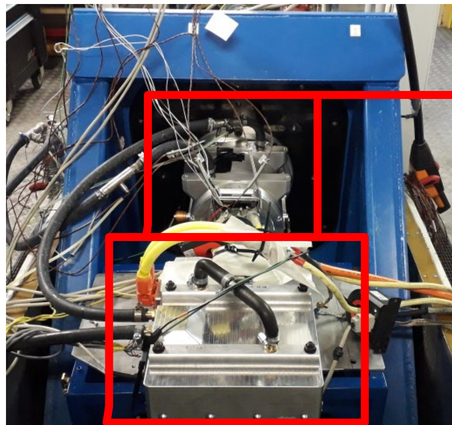
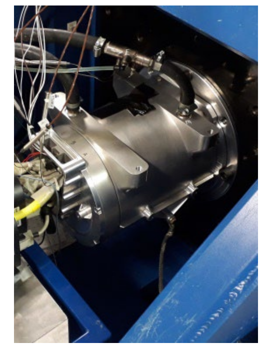
ReFreeDrive

Motor Testing

PMa SynRel – 75 kW motor

ReFreeDrive
PMa SynRel 75 kW





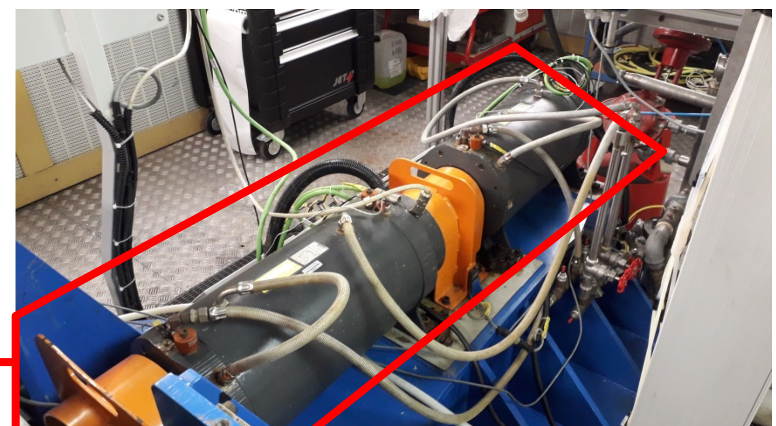
IFPEN Test Bench

Up to:

- 126 kW
- 390 Nm
- 19000 rpm

SiC Inverter

Load Machines

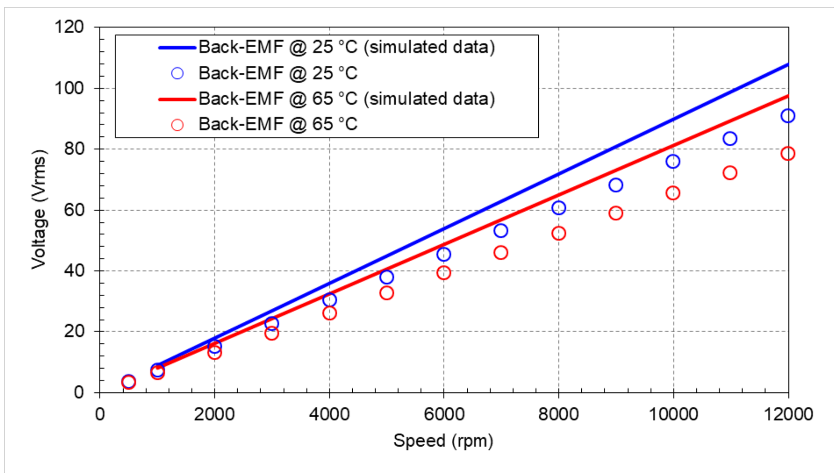


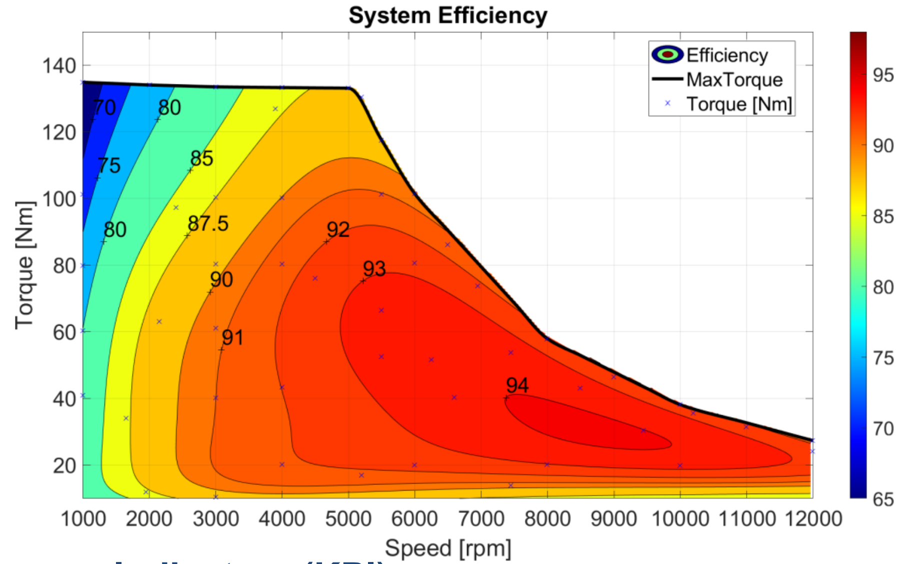
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770143

Motor Testing

PMa SynRel – 75 kW motor

- Most of the **target performances were achieved** according to our key performance indicator
- However, mainly due to **weaker magnets than anticipated** the peak torque and power are lower than expected. Investigation in progress.
- **The efficiency of the system (motor + inverter) on the driving cycle is 90 %.**





Motor Key Performance Indicators (KPI)

Parameter	Unit	RFD goal (min)	Achieved	RFD goal (max)
Specific peak power	kW/kg	3.1	**3.64**	-
Specific peak torque	Nm/kg	5.0	**6.97**	-
Active parts weight	kg	-	**19.5**	24
Peak efficiency	%	96	**96.3**	-

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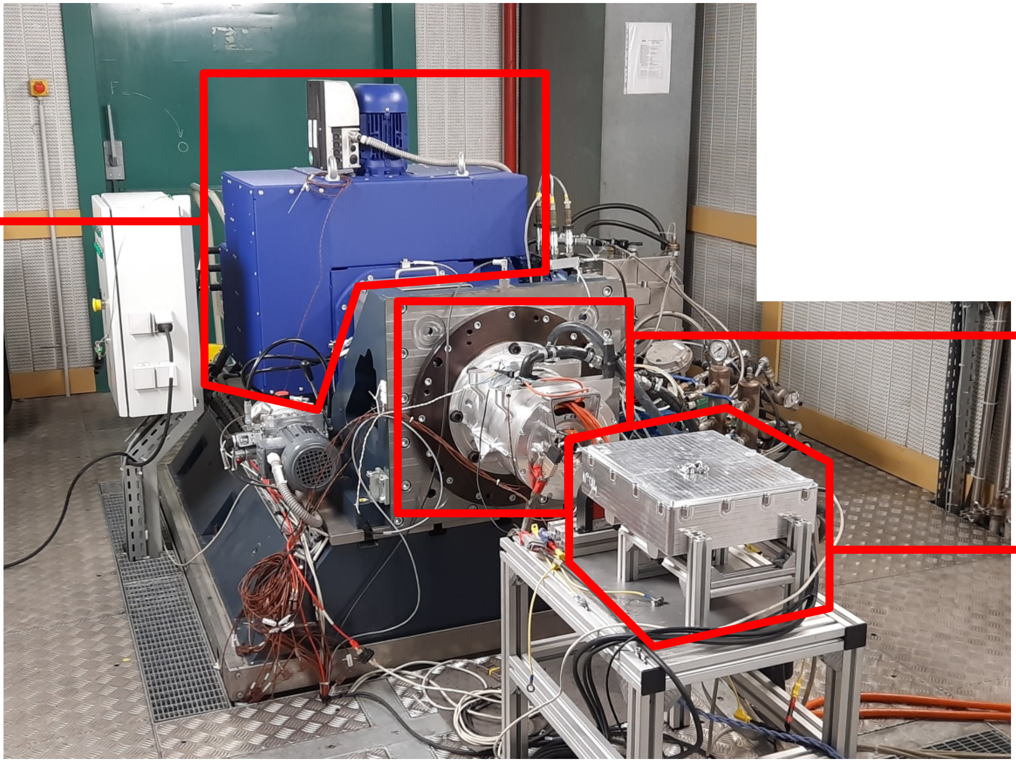
Motor Testing

