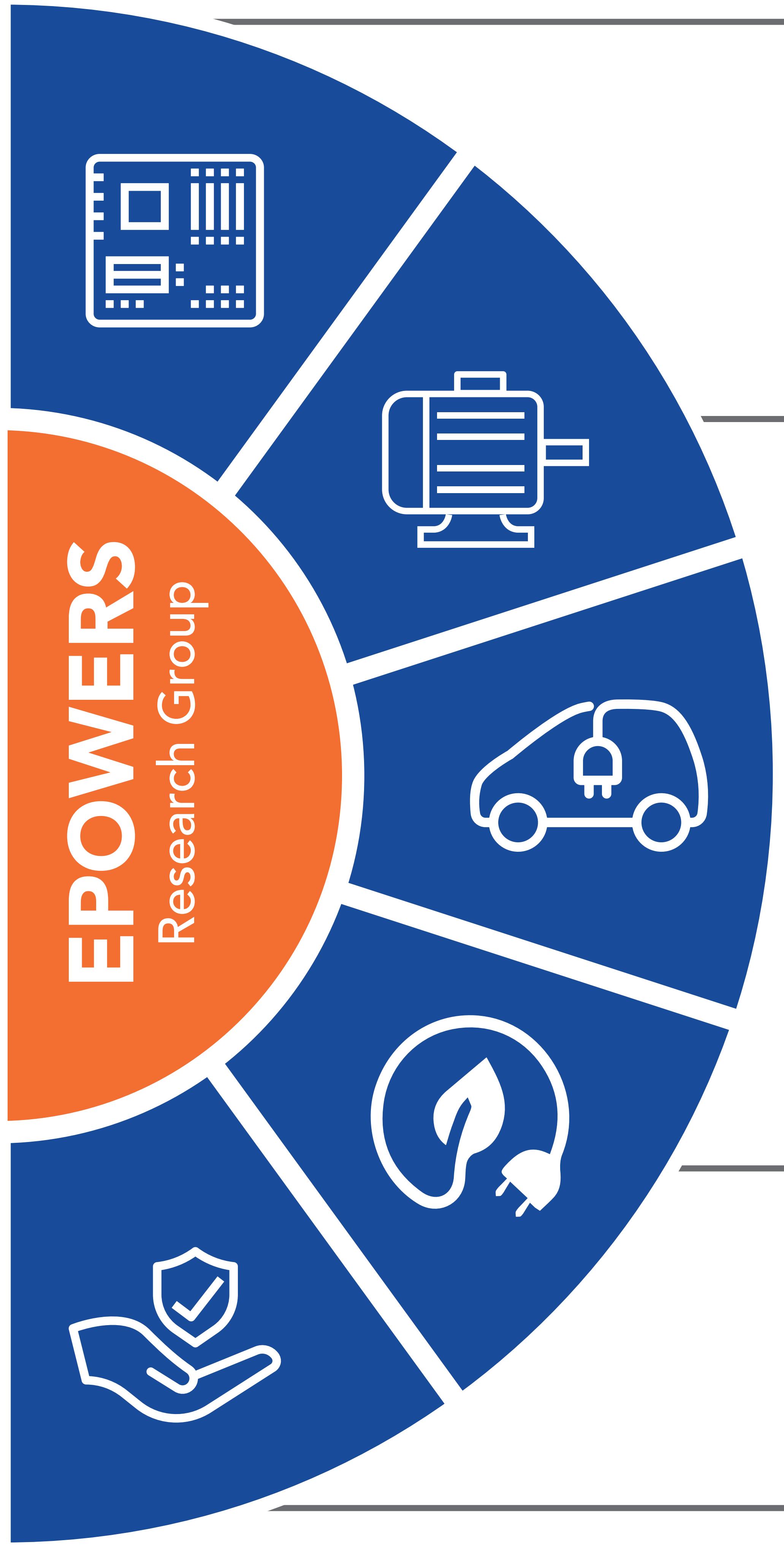
EPOWERS Research Group:
Efficient POWER Electronics, POWERtrain and Energy Solutions

EPOWERS Research Group: Research Portfolio
MOBI Research Centre & ETEC Department
Vrije Universiteit Brussel (VUB)

VUB EPOWERS EFFICIENT POWER ELECTRONICS, POWERTRAIN & ENERGY SOLUTIONS RESEARCH GROUP

VUB mobi ELECTROMOBILITY RESEARCH CENTRE

EPOWERS Research Portfolio



Power Electronics

Charging Systems
Inverters & multi-level converters
DC/DC converters & Active Front-End (AFE)
Battery Management Systems (BMS)

Electrical Machines

Design and Optimization
System Control
Performance Assessment

Vehicle Powertrains

Digital Twin Powertrain
Codesign Optimization Framework
ECO-energy management strategies
Fleet Electrification

Smart Green Grid Solutions

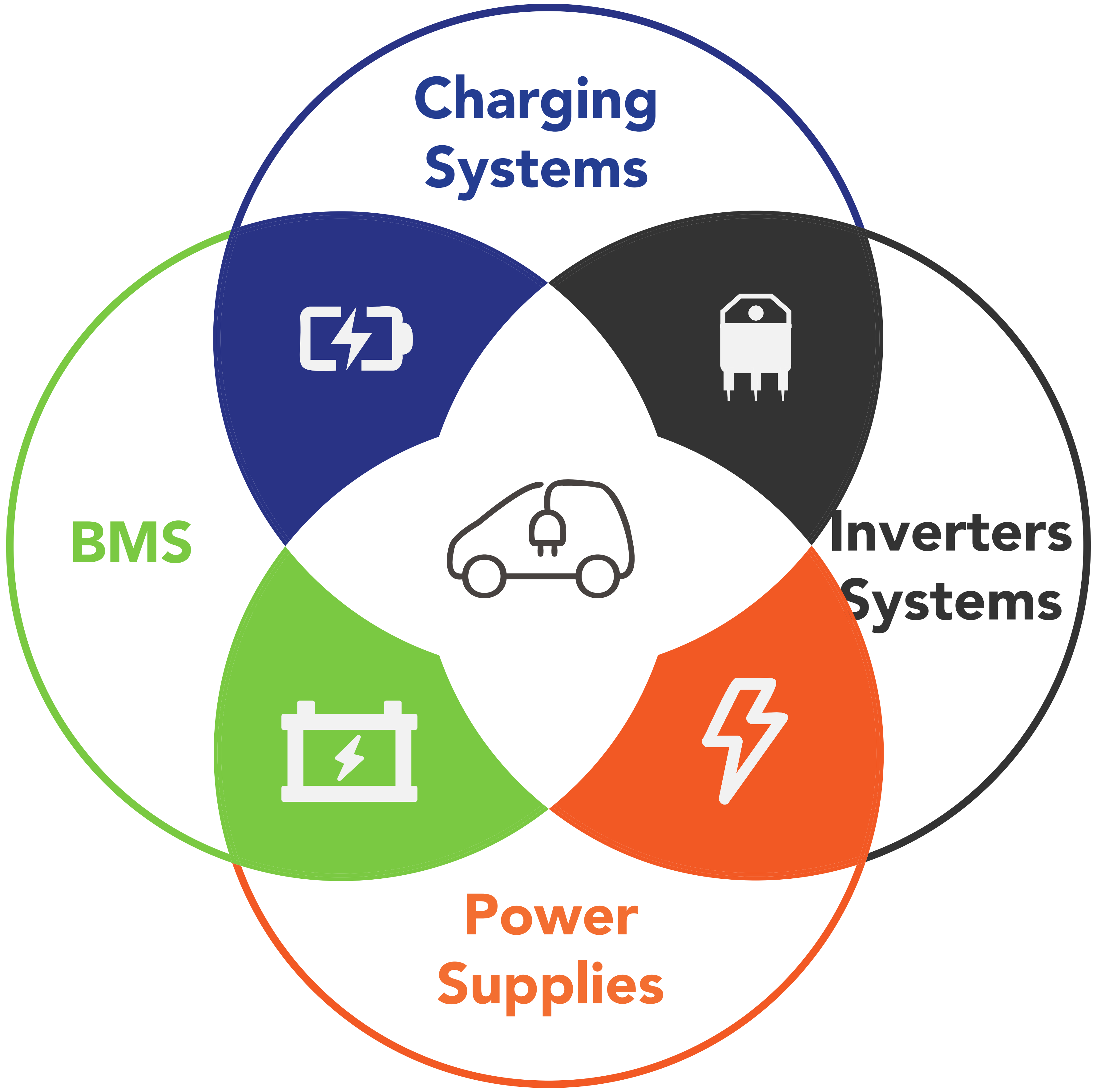
Design, Optimization and Sizing of Green assets
Energy-Thermal Management and Control system
Optimal Charging & V2X (V2G, V2B, V2H, V2D) Strategies

Digital Twin and Reliability

Virtual prototyping and validation of PE converters
Virtual vehicles simulation and Fleets management
Lifetime testing/ALT testing and RUL estimation

V2X-Vehicle to everything ALT-Accelerated Lifetime Testing, RUL-Remaining useful lifetime

Power Electronics Research Track



Charging Systems

- On-board chargers & V2X
- Off-board chargers & V2X
- Wireless charging systems & V2G
- Integrated Chargers
- Thermal design and optimization
- Advanced control: MPC, ANN

Inverter systems

- Modular Multi-level Inverters
- Traction inverters (VSI & ZSI)
- Grid-connected inverters (VSI & ZSI)
- Thermal design and losses optimization
- Advanced control: MPC, PSO based IFOC, DTC, ANN-control

DC/DC and AFE converters

- Modular multiport DC/DC
- HV-LV DC/DC
- Active Front-End (AFE)
- Thermal design and optimization
- Advanced control: MPC, Sliding mode control, ANN-control

Battery Management Systems (BMS)

- Passive balancing systems
- Active balancing systems
- MLC for module balancing-BMS
- Predictive control-based balancing

V2X- Vehicle to everything, MPC-Model predictive control, ANN- Artificial neural network, PSO- Particle swarm optimization, IFOC-Indirect field-oriented control, DTC-Direct Torque Control

Power Electronics

Charging Systems: Modular On-Board Charging systems

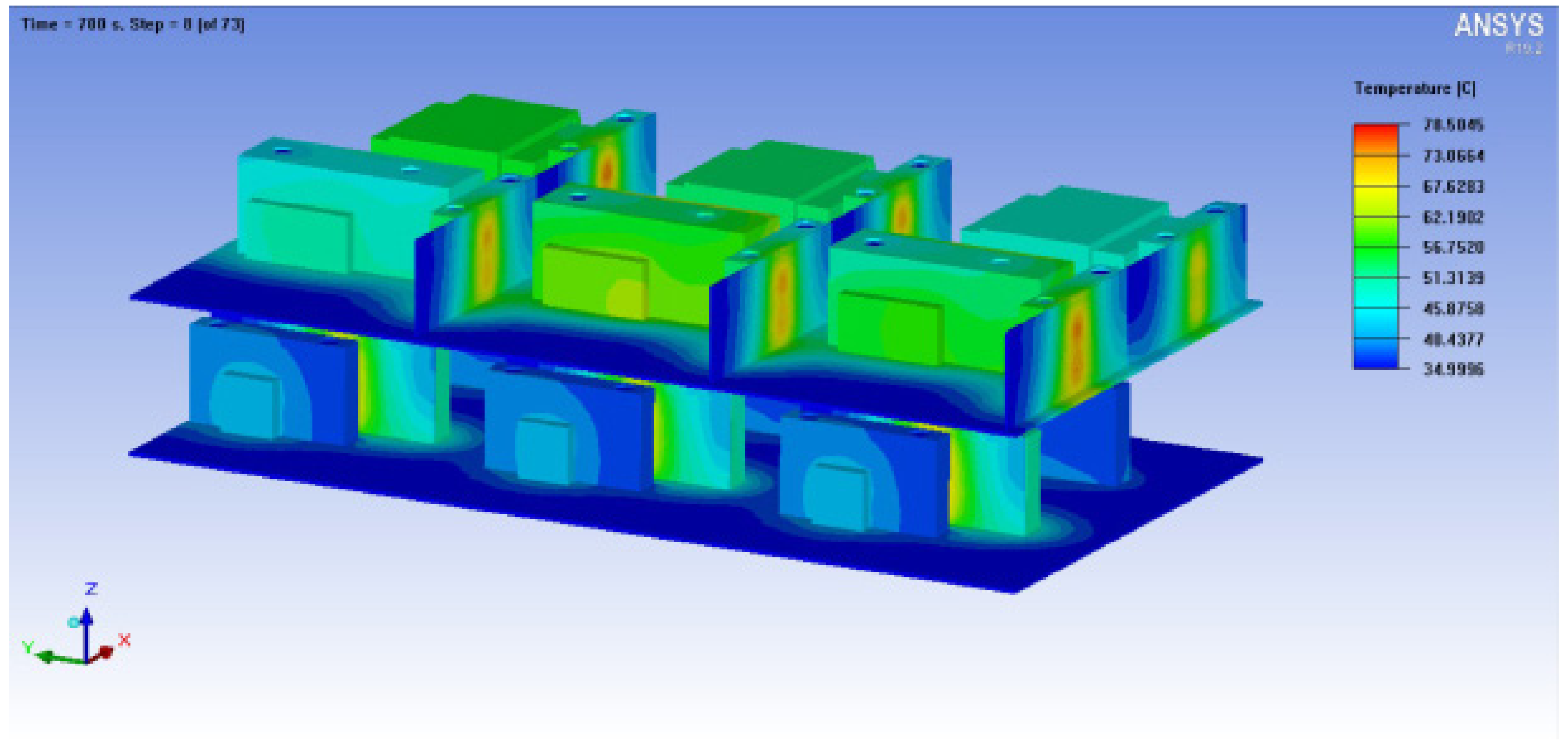
1. Design Specification & Optimization
2. Converter Analysis and control
3. OBC Modeling & Virtual Prototyping
4. Hardware Development and Testing

- Power Density
- Efficiency
- Reliability
- Cooling selection
- Advanced Topology
- WBG Devices (i.e., SiC and GaN)

- Electrical model
- Magnetic model
- Optimal control: Iterative adaptive frequency control with minimum THDi
- V2X (V2G, V2B, V2H, V2D)

- Physics based (3D)
- Universal loss model
- Electrical transient model
- Average loss model
- Map-based model
- Equivalent thermal models
- Multi core HiL model

- WBG technology
- Compact busbar & cooling
- Modular designs
- Local measurements
- Full load testing
- Testing at different ambient conditions

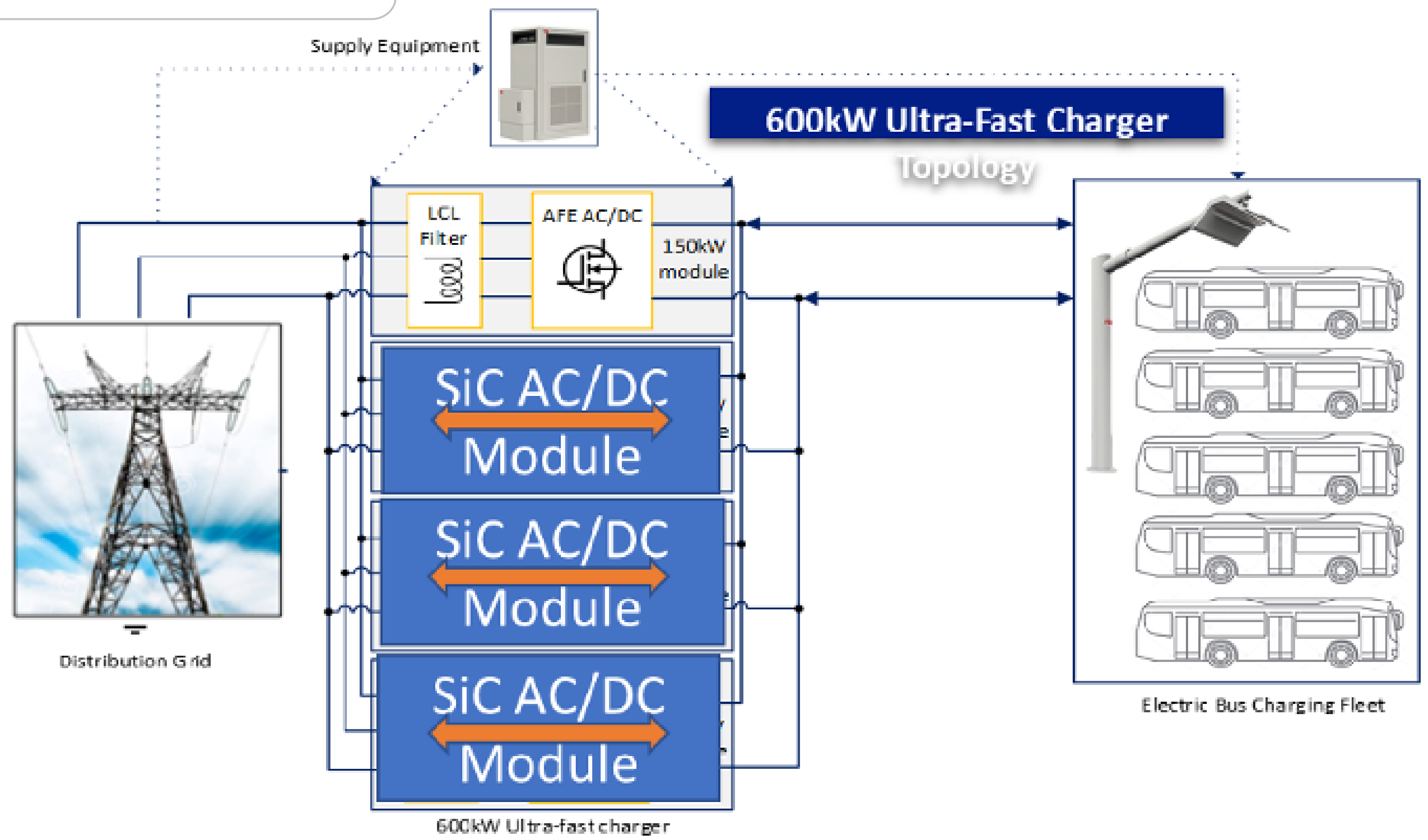


SiC-Silicon Carbide, GaN- Gallium Nitride, THD-Total Harmonic distortion, V2X-Vehicle to everything, HiL-Hardware-in-the-loop, WBG-Wideband gap

Power Electronics

Charging Systems: Modular Off-Board Charging systems

1. Design Specification and Optimization	2. Converter Analysis and Control	3. Thermal Modeling and Cooling	4. Hardware Prototype and HiL Testing
• Topology • Power devices • Passive filter design • Power density • Efficiency • Reliability • V2X (V2G, V2B, V2H, V2D)	• Modular converter design • Dynamic & linear modeling • Static Stability analysis • Dynamic analysis • Advanced control: H-infinity control based on GA, adaptive PI control based on PSO	• Dynamic loss modeling • Filter loss modeling • Thermal modeling • Cooling system modeling • Simulation testing • Virtual prototyping	• Real-time HiL testing • Modular designs • Inductor design • Integrated gate driver • Modular cooling system development



Substation: Power Converter

Ga- Genetic Algorithm, HiL-Hardware-in-the-loop

Power Electronics

Charging Systems: Wireless Power Charging Systems

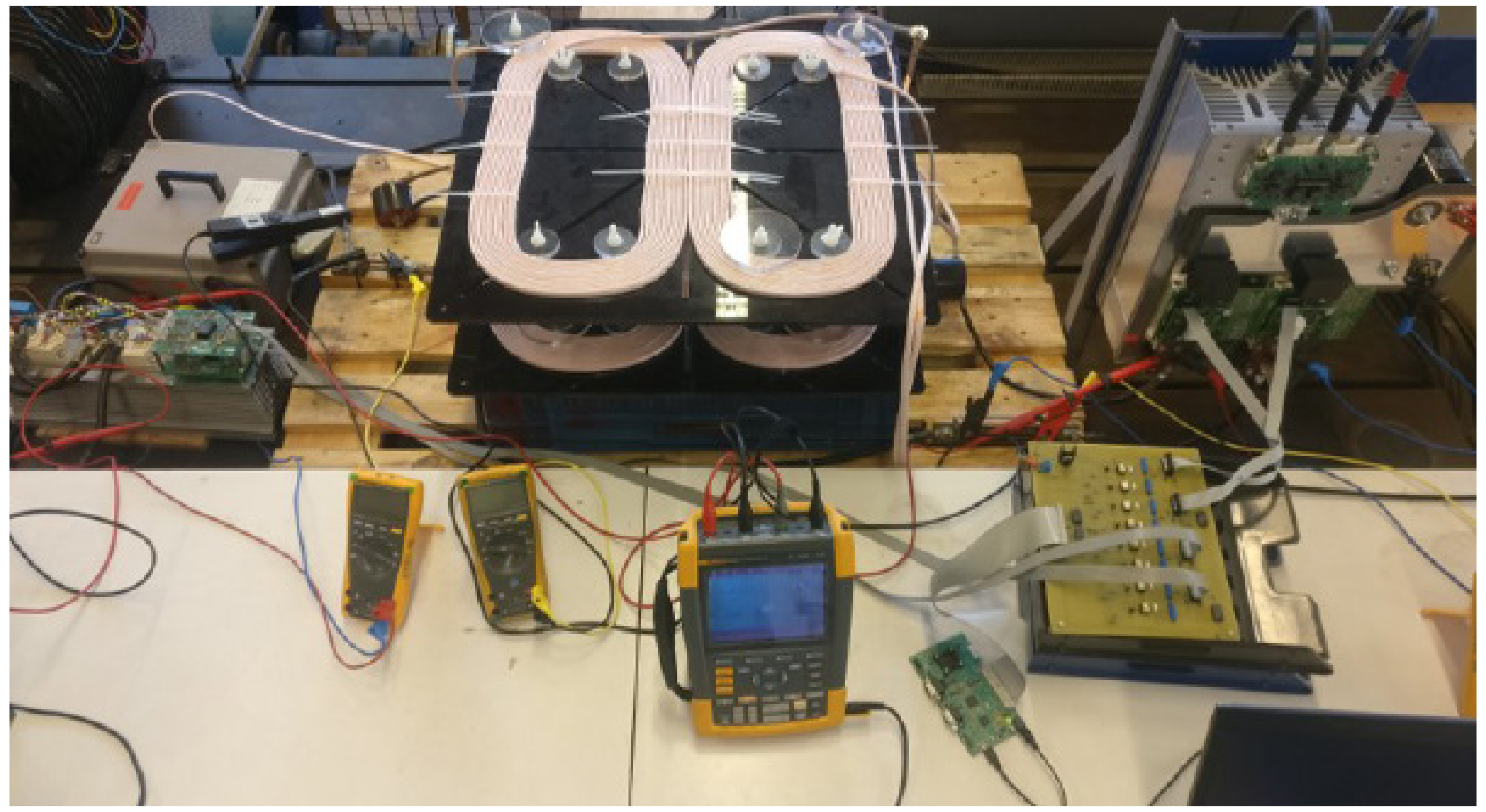
1. Design Specification and Optimization
2. Converter Analysis and Control
3. Flux Modelling
4. WPC Prototype Design and Testing

