



Three phase LLC Resonant Converter in Railway Applications: An Advanced Solution for Battery Charging

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Department of Electric Drives and Traction

Focus on the Development, Simulation and Design:

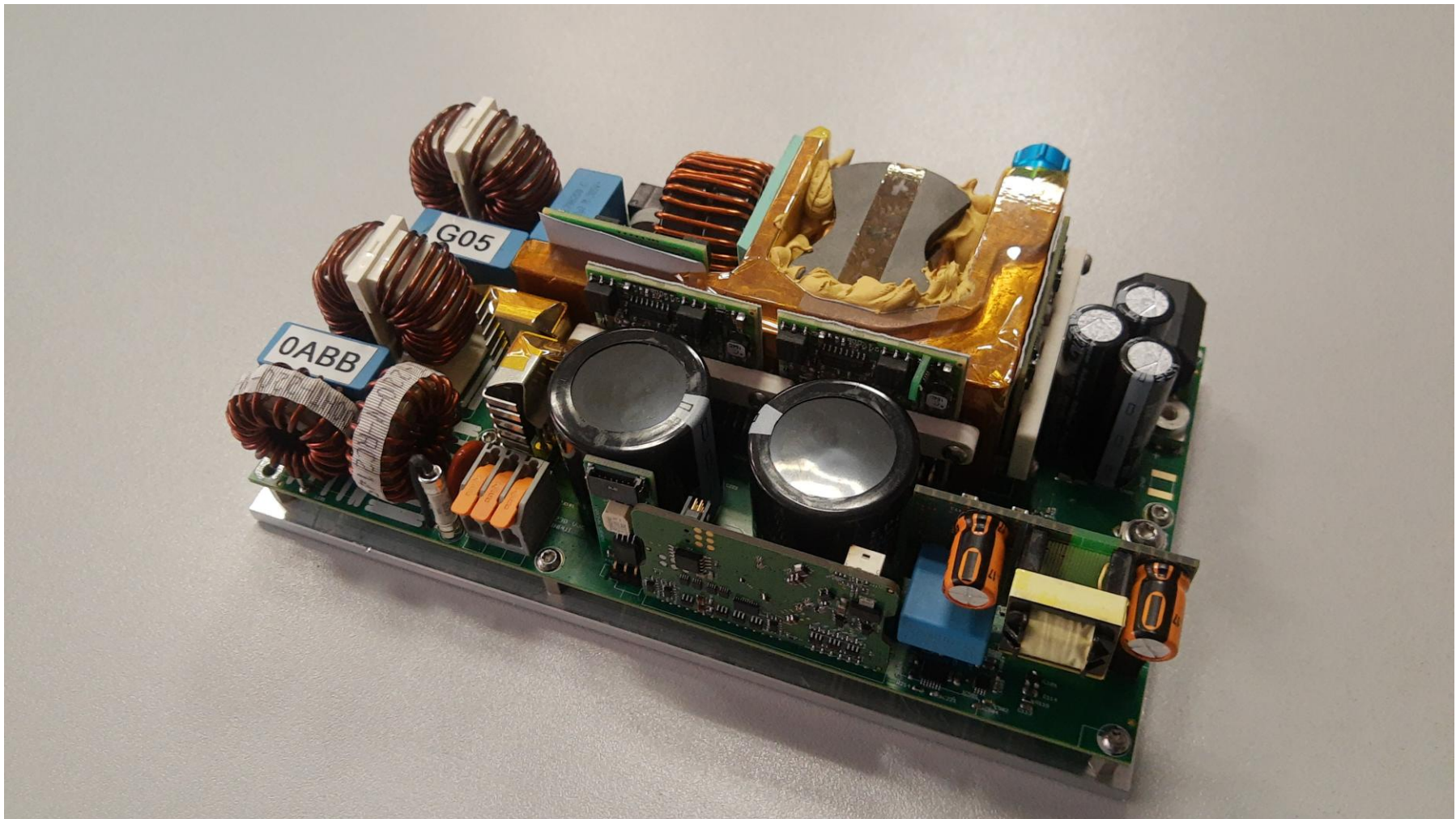
- Control system
- Power convertors
- Electrical Machines
- Electric Drives
- Design with WBG semiconductors



