Contents of Work Package 3-WP04 Electric and Hybrid Powertrains and Energy Optimal Management
4-WP07 Electric and Hybrid Powertrains

3-WP04: Electric and Hybrid Powertrains and Energy Optimal Management

4-WP07: Electric and Hybrid Powertrains

Coordinator of the WP

Faculty of Electrical Engineering, University of West Bohemia in Pilsen, prof. Ing. Zdeněk Peroutka, Ph.D., doc. Ing. Tomáš Komrska, Ph.D.

Participants of the WP

Škoda Auto, Škoda Electric

Main Goal of the WP

New components and powetrains for future electric and hybrid vehicles, new concepts, increasing power density, increasing efficiency, energy optimal management

Partial Goals for the Current Period

First concepts and samples, main principles, component selection, first algorithms

Contents of Work Package 3-WP04 Electric and Hybrid Powertrains and Energy Optimal Management 4-WP07 Electric and Hybrid Powertrains

RESULTS 06/2026 - DP NPO (FACME)

3-WP04-001: New Generation of Electric Vehicle Powertrain, Fuzit, UWB, 06/2026

3-WP04-002: Energy – optimal management of the fleet of partial trolleybuses and feeding infrastructure, Gfun, UWB+SELC, 06/2026

3-WP04-003: New conceptual solution of traction drives, Gfun, UWB+SA, 06/2026

RESULTS 2023 – 2025 (FEFEFOV)

4-WP07-001: New Generation of Traction Converters, G-fun, UWB+SELC, 12/2025

4-WP07-002: Report: New Generation of Traction Converters, O, UWB+SELC, 12/2025

4-WP07-003: New Conceptual Solution of Traction Drives, O, UWB+SA, 12/2025

4-WP07-004: Analysis of electric vehicle drive variants from the point of risks of structural materials availability & Perspective converter structures for electric transport and their electric and EMC influences (doc. Mindl, CTU)

RESULTS 2026 – 2028

4-WP07-101 - New Generation of Electric Vehicle Powertrain, P, UWB, 12/2028

4-WP07-004 - Innovative solution of power electronic system for vehicles, Fuzit, UWB, 12/2028

4-WP07-005 - New Generation of Traction Converters, Gfun, UWB+SELC, 12/2028

4-WP07-006 - New conceptual solution of traction drives, Gfun, UWB+SA, 12/2028

3-WP04 Electric and Hybrid Powertrains and Energy Optimal Management (FACME)

3-WP04-001: New Generation of Electric Vehicle Powertrain

LEG

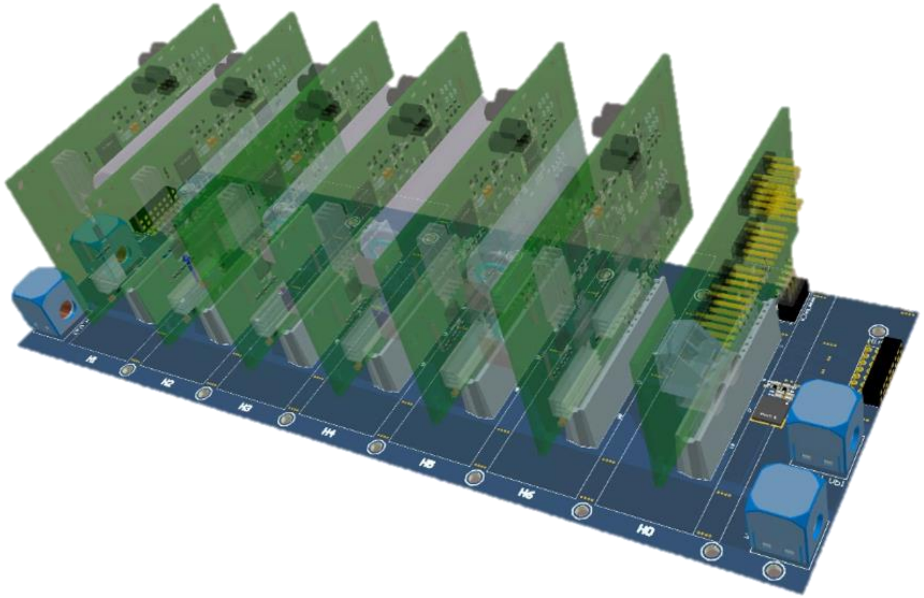
6 cell + 1 master
Serially graded
Vult, Curr leg meas

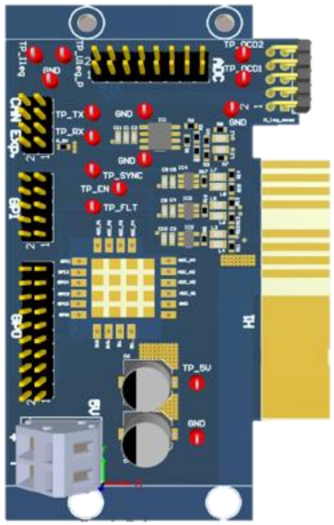
Master module

TI F28377S
CAN
ENable out
SYNC out
FauLT in
Volt, Curr Leg measu

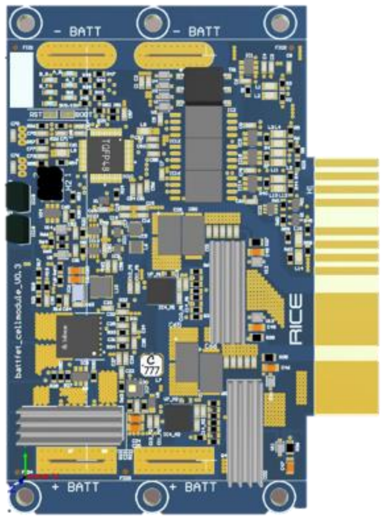
Cell module

TI F280021
2 * Lixx 18650 / 26650
PV input 60 V_{max}
4Q, 50 $A_{nom,}$
HW U_lim: 3 – 5 V
Fsw 20 kHz