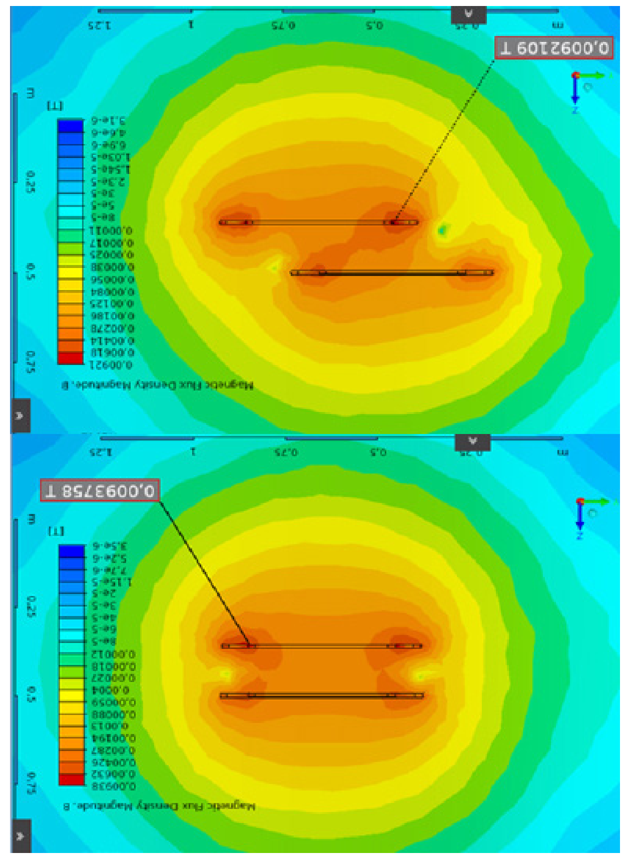
- Topology
- Devices (SiC, GaN)
- Resonant components
- Power rating
- Switching frequency

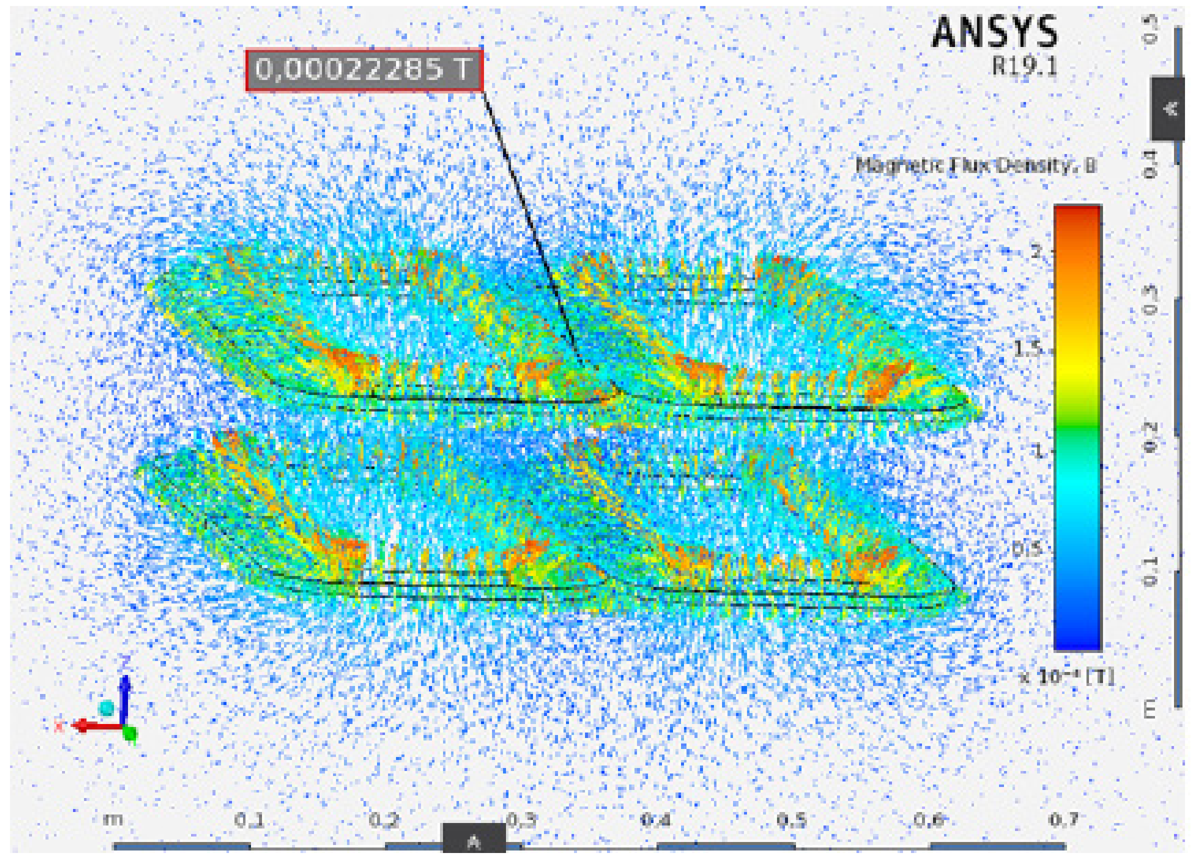
- Phase Shift Control, PWM Modulation, PID controller
- Steady-state analysis
- V2G, G2V
- Transient analysis

- Physics based 3D Flux distribution modelling
- System loss model

- GaNs, SiC devices
- Integrated gate-drives
- Coil design optimization 3.7 kW -7.7 kW-22 kW
- Modular design
- High frequency inverter PCB (kHz)





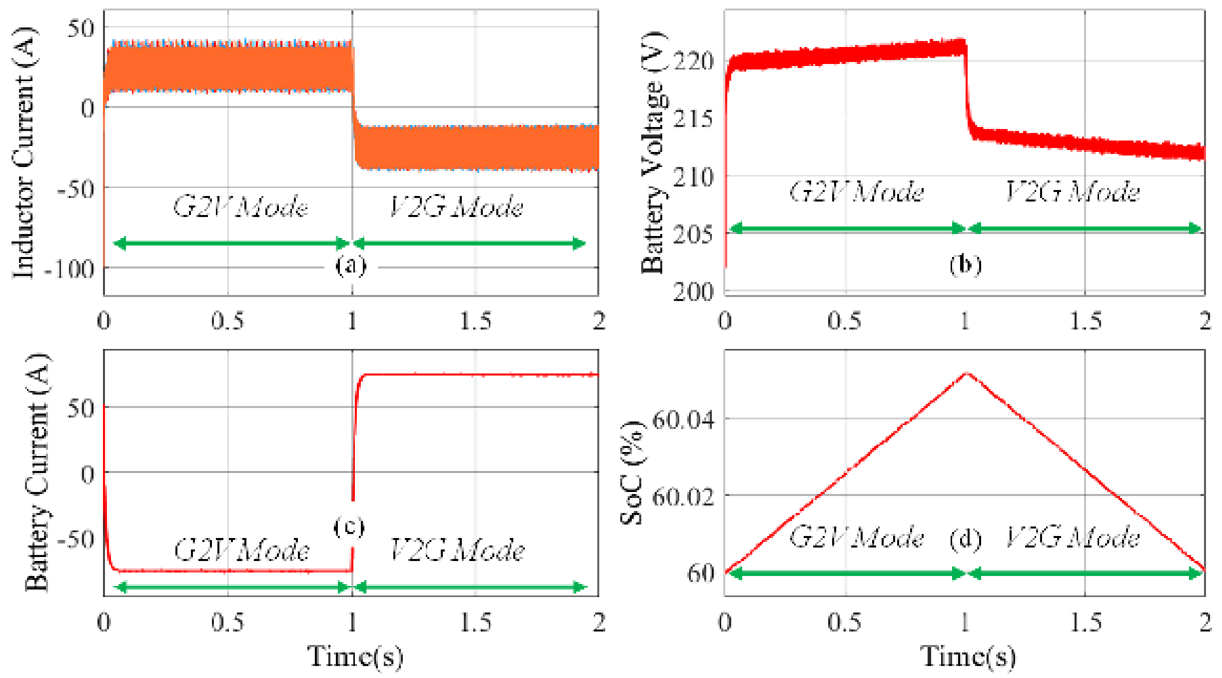


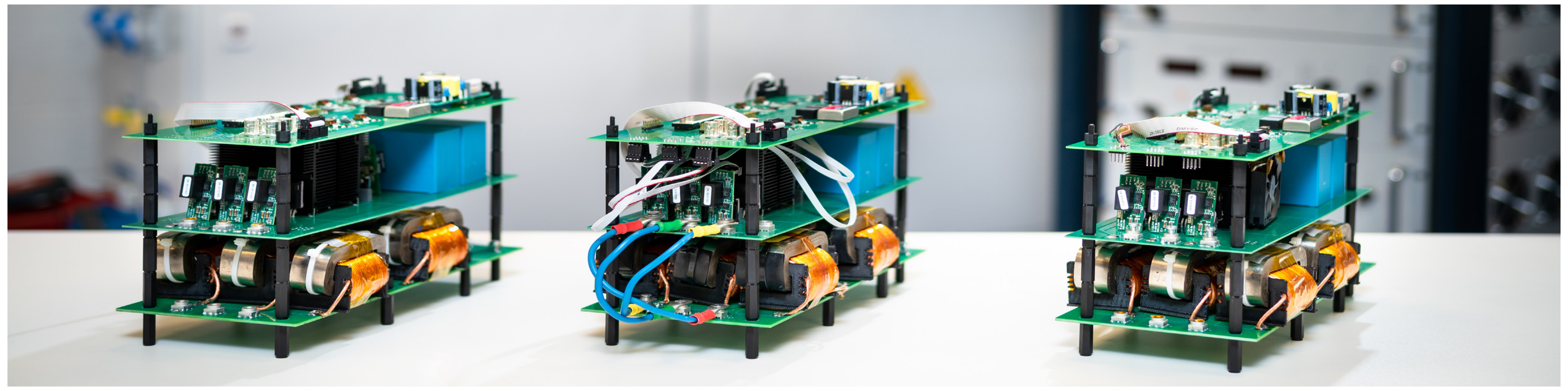
GaN- Gallium Nitride, SiC-Silicon Carbide

Power Electronics

Charging systems: Multifunctional Integrated Charger systems

1. Design Specification and Optimization	2. Converter Analysis and Control	3. Thermal Modelling and Cooling	4. Hardware Prototype and HiL Testing
• Multifunctional and Flexible Design • Efficient Power Converters • Compatible Motor Configuration • Voltage and Power Level selection	• Steady-state analysis • Transient analysis • Optimized and Intelligent Control • Adaptive Data Capturing • RT-Control Design (DSP, FPGA) • Reactive Power Compensation • Voltage Regulation and and Harmonic Reduction	• Dynamic loss modeling • Detailed Thermal modeling • Efficient cooling modelling in FEM • Battery thermal modeling in FEM	• Optimal passive component design • Multi-layer PCB design • Integrated gate-drivers • Distributed Cooling System • Real-time HiL Testing



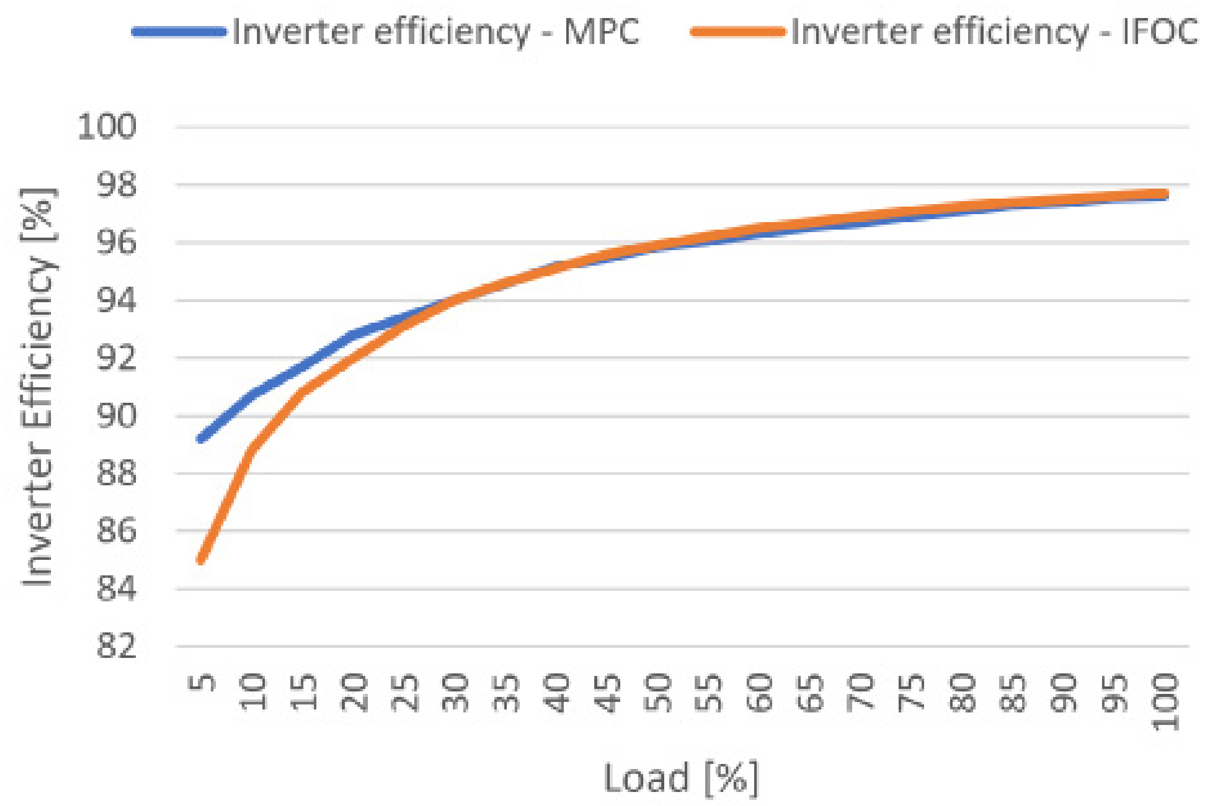


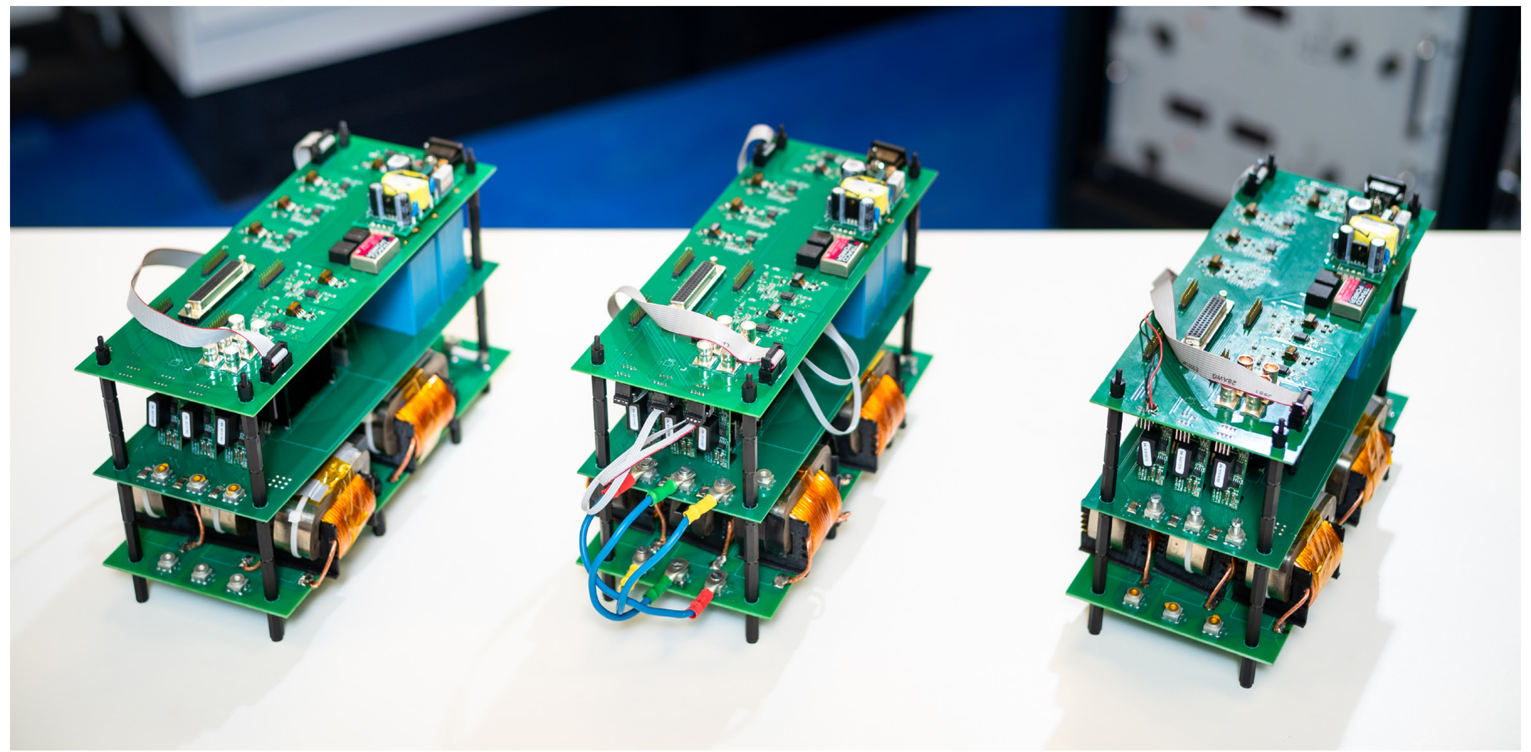
DSP-Digital Signal Processing, FPGA-Field Programmable Gate Arrays, FEM-Finite Element Method, PCB-Printed circuit board, CAD- Computer-Aided Design ,HiL-Hardware-in-the-loop

Power Electronics

Inverter Systems: Modular Inverter systems

1. Design Specification and Optimization	2. Converter Analysis and Control	3. Performance Evaluation	4. Prototype Design and Testing
• Topology selection • Technology (Si, SiC, GaN) • DC-link capacitor • Efficient cooling system • Switching frequency • Power density • Reliability	• Steady-state analysis • Transient analysis • Load response analysis • Advanced control: optimal switching vector MPC for VSI, PSO-based IFOC & DTC • RT-controller design (DSP, rapid prototyping, FPGA)	• Line voltage harmonic • Phase current harmonic • DC-link voltage ripples • Switch voltage stress • Inductor current ripples • Efficiency • Obtainable AC voltage • Thermal design validation	• Modular designs • Integrated gate-drives • Passive component size • Load testing (No-Load to 100%)



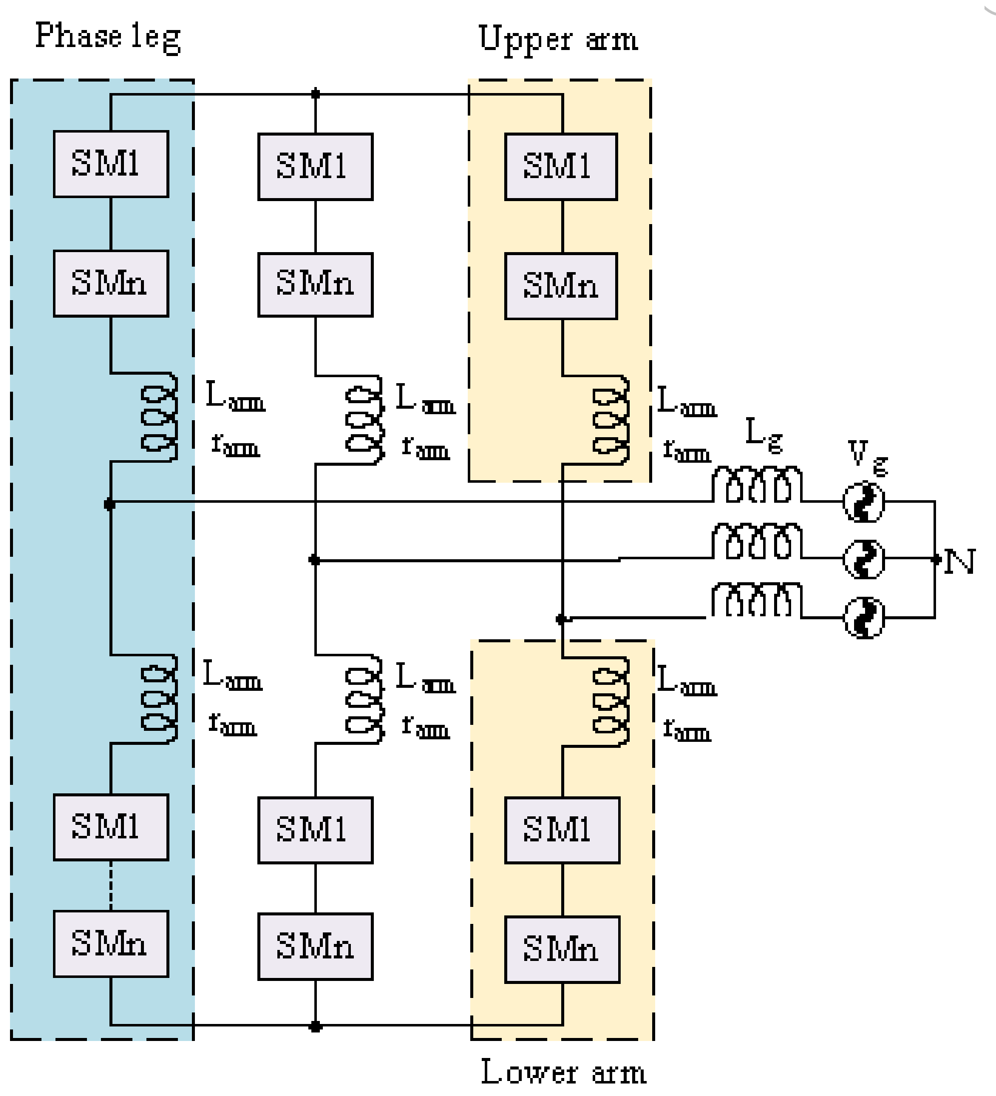


Si-Silicon, SiC-Silicon Carbide, GaN- Gallium Nitride, MPC-Model Predictive control, PSO- Particle swarm optimization, IFOC-Indirect field-oriented control, DTC-Direct Torque control, DSP-Digital Signal Processing, FPGA-Field Programmable Gate Arrays

Power Electronics

Inverter systems: Modular Multilevel Inverter systems

1. Design Specification and Optimization	2. Converter Analysis and Control	3. Electro-Thermal Modeling and Cooling	4. Prototype Design and Hardware Testing
• Multilevel voltages • Modular topology selection • Submodule devices • Passive components • WBG semiconductors • Cooling Optimization	• Mathematical modelling • Steady-state analysis • Transient analysis • Output current control • Submodule balancing • Circulating current elimination • Model predictive control	• Electro-thermal modeling • Mechanical modeling • Detailed thermal analysis in FEM • HiL modeling for control validation	• SiC & GaN power devices • Modular designs • Scalable designs • Modular cooling • Integrated gate driver • Full-load testing via scaled lab DC microgrid



SiC-Silicon Carbide, GaN- Gallium Nitride, FEM-Finite element method, HiL-Hardware-in-the Loop

Power Electronics

Inverter systems: Scalable Multi-Inverter systems

1. Design Specification and Optimization
2. Converter Analysis and Control
3. Performance Evaluation
4. Prototype Design and Testing

1. Design Specification and Optimization

- Multi-Inverters/Multiport
- Fault-Tolerance Strategies
- Technology selection (Si, SiC, GaN)
- Switching frequency
- Passive components sizing