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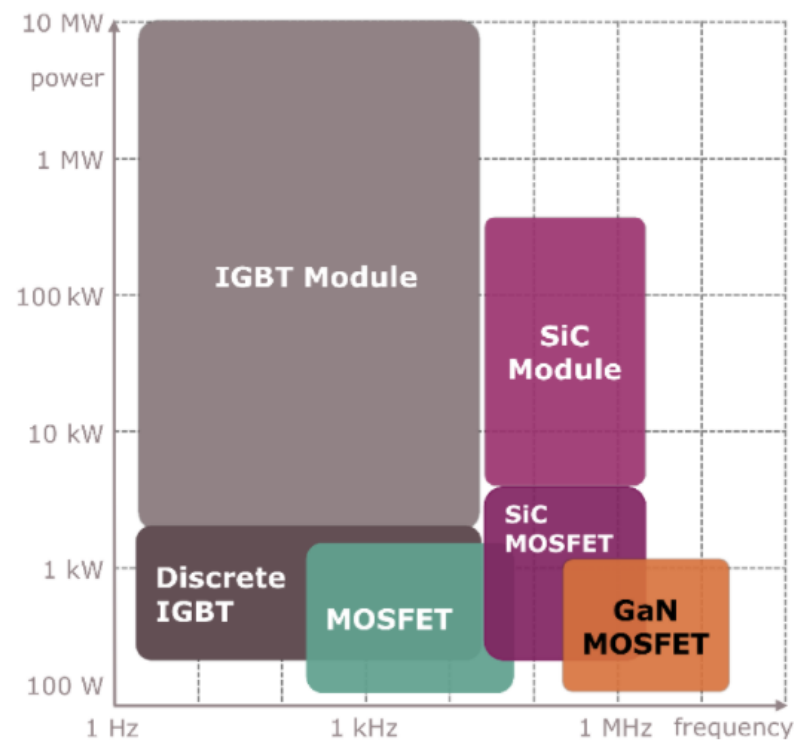
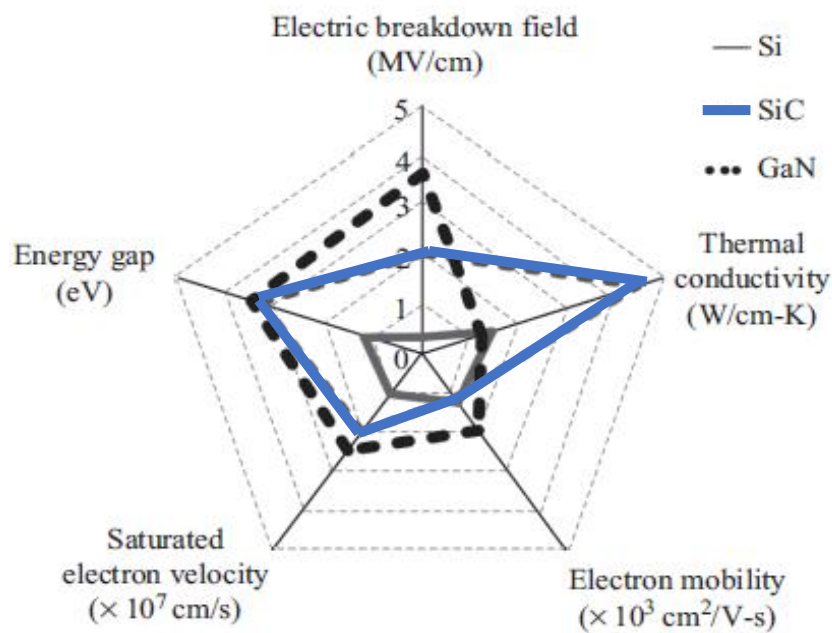
Previous Research - GaN Based Charger