PMa SynRel – 200 kW motor

Load Machine



ReFreeDrive
PMa SynRel 200 kW

SiC Inverter

IFPEN Test Bench

Up to:

- 250 kW
- 500 Nm
- 20000 rpm

- Tests on the ReFreeDrive PMa SynRel 200 kW motor are close to completion at IFPEN
- We are expecting to have lower magnet performances than expected (identical to 75kW)
- **The measured motor peak efficiency is 96.3 %**

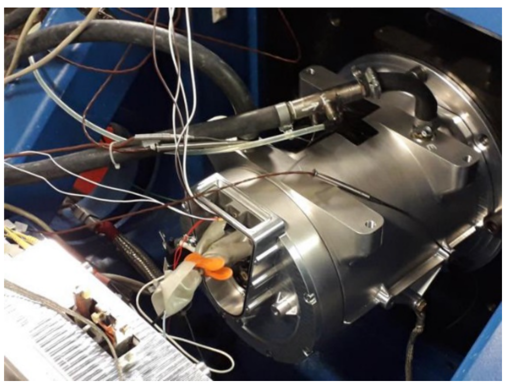
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770143

ReFreeDrive Project Overview

Next steps

December 2020

March 2021

Motor & Integrated powertrain testing	In-vehicle integration
 	

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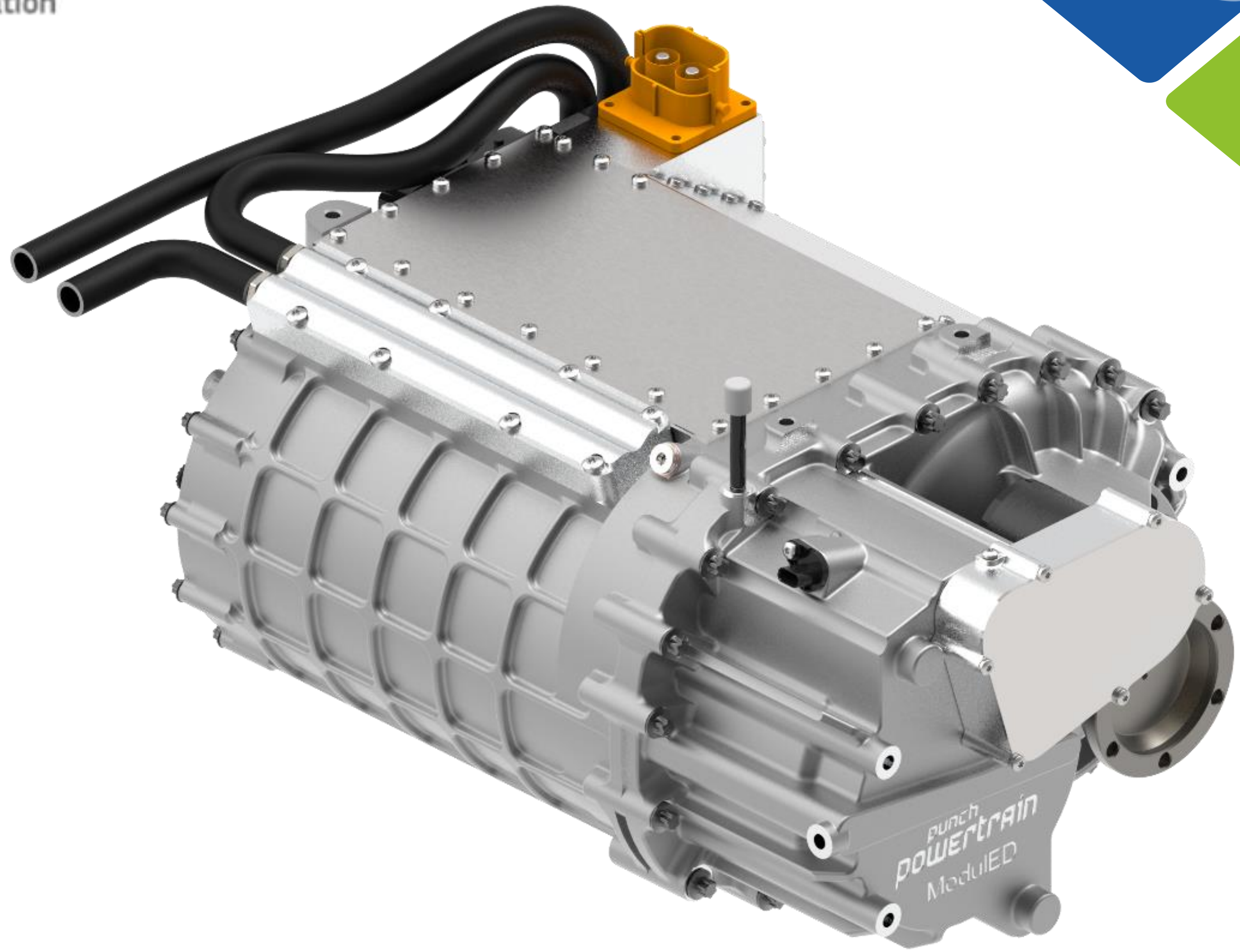
ReFreeDrive

Thank you for your attention!

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 770143

European Commission

Horizon 2020
European Union funding
for Research & Innovation



MODULED

MODULar Electric Drivetrain

Webinar 18-09-2020

LANNELUC Charley

This project has received funding from the European Union's Horizon 2020 research and innovation programme

Agenda

1. Introduction to the ModulED project

2. Main achievements

    a. PowerTrain layout
        Specifications and layout
        Cooling concept
        Coolant distribution design : Inverter and motor cooling

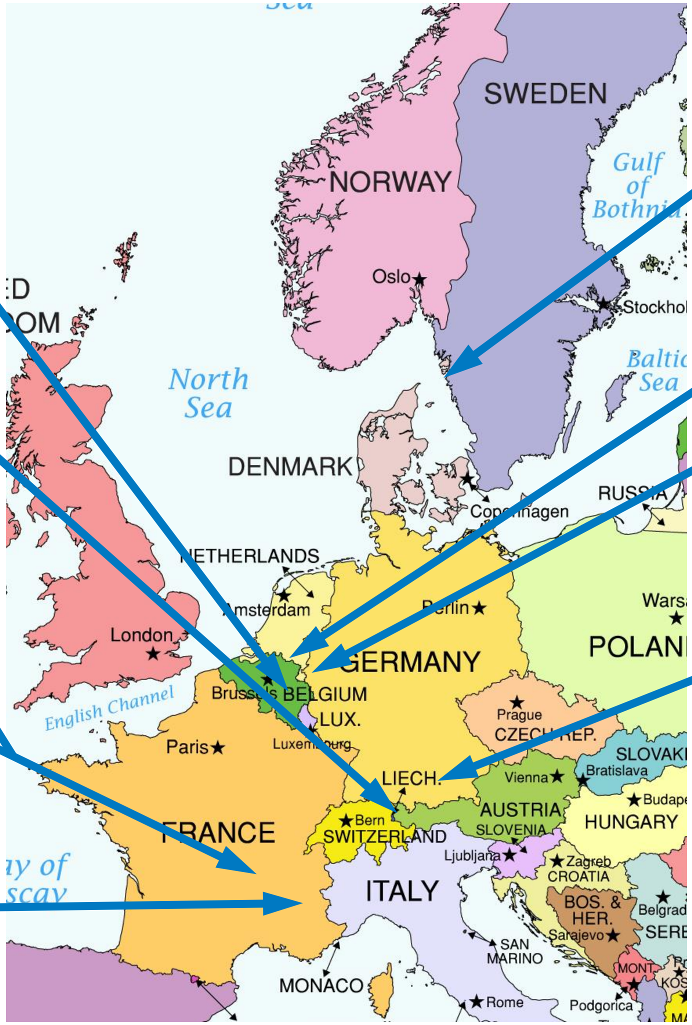
    b. GaN based inverter
        Design & integration
        Efficiency

    c. Electric motor
        Multiphase motor design with optimized magnetic materials
        Injected magnet

