Design and Control of DC-DC Converter for Ultrafast Battery Charger for Electrical Vehicles

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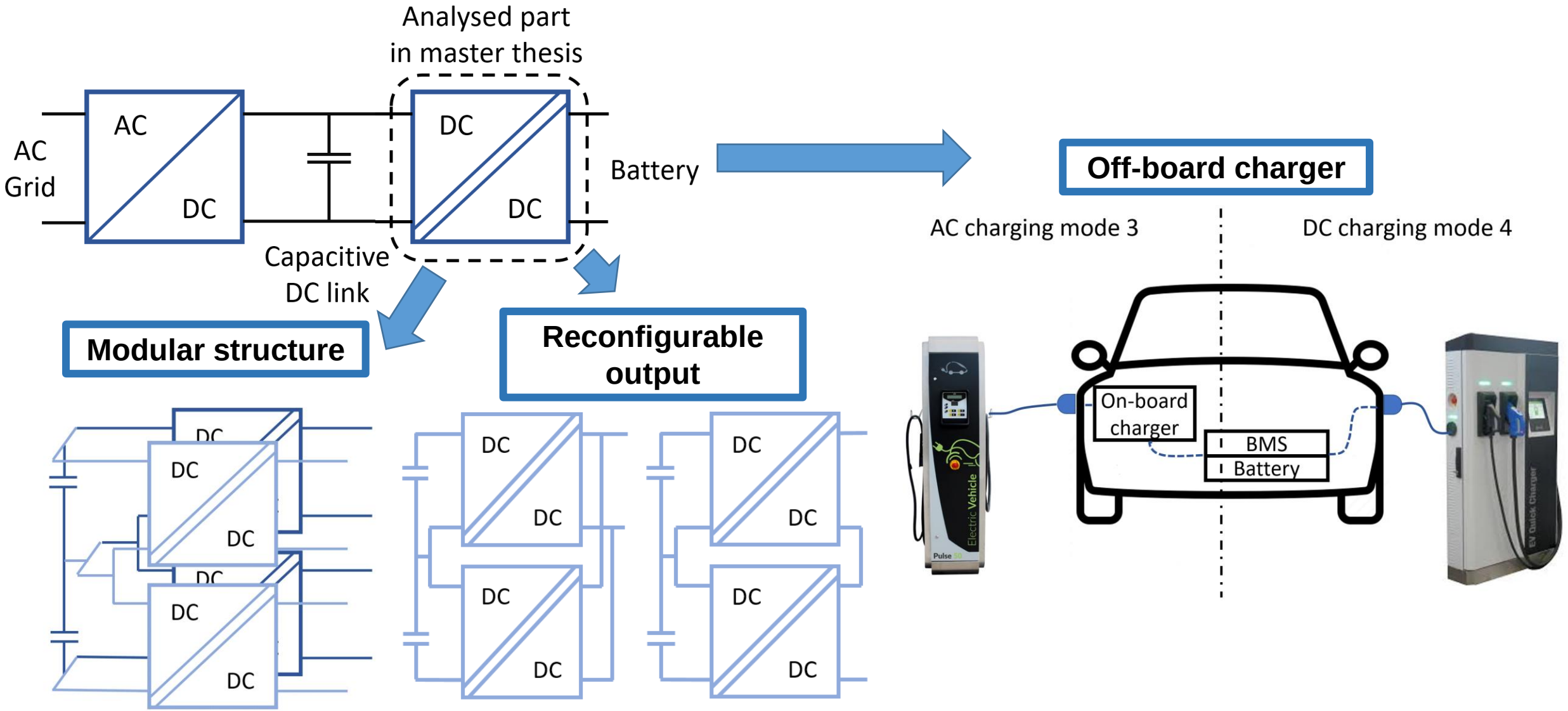
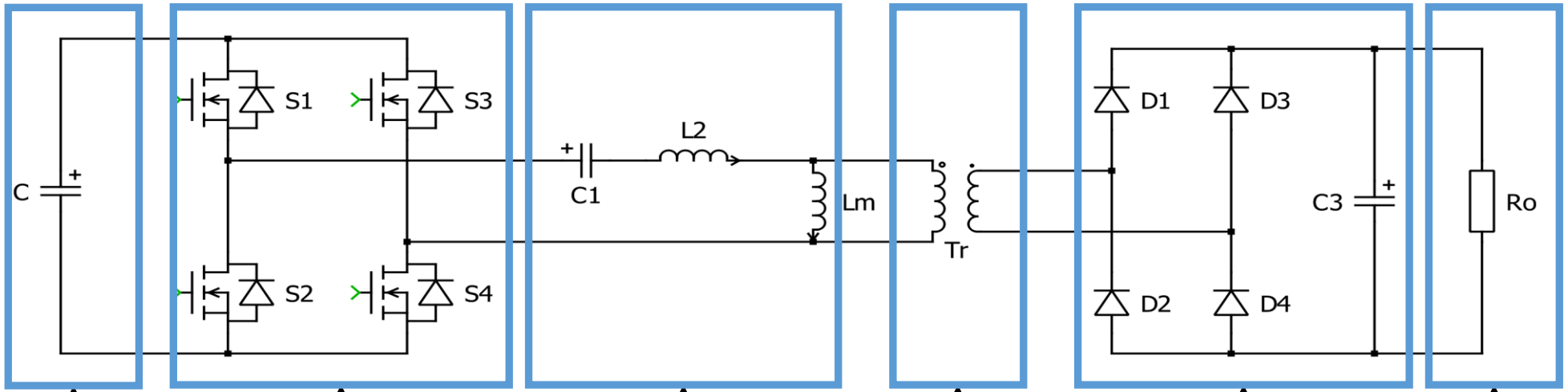
Outline