master

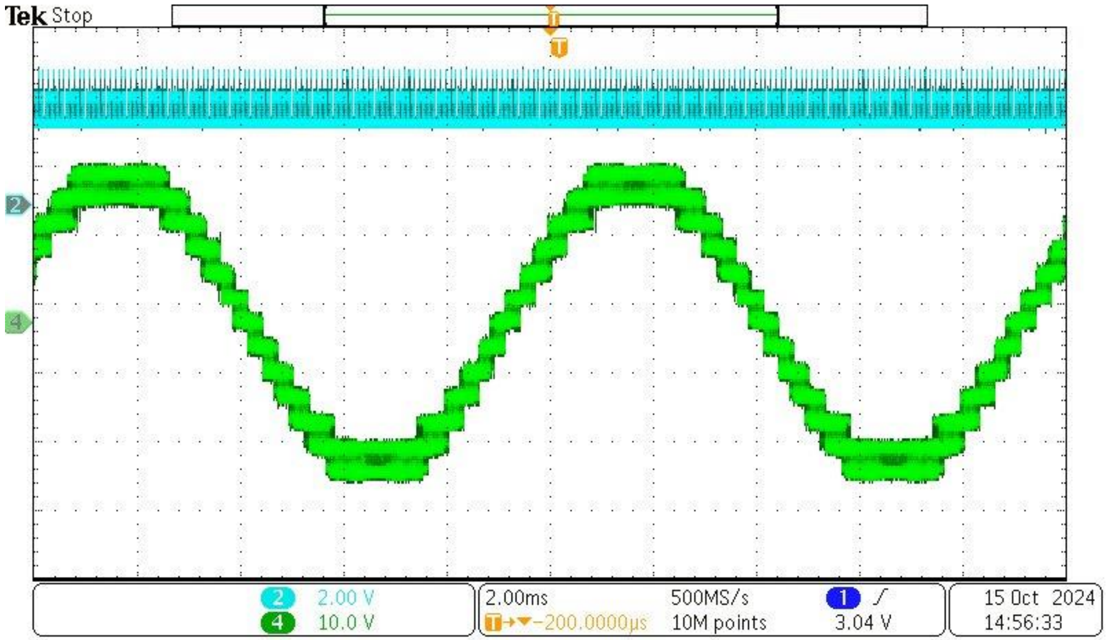


cell top

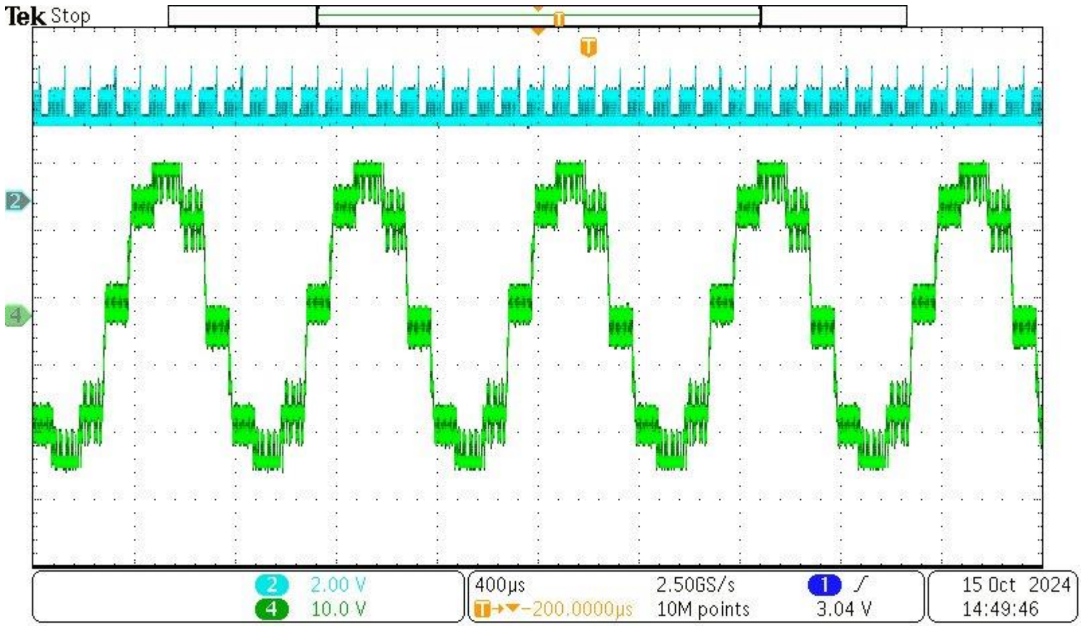
cell bottom

3-WP04-001: New Generation of Electric Vehicle Powertrain

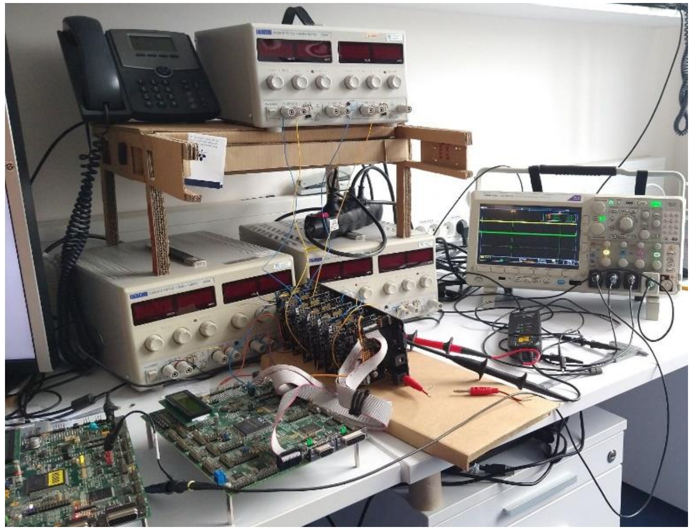
Leg 6 ch
fout = 100 Hz

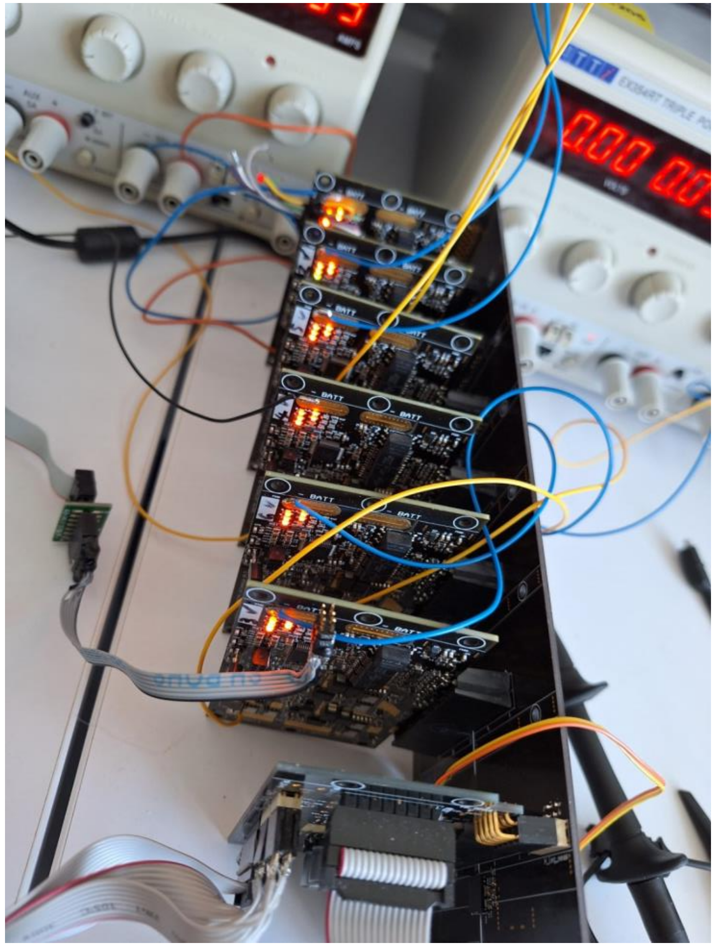


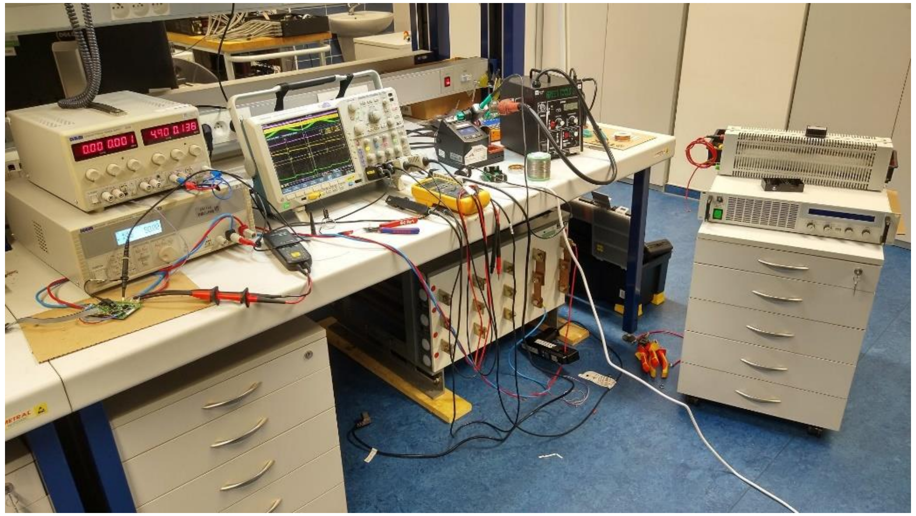
Leg 6 ch
fout = 1250 Hz



3-WP04-001: New Generation of Electric Vehicle Powertrain

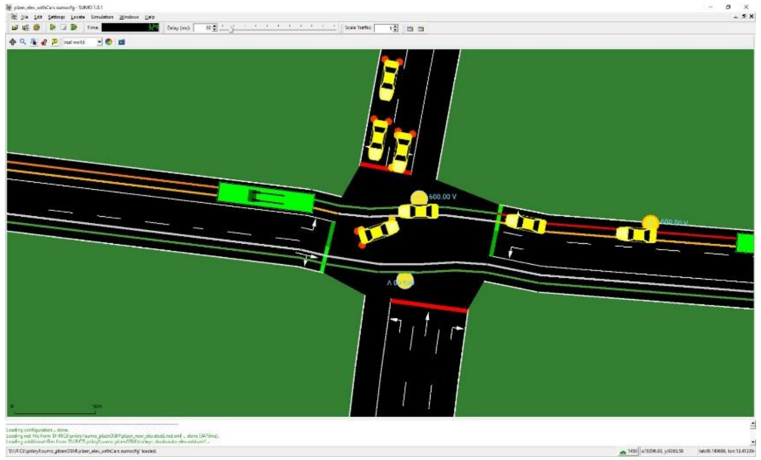