2. Converter Analysis and Control

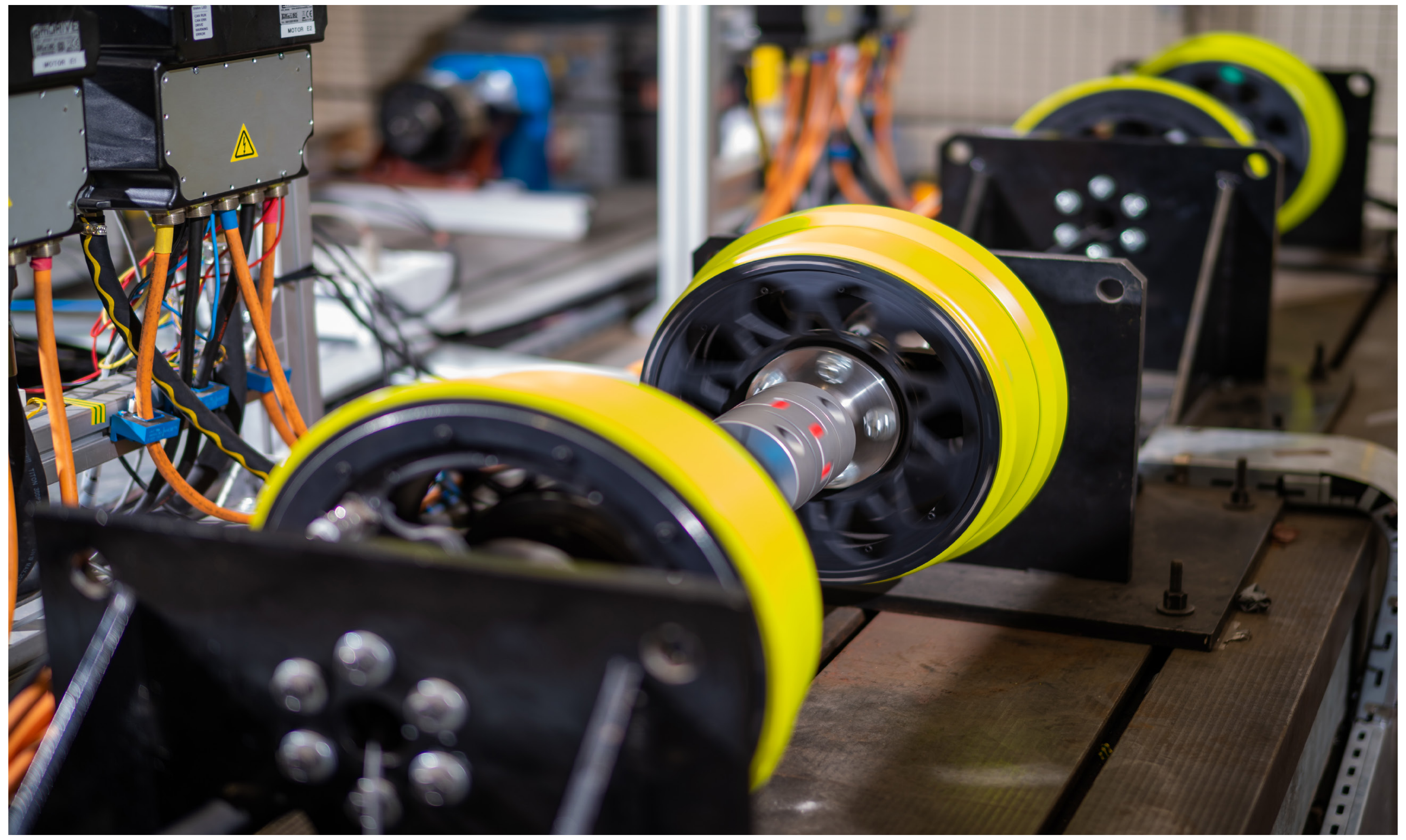
- Integrated Motor Control
- Torque Vectoring
- Torque ripple reduction
- Steady-state analysis
- Transient analysis
- Load response analysis
- RT-controller design (DSP, rapid prototyping, FPGA)

3. Performance Evaluation

- Efficiency assessment
- Reliability assessment
- Thermal design validation

4. Prototype Design and Testing

- Scalable prototype
- Cooling system design
- Full load testing
- Torque Vectoring validation
- Torque ripple validation
- Fault scenarios testing



Si-Silicon, SiC-Silicon Carbide, GaN- Gallium Nitride, DSP-Digital Signal Processing, FPGA-Field Programmable Gate Arrays

Power Electronics

Multiport and Modular HV DC/DC Converter systems

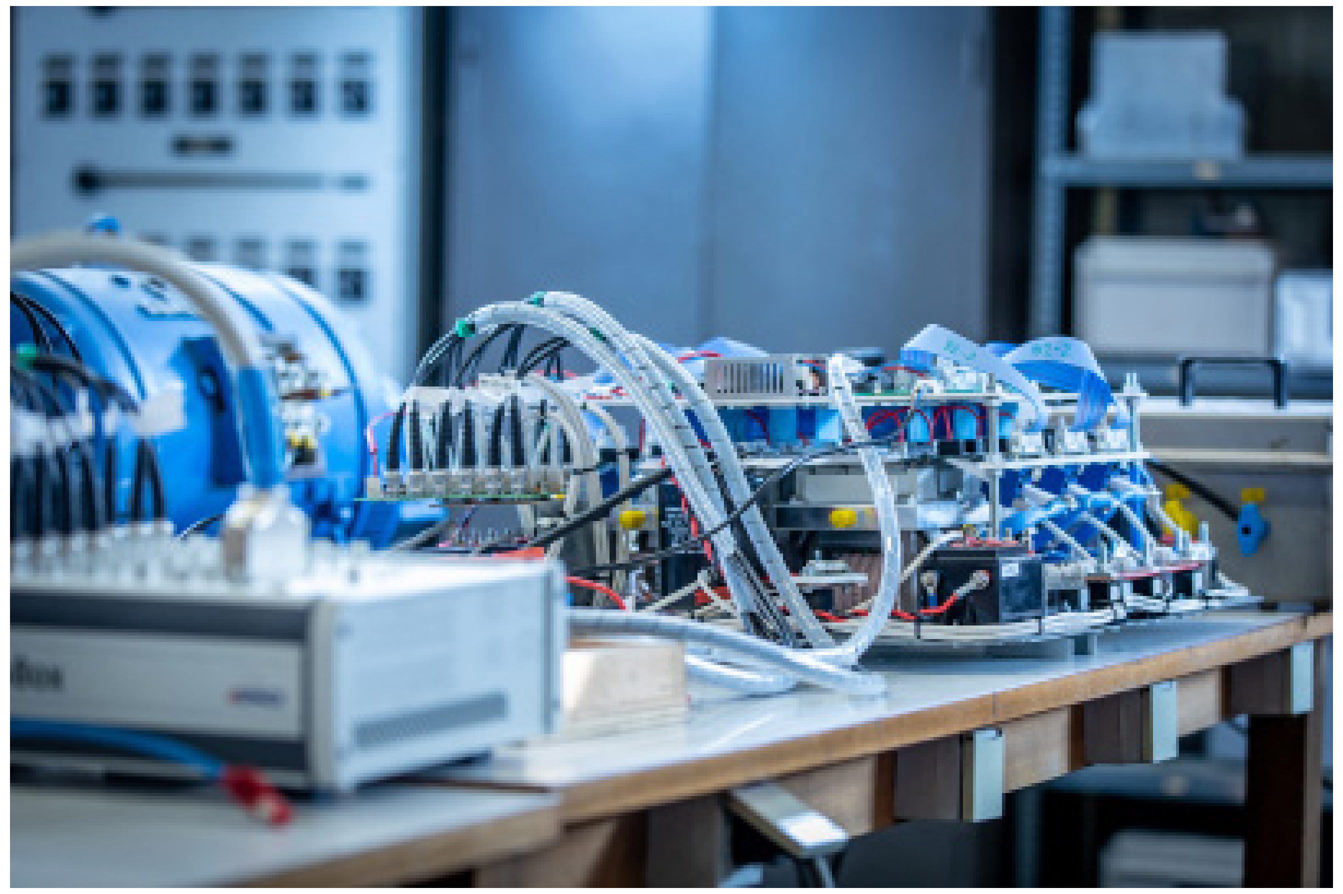
1. Design Specification and Optimization
2. Converter Analysis and Control
3. Electro-Thermal Modelling
4. Converter Prototype Design & Testing

- Topology selection
- Devices (Si, SiC, GaN)
- Passive components
- Switching frequency selection
- Heatsink (Air/ Liquid)

- Steady-state analysis
- Transient analysis
- Load response analysis
- Optimal control: MPC, sliding mode control, ANN-based
- RT-controller design (DSP, rapid prototyping, FPGA/dSPACE)

- Scalable modeling
- Physics based (3D) modeling
- Universal loss modeling
- Electrical transient modeling
- Average loss modeling
- Map-based modeling
- Equivalent thermal modeling
- Multi core HiL modeling

- WBG technology
- Compact busbar and cooling design
- Modular designs
- Multifunctionalities testing
- Full load testing ~250kW



Si-Silicon, SiC-Silicon Carbide, GaN- Gallium Nitride, MPC-Model predictive control, DSP-Digital Signal Processing, FPGA-Field Programmable Gate Arrays , HiL-Hardware-in-the-loop

Power Electronics

Battery management systems (BMS): Active Battery Management Systems (ABMS) and Balancing Circuits

1. Design Specification and Optimization

2. BMS balancing techniques

3. Electro-Thermal Modelling and Cooling

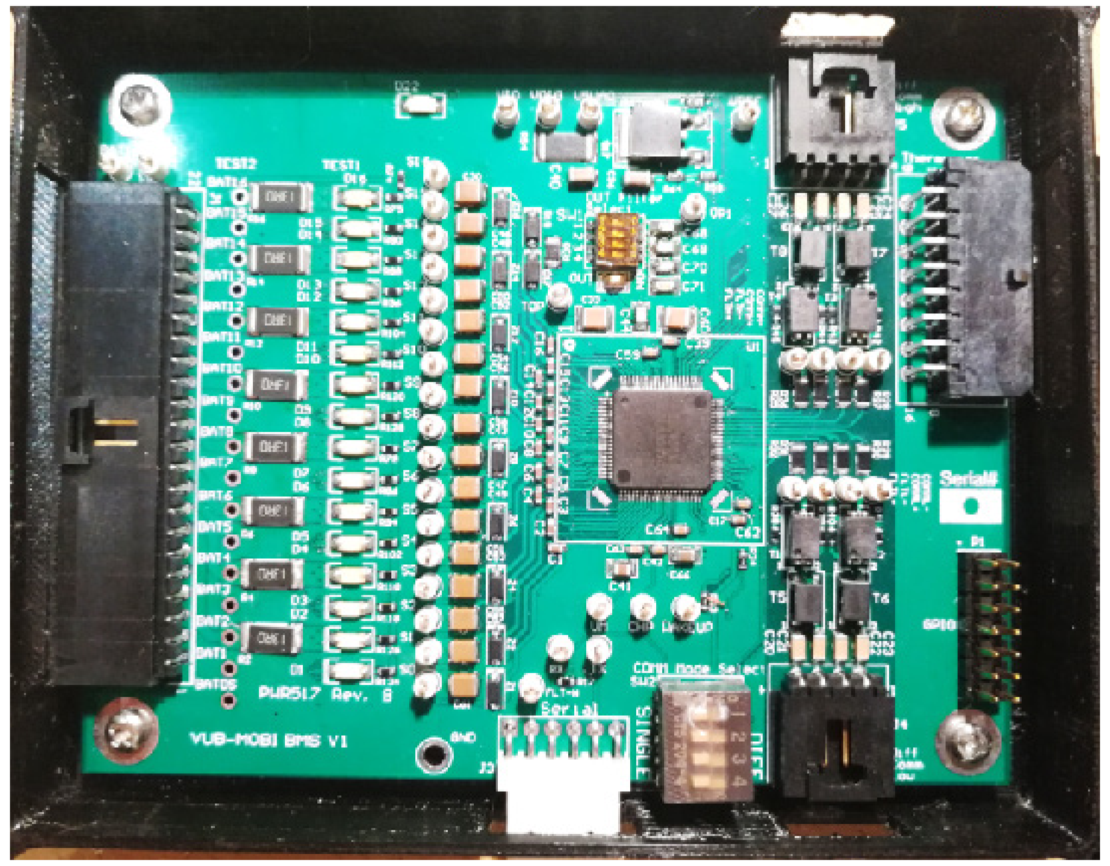
4. Prototype Design and Hardware Testing

- Passive and Active BMS Topologies
- Multilevel balancing concept (MBC)
- Modular BMS
- Active Fast BMS
- Performance Evaluation:
  - Vehicle applications
  - Stationary applications

- Circuit topology optimization
- Predictive control-based balancing (i.e., Model Predictive control (MPC))
- Energy Balancing Enhancement

- Digital twin of the BMS of balancing circuits
- Component sizing and selection of the BMS
- Integrated and modular cooling of the balancing circuit

- SiL development
- P-HiL development
- Modular BMS prototype (i.e., manufactured Flex BMS v1)
- Full Scale testing

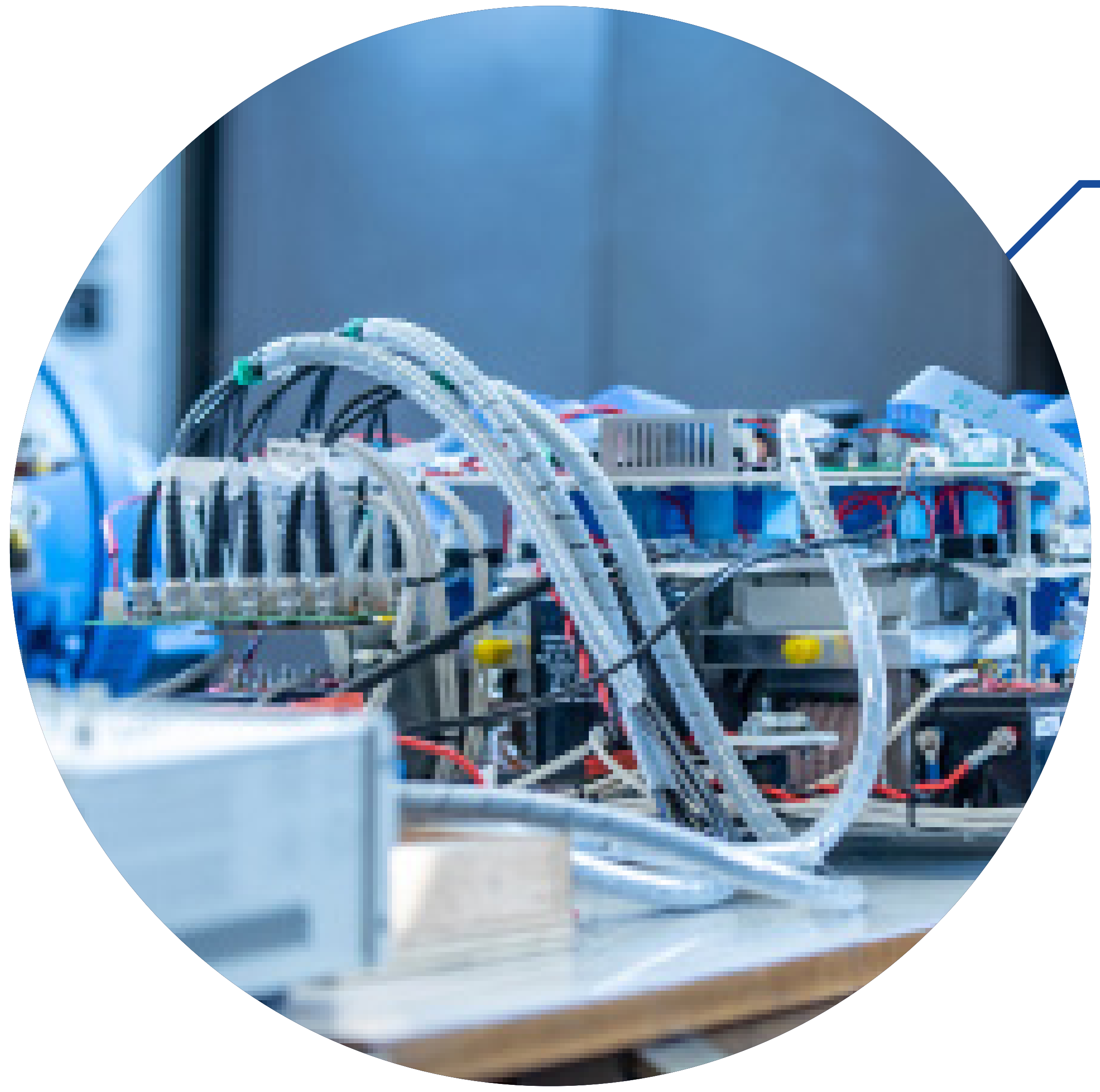


Flex BMS v1

SiL-Software-in-the-loop, P-HiL- Power Hardware-in-the-loop

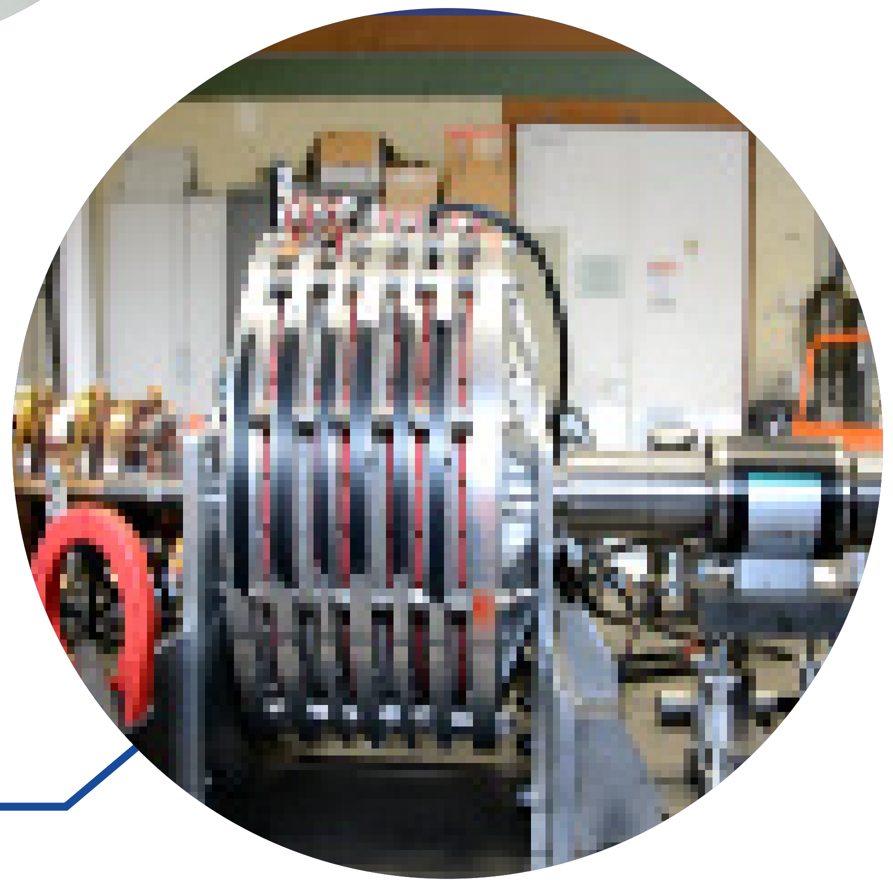
PE Research Infrastructure: *Power Electronics Innovation Lab (PEIL)*

Smart Modular power systems up to 800kVA



Advanced PE Converter Testbench & Performance Testing Up to 250kW

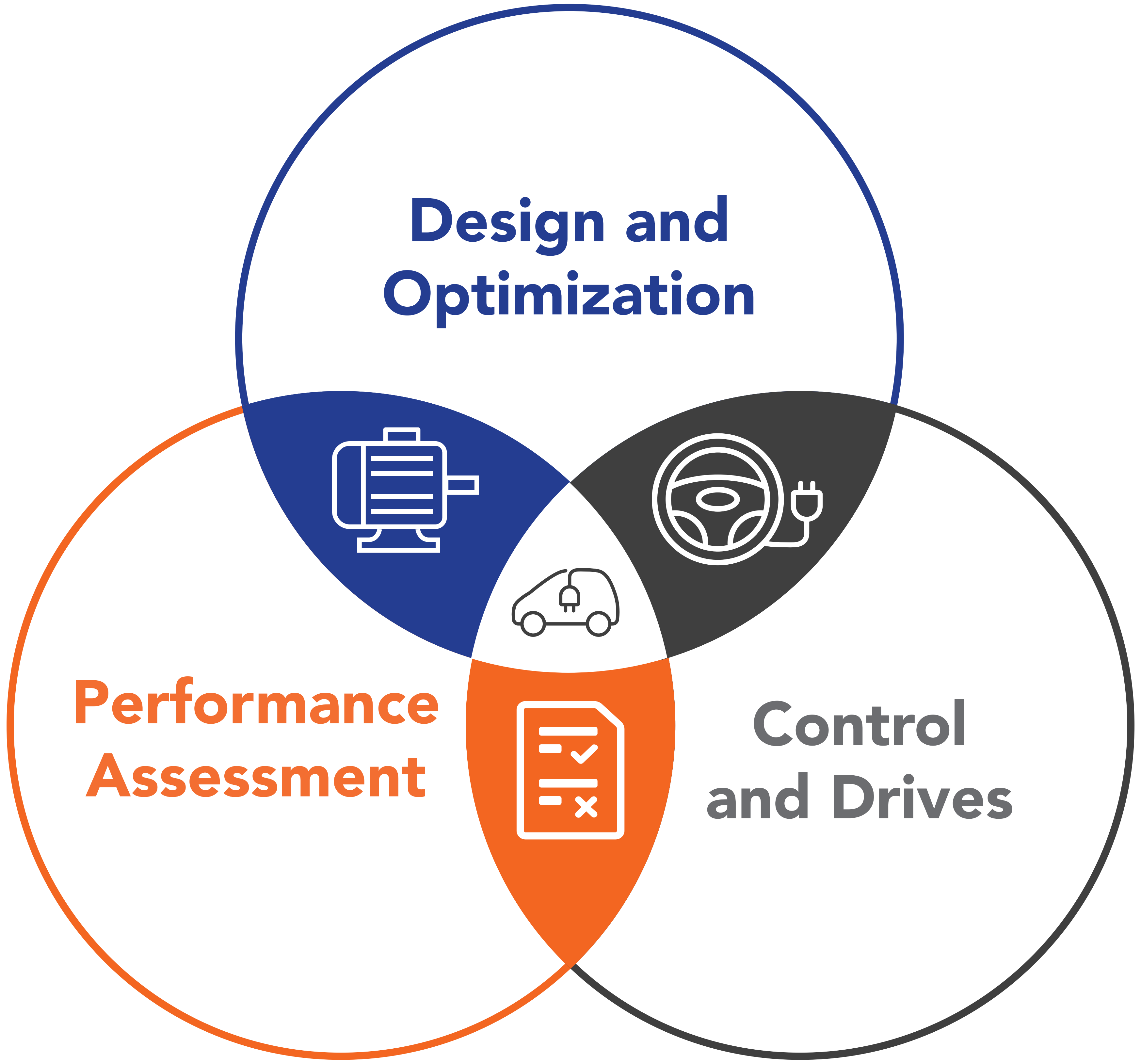
Grid and dynamic load setup for the DUTs