- Charger Structure
- LLC Hardware Design Method
- LLC Control Design
- Validation through Simulation
- Conclusion

Structure of the Charger



LLC Schematic



DC link

Controlled switch network

Resonant tank

Transformer

Uncontrolled rectifier and output capacitor

Load (battery)

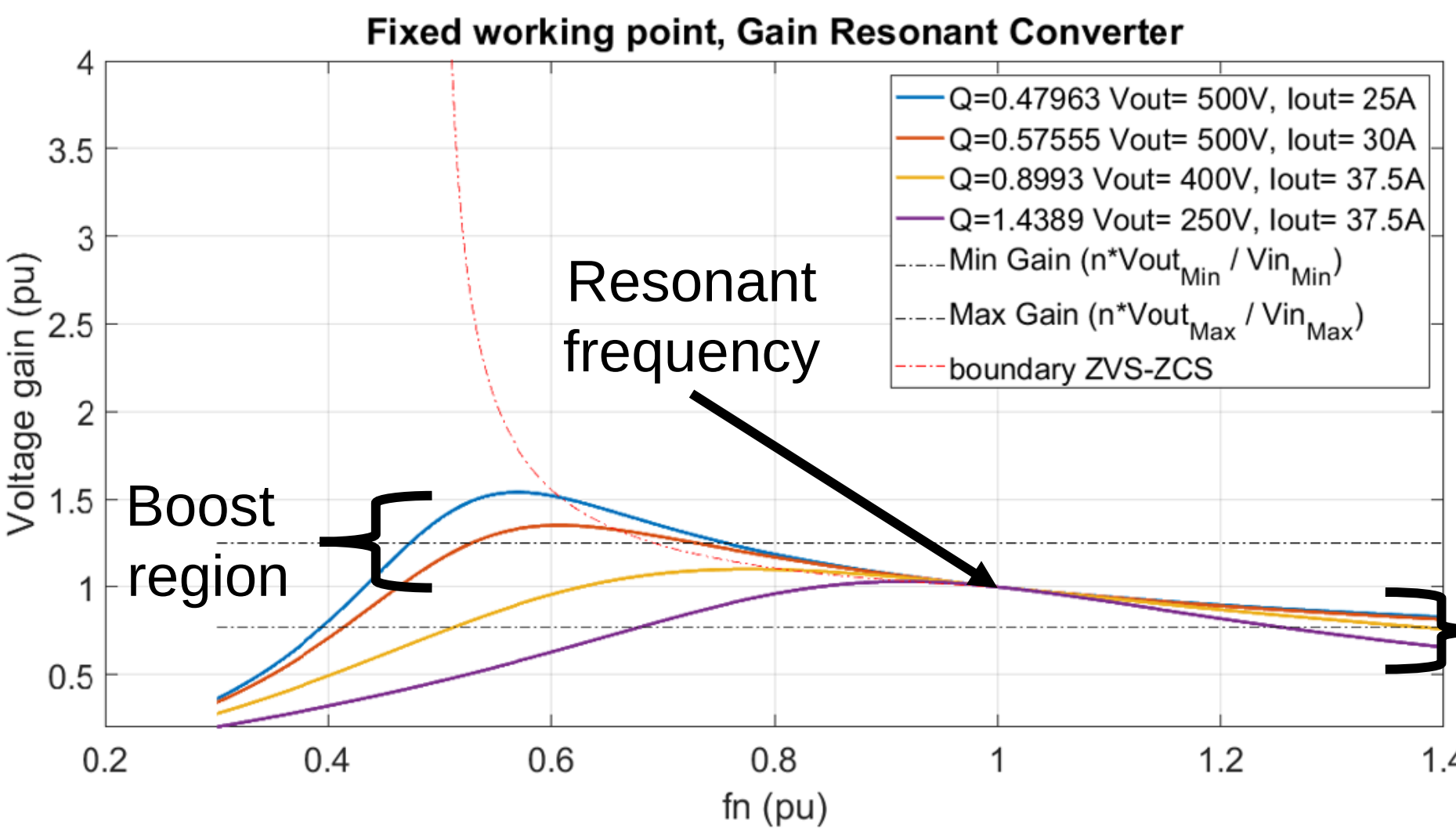
It generates a square wave voltage (duty cycle equal to 0,5)