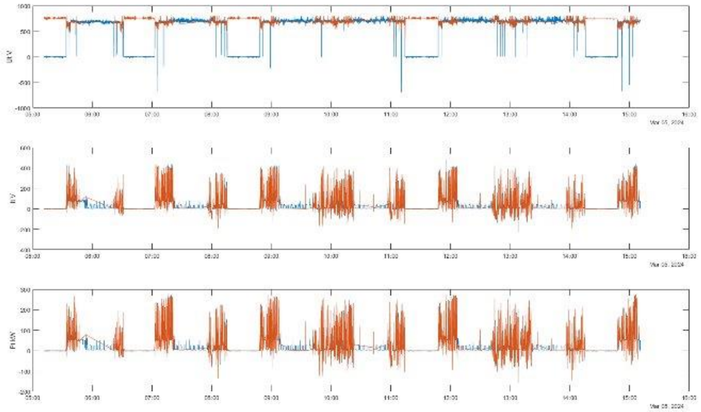


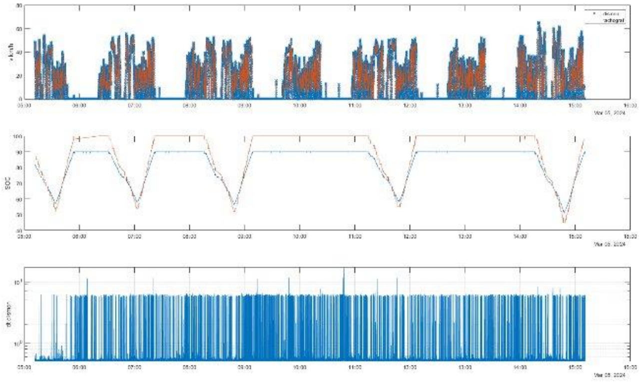


3-WP04-002: Energy-Optimal Management of the Fleet of Partial Trolleybuses

- Stage I completed
- ASTRID replaced by DISMON due to sampling frequency issues
  - Random gaps in transmitted data
- Simulation model for trolleybus lines finished
- Parametrized model of power management in Matlab
  - Being ported to SUMO
- Overall calibration of SUMO + power management by 12/2024