Conclusions

This project has received funding from the European Union’s Horizon 2020 research and innovation programme

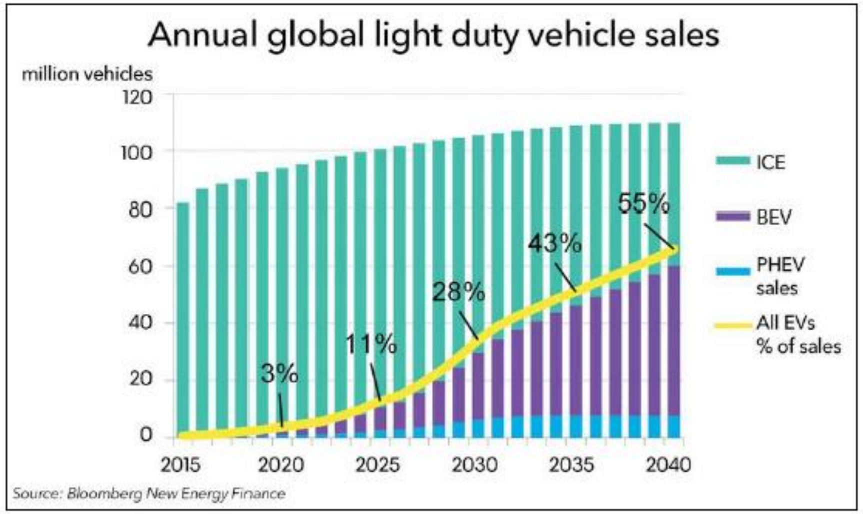
Introduction to the ModulED project



moduled-project.eu/

This project has received funding from the European Union's Horizon 2020 research and innovation programme

Introduction to the ModulED project



1. Take up of e-mobility at larger scale in the coming years
2. Need to have powertrain solutions ready for mass-market within the next 5 years
3. Critical material is of concern for Europe: reduce dependence on rare earth materials
4. Modular solutions allows addressing different markets
5. Optimisation at component and vehicle level
6. Emerging power electronics devices
7. New manufacturing techniques for motor production

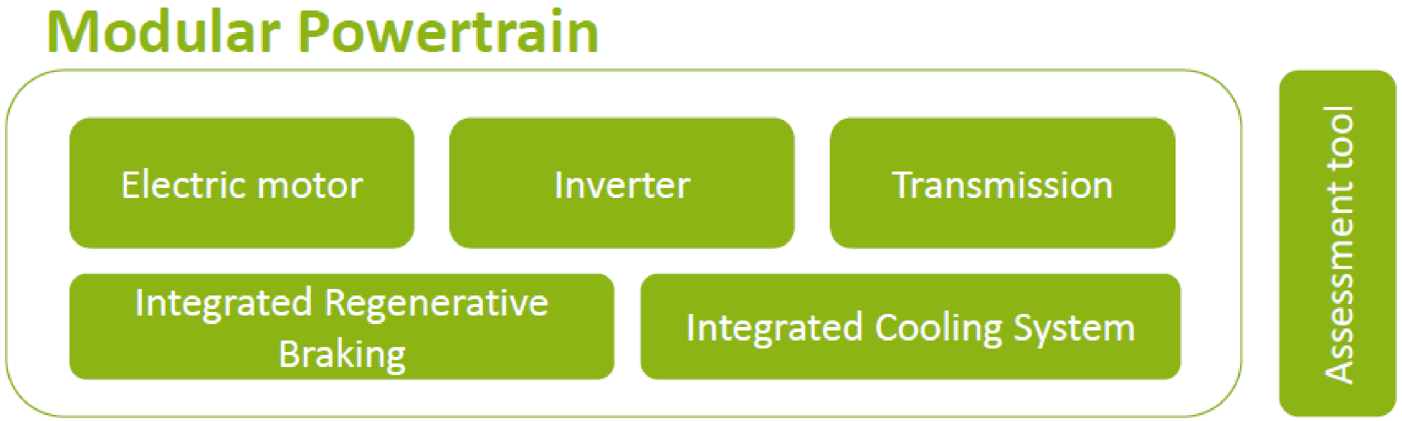
The total costs of the project represent EUR 7,022,867.50. This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 769953

This project has received funding from the European Union's Horizon 2020 research and innovation programme

Introduction to ModulED project

ModulED aims at developing a **new generation of modular electric powertrain** for BEV (Battery Electric vehicle) and HEV (Hybrid Electric Vehicle), **up to full scale demonstration** integrated in a BEV platform. During the project, the consortium has developed an innovative modular powertrain platform new technologies including:

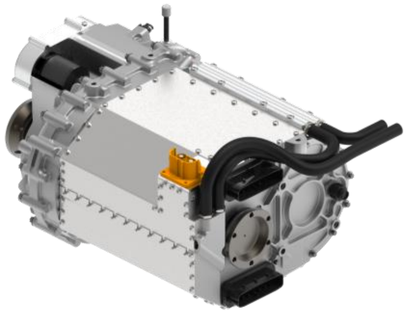
- 6 phase electric motor using less rare-earth magnets
- Inverter using latest generation of GaN semiconductors
- Optimized transmission and advanced cooling features
- An integrated regenerative braking with extended range of energy recuperation
- Reduced sizing
- Advanced control with higher fault tolerance



This project has received funding from the European Union's Horizon 2020 research and innovation programme

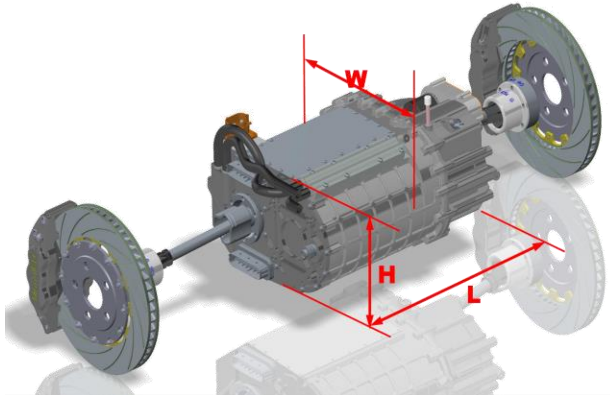
PowerTrain layout

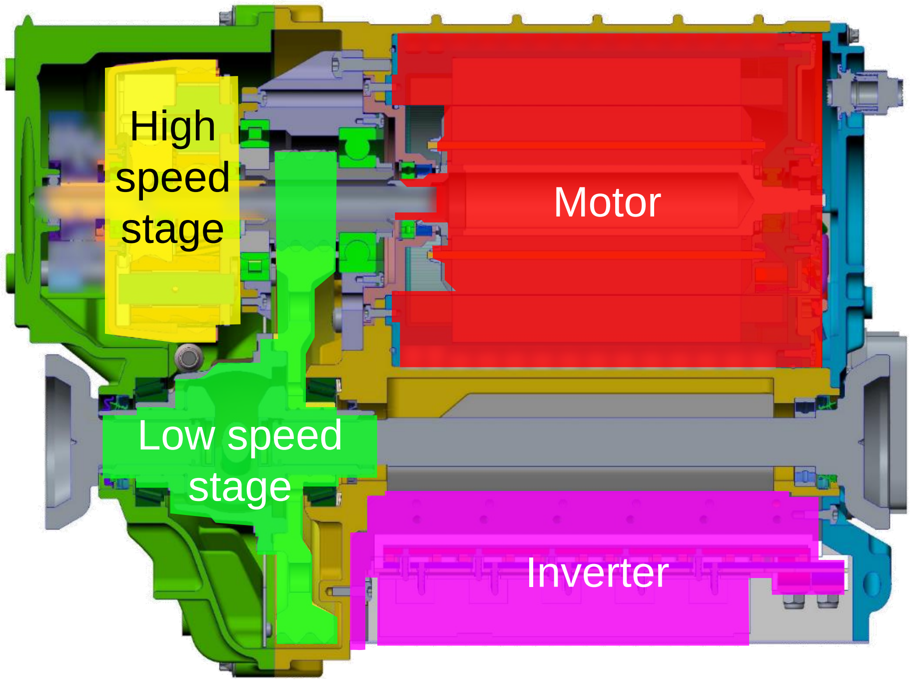
- Scope of Punch Powertrain:
  - **Innovative** & **compact** 2-speed reducer
  - **Compact** full **system integration**
  - **System** level **validation** & integration in **demonstrator**