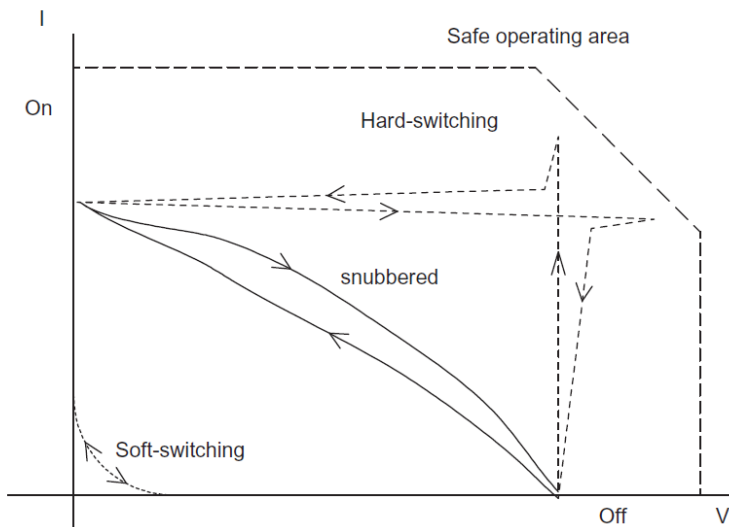
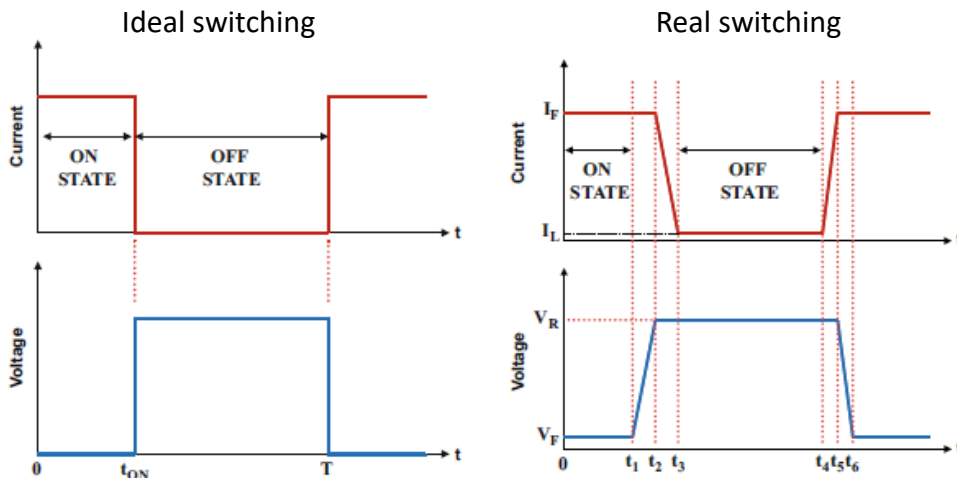
Introduction

Three type of material for Semiconductor power Switch:





Losses in power electronics systems



- Power semiconductor losses – Main Topic of study
 - Switching losses
 - Conduction losses
 - Reverse recovery losses (internal or external diode)
 - Gate driver losses