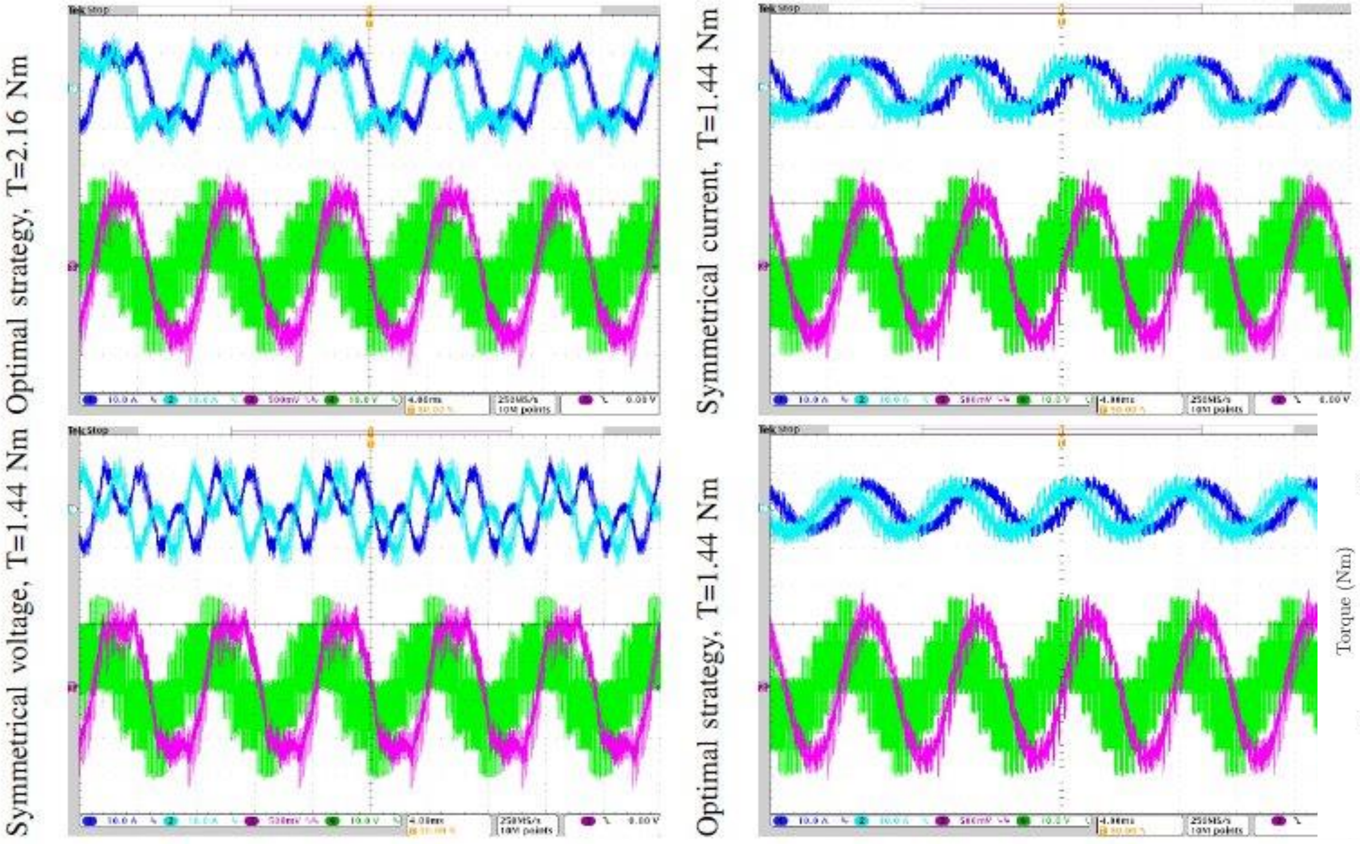


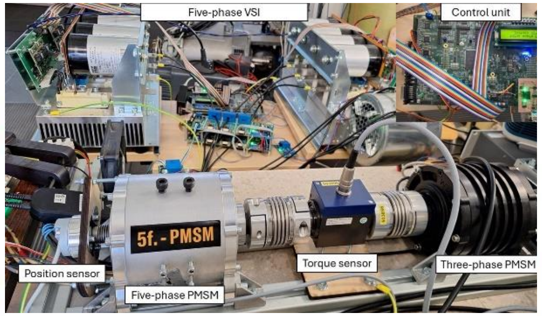


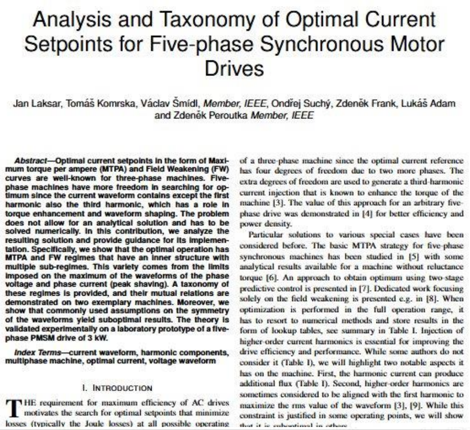
3-WP04-003: New conceptual solution of traction drives

Analysis and Taxonomy of Optimal CurrentSetpoints for Five-phase Synchronous Motor Drives

- Unification of the theory of different control strategies
- Experimental validation

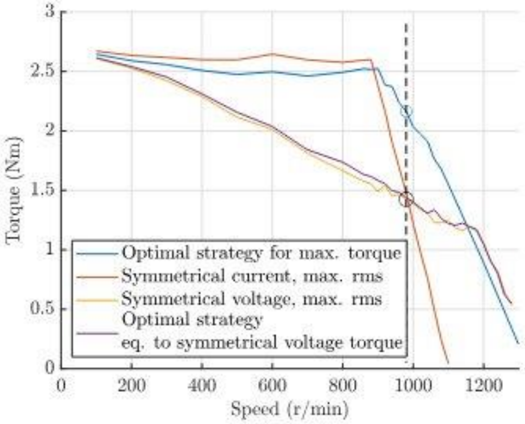


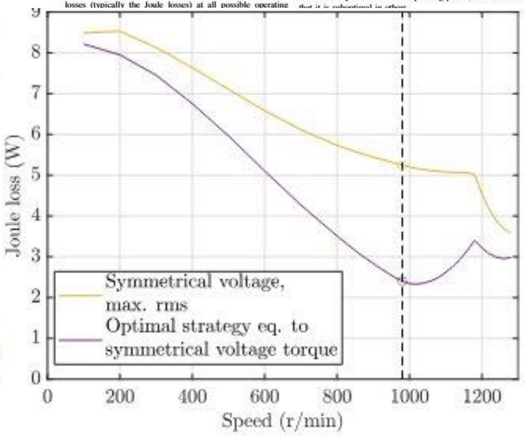



Analysis and Taxonomy of Optimal Current Setpoints for Five-phase Synchronous Motor Drives

Jan Laksar, Tomáš Komrska, Václav Šmídl, *Member, IEEE*, Ondřej Suchý, Zdeněk Frank, Lukáš Adam and Zdeněk Peroutka *Member, IEEE*

I. Introduction

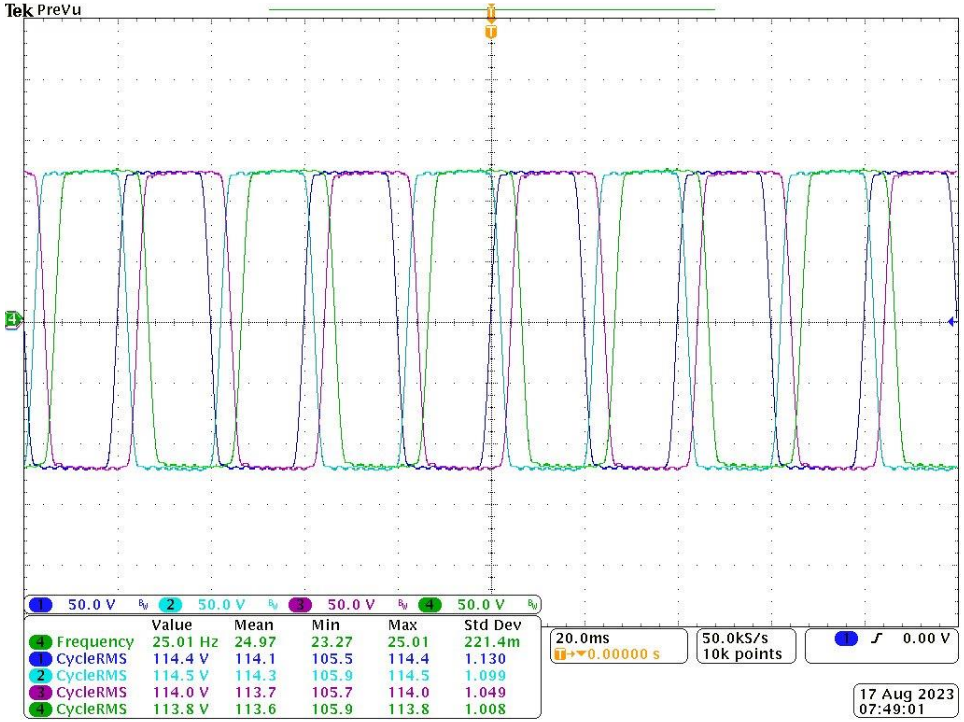


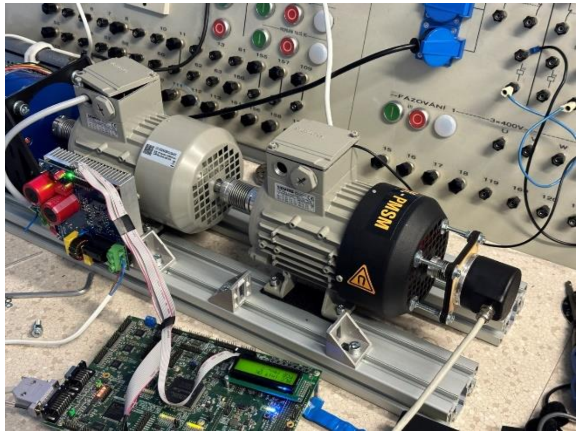


3-WP04-003: New conceptual solution of traction drives

Prototyping and testing

- Prototyping and testing
  - Special PM rotor construction
  - back-emf modification
  - Comparison with three-phase motor





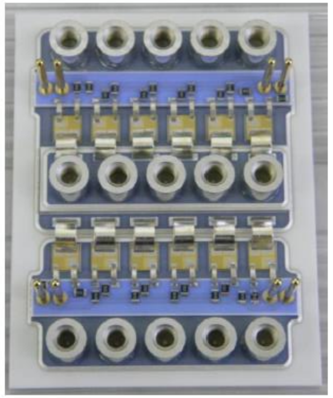
Contents of Work Package 3-WP04 Electric and Hybrid Powertrains and Energy Optimal Management
4-WP07 Electric and Hybrid Powertrains