Motor peak power	160 kW
Inverter peak power	100 kW
Transmission ratios	1/21.65 & 1/12.03
Size (LxWxH mm):	573 x 420 x 304

- Objectives:
  - Evaluate 2-speed concept regarding **shift quality, noise** & **lubrication** challenge
  - Evaluate highest risks of compact **integration** (e.g. **thermal management**)
  - Gain **knowledge** by cross-country experts collaboration





This project has received funding from the European Union's Horizon 2020 research and innovation programme

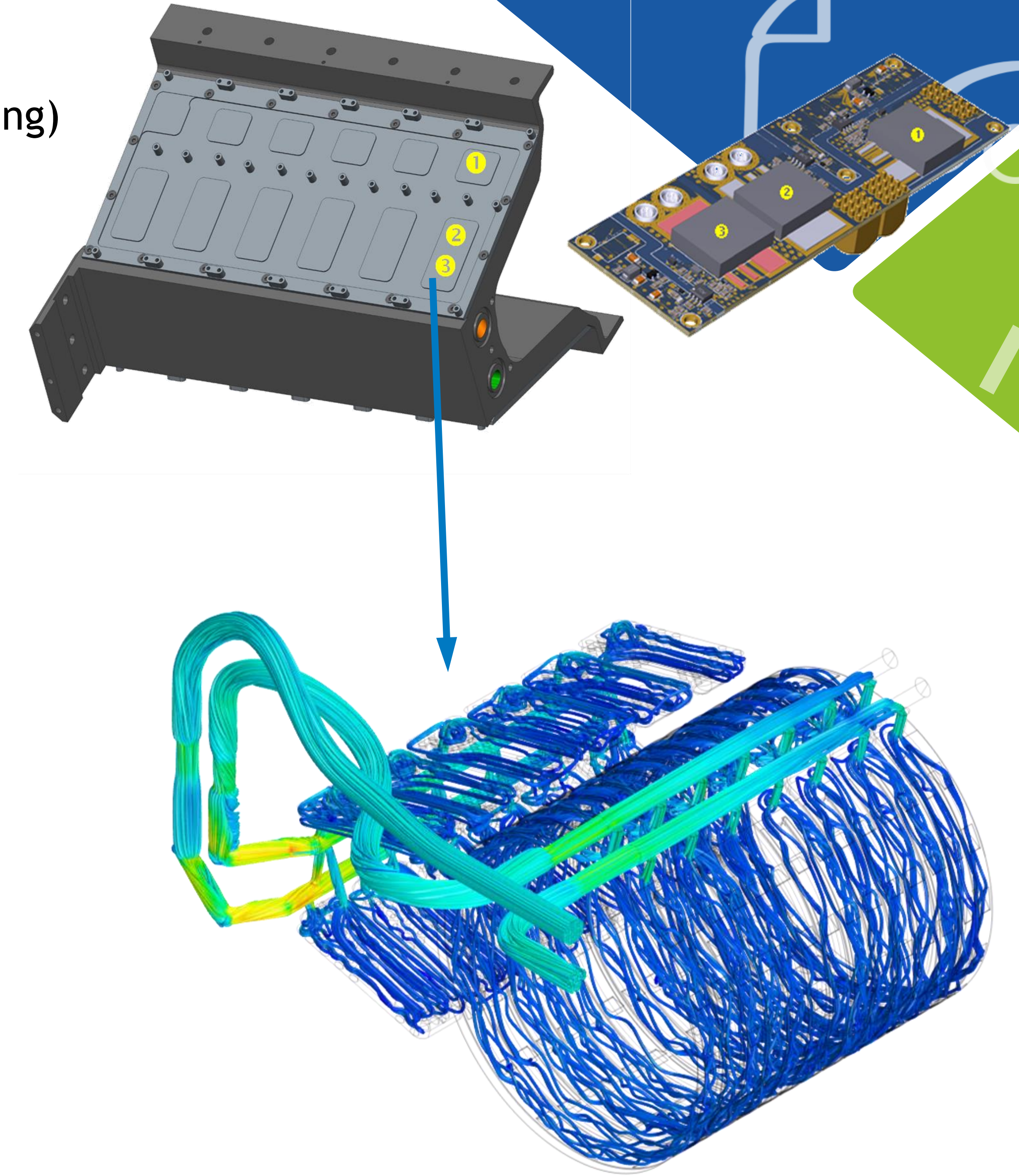
Cooling concept

- Cooling divided in 2 subsystems (inverter and motor cooling)
- Can be connected in series and in parallel
- Series connection applied
- Inverter cooling first

<u>Cooling specifications</u>

- Flows expected up to 15 l/min.
- Simulations performed for flows up to 20 l/min.

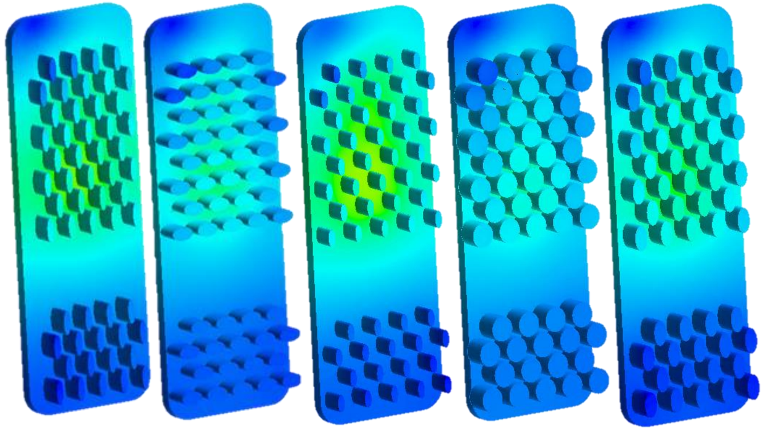
- Pressure drop of the powertrain cooling versus flow rate
- The limit of a 50W pump added
- The pump will able to operate at lower power