- Losses in magnetic elements
 - Core losses
 - Conduction losses

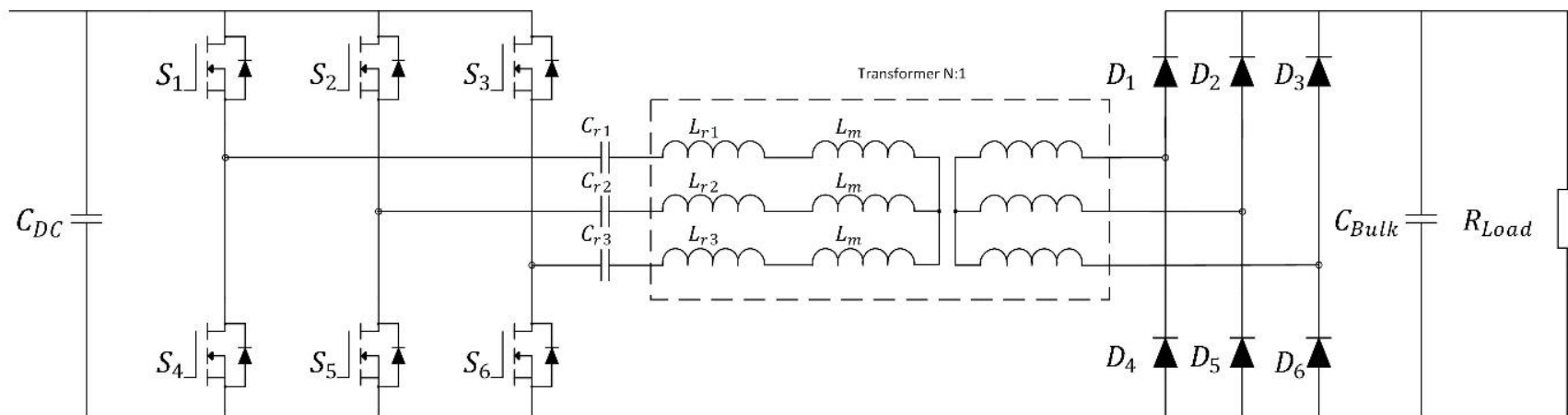


- Losses in capacitance
 - Series resistances
 - Leakage current
 - Equivalent series inductances





Introduction of the Topology



There are several key elements:

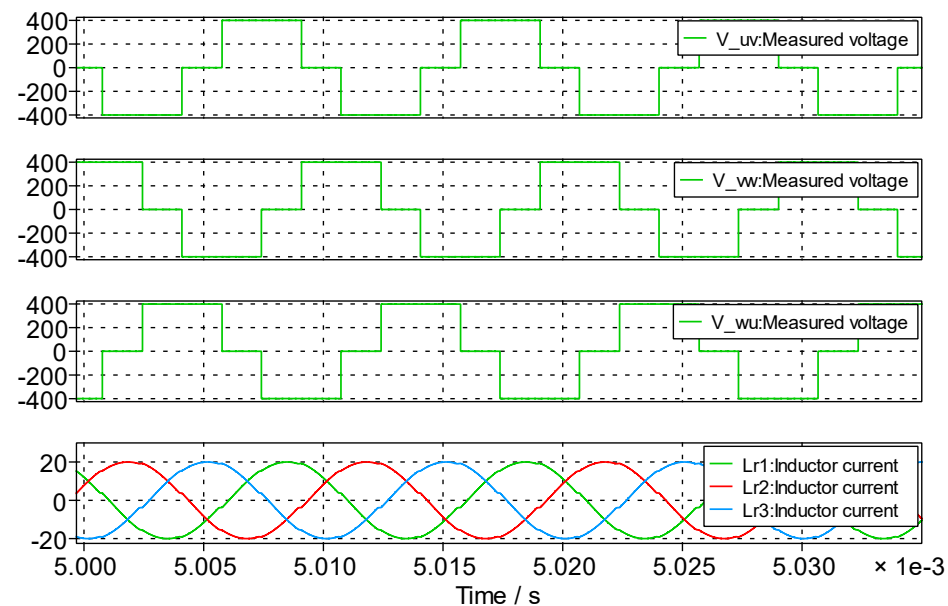
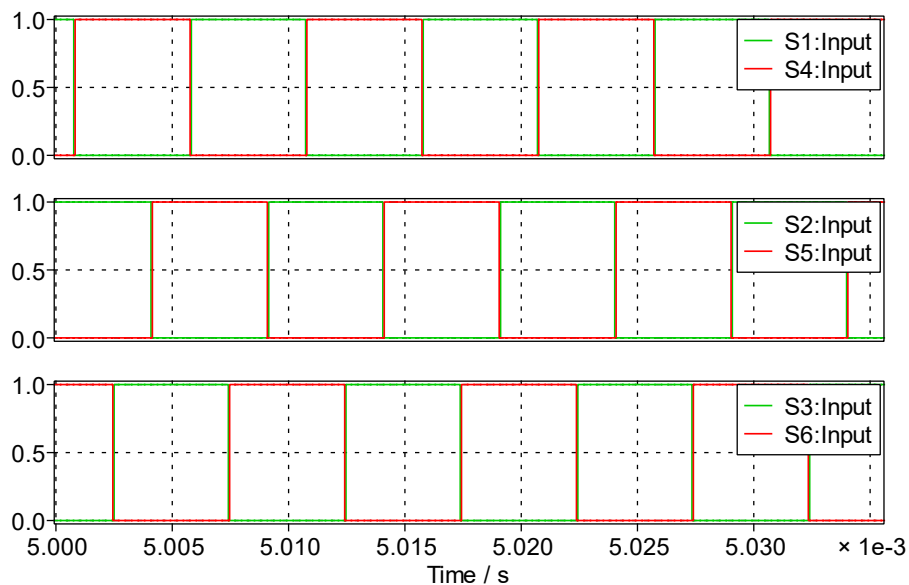
1. LLC resonant tank for soft switching operation
2. Three phase Transformer, low ripple on the secondary side, smaller C_{Bulk} on output side
3. Resonant inductor is a part of transformer