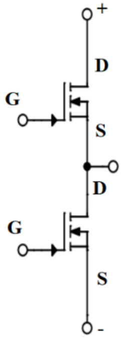
4-WP07 Electric and Hybrid Powertrains (FEFEFOV)

4-WP07-001&002: New Generation of Traction Converters

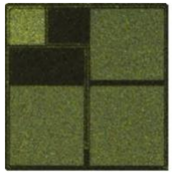
Ultra-high power density traction converter based on SiC:

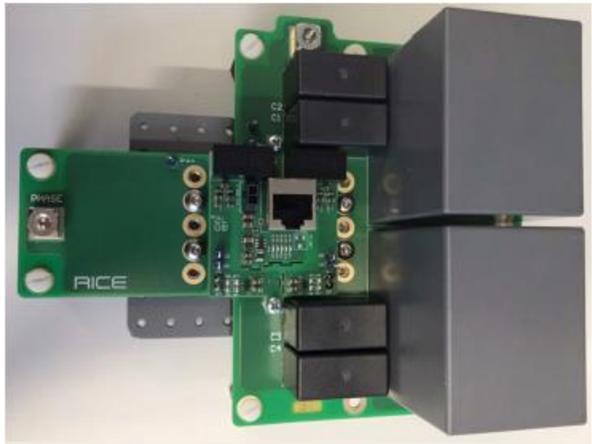
- *Employment high speed transistor (SiC)*
- *Utilizing TPC technology (Thick Printed Copper) and bare dies to manufacture custom power module with* integrated *parts of soft switching circuitry and/or driving cct, possible use of structured ceramic substrates* Al_2O_3*, AlN...*





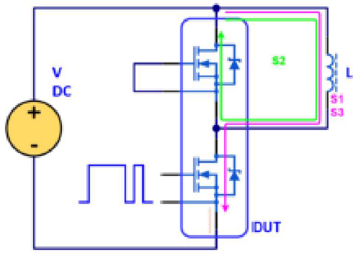
- *100um Ag,* Al_2O_3 *96 %, 1 mm*
- *Ag plated Cu strips*
- *QPM3-0750-0012C*
  SiC MOSFET 750V 12mΩ (CREE)
- *Tested on the prototype of SSCB (Solid State Circuit Breaker)*

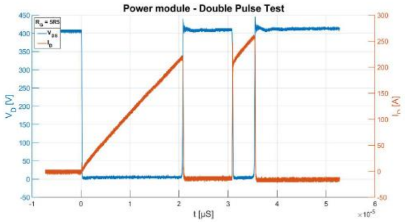


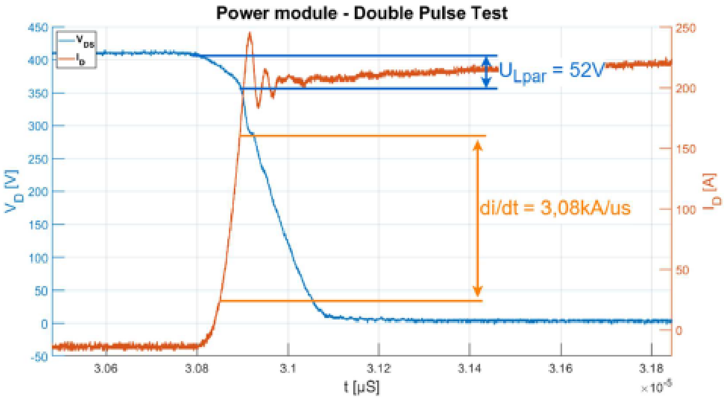


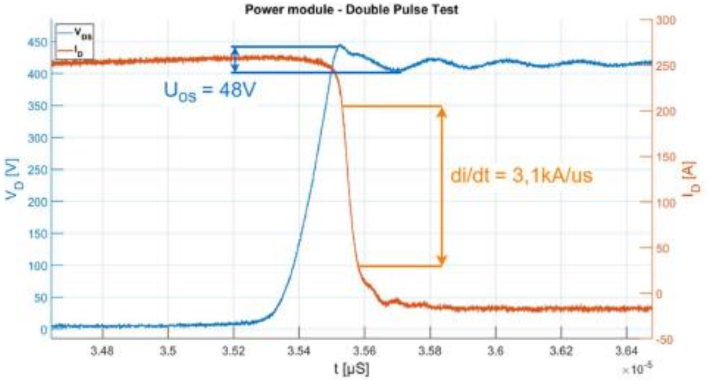
Developed SiC power module circuit

- *Double pulse test (DPT)*









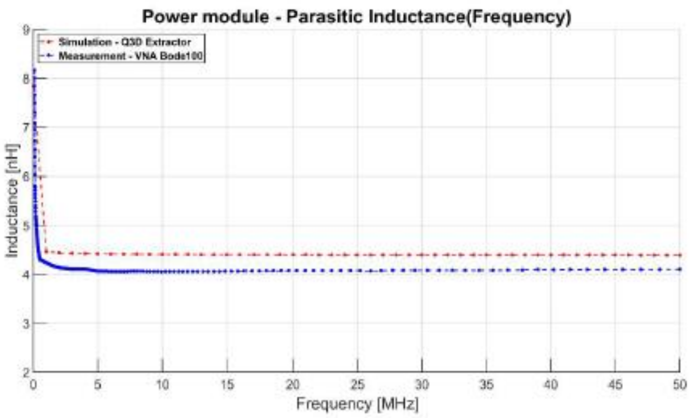
4-WP07-001&002: New Generation of Traction Converters

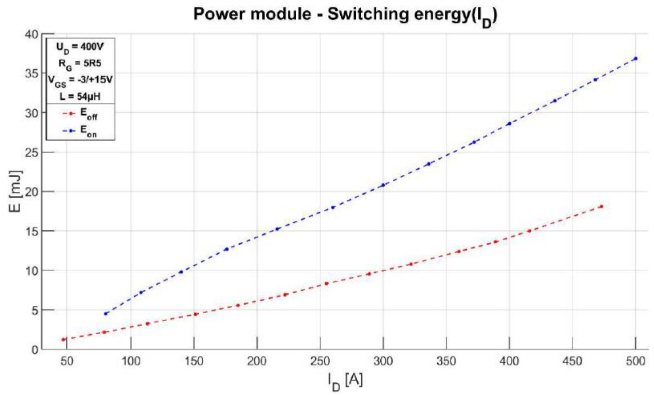
$$U_{Lpar} = L_{par}\frac{di}{dt}$$

1	2
$U_{Lpar} = 52\ V$ $\frac{di}{dt} = 3{,}08\ kA/\mu S$	$U_{os} = 48V$ $\frac{di}{dt} = 3{,}1\ kA/\mu S$
16,8 nH	15,4 nH

Parasitic inductance of the power module:

- *Extracted from power module geometry by Ansys Q3D: LparM = 4,397 nH at 25 MHz*
- *Measured with the Vector analyzer BODE 100: LparM = 4,075 nH at 25 MHz*