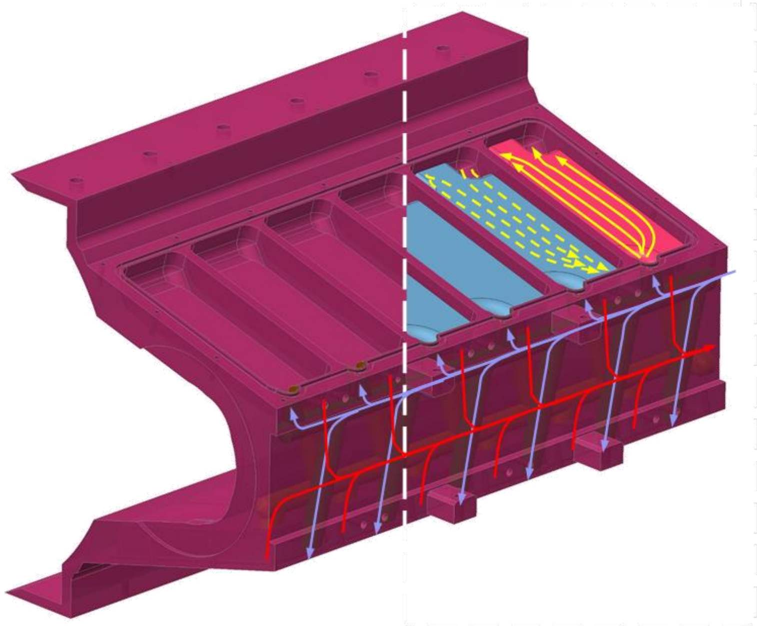


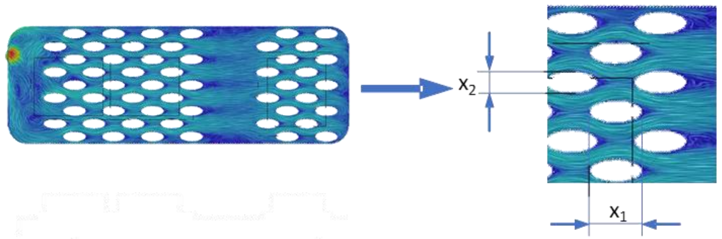
This project has received funding from the European Union’s Horizon 2020 research and innovation programme

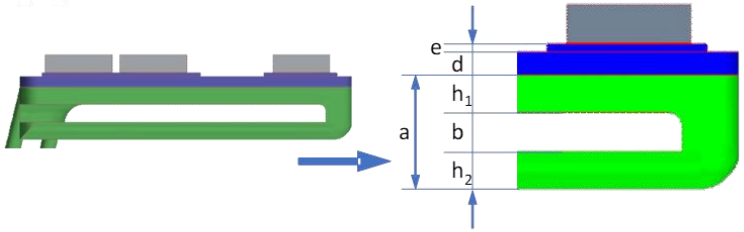
Inverter cooling

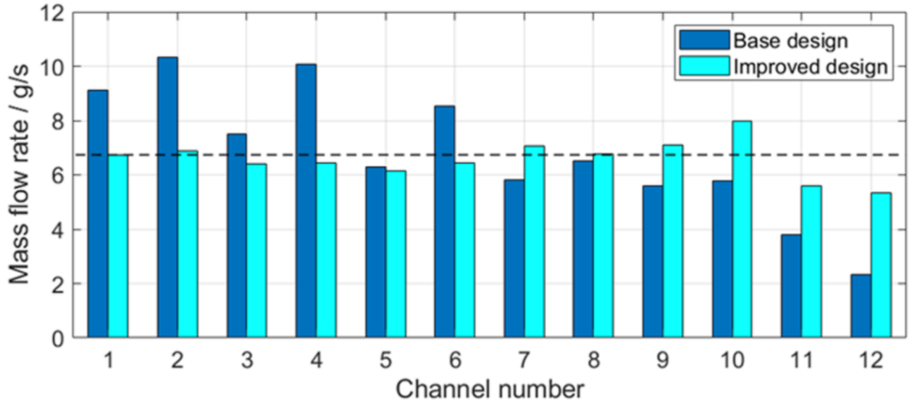
- Achieve mass flow uniformity between cooling pockets (parallel flows)
- Realise good heat transfer from GaN transistors to coolant
- Low pressure drop







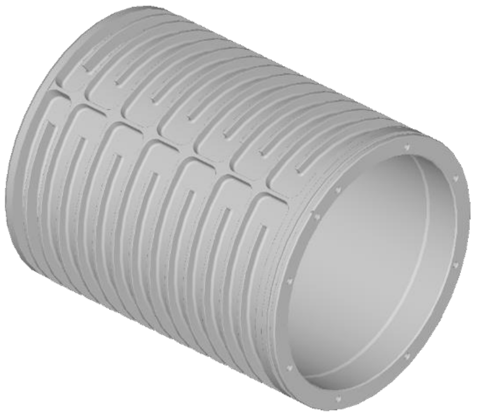


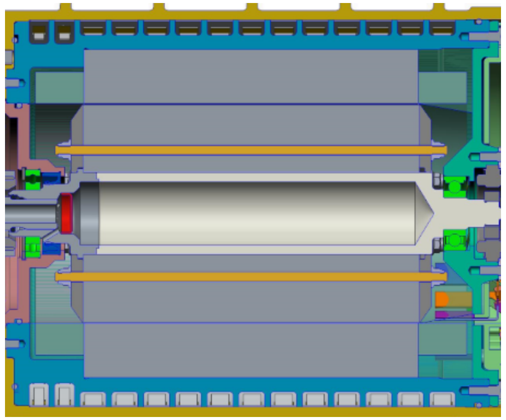


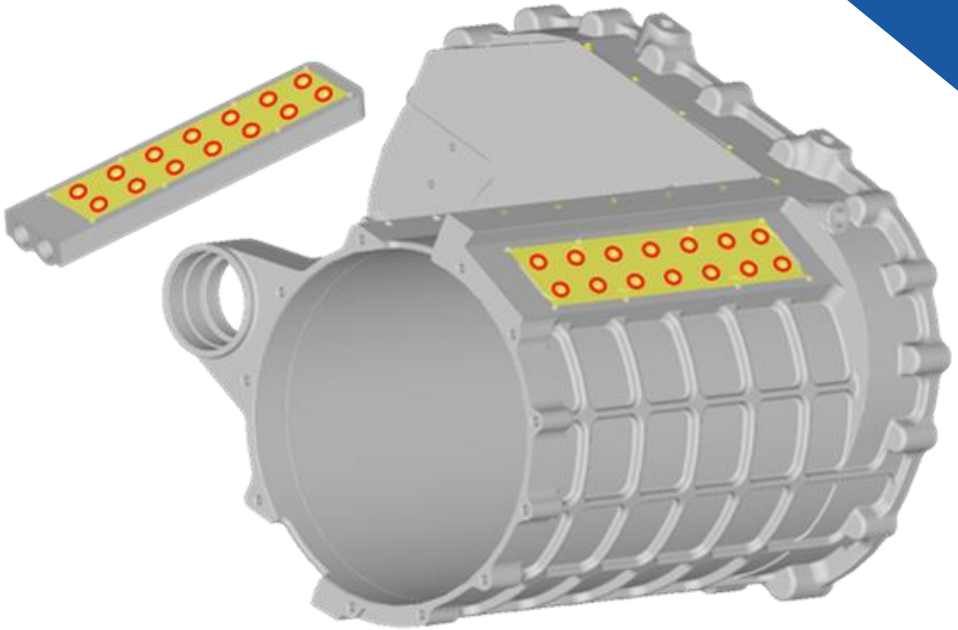
This project has received funding from the European Union's Horizon 2020 research and innovation programme

Motor cooling

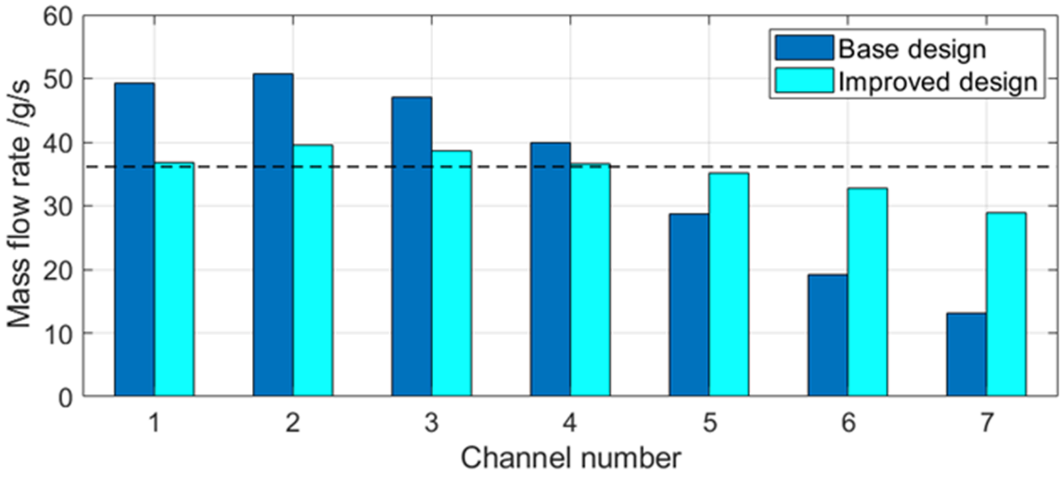
- Stator cooling: 7 parallel, circular channels
- 3D CFD/CHT simulations for cooling performance, flow uniformity and pressure drop