Multiple Electrical Machines Group up to 250kW

Programmable Source / Load 1000V (160kW)

Electric Machines (EM)



Design and Optimization

- Electromagnetic 2D and 3D FEA Design
- Magnetic Circuit and Winding Design of EM using Analytical Methods
- Thermal Analysis of EM
- Multidisciplinary optimization

Control and Drives

- System Analysis of converter fed Machines
- WBG-based Modular Multi-level Inverters
- WBG-based Z-Source Inverters (ZSI)
- Advanced control: MPC, PSO based IFOC, DTC, ANN-control

Performance Assessment

- Digital Twin validation
- Measurements on Motors and Converters
- Test Setup for In-Wheel Motors

FEA-Finite Element Analysis, MPC-Model predictive control, ANN- Artificial neural network, PSO- Particle swarm optimization, IFOC-Indirect field-oriented control, DTC-Direct Torque Control

Electric Machines (EM)

Brushless Doubly Fed Reluctance Motor/Generator (BDFRM/BDFRG)

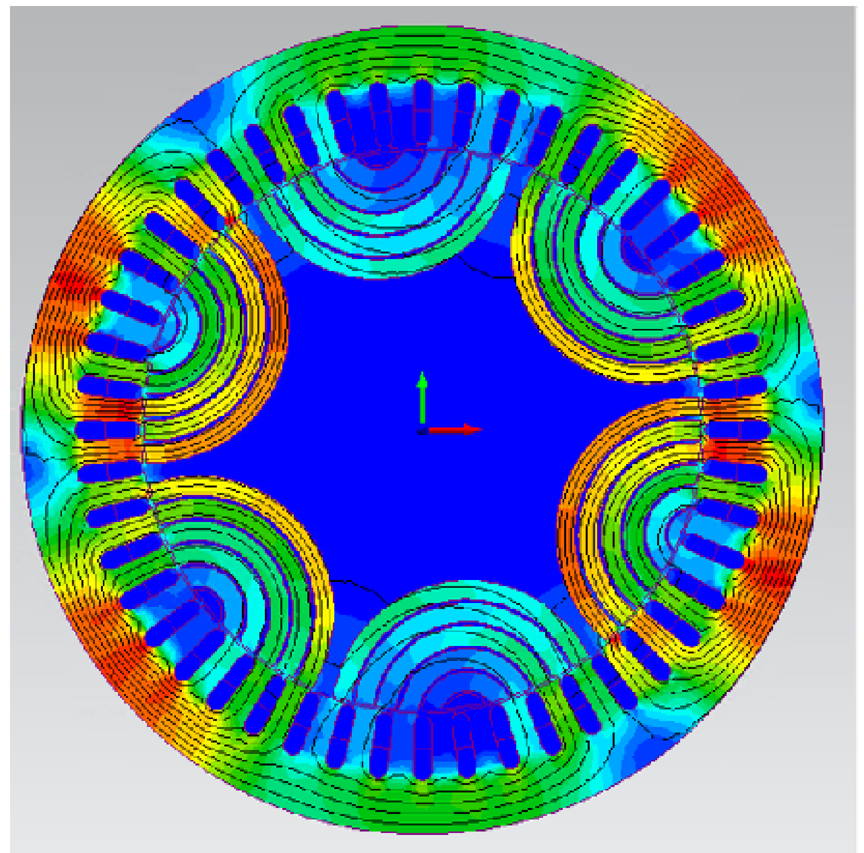
1. Design Specification and Optimization
2. Modeling and Control Approach
3. Performance Evaluation
4. Prototype Design and Hardware Testing

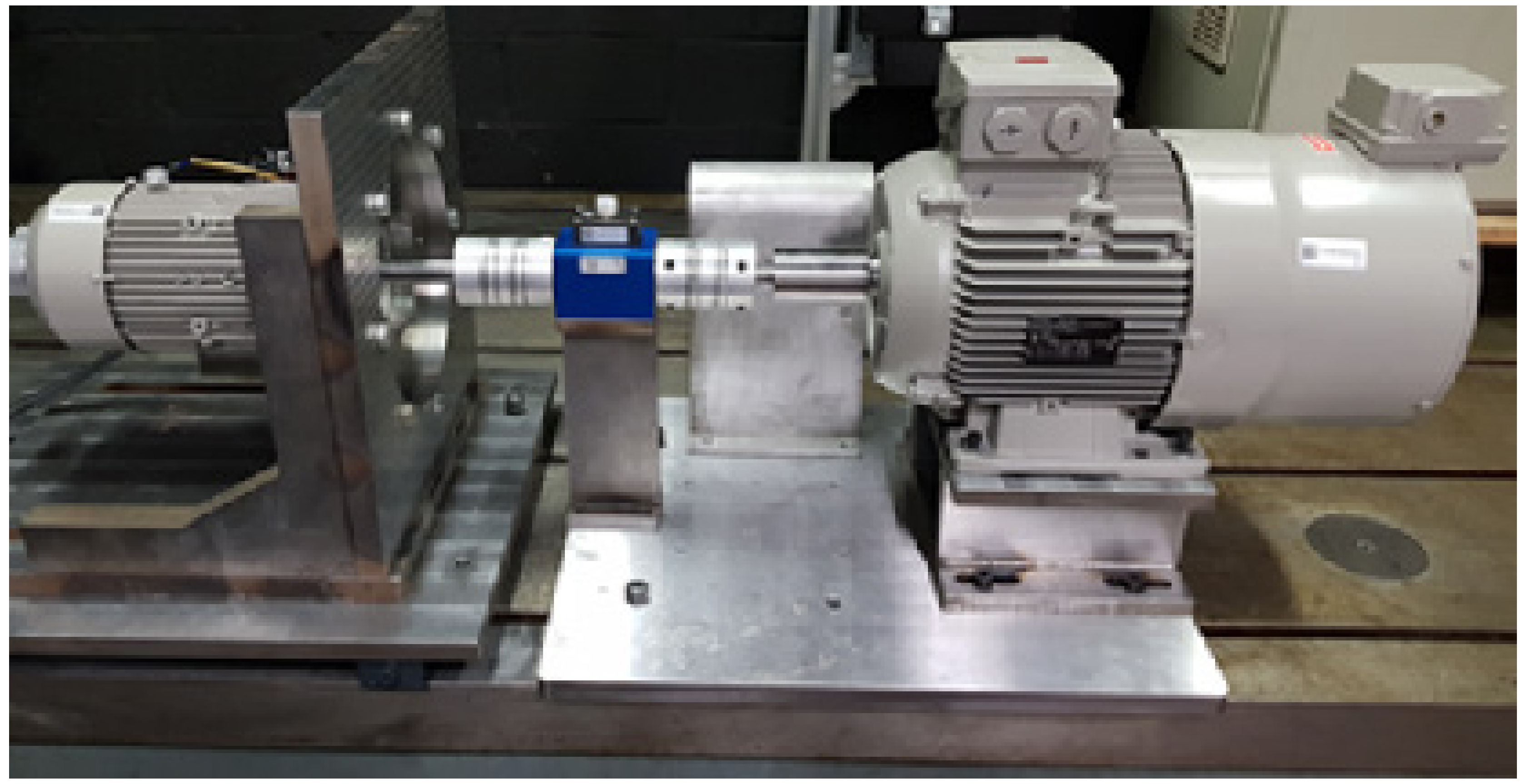
- Drive system design
- Variable speed
- Cost minimization
- Rotor structure design

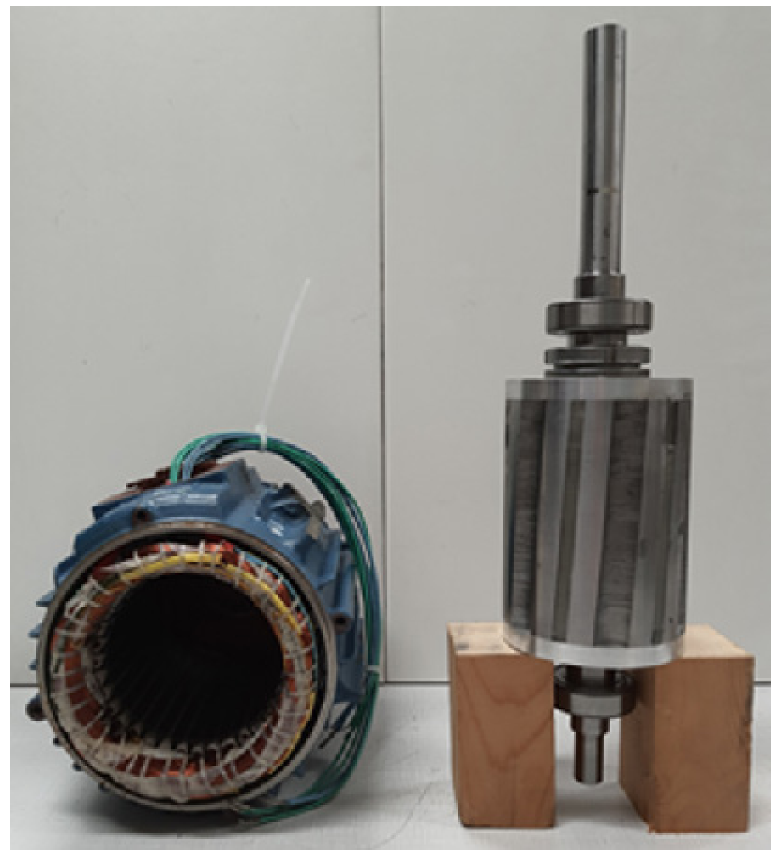
- Analytical modeling
- Finite Element Analysis (FEA)
- Reluctance Network modeling
- Active/Reactive Power Control

- Efficiency assessment
- Power Factor
- Cost Analysis

- DT validation
- FEA Validation
- Rapid Control Prototyping
- 7.5 kW flexible testbench







Electric Machines (EM)

Switched Reluctance Machines (SRM)

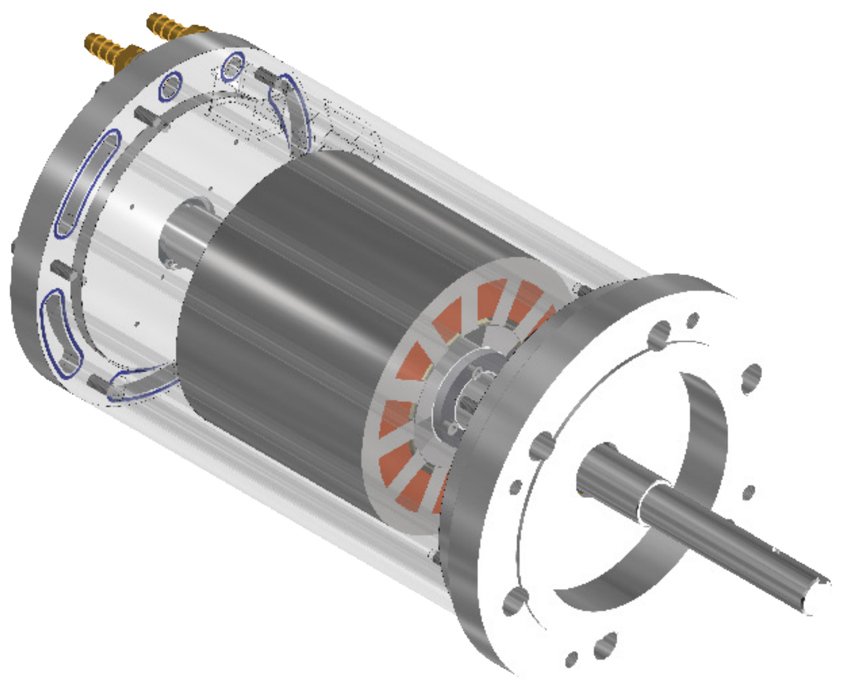
1. Design Specification and Optimization
2. Modeling and Control Approach
3. Performance Evaluation
4. Prototype Design and Hardware Testing

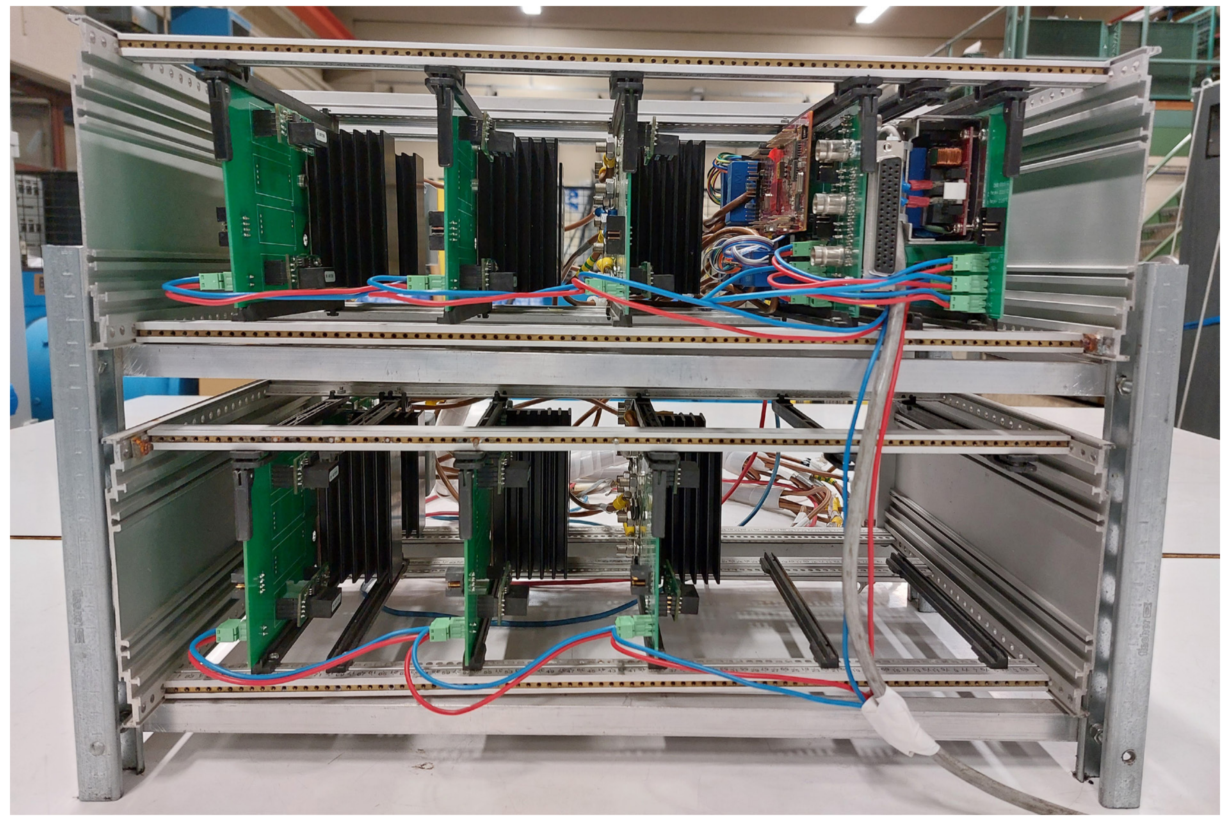
- Segmental configuration
- Multi-stack configuration
- Stator structure
- Rotor structure
- Integrated drive systems

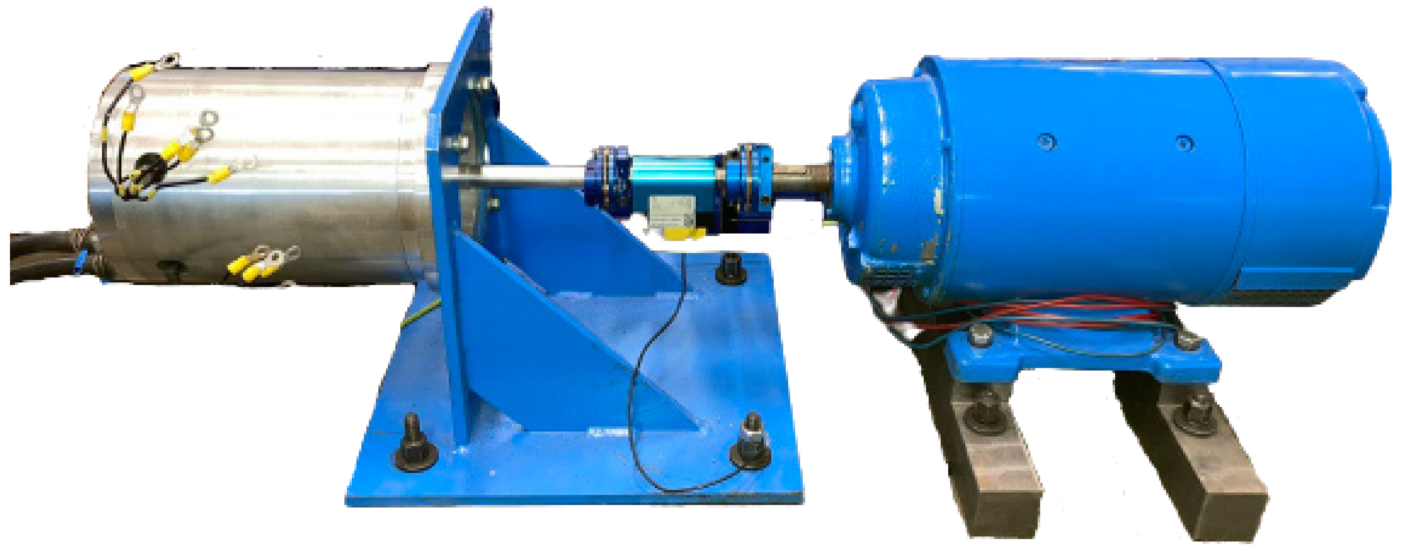
- Finite Element Analysis
- Physical modeling
- Controller design

- Flux feedback control
- Current control
- Speed control
- Torque feedback control
- Average torque
- Torque ripple

- Scaled design
- Multifunctional drives
- Rapid prototyping and DSP, FPGA/dSPACE control
- Efficient cooling system







DSP-Digital Signal Processing, FPGA-Field Programmable Gate Arrays

Electric Machines (EM)

PMSM- Inwheel Machines

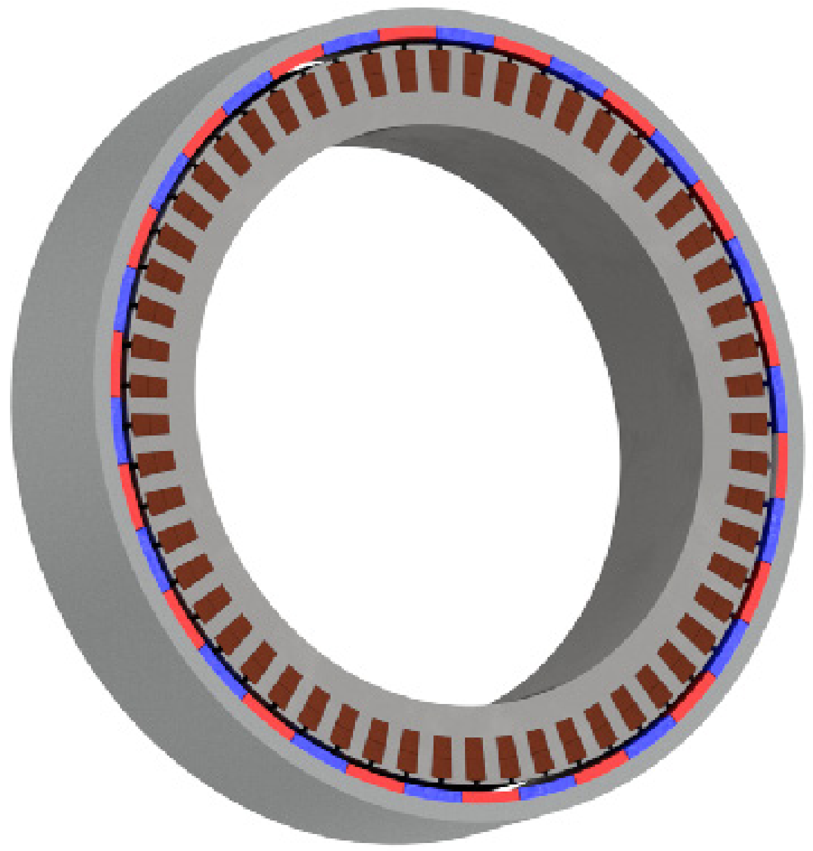
1. Design Specification and Optimization
2. Modeling and Control Approach
3. Performance Evaluation
4. Prototype Design and Hardware Testing

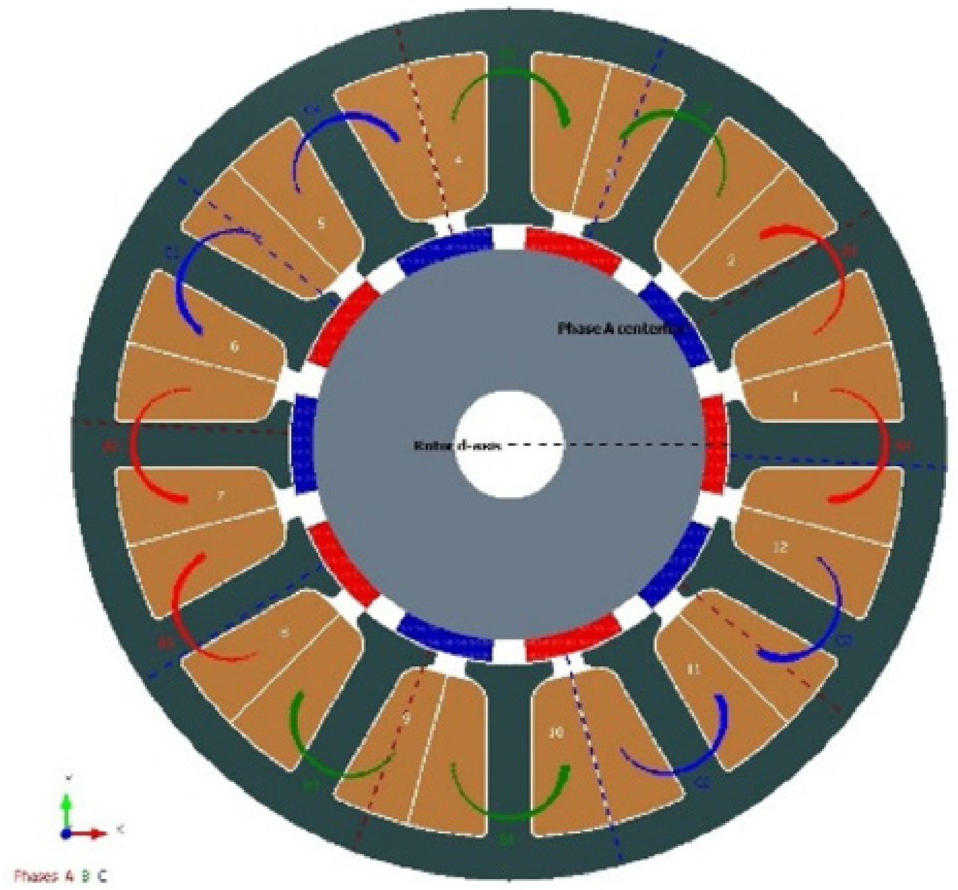
- Machine design optimization
- Internal or external rotor
- Magnetic geometry optimization
- Integrated drive systems
- Integrated and non integrated cooling concepts