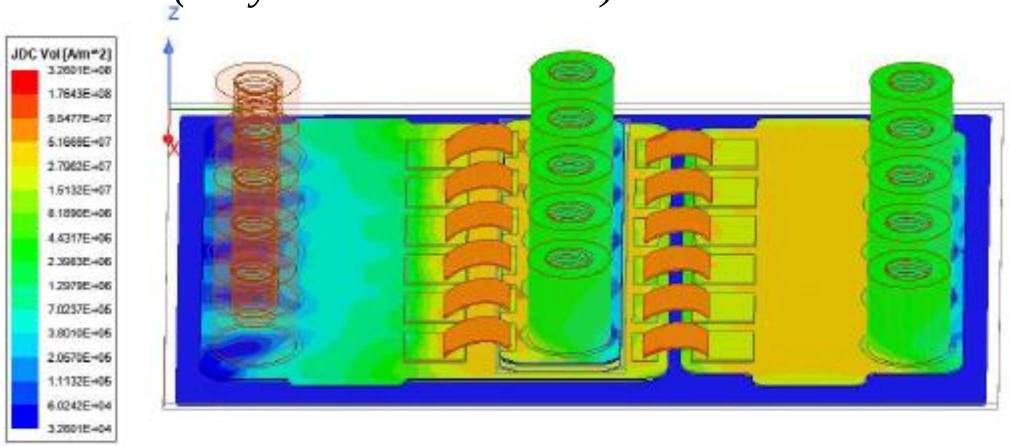


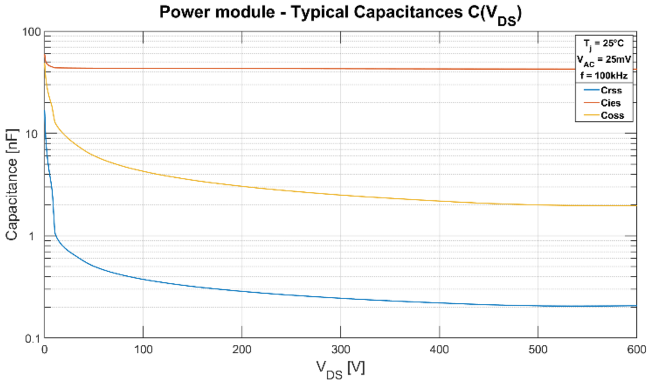
Switching energies depends on I_D

Main parameters of static and dynamic characterization:

- $R_{DS(on)} = 3{,}3\ m\Omega$; $Tj = 150\ °C$
- $U_{GS(th)} = 1{,}43\ V$; $Tj = 150\ °C$
- $I_{DSS} = <100\ \mu A$; $Tj = 150\ °C$
- $E_{off} = 31\ mJ$; $ID = 436\ A$, $R_G = 5R5$
- $E_{on} = 15\ mJ$; $ID = 416\ A$, $R_G = 5R5$

Current density distribution for 350 Arms (Ansys simulation results)



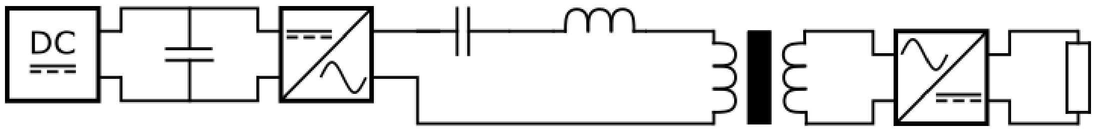


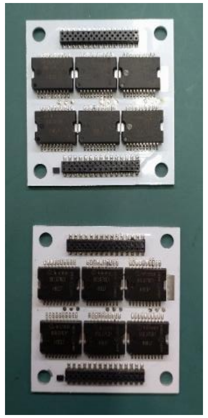
Power module typical capacitances

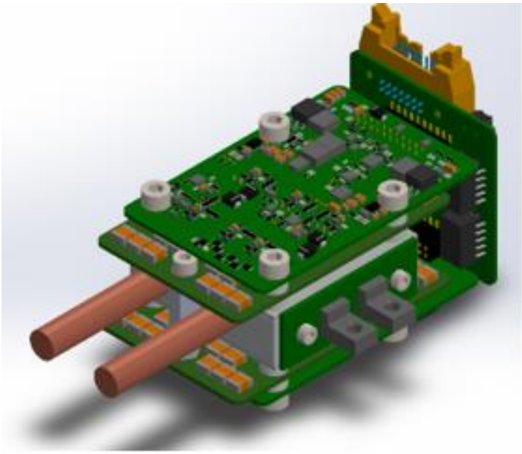
4-WP07-001&002: New Generation of Traction Converters

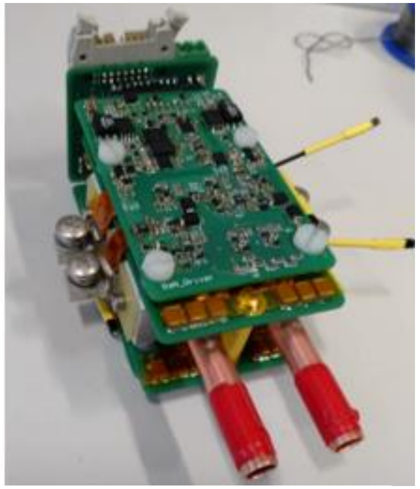
Ultra-high power density traction converter based on GaN:

- *Actual voltage levels up to 1200V (higher for specific application only – 900 and 1200V)*
- *Actual $R_{DS(ON)}$ ~ 25mΩ @ 600/650V (lower $R_{DS(ON)}$ dies available)*
- *Lowest switching losses → High frequency application*
- *LLC GaN based DC/DC power converter with water cooling*





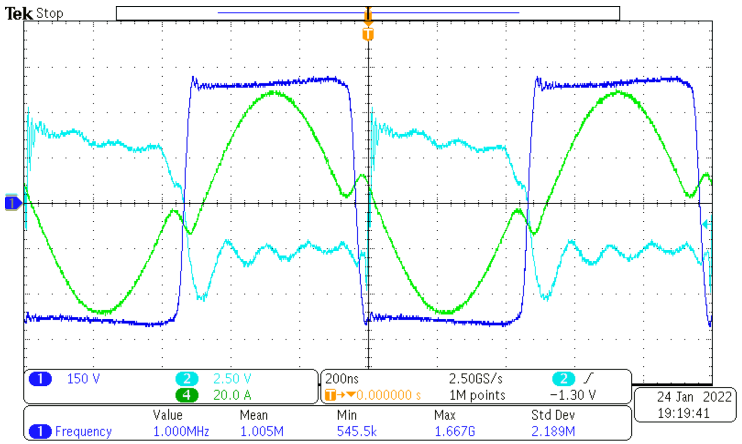


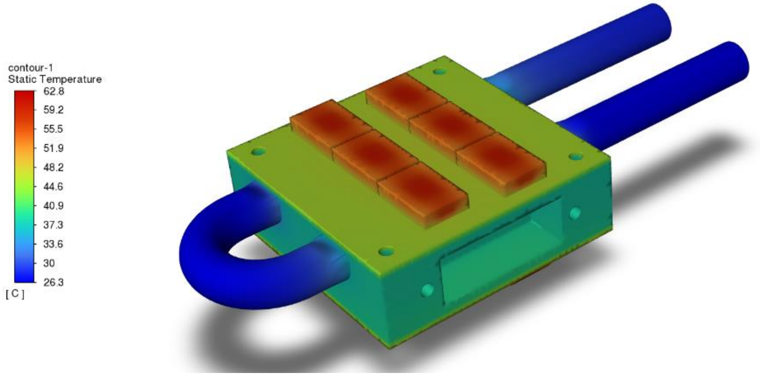


RICE GaN inverter 10kW@1MHz for auxiliary PSU

Tab.: Parameters of resonant circuit

Input voltage	U_{DC}	400 V
Rated power	P	10 kW
Switching frequency	f_{SW}	1 MHz
Resonant capacitor	C_R	50 nF
Resonant inductance	L_R	470 nH
Magnetic inductance	L_M	4 µH
First resonant frequency	f_{R1}	1038 kHz
Second resonant frequency	f_{R2}	336 kHz