It is a filter and has variable impedance value

It provides the galvanic insulation

It rectifies and filters the current delivered to the battery

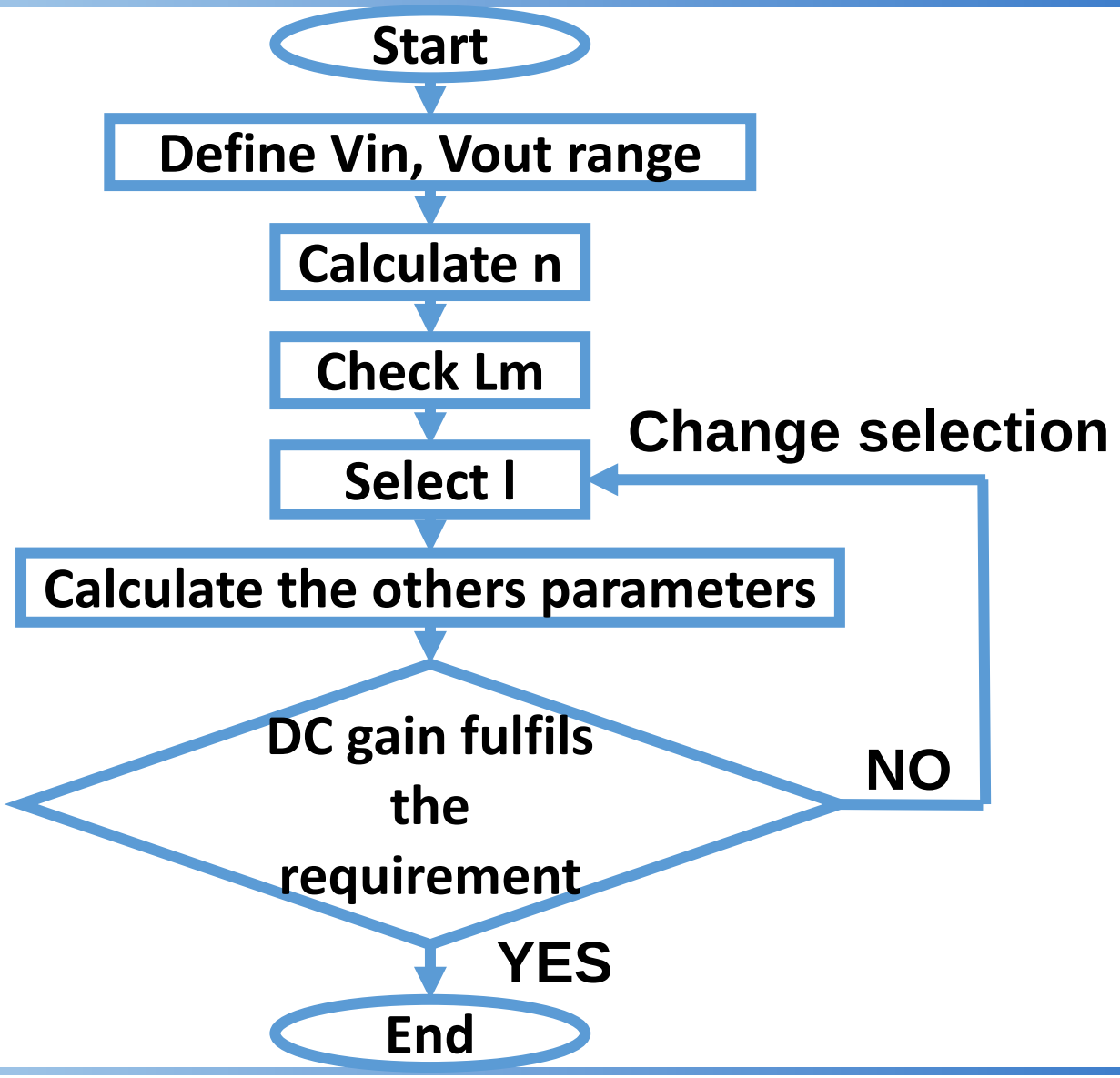
LLC Resonant Tank Impedance