- Finite Element Analysis
- Multi-Physics Modeling (Coupled Electromagnetic and Thermal Model)
- Digital-Twin (synchronizing of the physical & digital models)
- Advanced controller design

- Efficiency mapping
- Torque and speed control
- Machine and inverter temperature
- Parameter sensitivity analysis

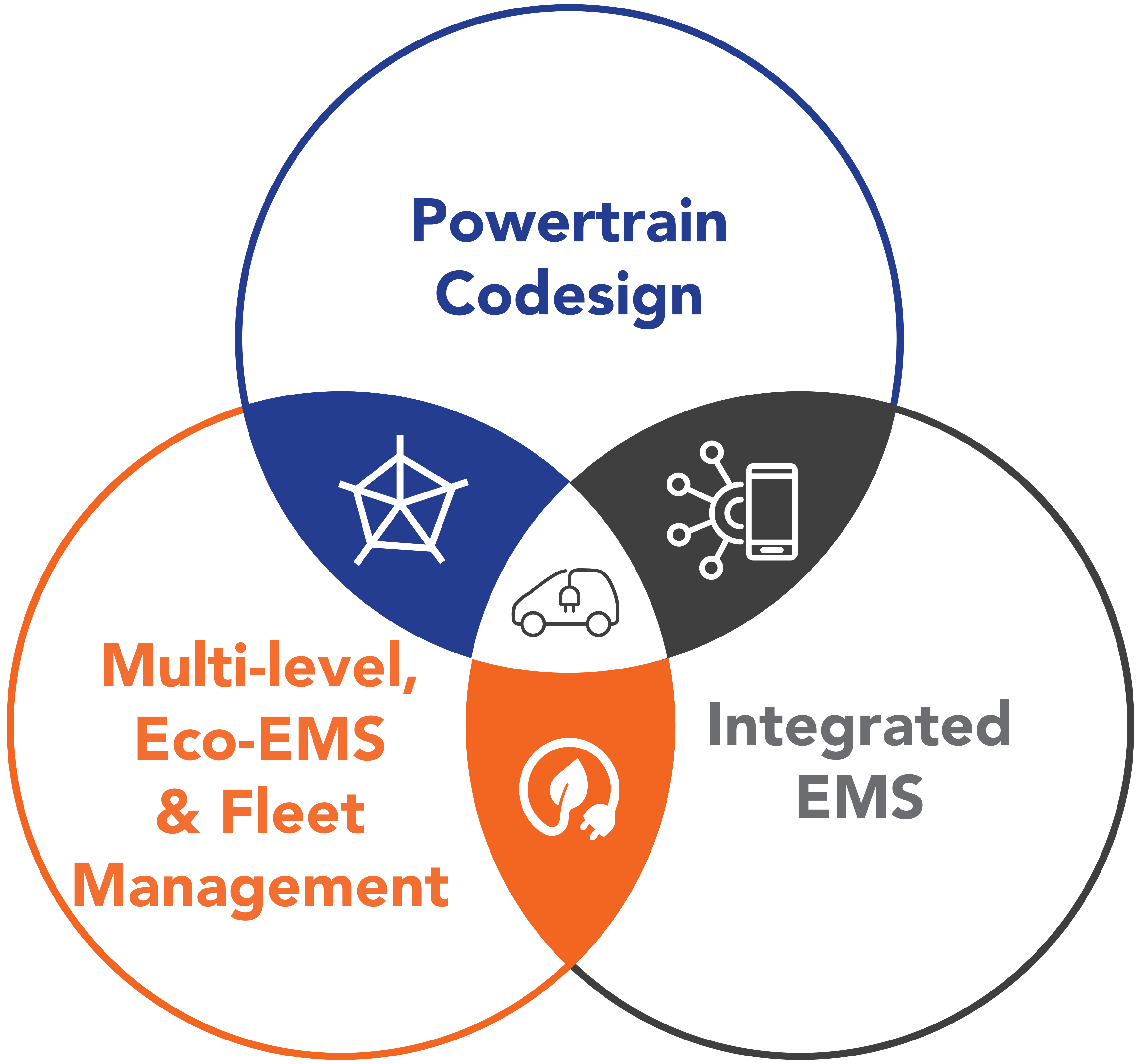
- Scaled design
- Torque ripple measurement
- Multifunctional drives
- Rapid prototyping and DSP, FPGA/dSPACE control
- Efficient cooling system





DSP-Digital Signal Processing, FPGA-Field Programmable Gate Arrays

Vehicle Powertrain Codesign Optimization, Multi-level Integrated EMS & Electrification



Powertrain Co-Design Optimization

- Virtual Simulation Platform based on forward/backward facing models
- Modular Scalable Models (ICE, EM, Battery, gearbox)
- Hardware-controller coordination = codesign
- SiL/MiL optimization

Integrated EMS for Plug-in/Hybrid/Electric/Connected Vehicles

- Rule-based EMS
- Optimization-based EMS
- Learning-based EMS

Multi-level and Eco-EMS Strategies for Plug-in/Hybrid/Electric/Connected Vehicles and Fleets

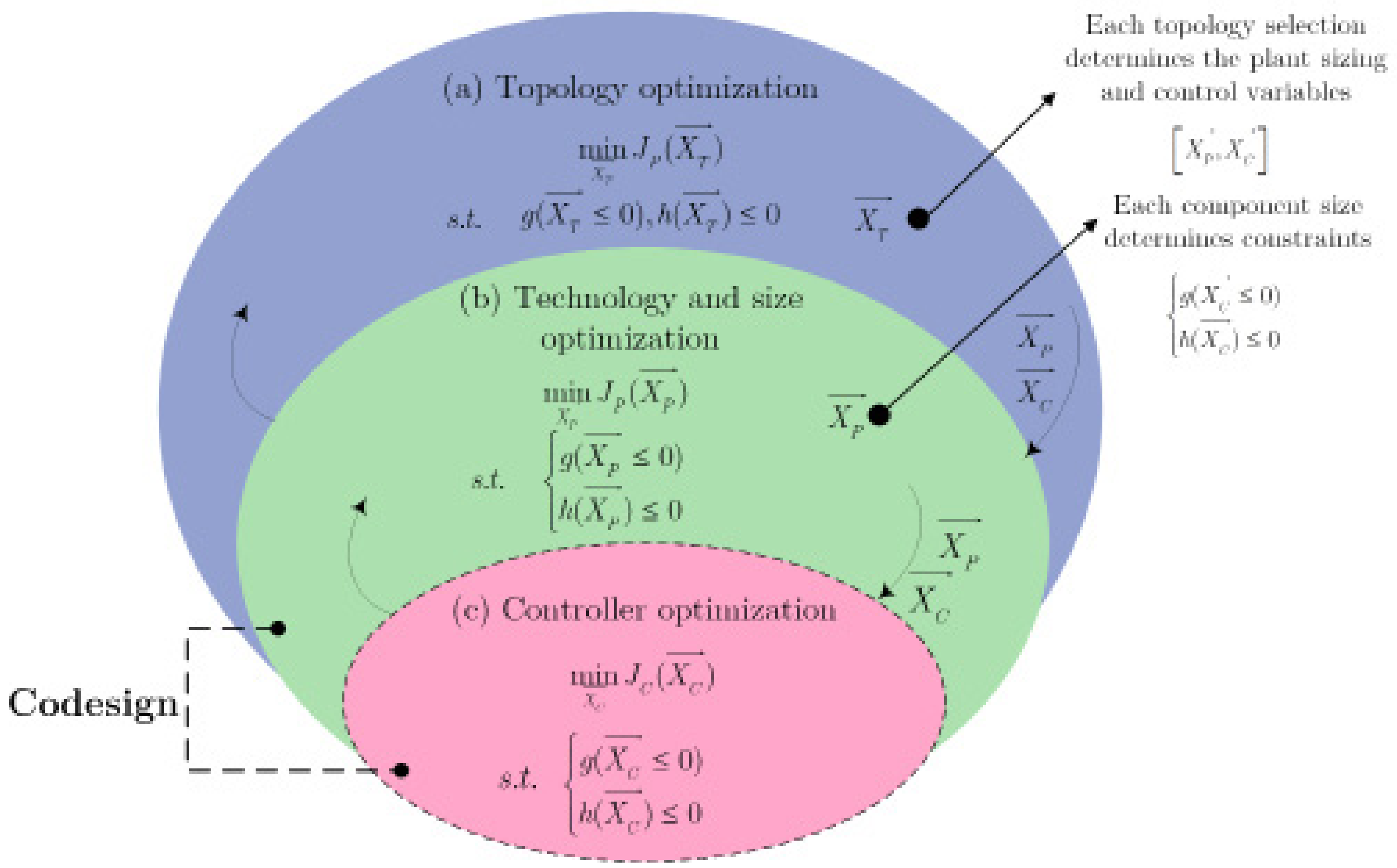
- Full Electrification of bus-lines in cities
- Eco-driving
- Eco-charging
- Eco-comfort

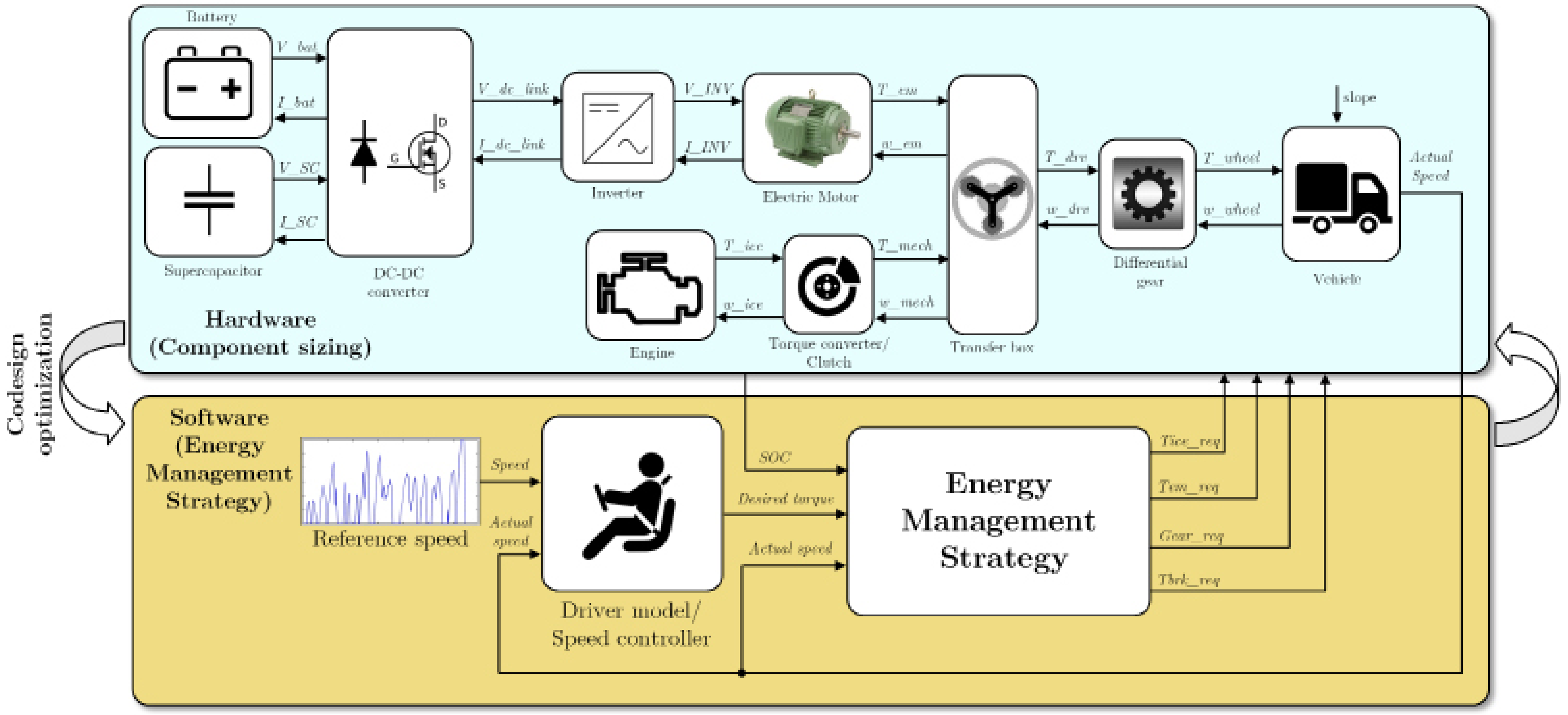
ICE-Internal Combustion Engine, EM-Electrical Motor, SiL-Software-in-the-loop, MiL-Model-in-the-loop, EMS- Energy Management system

Vehicle Modelling and Optimal Co-design framework for EVs/HEVs

Powertrain Co-design Optimization

1. Vehicle modelling	2. Design specification & optimization	3. Codesign Methodology	4. Virtual Testing and HiL Testing
• Powertrain modeling (backward, forward facing) in 1D simulation tool • Powertrain thermal, electro-mechanical and mechanical modeling	• Technologies and sizing • Integrated thermal management strategies • Integrated energy management strategies	• Coordination method (alternating, nested, simultaneous) • Codesign = 'sizing' + 'control' optimization • Evolutionary-based optimization algorithms	• Battery SoC regulation • Battery chemistry limitations • Experimental limitations • Minimization of the fuel consumption • HiL tests: real-time implementation

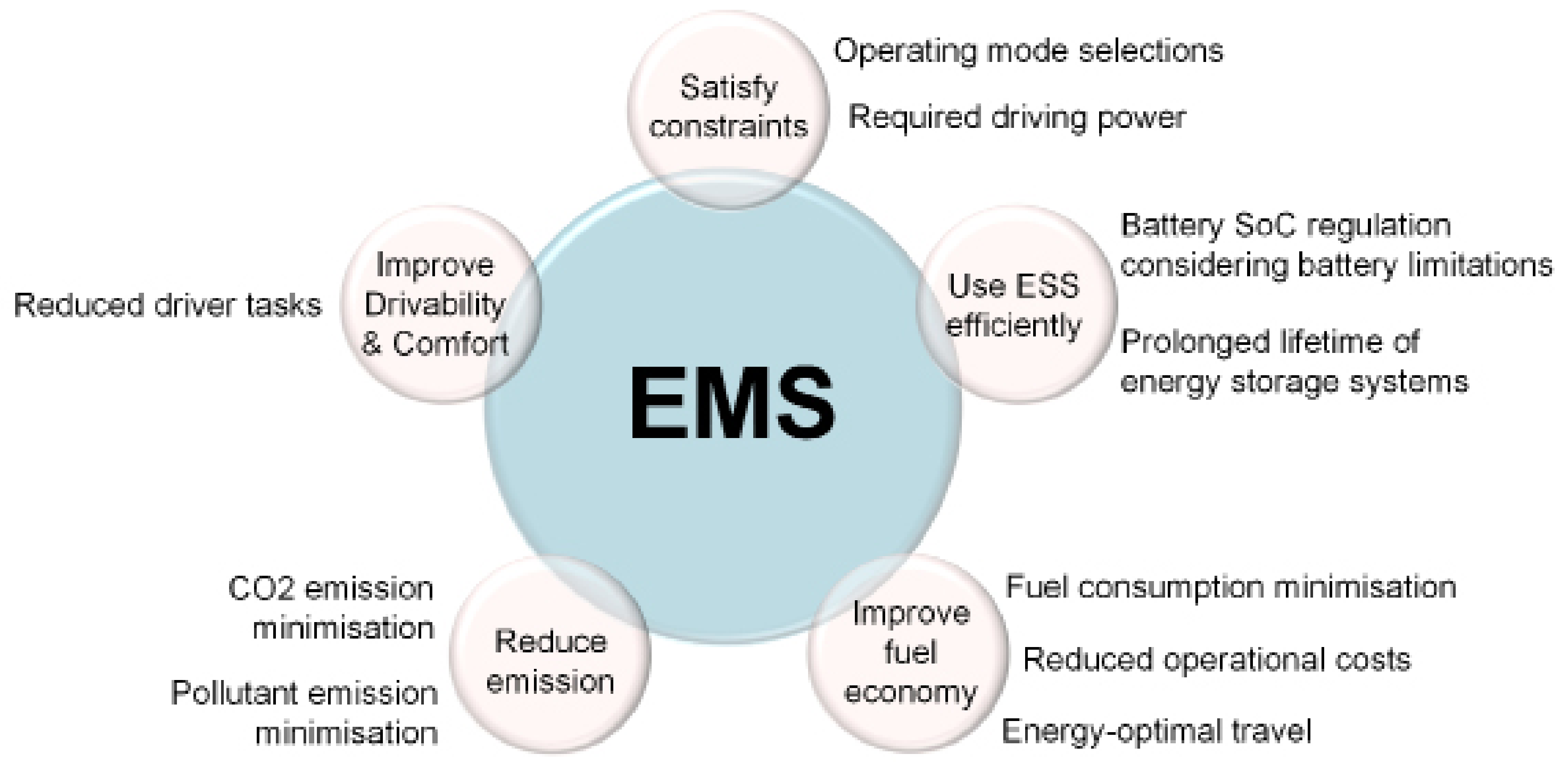


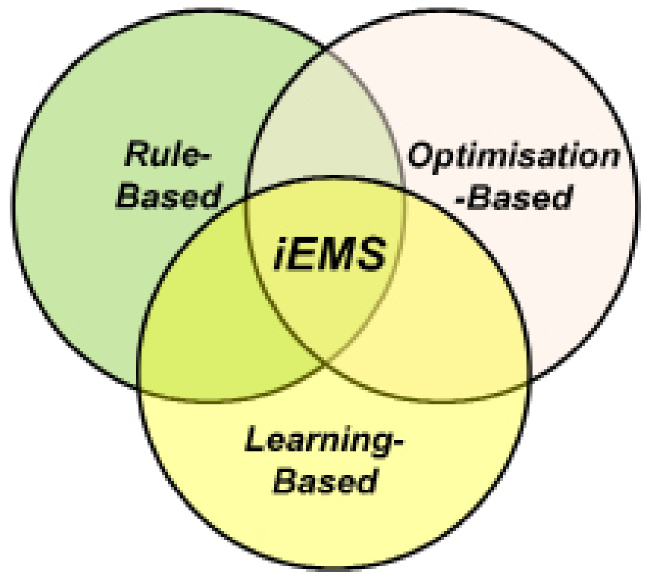


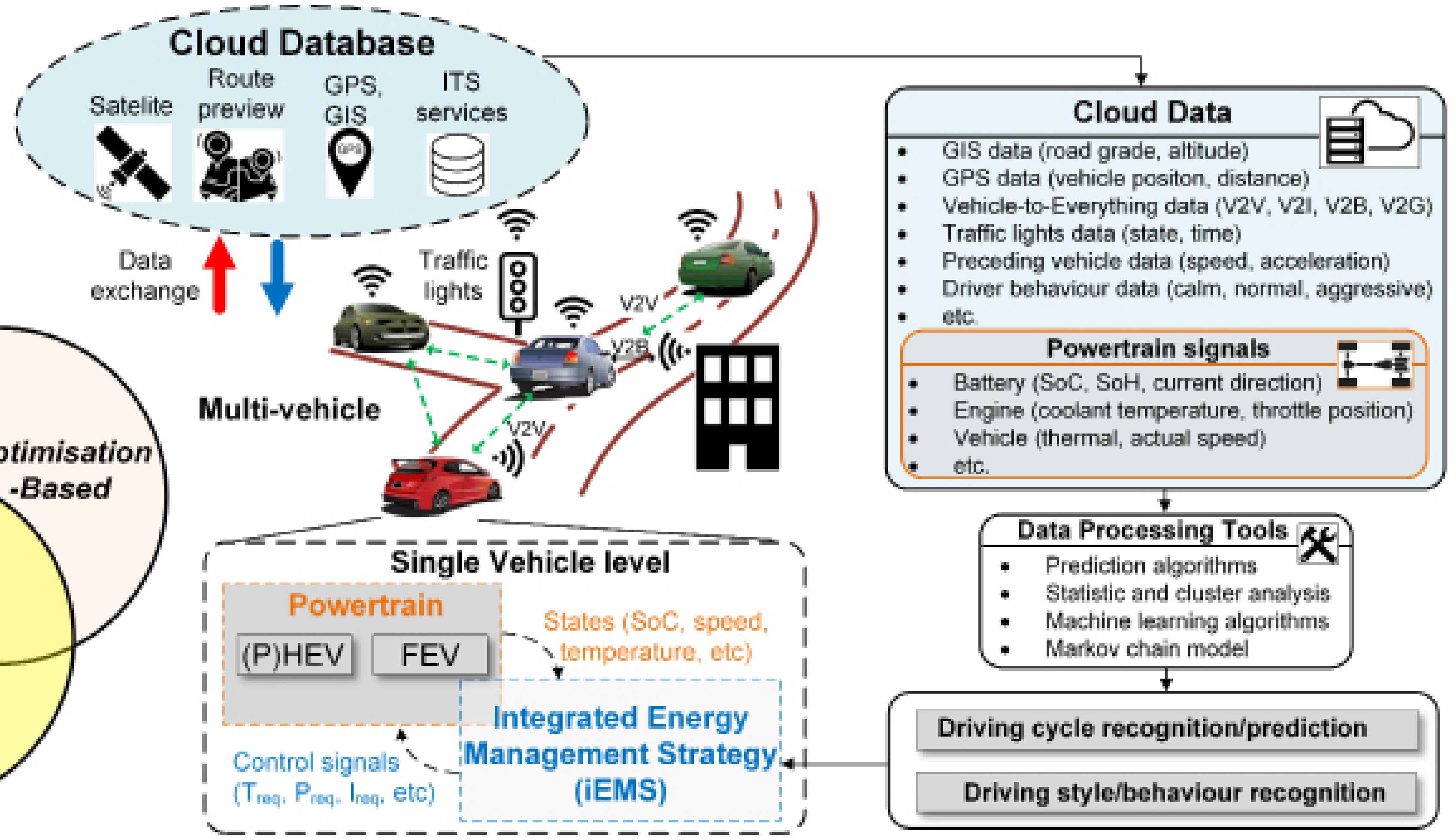
Vehicle Modelling and Optimal Co-design framework for EVs/HEVs

Integrated EMS for Plug-in/Hybrid/Electric/Connected Vehicles

1. Standard EMS	2. Optimization-based and prediction-based EMS	3. Next generation of controllers
• Rule-based (RB) • Adaptive Low Pass Filter (LPF) control • Kinetic Strategy (SoC= f(v)), Average Power Strategy (APS)	• Equivalent Consumption Minimization Strategy (ECMS) based on DP/GA/PSO • Predictive EMS based on ANN • EMSopti based on GA, PSO, Krill Herd (KH), Ant Lion Optimization (ALO)	• Developing and testing new agent-based algorithms for online training and optimization, i.e., Deep Reinforcement Learning (DRL)







DP- Dynamic Programming, GA-Genetic Algorithm, PSO- Particle swarm optimization

Vehicle Fleet Electrification & Energy Management– ECO Strategies

Multi-level and Eco-EMS Strategies for Plug-in/Hybrid/ Electric/Connected Vehicles and Fleets

1. Full Electrification of Bus-lines in Cities

- Bus lines specifications
- Optimal location of the charging systems for the bus-lines
- Depot optimization
- Codesign optimization for the fleets
- TCO assessment