- Parameter sweep for flow feed channels
- Flow uniformity in 7 parallel channels
- Pressure drop optimised

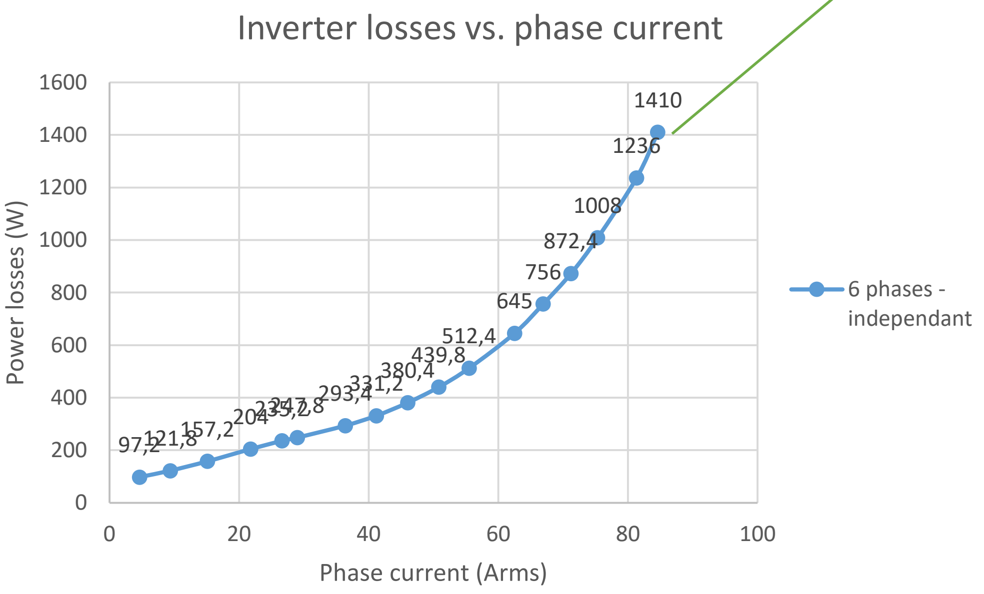


This project has received funding from the European Union's Horizon 2020 research and innovation programme

GaN inverter : power results

- Topology allowing to put motor phases in series or parallel
- Reconfigurable machine increasing fault tolerance management
- Latest GaN semiconductor, generating lower losses, more efficient inverter
- Coolant circuit power pump decreased
- Compact and modular

Inverter efficiency 98% @ 62 kW

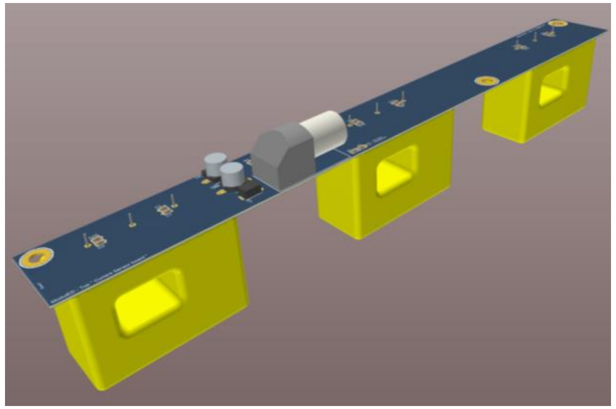


GaN inverter test with one motor phase

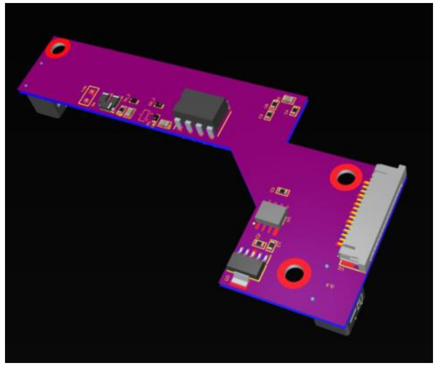
This project has received funding from the European Union's Horizon 2020 research and innovation programme

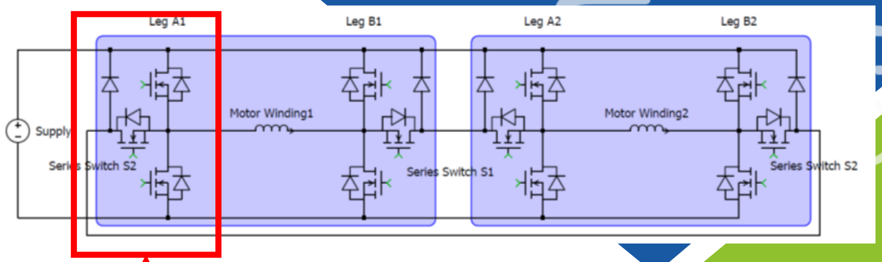
Design

Current sensor board (x2)

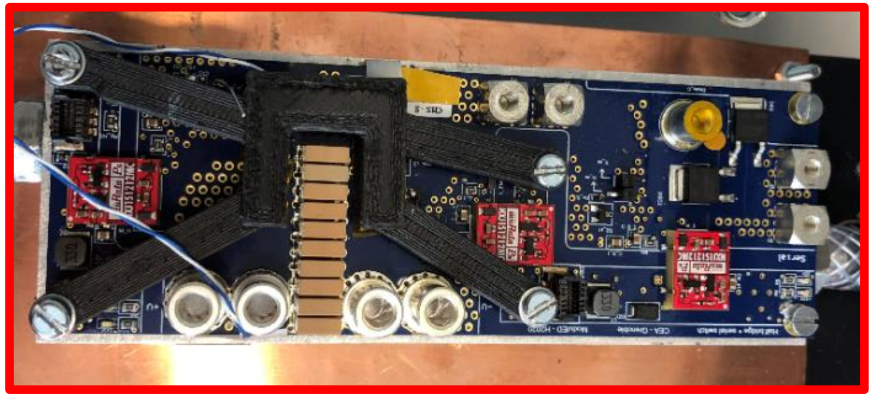


Interface board (x12)





GaN power PCB (x12)



Control and communication (x2)

This project has received funding from the European Union's Horizon 2020 research and innovation programme

& integration =>

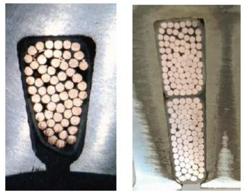
Transmission design and cooling system

This project has received funding from the European Union's Horizon 2020 research and innovation programme

Multiphase motor design with optimized magnetic materials

- Optimized high rpm (>22.000 rpm) ✅ 22.500 rpm
- higher efficiency than state-of-the-art buried permanent magnet motors (96%) ✅ 97%
- More sustainable design, with reduced amount of rare earth magnets, target 45%) ✅ 52%
- Solution with mold injection of magnet material for improved rotor manufacturing ✅
- Substantially better TCO than state-of-the art; cost of motor less than 50% ✅ 47%
- Stator with FLW (Formed litz wire) for lower Cu losses ✅
- Investigation of using rare-earth free ferrite magnet for total motor cost reduction ✅