Modulation Strategy

Phase shift 120 degree between each phases





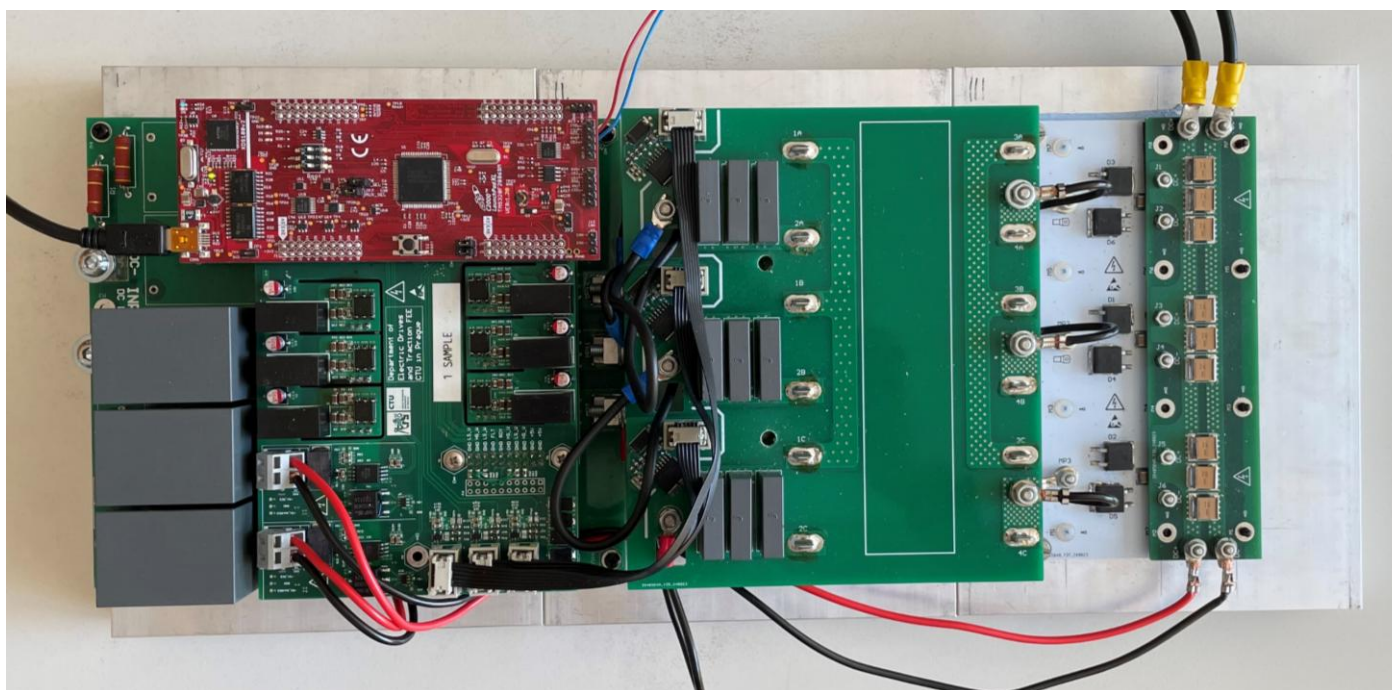
Converter Parameters

Cr	Resonant capacitors	117 nF
Lr	Resonant inductor	20 μ H
Lm	Magnetization inductance	115 μ H
TR	Transformer Turn Ration	14:15
Fsw nominal	Nominal switching frequency	100 kHz
Fsw range	Operational frequency range	75 – 150 kHz
Size	Length, wight, heigh	45 cm x 20 cm x 10 cm
Control by	Launch Pad	TMS320F28069 - Ti