2. Eco-Driving

- Extended driving range of vehicles
- Eco driving algorithms including boosting operational limits techniques
- Energy consumption minimization with integrated Eco driving

3. Eco-Charging

- Smart Charging strategies including optimized charging/DC charging power, charging time, number of super-fast and depot chargers
- Smart rescheduling of fleets
- Minimization of grid impact during charging/discharging processes
- TCO optimization at fleet level
- Respect pre-conditioning required by thermal management system (TMS)

4. Eco-Comfort

- Optimized on-board thermal management algorithms
- Delivering the maximum level of comfort to passengers
- Smart pre-conditioning strategies for the cabin and the powertrain systems

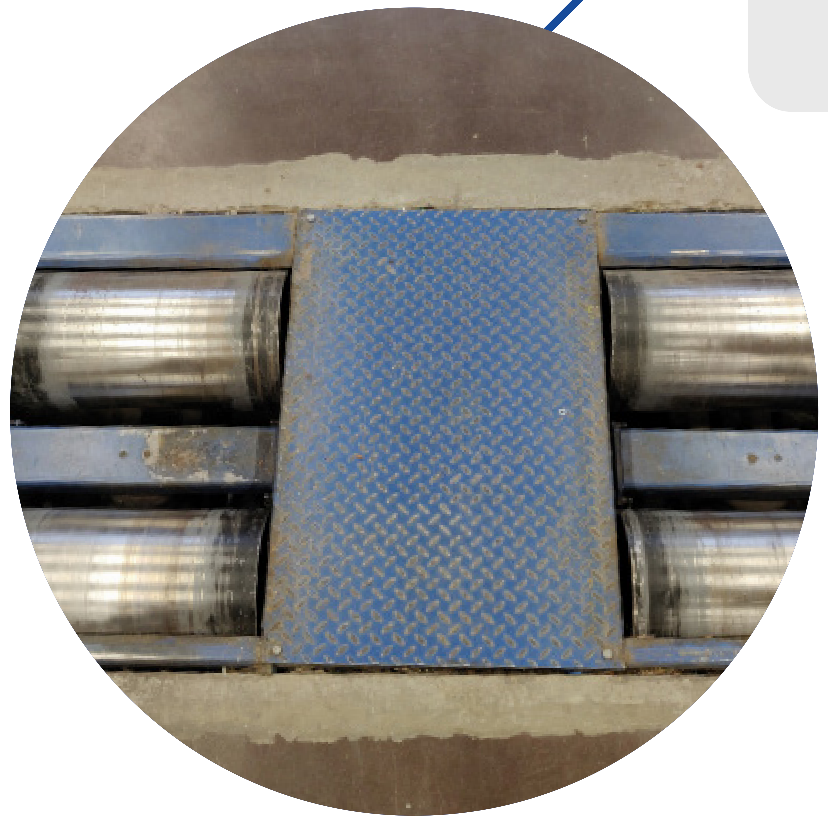
TCO-Total cost of ownership

Powertrain Research Infrastructure: *Powertrain Innovation Lab (PIL)*

Open Vehicle Powertrain Platform - OVPP

Driver-in-the-loop Simulator (DiL)

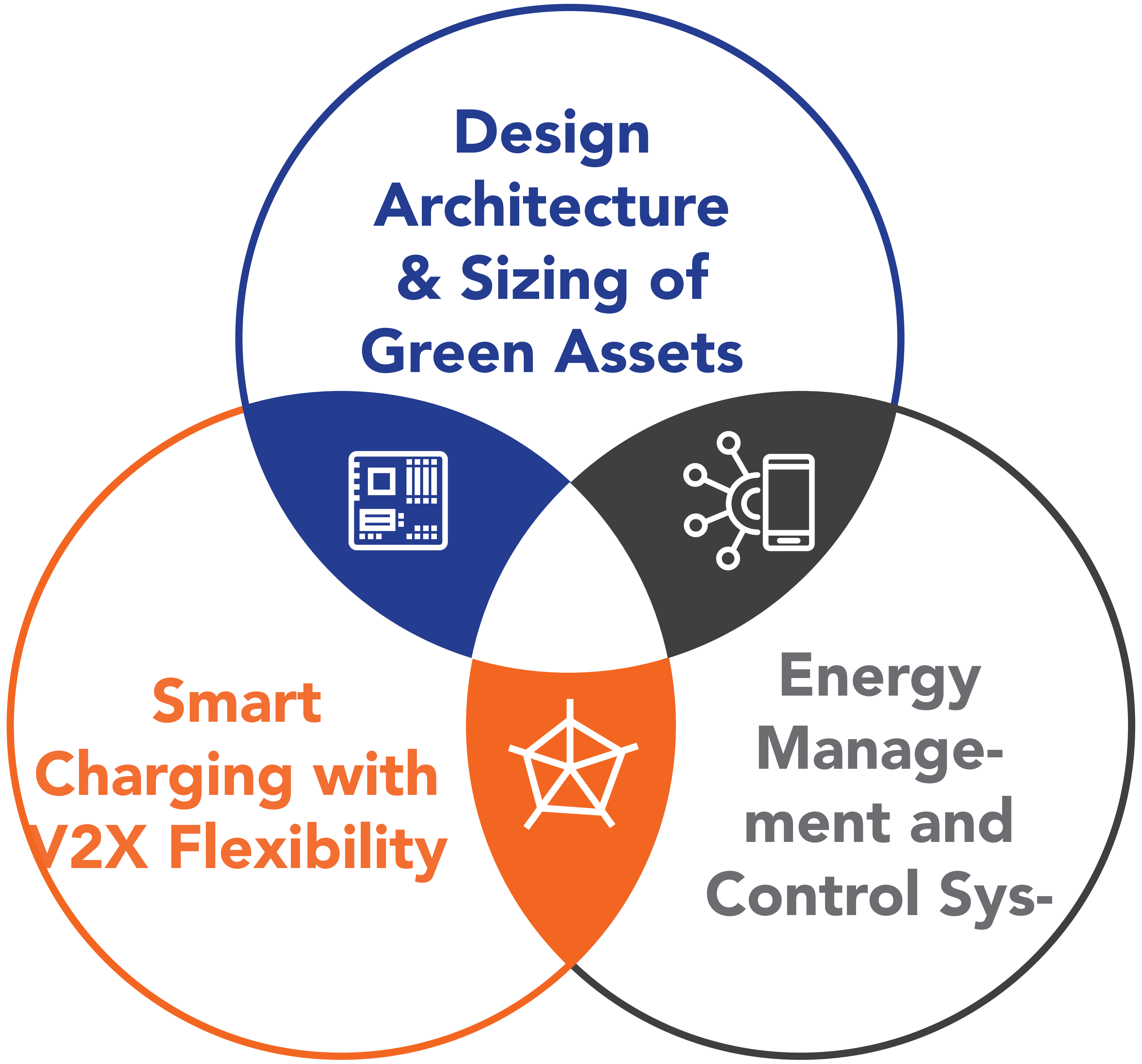
Vehicle Dyno-roll Bench (200km/h)



Automated Test Bench for EV

Mobile Battery Pack System

Smart Green Grid Solutions – Architecture & EMS



Design architecture & sizing of Green assets

- PV-EV charging systems
- ESS-EV charging systems
- PV-ESS system
- Smart buildings
- Small-Scale DC Microgrids
- Parking lots and Depots with V2X

Energy management and control systems

- Rule-based EMS
- Optimization-based EMS
- Learning-based EMS
- Self-Healing (SH) EMS
- IoT-based control of assets

Smart Charging with V2X flexibility

- Cost optimization
- Power quality and Power flow
- Grid impact
- Self-consumption
- V2X (V2G, V2B, V2H) management

PV-Photovoltaic, EV-Electric Vehicle, ESS-Energy Storage System, EMS- Energy Management system, V2X-Vehicle-to-everything

Smart Green Grid Solutions – Architecture & EMS

Design architecture & sizing of Green assets

1. Assets Design Optimization	2. Optimal Operation of Green Assets	3. Smart Neighbourhood Integration

1. Assets Design Optimization

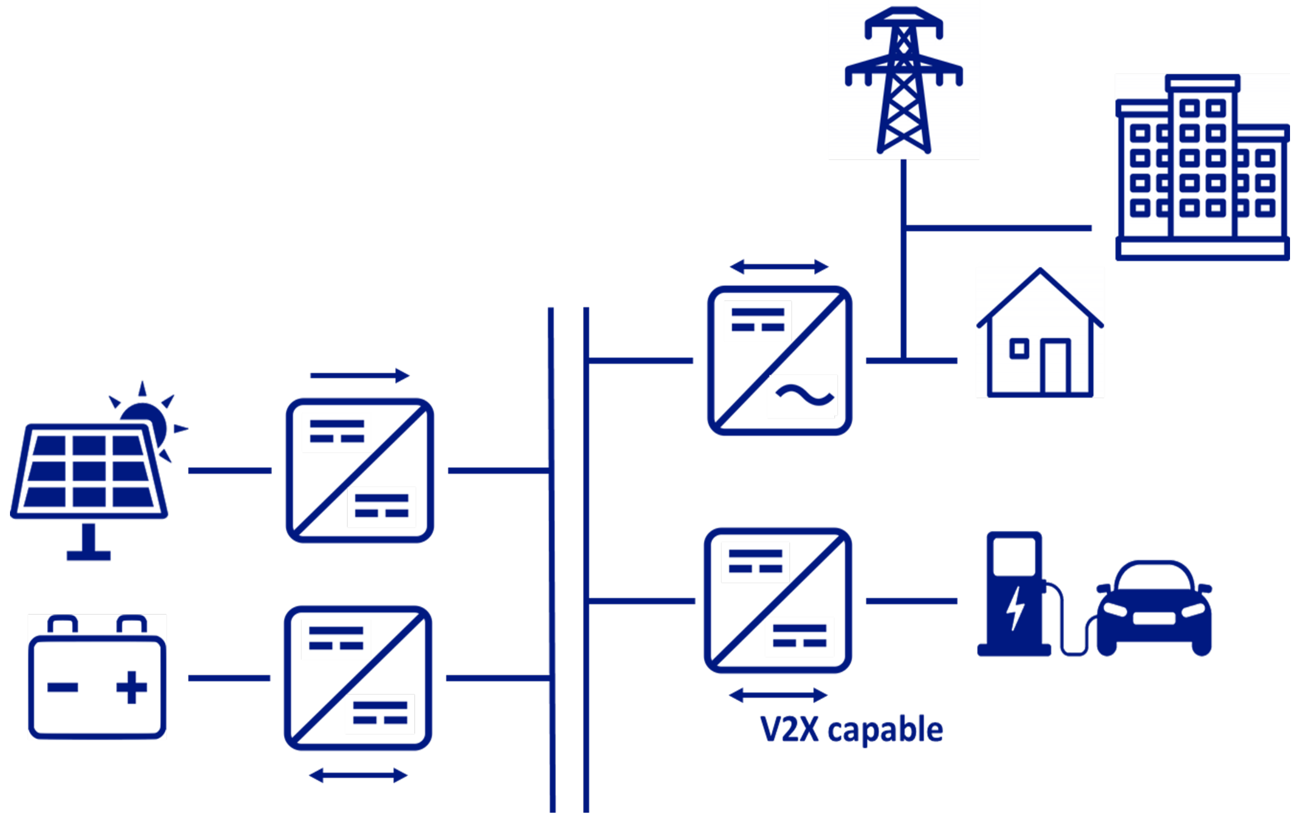
- Integration of EV charging stations incl. V2X, PV units, ESS and household consumption
- Sizing to minimize the price of OPEX and APEX for all assets
- Guaranteeing electricity can be used locally with sufficient generation/storage capacity

2. Optimal Operation of Green Assets

- Energy management to optimize the power flow between the assets
- Constitution of small-scale DC Microgrids
- Joint optimal operation of Green Energy Assets

3. Smart Neighbourhood Integration

- Analysis of integration into higher-level neighbourhoods
- Impact on the LV and MV grids
- Optimization of large EV fleets and electric buses charging stations incl. V2G
- Involvement of the grid operator in the optimization loop
- Centralized and distributed controls



PV-Photovoltaic, ESS-Energy Storage System, OPEX-Operating Expenditure, APEX- Asset Performance Excellence

Smart Green Grid Solutions – Architecture, Grid Monitoring & EMS

Energy management and control systems & Smart Charging with V2X flexibility

1. EV Charging Optimization including V2X

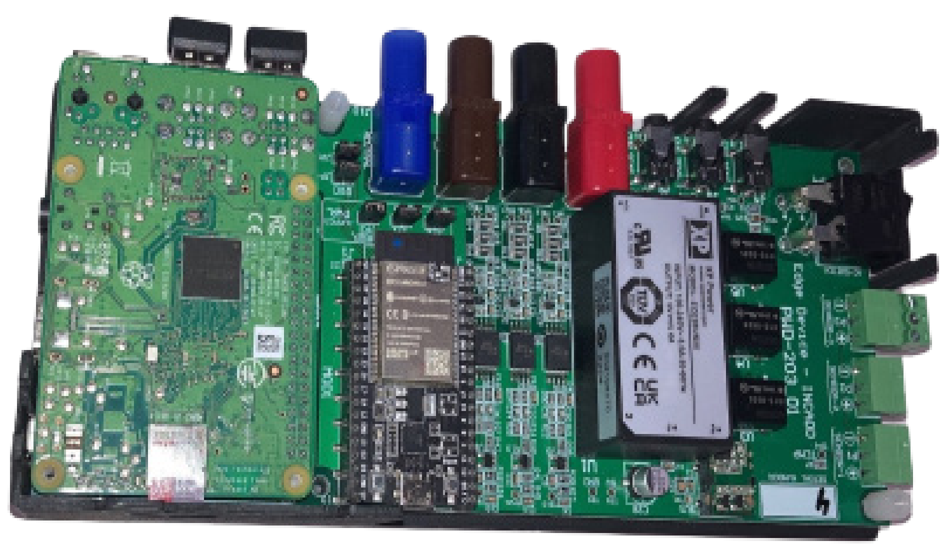
- Real-time scheduling of EVs
- Cost reduction for EV fleets
- Satisfying grid constraints
- Optimized operation of EV charging equipment
- Smart V2X (V2G, V2B, V2H, V2D) integration
- Smart power quality monitoring of grid voltages

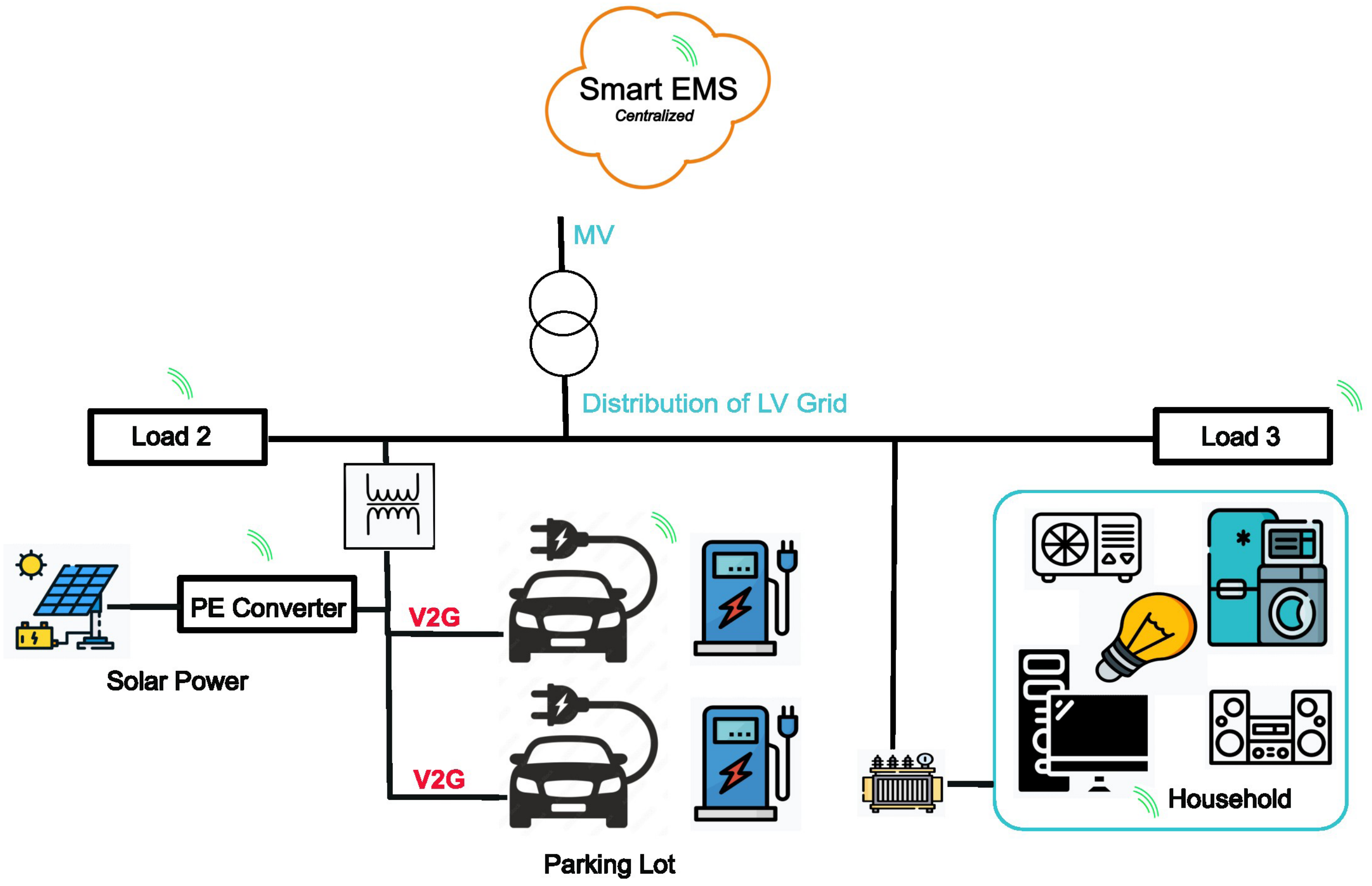
2. Optimal Energy Management in the microgrid

- Advanced EMS for optimized power flow in DC-microgrid
- Maximization of self-consumption within the DC-microgrid
- Provision of extra services to DC-microgrid (predictive load, peak shaving, load shifting, Power quality)
- Self-Healing (SH) algorithm to increase system availability and lifetime
- Fleet management with real-time monitoring and centralized data analysis
- Condition monitoring for improved and reliable grid operation

3. Future Trends

- SiL & HiL testing
- Machine learning based algorithms
- Fleet maintenance scheduling and on-air software updates





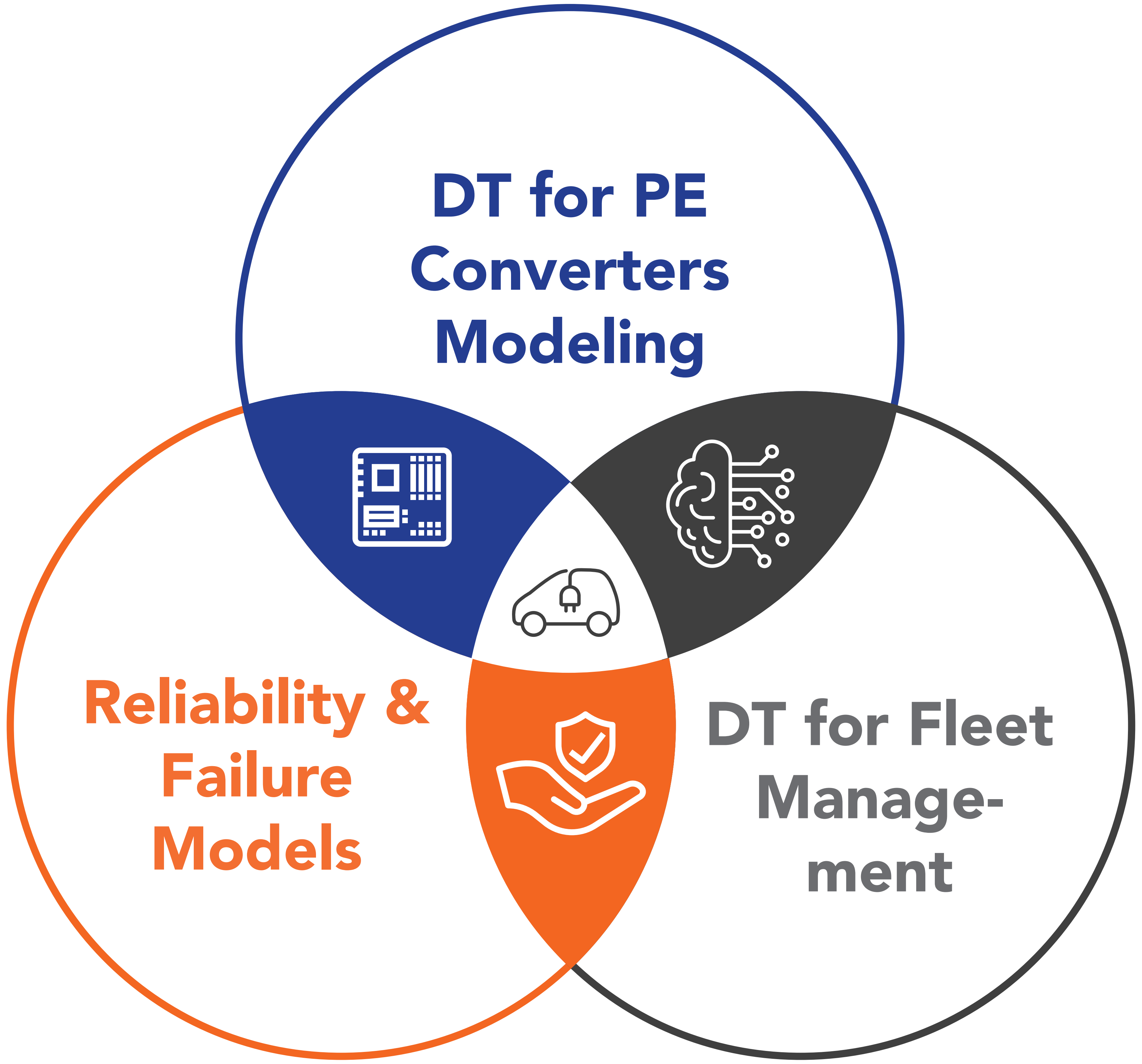
Charging and V2X Research Infrastructure: *Joint Smart Charging Lab (JSCL)*

Charger Testing and Certification

Charging Systems Lab: Grid Emulator

Charging Systems Lab:
EV charging Analyzer/simulator

Digital Twin (DT) and Reliability Assessment



DT for PE converters modeling

- Digital Twin for Design (DT4D)
- Digital Twin for Reliability (DT4R)
- Cloud connectivity
- Digital Twin for validation (DT4V)
- Digital Twin for control (DT4C)
- Virtual prototype

DT for EVs and Fleet management

- Virtual fleet simulation
- Cost Optimization
- Improve Reliability
- Predictive maintenance
- Fleet Resilience
- Improve safety

Reliability & Fault tolerant PE models

- Physics of failure-based analysis
- ALT of converters/components
- Converter level reliability assessment
- Online condition monitoring
- Fault localization
- Fault tolerance