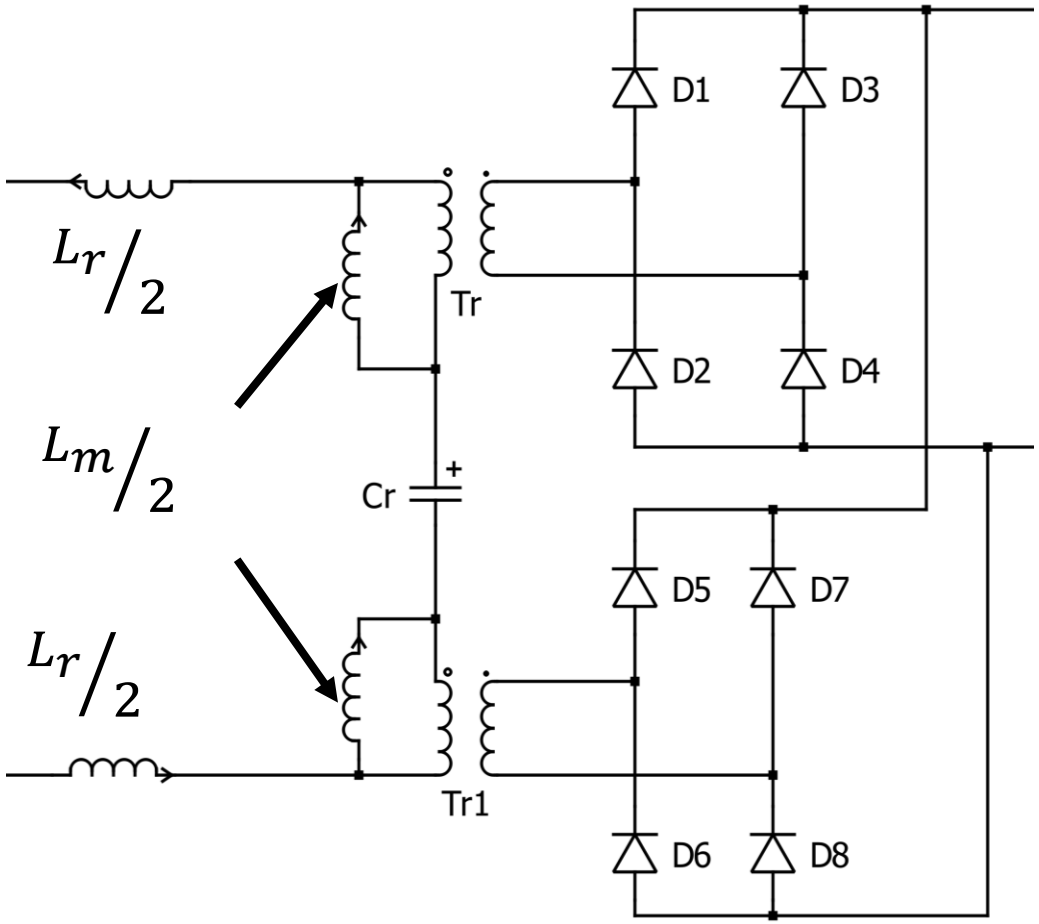


Switching frequency regulation

Output voltage regulation

LLC Design Method

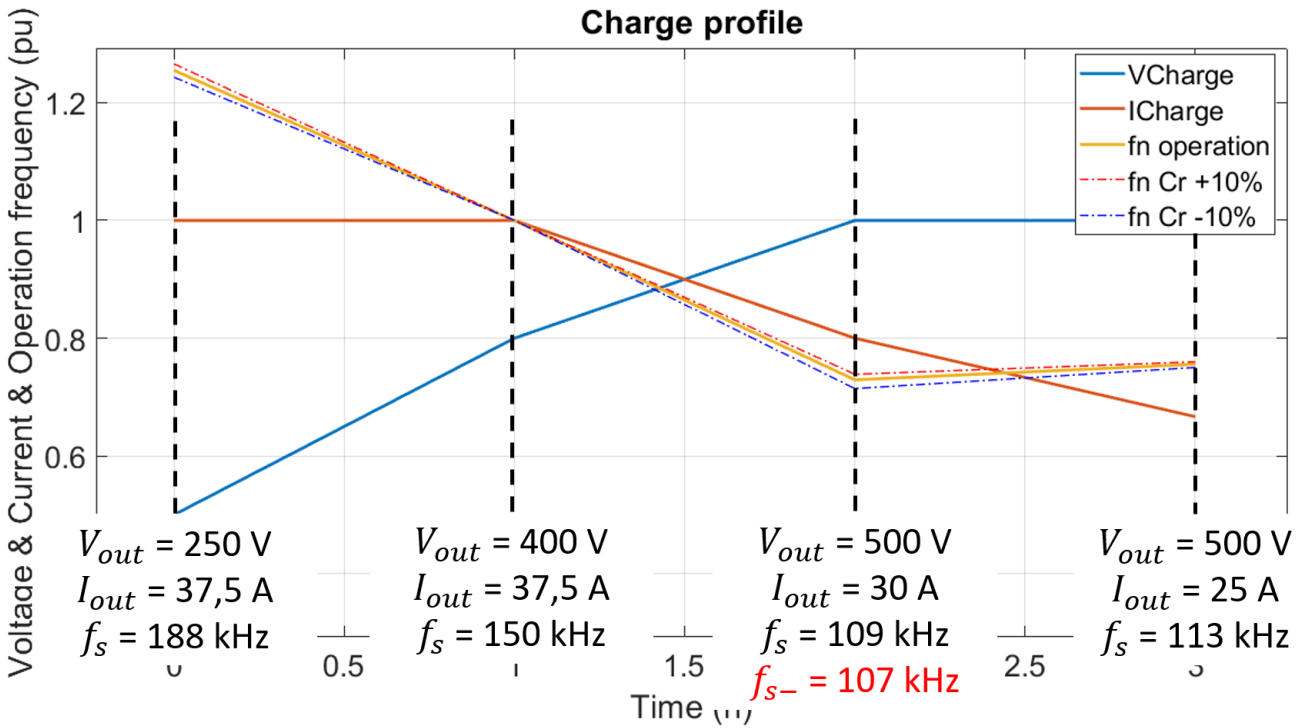




LLC Design – Output Data

Optimized parameters value