BRUSA

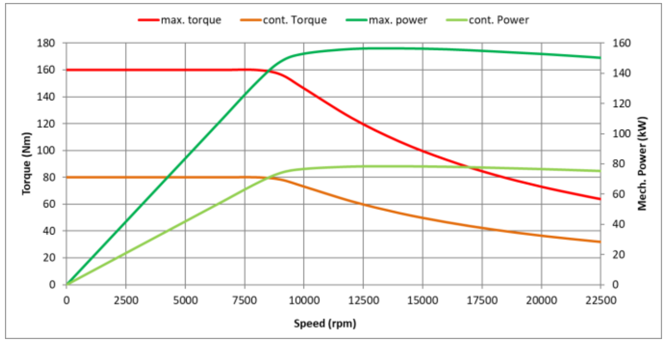


Specifications and comparison to BMW i3

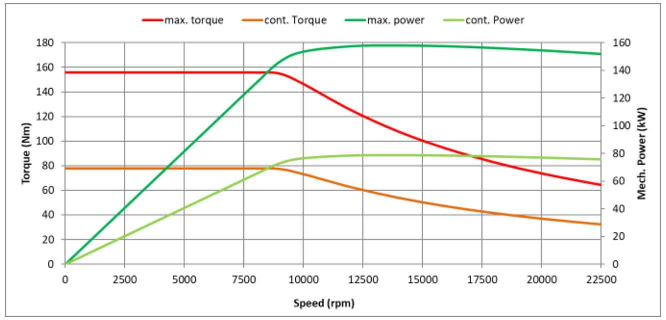
Specifications	ModulED Motor NdFeB	ModulED Motor injected	BMW i3 NdFeB	Unit
Peak current 6ph	225	225	410	Arms
Winding type	FLW	FLW	PIW	-
Number of phase	6	6	3	-
Nominal speed	8600	8600	5000	rpm
Max. motor speed	22500	22500	11400	rpm
Peak torque	160	156	250	Nm
Peak power	157	158	131	kW
Nominal battery voltage	320	320	360	VDC
Stator outer diameter	176	176	242	mm
Stator inner diameter	118	118	180	mm
Active length	179	179	130	mm
Magnet weight	1.32	1.73	2.02	kg
Reference DC voltage	360	360	360	VDC
Peak power @ 360VDC	177	178	131	kW
Magnet weight per power	7.5	9.7	15.4	g/kW
Magnet amount reduction to reference motor	**52%**	**40%**	**0%**	

Powercurves

ModulED NdFeB



ModulED injected



Patents

1_Motor mit NdFeB
Patent number: DE102018128146.3
Priority date: 9 Nov. 2018
To be published: May 2020

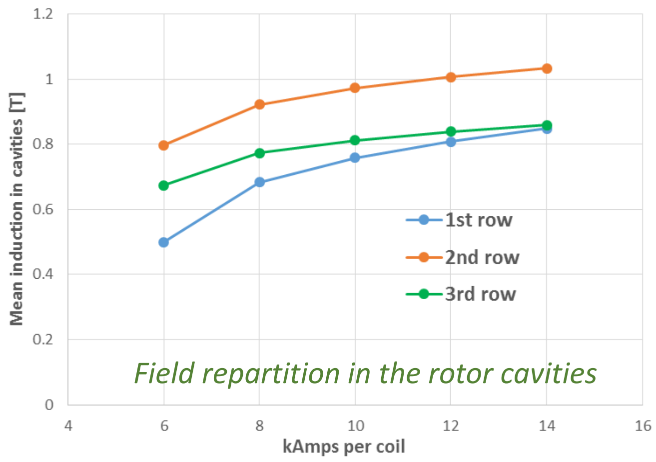
2_Motor mit «injected magnets»
Patent number: DE10201910739.4
Priority date: 22 March 2019
To be published: Sept. 2021

3_Stator with Form Litz Wires (FLWs)
Patent number: DE102018101231.4
Priority date: 19 Jan 2018
To be published: July 2019
(prepared before start of H2020)

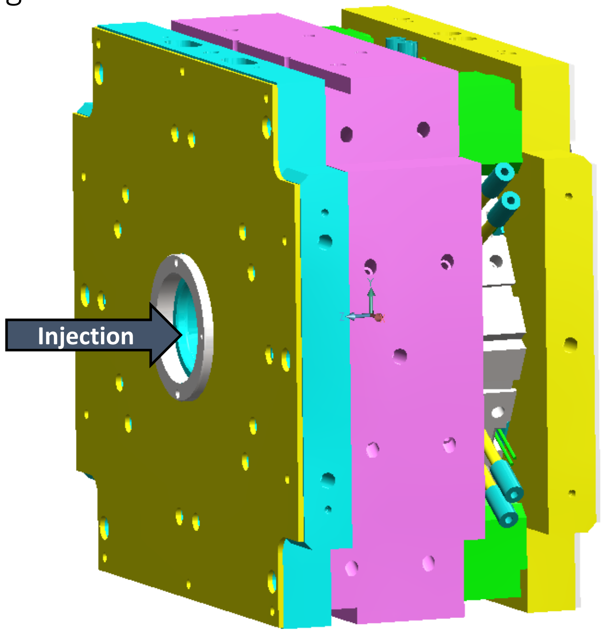
This project has received funding from the European Union's Horizon 2020 research and innovation programme

Direct injection of bonded magnets into the rotor

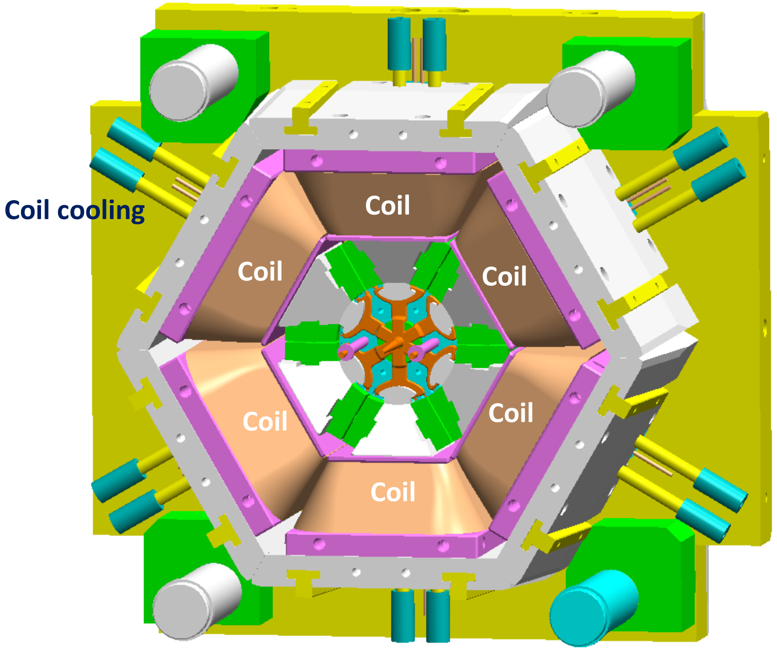
- Magnetic design of the mould includes magnetic shunts allowing homogenous field repartition
- The 3D design of the mould is completed, taking into account all specific requirements of the MODULED rotor injection (large number of cavities in a stack of laminations)
- Manufacturing of the equipment and test rotors is in progress
- Impact of injection pressure studied
- magnetising simulation



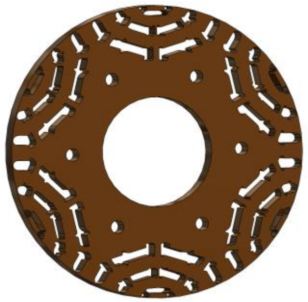
Field repartition in the rotor cavities



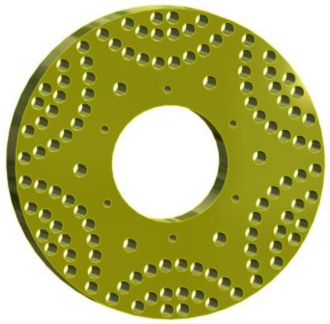
Mould in the closed state



View of the interior



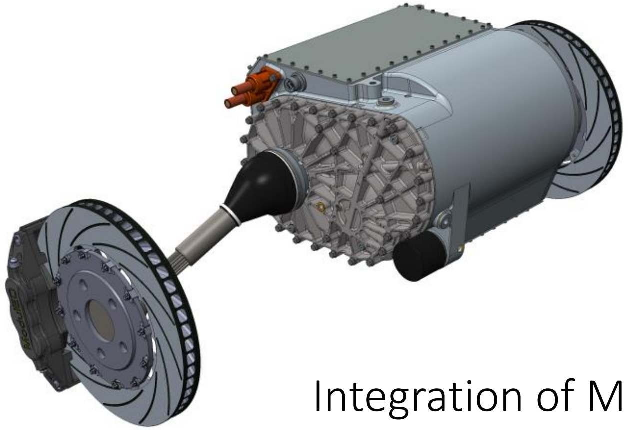
Actual rotor (FeSi lamination)