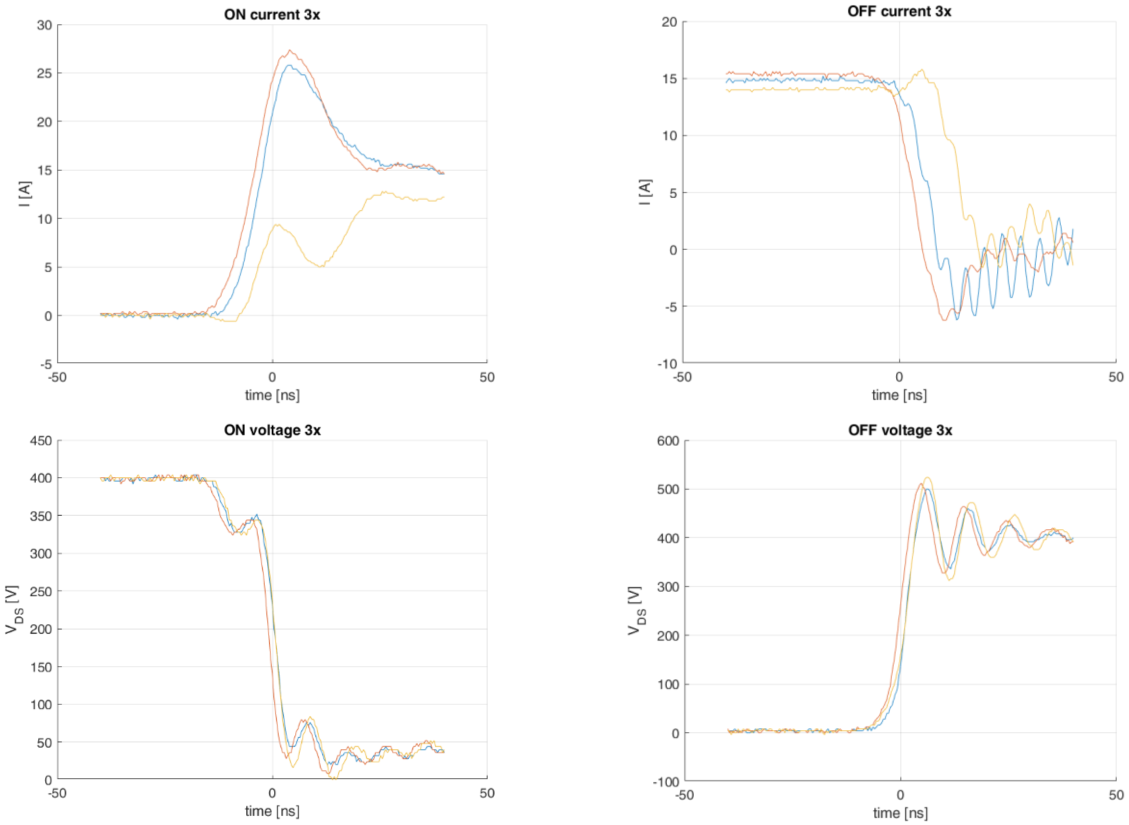




Thermal distribution of the inverter temperature on the heatsink – 3D simulation Ansys-Fluent

4-WP07-001&002: New Generation of Traction Converters

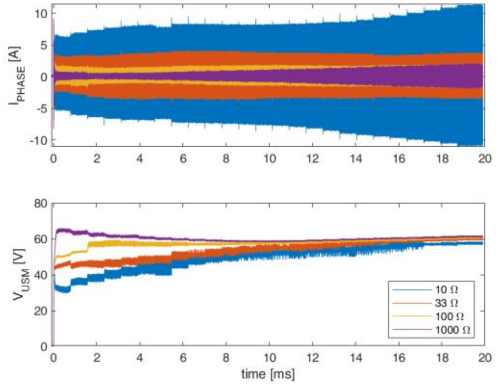
- *Testing of the LLC GaN power converter*
- *Current distribution through three parallel GaN devices*
- *Double pulse test at 400V and 45A*

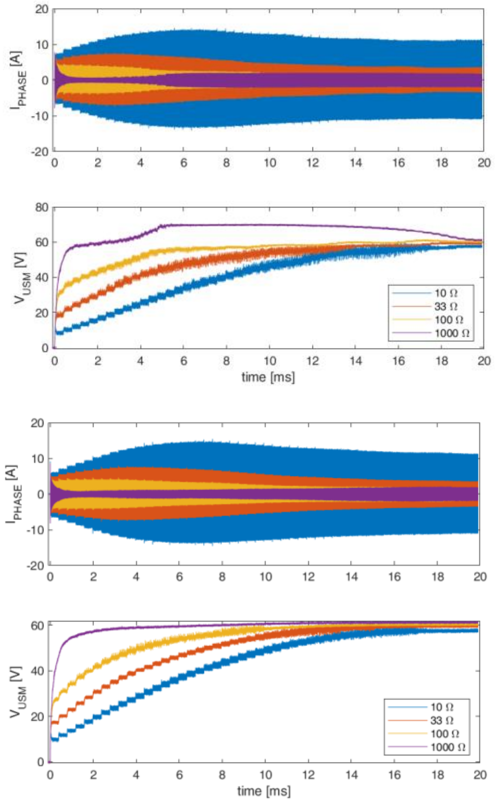


Starting strategy of the LLC topology

- *Elimination of the inrush current of the LLC topology*
- *Testing for the different load conditions at the start (10, 33, 100 and 1000Ω)*

1. *Start by changing the switching frequency*
2. *Start by changing PWM*
3. *Start by changing the phase shift*

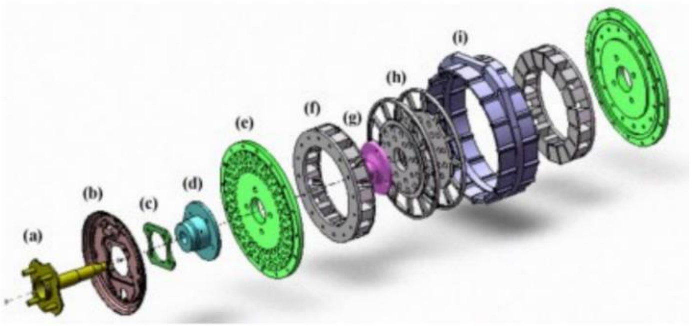




4-WP07-003: New conceptual solution of traction drives

Electric machines with reduced permanent magnet volume

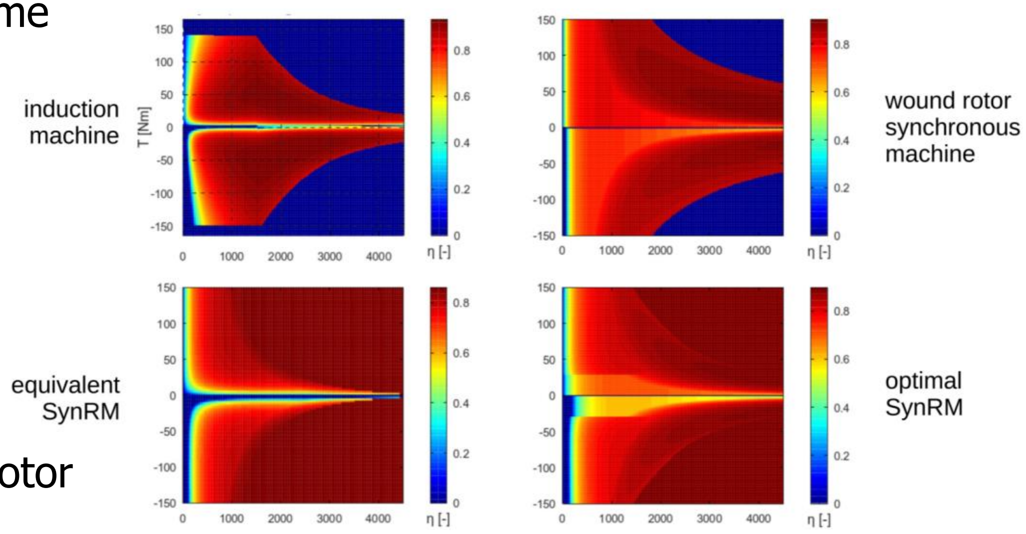
- Review
    - Wound Rotor Synchronous Machines, Switched Reluctance Machines, Permanent Magnet Assisted Synchronous Reluctance Machines, Induction Machines, Consequent Pole Machines, Axial Flux Permanent Magnet Machines