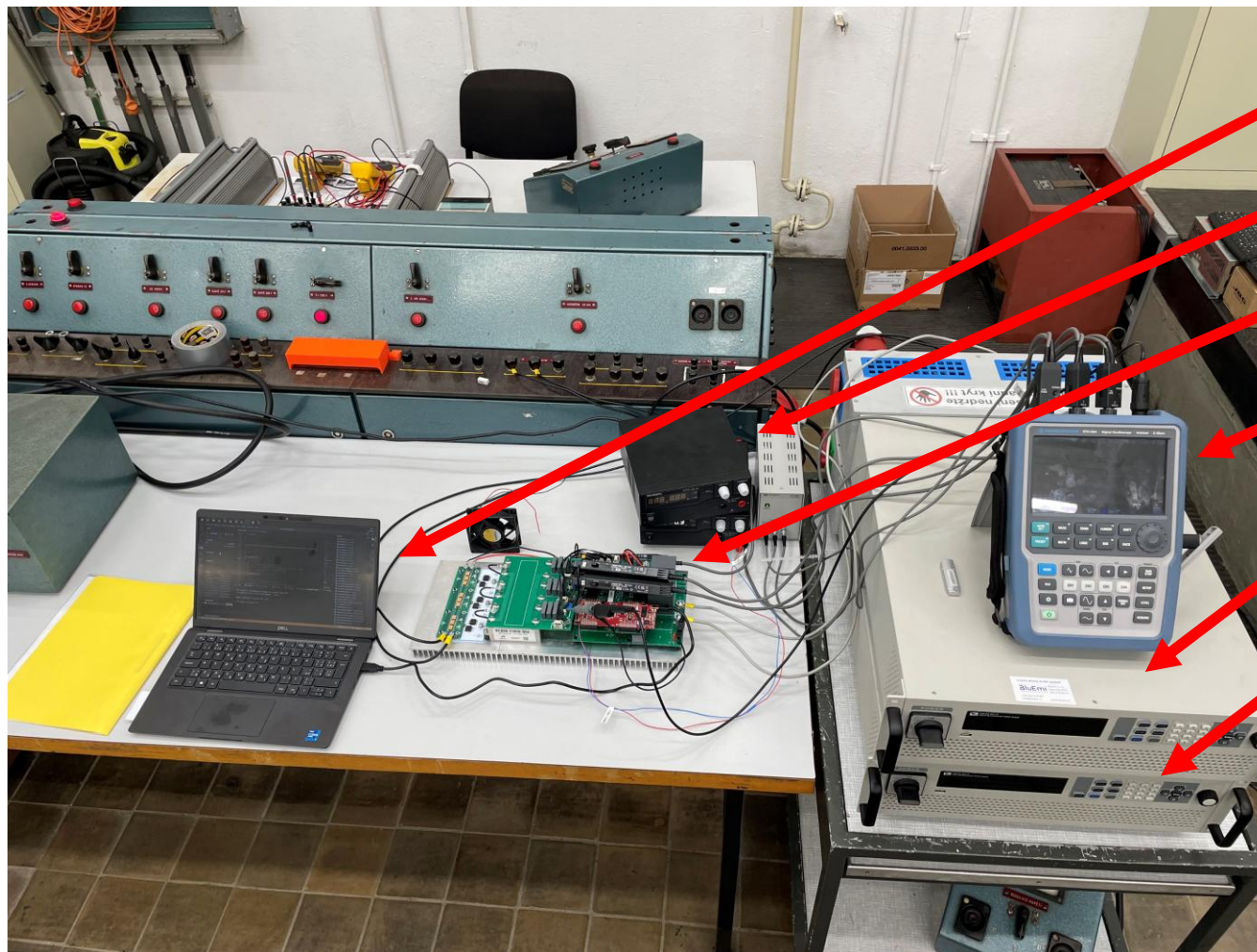


Converter Top View





Measurement Setup



Control PC

Aux. Power Supply

Power Converter

Oscilloscope

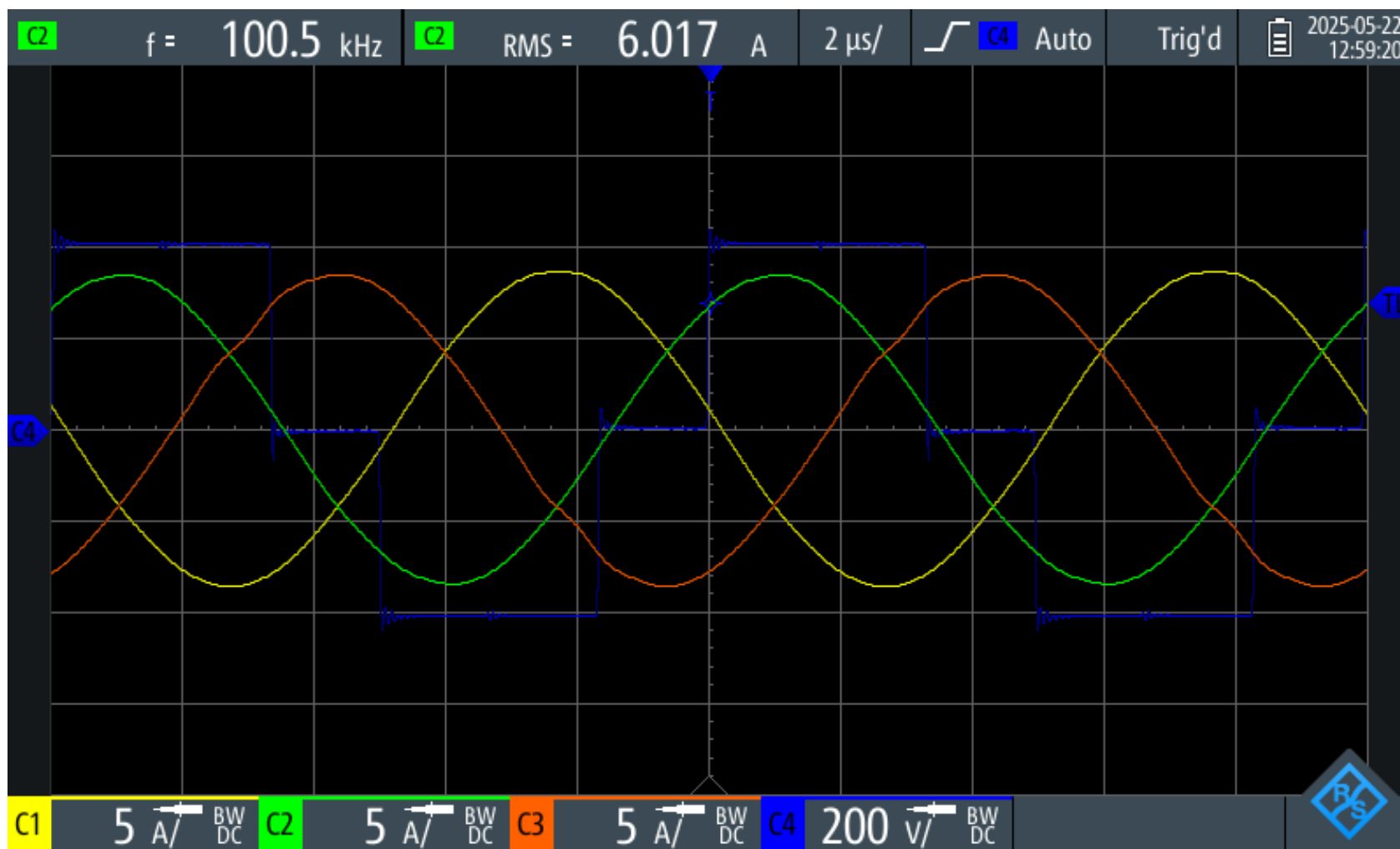
Power Supply

Load





Output Waveforms



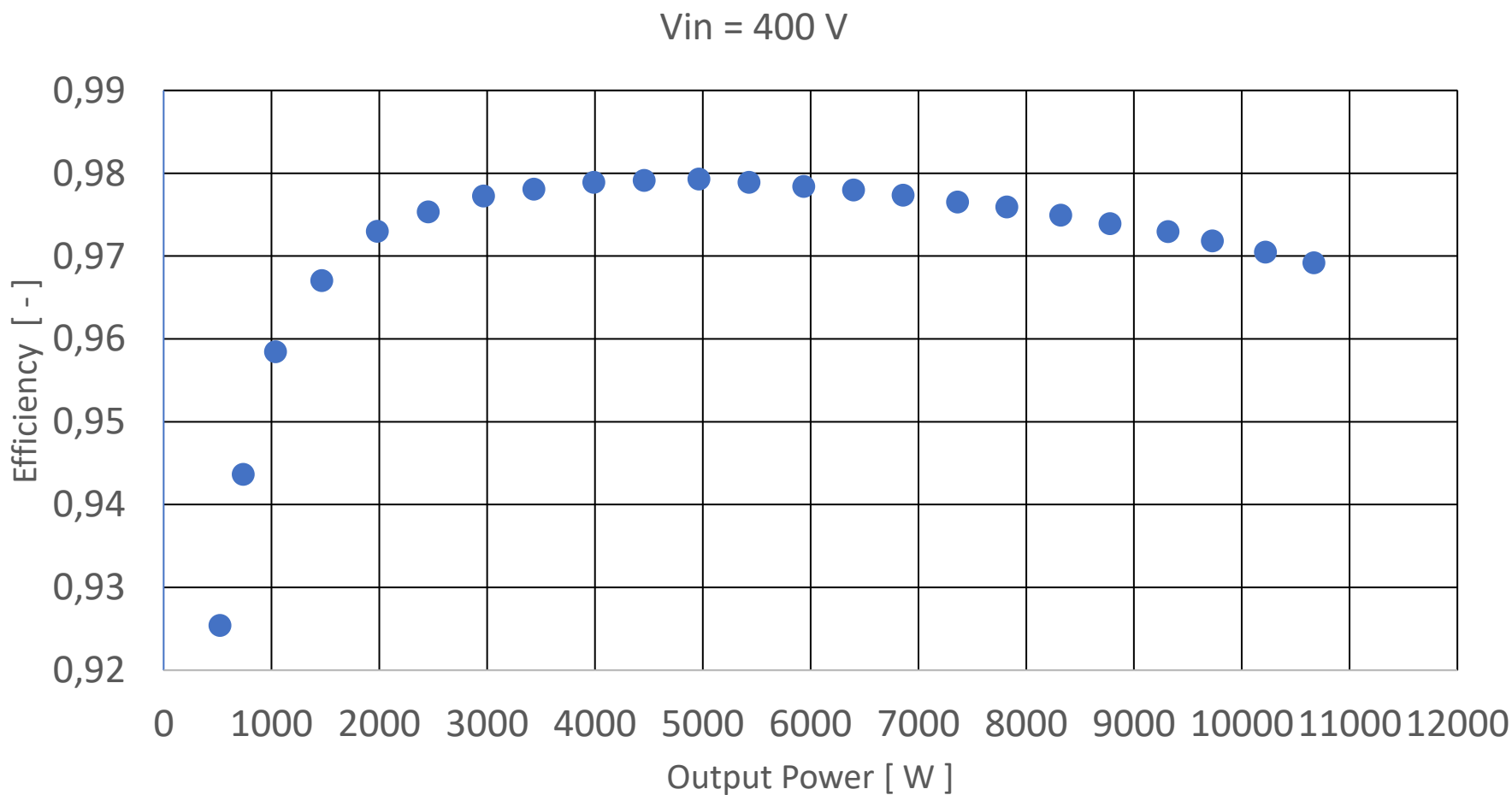
Ch 1 – Current Phase U
Ch 2 – Current Phase V

Ch3 – Current Phase W
Ch4 – Voltage (U,W)





Measured Efficiency

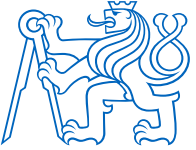




Conclusion and Future Work

- A Three-phase LLC resonant converter was designed and tested
- Achieved power about 10.5 kW with peak efficiency of 97.7 %
- High power density reached
- Modulation design
- Reduce size of passive component with 100 kHz operational frequency
- Future work – current balancing and topology reconfiguration





Thank you for your attention

Q/A