Rotor for tests (plain steel)

This project has received funding from the European Union's Horizon 2020 research and innovation programme

System demonstration and validation



Integration of ModulED powertrain and regenerative braking system in vehicle

Vehicle validation on chassis dyno & proving ground

Vehicle demonstration and closing event

This project has received funding from the Europe
Union's Horizon 2020 research and innovation programme

Conclusions

Thanks to the adoption of **efficient semiconductors (GaN/SiC)**, **innovative motors** (more efficient and greener), **hybrid powertrain and hybrid cooling building blocks** will be developed during the project, enabling a new concept for the BEV and HEV market: the modularity.

By providing low-cost, efficient and versatile powertrain, the ModulED is addressing the needs of the cars manufacturers to be able to respect the CO_2 emission regulations worldwide. In addition, **reducing the amount of rare-earth elements needed per kW (-50%)** will also have a positive impact on the environment.

The combination of all research and developments during the ModulED project will enable the consortium to reach the following impacts:

- **Costs reduction:** 15% reduction thanks to Motor: -20% (rare earth magnet), other components: -5%;
- **At motor level:** increase of the power density of 100% and 100% increase in maximum operating speed (22 000 RPM);
- Compatibility with engine coolant temperatures allowing hybrid applications with a single powertrain cooling system and ability to operate at 90˚C.

This project has received funding from the European Union's Horizon 2020 research and innovation programme

Contact

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End of presentation

Thank you

This project has received funding from the European Union's Horizon 2020 research and innovation programme

Q&A Session

1) What is the speed of the motor (DRIVEMODE)?
The motor is designed for 20000 rpm.

2) Is it possible to know the weight of this power train (DRIVEMODE)?
The total weight of the powertrain is about 57 kg.

3) The motor used in the DRIVEMODE IDM project was developed with which software? Is the motor an internal magnet?
Altair FLUX 2D was mainly used for the design, Motor CAD was also used at some stage of designing.
Yes the motor is an internal PMSM.“

4) By increasing the power density, how are the thermal challenges being taken care of without changing the cooling arrangements (DRIVEMODE)?
The cooling arrangement were changed with added coolant pumps, increased flow rate and splitting the cooling loop to supply two IDMs.

5) What are the Standards that are followed by IDT testing specifically for Drive Motor testing ? (DRIVEMODE)
IDM testing was performed with respect to the System Requirements defined in WP2. However, the e-motor WP performed their own component testing (AVL, Thien e-Drives),

6) Have you performed a 30 min power test ? (DRIVEMODE)
Continuous and steady torque for 30min at 100km/h yes

Q&A Session

7) As current 4Ws are using 360-440 V Battery pack, what are the challanges if we shift battery to 800V DC ? (DRIVEMODE)
Mainly, component rated for 800V and insulation requirements... But basically there will not be any major change in safety requirement from 400V to 800V, as both are below 1500V which is the next level...

8) What is the vehicle clearance from the ground? (DRIVEMODE)
120mm

9) Which are the SiC use advantages in terms of performance and durability? (DRIVEMODE)
The main advantage of using SiC is reduction of the switching losses (by around 90%) that allows to downsize the thermal management equipment in comparison to the same power and frequency Si devices.
For the durability question Semikron responsible for the SiC module would have the accurate answer, but to my undestanding SiC's are generally durable (good current rating) with respect to equivalent IGBT's."

10) What is the volume of the trunk after integration? DRIVEMODE
This is a prototype vehicle, do I dont think this matters. However, this packaging will obviously not be the final production car...

11) Drivemode: why did you choose to design the powertrain with a three-speed gearbox? doesn't this add reliability issues ad O&M costs? DRIVEMODE
Gear box is 1-speed (3-stage yes) with a fixed 14.1:1 gear ratio.

Q&A Session

12) Why two motors? It seems costly, and front-wheel-drive car probably doesn't need the added performance. DRIVEMODE
Topology wise having one power train per axle does have it's advantages, such as more straight forward way of distributing the power to the wheels on each side. From control/software perspective that is. You can have a look at Deliverable 2.1. The demo vehicle was classified as M class and power/torque requirements lead to choice of F2 (front wheel two motor setup) configuration. Furthermore, the project objective was modularity and replicability to fullfill different market segment with only one type/side of IDM module.“

13) DRIVEMODE: you have chosen a 3-speed gearbox, whereas most vehicles today still have single stage...how do you consider cost & reliability of your gearbox in later mass series application?
For the general question the gearbox has fixed 1-speed 14.1:1 gear ratio. As for the cost, reliablity and mass production topics BorgWarner (the consortium partner) would be able answer in more detail.

14) Could you tell us about the weight of this IDM ? DRIVEMODE
e-Motor: ~30kg,
Inverter: <5kg,
The gearbox is about 22 kg, including the coolant.

15) ReFreeDrive - What is the distance kept between rotor stack and endrings?“
I assume you refer to the fabricated cage rotor. In die-cast cage, there is no space between endring and rotor stack. In fabricated cage, we use induction welding and considered 2-4 mm space. However, there is a trial and error approach and see what distance is acceptable for the process. These rotors are still to be manufactured."

Q&A Session

16) @ReFreeDrive What is the IACS value after die casting copper rotor?
95%

17) @ReFreeDrive Pure SynRel: Why did you use round wire instead of hairpin-winding? This makes it difficult to compare the results with the induction-Motor.
The different winding configuration needed with respect to the IM doesn't allows to use hairpin technology in the prototypes. Of course it is possible to design Pure syn Rel with hairpin technology

18) @ReFreeDrive Pure SynRel: There is a very strong decrease of the torque in field-weakening range, so you have only 25% of peakpower at high speed. Are there methods to overcome this drawback?
This was the challenge of the design, the wide speed range was a real problem and to enhance performance at high speed you need to remove the so called ribs. We have some ideas to do that, even by using structural resins check out papers on the website

19) DRIVEMODE - So does the NEVS vehicle indeed have two motors in the front?
Yes, 2x IDM's. One IDM per LF an RF wheels.

20) @Refreedrive : Any Specific reasons for not considering Switched Reluctance for this Project?
Switched reluctance motors is also an alternative, discarded because it has may have high torque ripple

Q&A Session

21) @Refreedrive : Are the designs of IM and SyncRel carried on same specifications: same torque vs speed requirements ? If yes, why Synrel design has a larger diameter for same torque ?"
Yes, same requirements, same maximum volume, same weight. The motors final dimensions were the result of the optmization steps“

22) DRIVEMODE - What are the challenges you faced when increasing this speed by 50% ? Don't we try to eliminate gear boxes by going to high speed, so what is the role of gear boxes in IDM?"
I assume the gearbox in this case is a tradeoff having high speed motor, required torque and the project object of the rare earth materials. The main challenge was a combination of mechanical-electromagnetic design of the air pockets around PMs. There need to be flux barriers and same time the structure need to avoid sharp corners which are the starting point of cracks in structure. Hence mainly the design is due to mechanical optimisation of the PM pocket shapes, along with PM sizes, locations, and angles.

23) @Refreedrive : Which duty cycle used in case. Any comparison against PMSM motor wrt to range of vehicle?
If you mean driving cycle, we're using WLTC3. The comparison between all the machines is not yet done since we're currently in the testing phase.