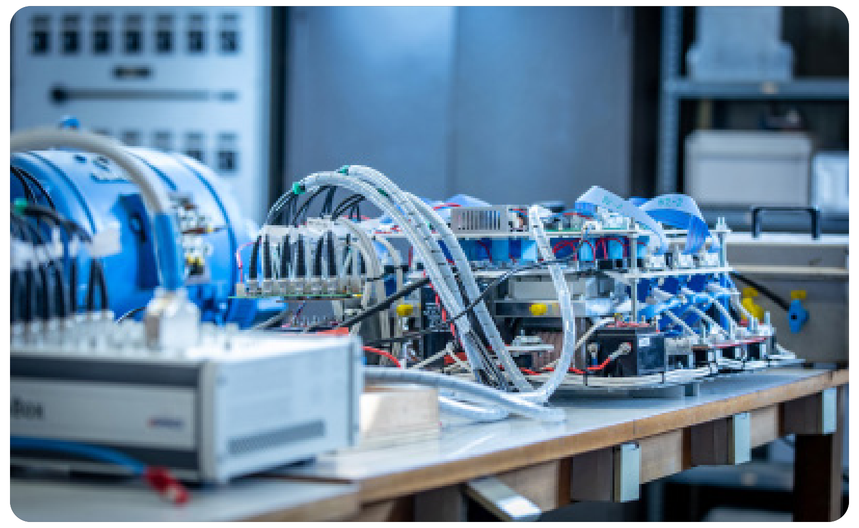
Digital Twin (DT) and Reliability Assessment

DT for PE converters modeling

Identification

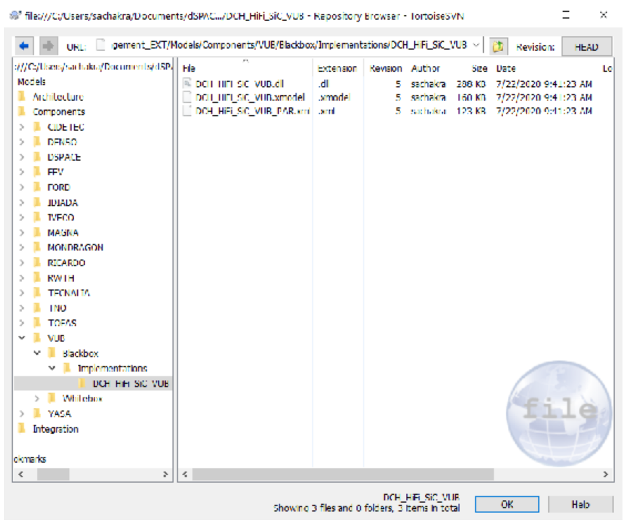
Device level loading

Testbench



Device Under Test
(PE converter)

Measurement



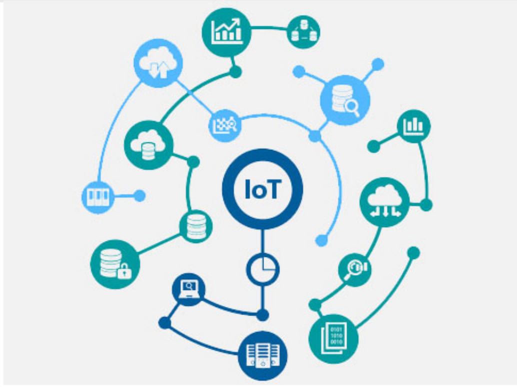
Database/
Cloud Storage

HPC

Data monitoring and cloud computation unit

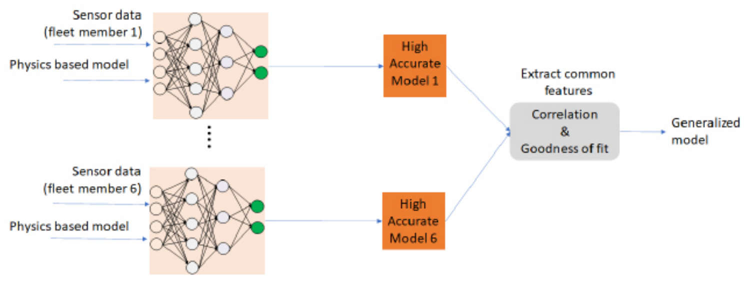
40 core CPU	32GB GPU
128GB RAM	Server OS
12TB HDD	VPS

IoT and Connectivity

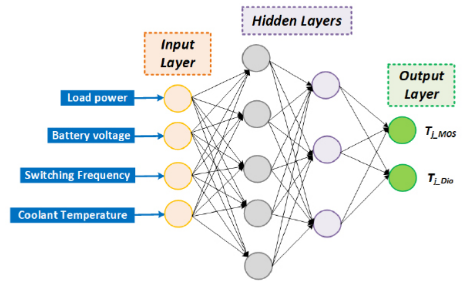


Digital Twin

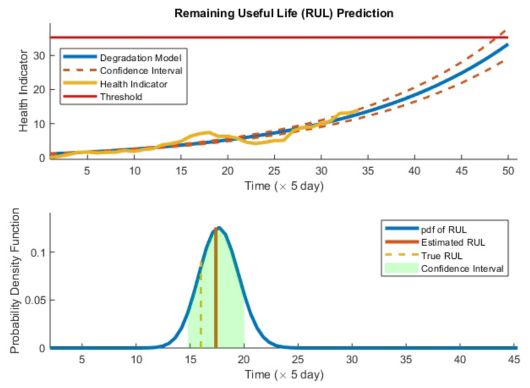
Learning Algorithm



AI-based
Virtual Model
(xMOD, FMU, dSPACE)



Predictive Maintenance
and Self-healing



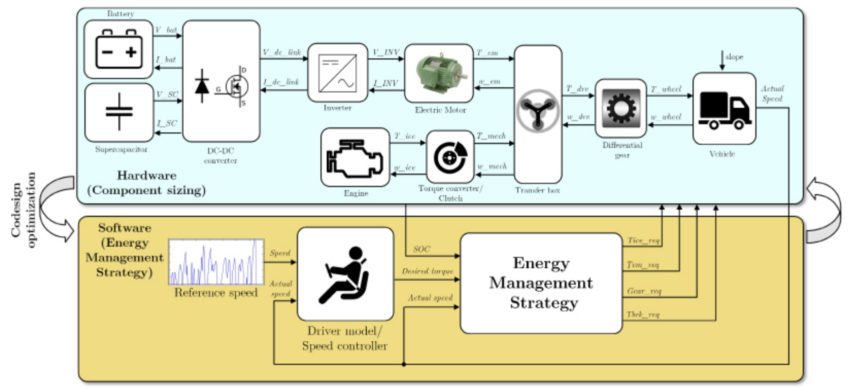
Benefits of Digital Twin for PE Converter Modelling

- Rapid prototype validation
- Validation of unorthodox topologies
- Quick remaining useful lifetime estimation
- Predictive maintenance
- Less time to market
- Autonomous cloud-based Testing
- Digitalization & Industry 4.0

Digital Twin (DT) and Reliability Assessment

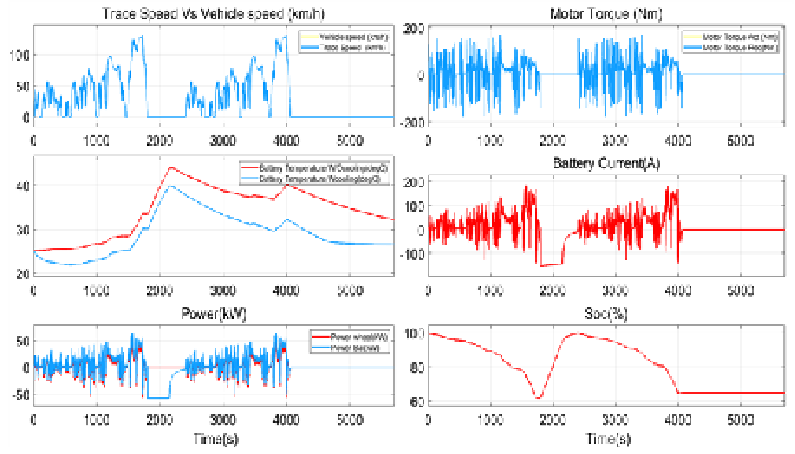
DT for Electric Vehicles (EVs)

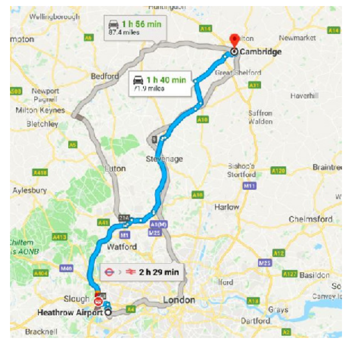
Simulation and Control

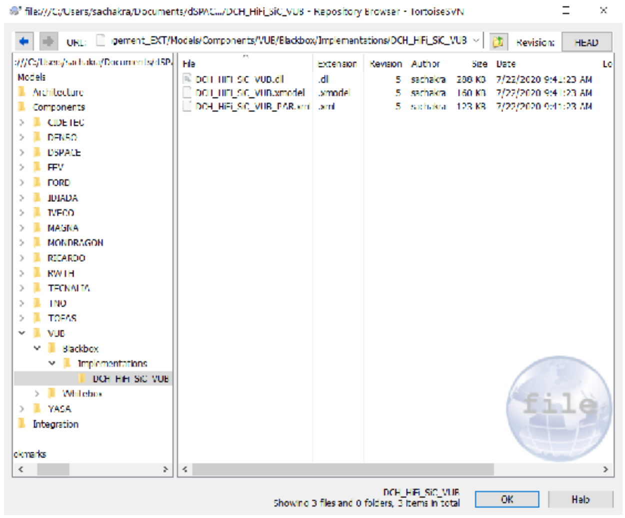


Powertrain, EMS, CMS,TMS

RT-Measurement







Grade, Velocity, Climate, Passenger Load

Database/ Cloud Storage

Digital Twin

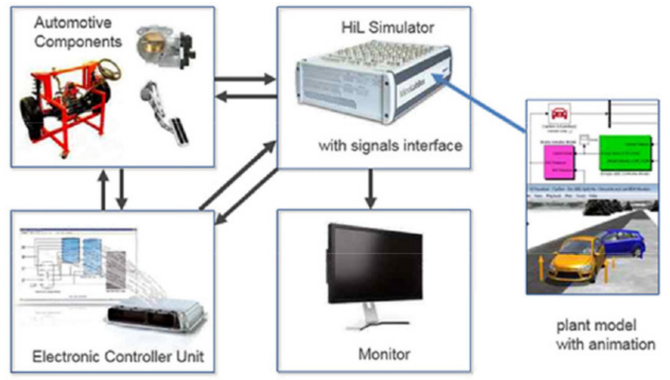
Predictive maintenance, SoC estimate of scenario, ECO Modes

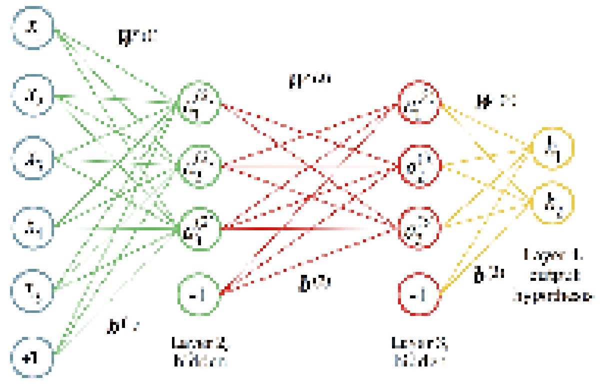
Digital Twin

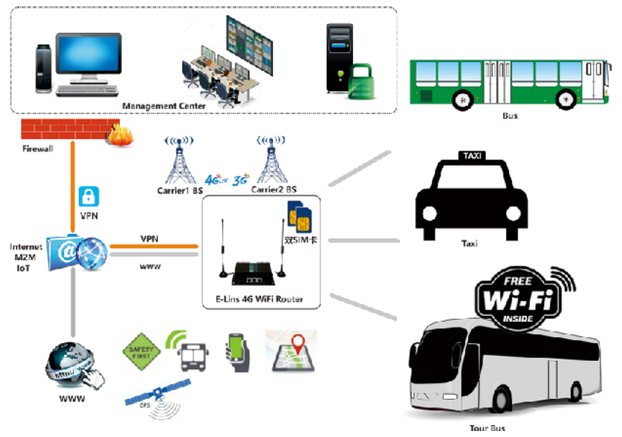
Virtual Real-time Model (dSPACE)

Learning Algorithm

IoT and Connectivity







Benefits of Digital Twin for EVs

- Quick Model Validation
- Optimization strategies
- Extreme scalability of the EVs
- Improve EVs safety and comfort
- Improve vehicle consumption

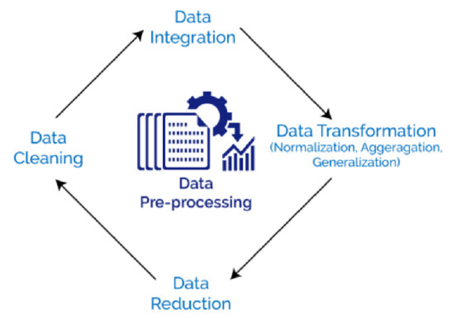
VUB EPOWERS EFFICIENT POWER ELECTRONICS, POWERTRAIN & ENERGY SOLUTIONS RESEARCH GROUP

Digital Twin (DT) and Reliability Assessment

DT for Fleet management

Fleet of E-Buses

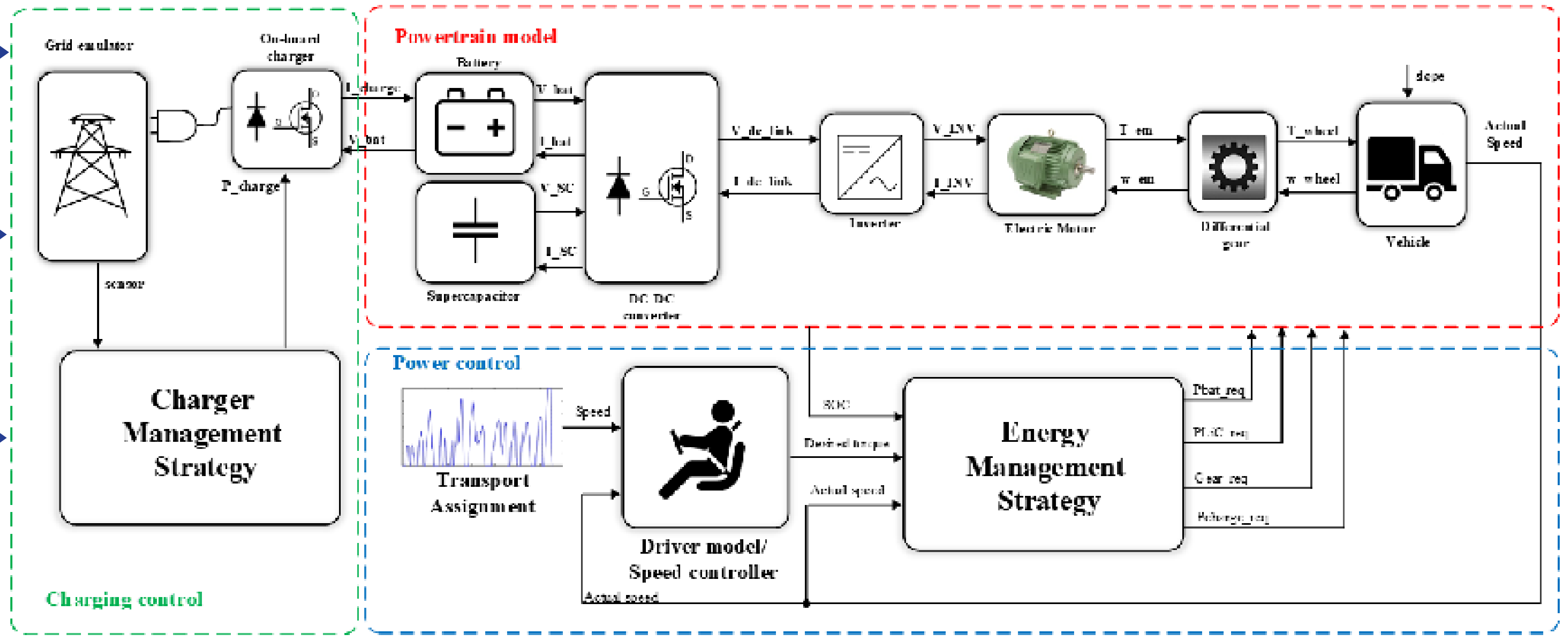
Sensor Data



Soc

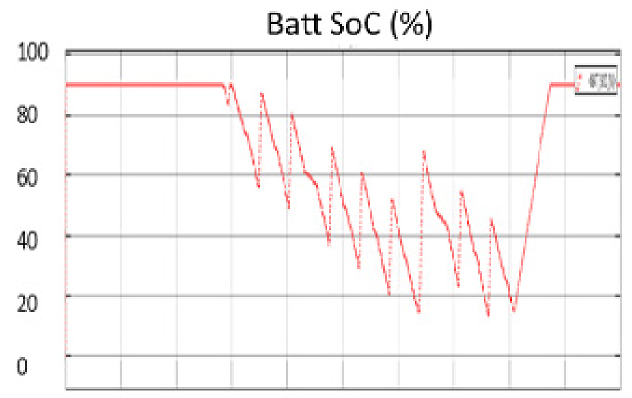
Reference Altitude

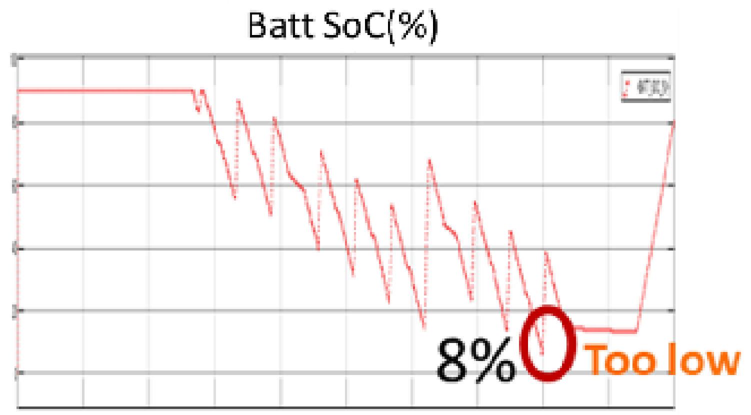
Reference Speed



Soc, Temp

Charging Profile





Charging power, duration, priority

Deep Learning Based Rescheduling

Prediction: Insufficient SoC for next trip

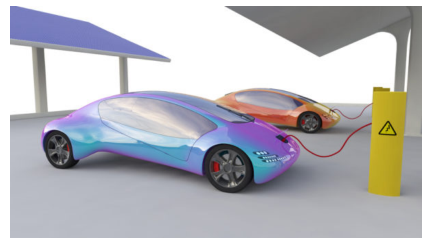
Benefits of Digital Twin for Fleet Management

- Predictive battery changing
- Rapid new charging schedule based on driving scenario
- Increase fleet management effectiveness, cause minimal disruption to bus schedule
- Increase life expectancy of Battery

Digital Twin (DT) and Reliability Assessment

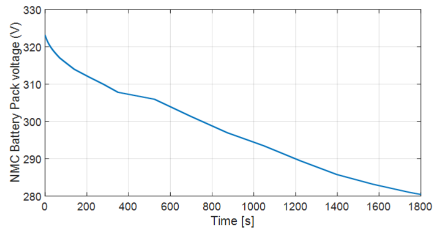
Reliability Assessment: Accelerated lifetime testing/Lifetime testing procedure

Identification



Load Profile

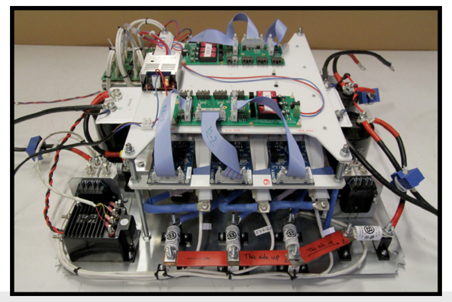
Speed
Profile
Temperature
Impact



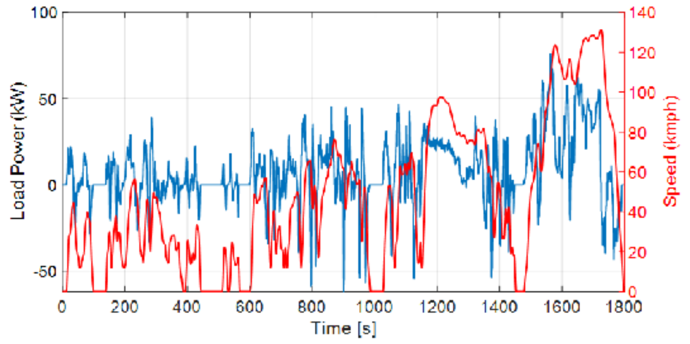
Characterization

Device Level Loading

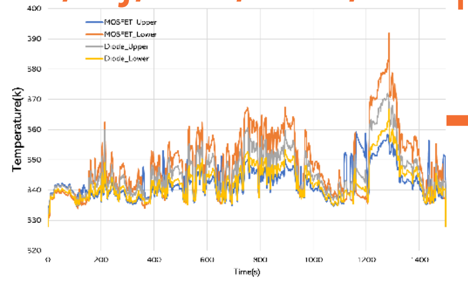
V_{Bat}
Load
T_{cool}



Power Electronics Converter Testbench (DUT)



Vds, Tj, Ids, Vth, Tcap



Reliability assessment models

System Level Lifetime

PDF
N, B

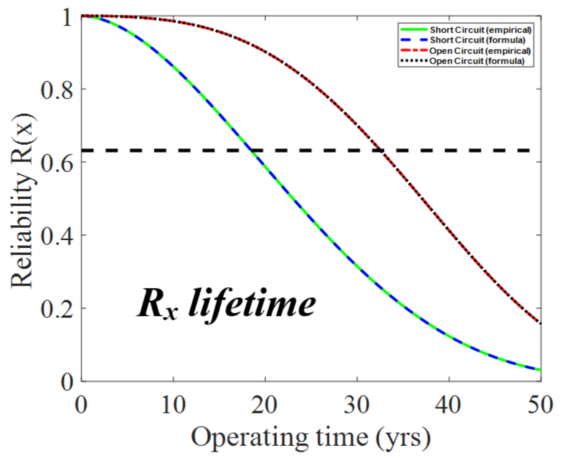
Monte Carlo Simulation & Weibull Fit

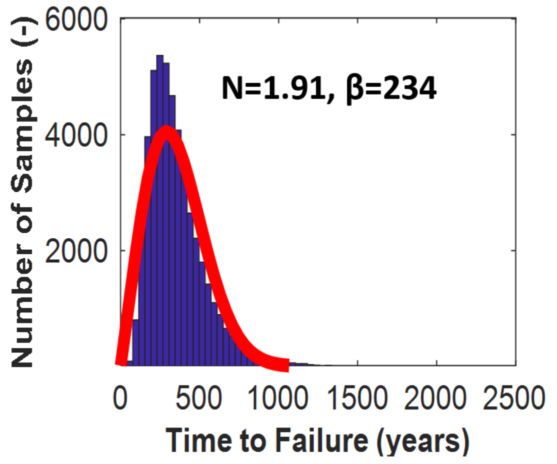
Dmg

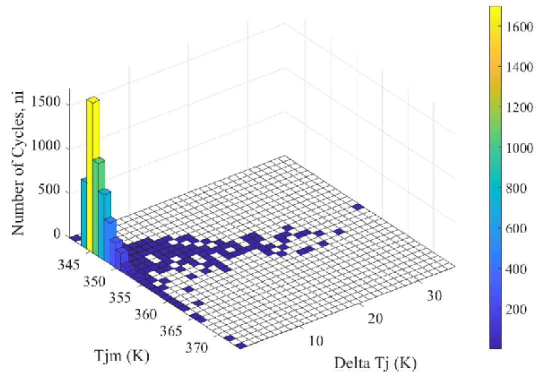
∑ *Accumulated Damage*

Counting Algorithm

Parametric Variations (%)