- Case study on determination of suitable permanent magnet free motor topology
    - Induction Machine, Salient Pole Wound Rotor Synchronous Machine, Segmented Synchronous Reluctance Machine with Supplemental Excitation

- To be done:
    - Comparative study between salient pole and cylindrical wound rotor synchronous machine
    - Study on machines with non-rare-earth permanent magnets
    - Electric motor prototyping
    - Testing

4-WP07-003: New conceptual solution of traction drives



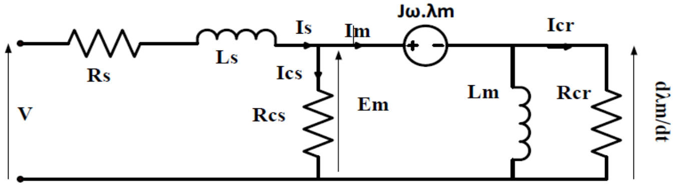
- Review on electric machines with reduced permanent magnet volume
  - Most used machines are wound rotor synchronous machines followed by induction machines
  - In some sources the iPMSM are distinguished as Permanent Assisted Synchronous Reluctance Machines
  - Other types of machines are in phase of academic studies
- Case study on determination of suitable permanent magnet free motor topology
  - The induction machine forms an average machine in terms of efficiency
  - The best efficiency provides wound rotor synchronous machine
  - The synchronous reluctance machines provide low efficiency without additional excitation, but their performance may be improved by additional excitation
  - In wide speed range the best performance is provided by wound rotor synchronous machine

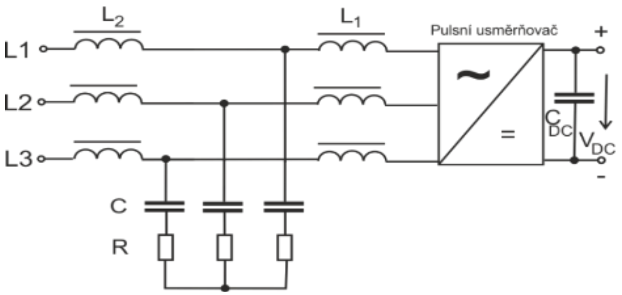
4-WP07-004: Analysis of electric vehicles drives variants from the points of risks of structural materials availability & Perspective converter structures for electric transport and their electric and EMC influencies

The task of the team

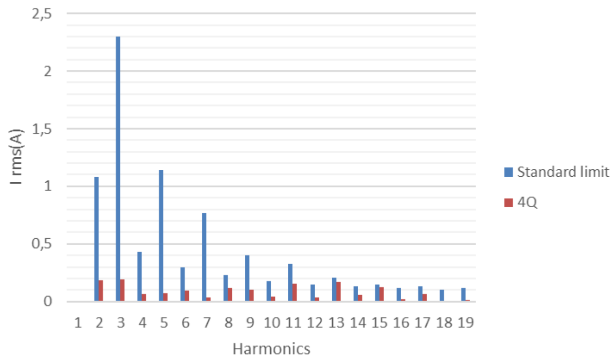
Analysis of electric vehicle drives variants from the point of risks of structural materials availability & Perspective converter structures for electric transport and their electric and EMC influences.

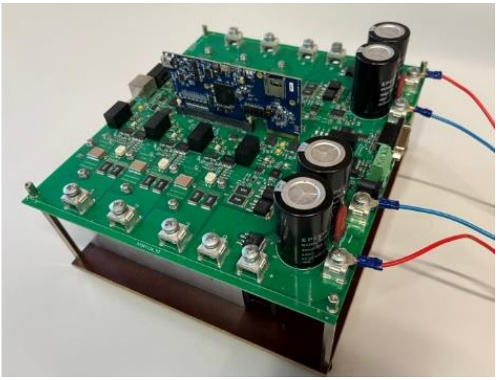
- Study of a functional sample of an electric drive with a synchronous reluctance motor with a power of 3 and 20 kW.
- Experimental verification of the propulsion system individual elements operating properties
- Electric drives eliminating the risk of rare materials applications.
- Focusing on synchronous reluctance machines.
- Investigation of basic theory of synchronous reluctance machines.
- Design of electronic inverter for synchronous reluctance motor.
- Preparation of functional sample of electronic inverter.



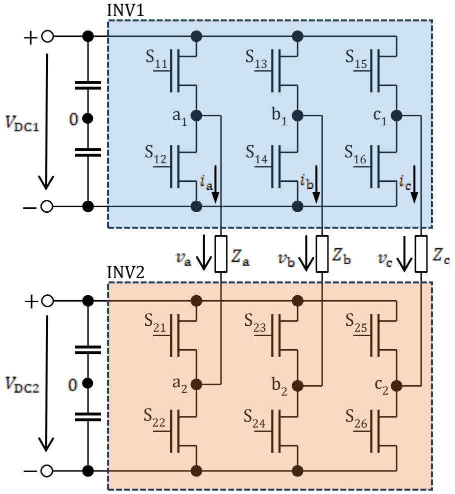


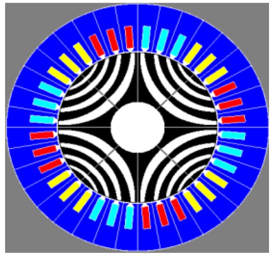
Converter structures for charging infrastructure and their EMC



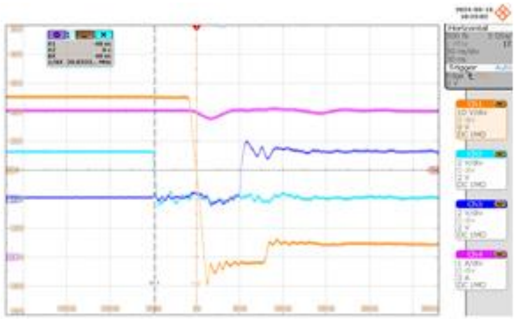


Prototype of GaN-based dual-inverter (DI) based on GaN transistors GS66516T from GaN Systems, with a switching frequency set to 50 kHz. In the DI configuration, the two DC links are supplied from two galvanically isolated laboratory DC sources, with each voltage set to 250 V.





Typical configuration of a modern 4-pole SynRM in which the rotor structure is adapted for a high saliency ratio.



Substitutional diagram of synchronous reluktance motor and turn-on transient for the load current 5 A. Ch1: Inverter line-to-zero voltage, Ch2: control signal for high-side switch, Ch3: control signal for low-side switch, Ch4: load current.

Thank you for your attention