Activities and Services

- DUT conformance testing up to 250 kW
- Device characterization
- HALT and failure diagnosis
- Wear out testing
- Mission-profile oriented Test
- Reliability-Oriented Design
- Fault progression
- Estimating Remaining Useful Lifetime

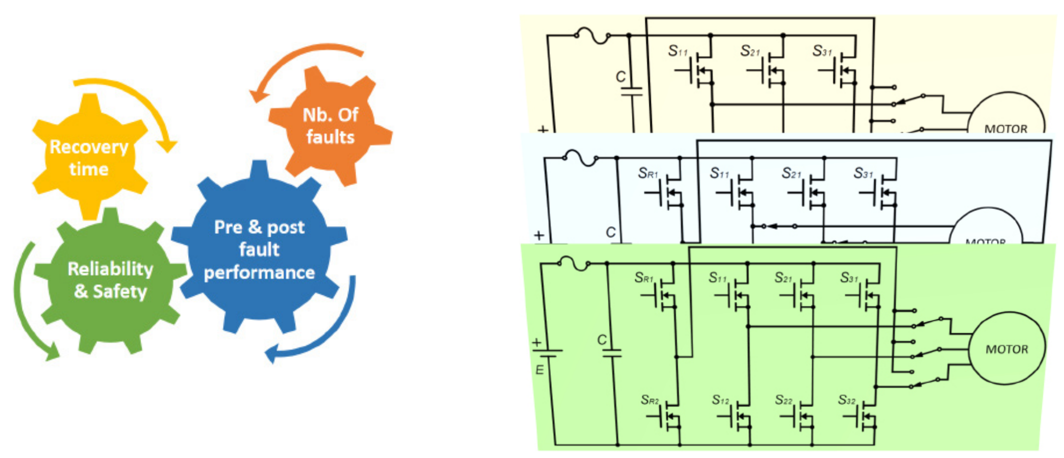
Targeted Testing

- Mission-profile based Test
- Power Cycling Test
  [IEC 60749-34:2011]
- Temperature Cycling Test
  [IEC 60749-34:2012]
- HALT Test [IEC 68-2-38]

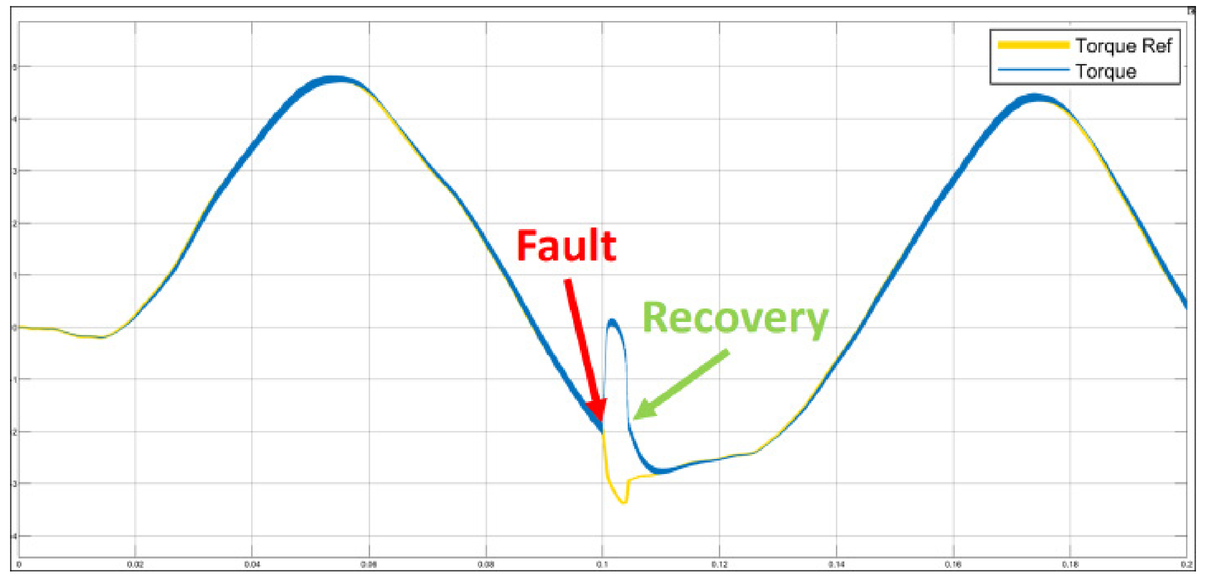
Digital Twin (DT) and Reliability Assessment

Fault Tolerance PE models

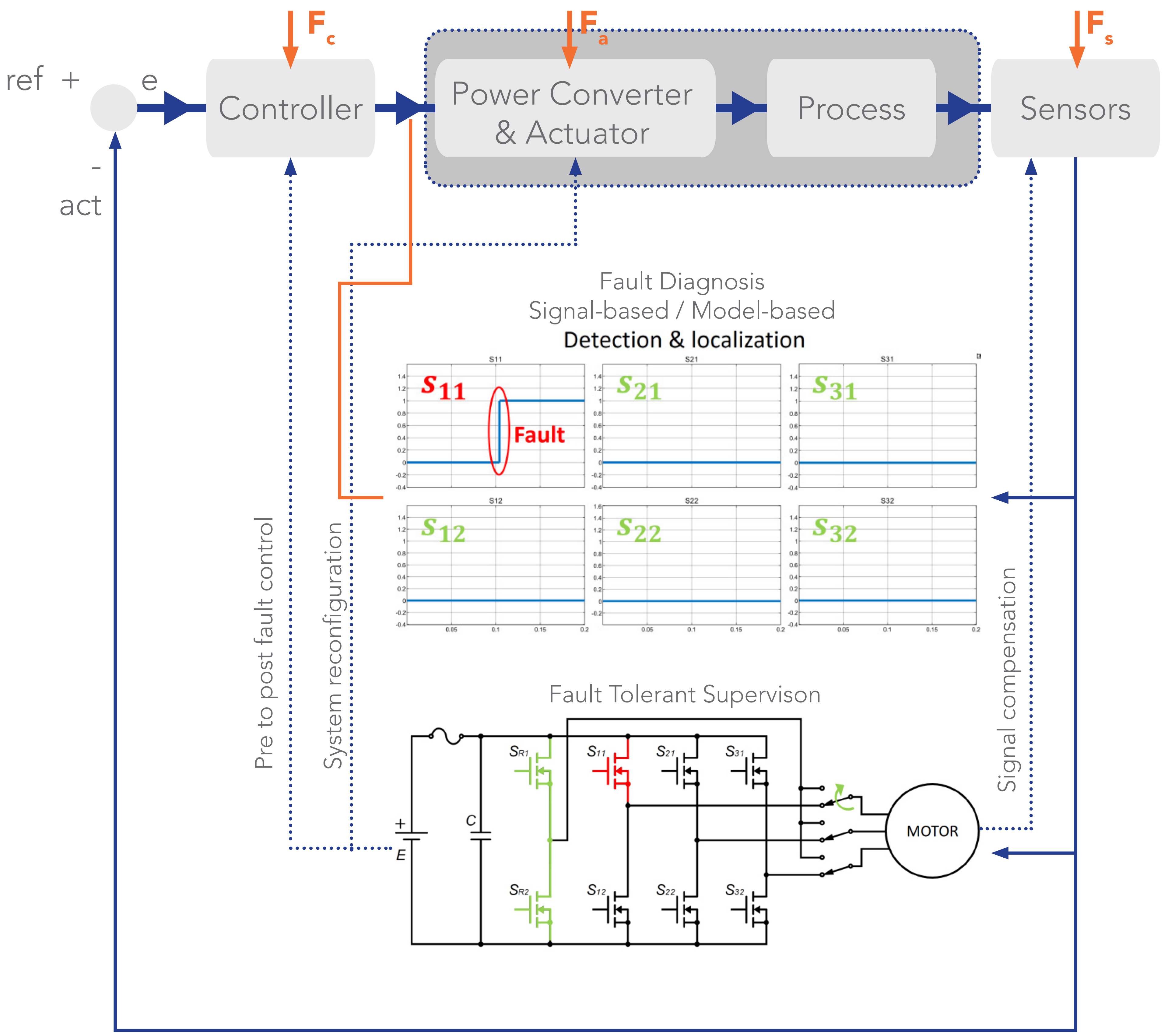
Design for Fault-Tolerance



Testing and Verification



Fault-Tolerant control



Methodology

- Identification of:
  - System Requirements & specifications
  - Fault modes & behaviors
- System optimization and selection of suitable fault tolerance strategy
- System modeling
- Implementation of fault detection and localization methods
- Fault isolation
- System Reconfiguration mechanisms
- Pre- and post-fault control
- Prototyping, testing and validation

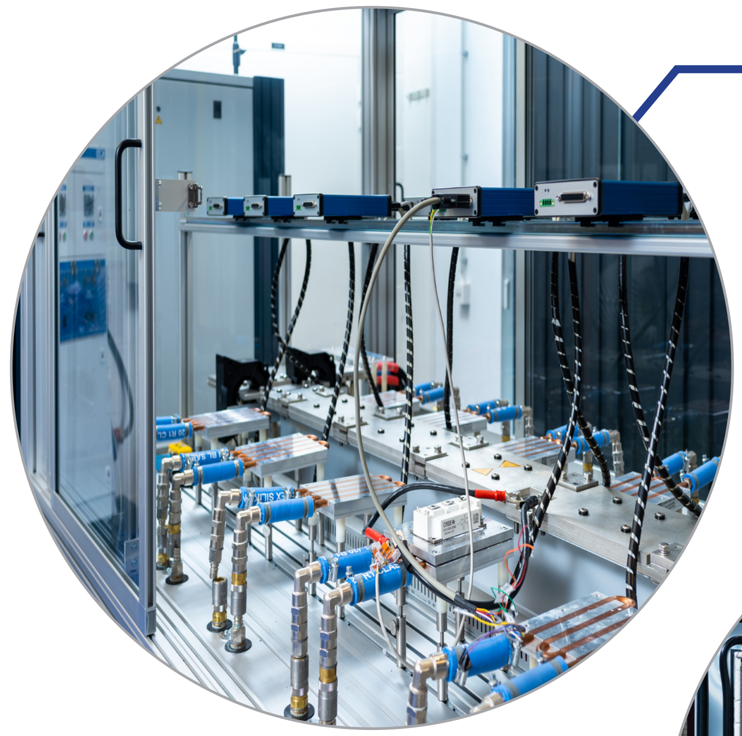
Key Activities and Features

- Fault tolerant converter modeling
- Converter faults characterization
- Fast fault detection, isolation and system reconfiguration
- Advanced control
- Cost reduction
- Improved reliability

Power Electronics Reliability Lab (PERL)

Dynamic Double Pulse Tester (DPT)

Accelerated Lifetime Tests (ALT) for Si, SiC , GaN and beyond



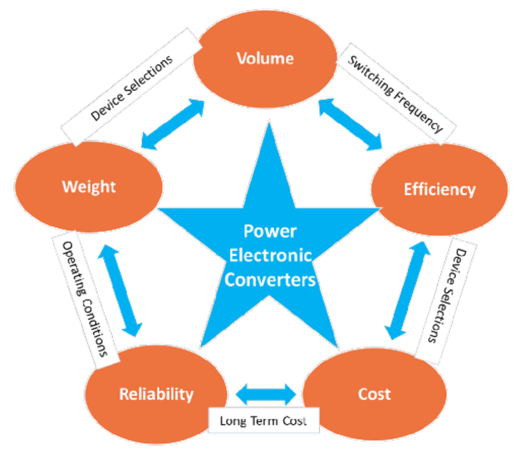
Advanced Cloud Computing Hydra PC

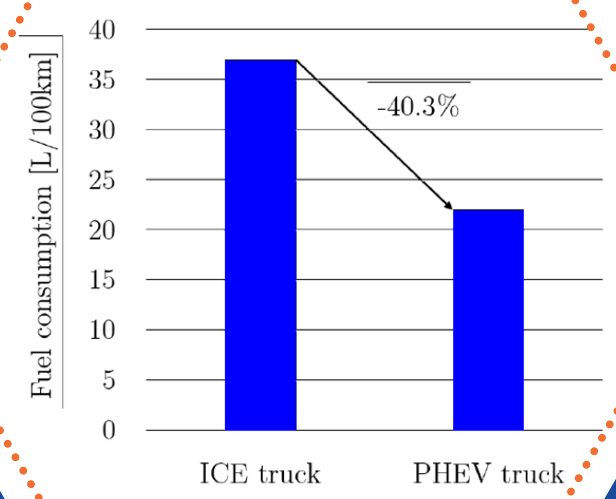
EMC Test Cabinet with Thermal Cycling

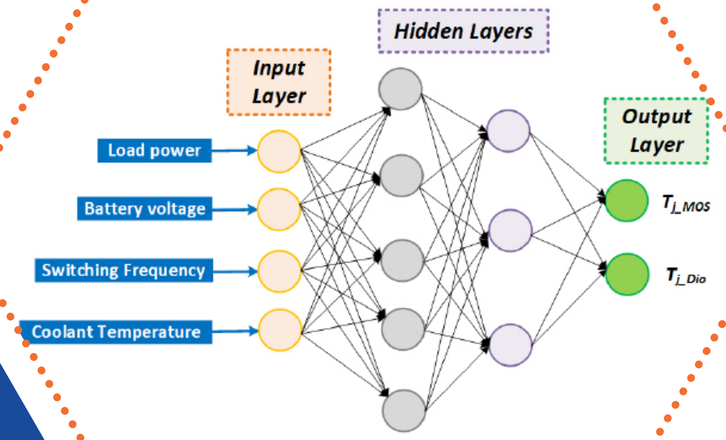
High Precision Data Capturing Equipment

Mission Profile Testing Device (MPT)

Our Tools







EMS Codesign Optimization Tool

ANN based PE Modelling Tool

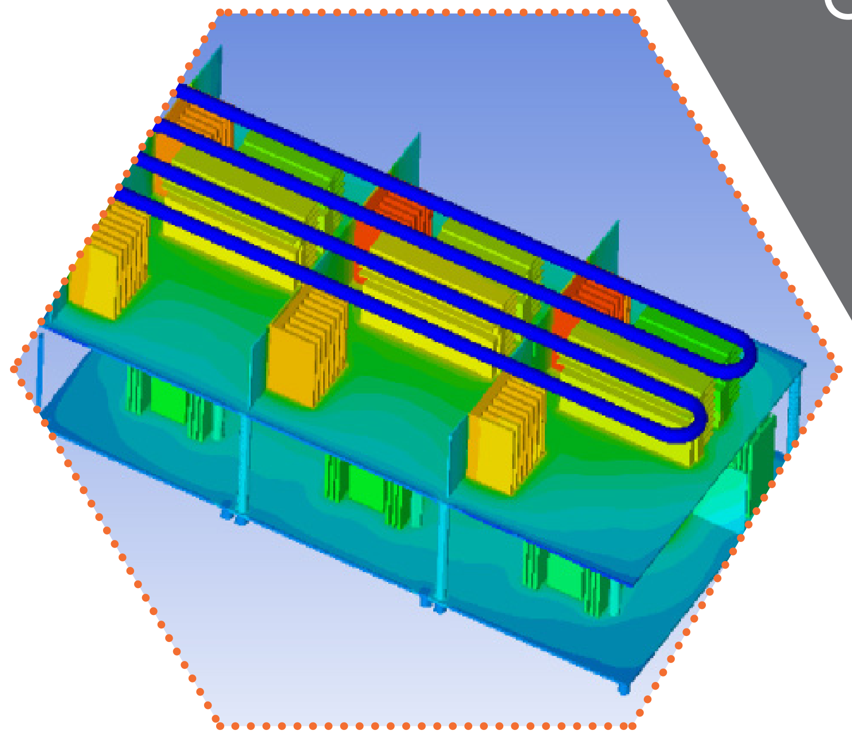
PE Converter Optimization Tool

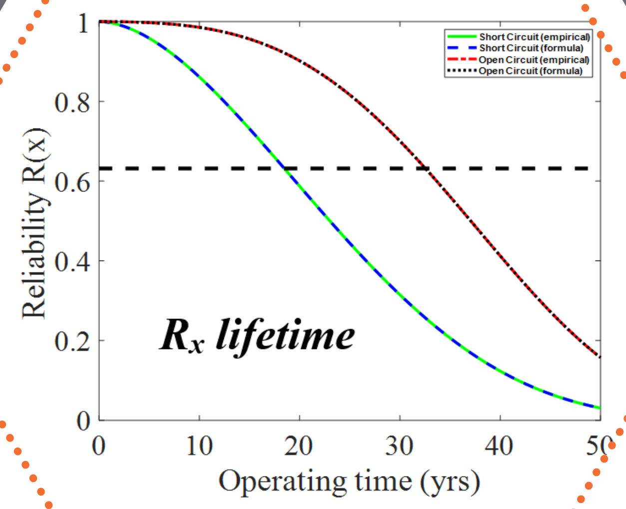
Reliability Assessment Tool

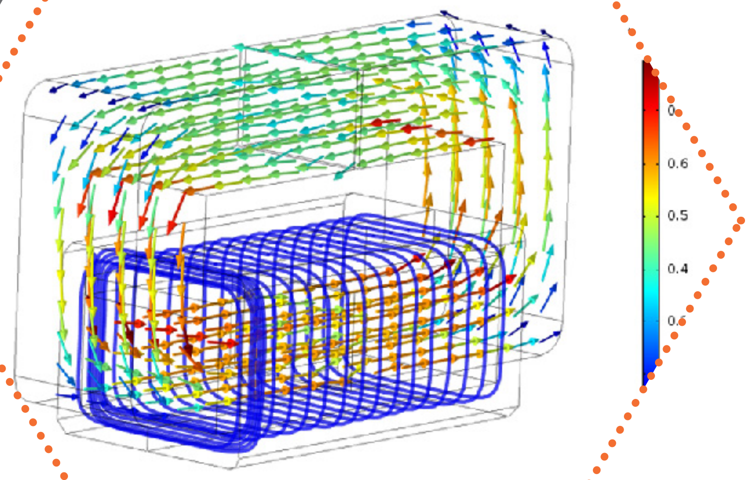
Virtual Prototype design Tool

PE Thermal Optimization Tool (CFD)

Digital Twin Modelling Tool (PE, EV)







Service Offer

Cloud connected EV modeling & EV Testing

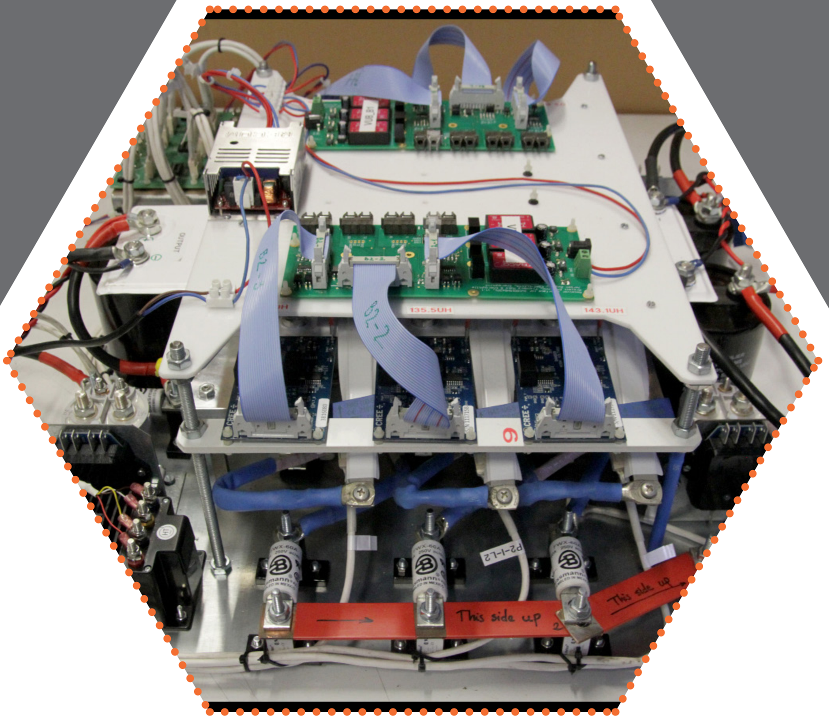
Smart Green Grid Solution (V2X)

Codesign Optimization for EMS,TMS & PE

Advanced PE converter Prototype design

DT Validation and Reliability Testing

ECO Algorithms implementation



HiL Testing of PE converters and motor controls

Interesting Projects

Bella
SiC GRID
NextETRUCK
ZEFES
HiEFFICIENT

LONG RUN
ORCA
obelics
GHOST
ASSURED

HIFI-ELEMENTS
High Fidelity Electric Modelling and Testing
SyrNemo
eLIPTIC
electrification of public transport in cities
HiPERFORM
EVOLVER

iSTORMY
URBANIZED
Safe DRIVE
eCHARGE 4DRIVERS
Achiles

Unplugged
EBRT2030
NEXTBMS
ECO-MOBILITY
OPEVA

NEMOSHIP
INCADD
MODULAR
DT4V
INfraREL-PE

EPOWERS Research Tracks

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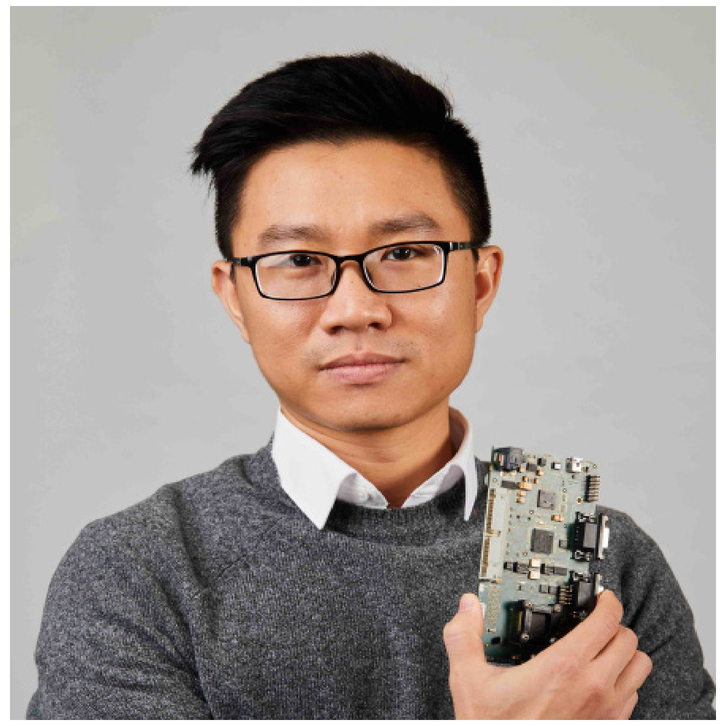

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POWERTRAIN & ENERGY SOLUTIONS
RESEARCH GROUP