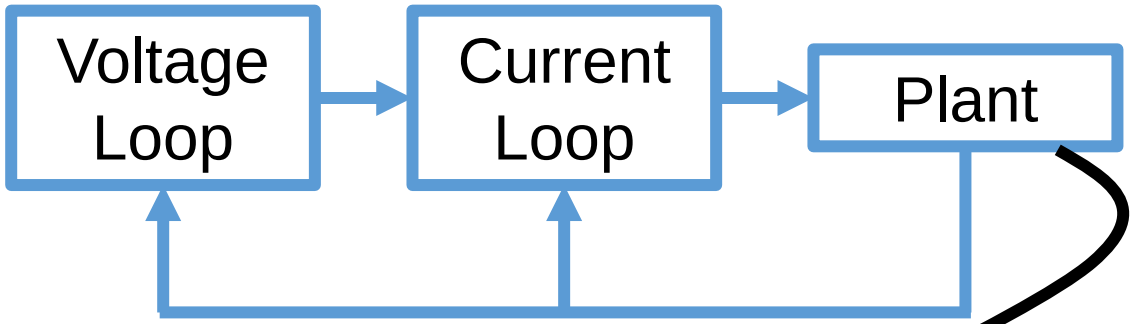
	Value	Number of components
$L_m\ [\mu H]$	12,5	2
$L_r\ [\mu H]$	4,125	2
$C_r\ [nF]$	136,46	1

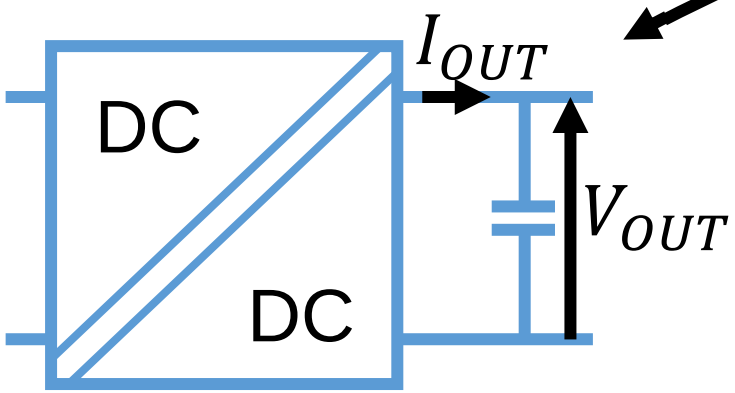


The switching frequency range is evaluated supposing a charge profile

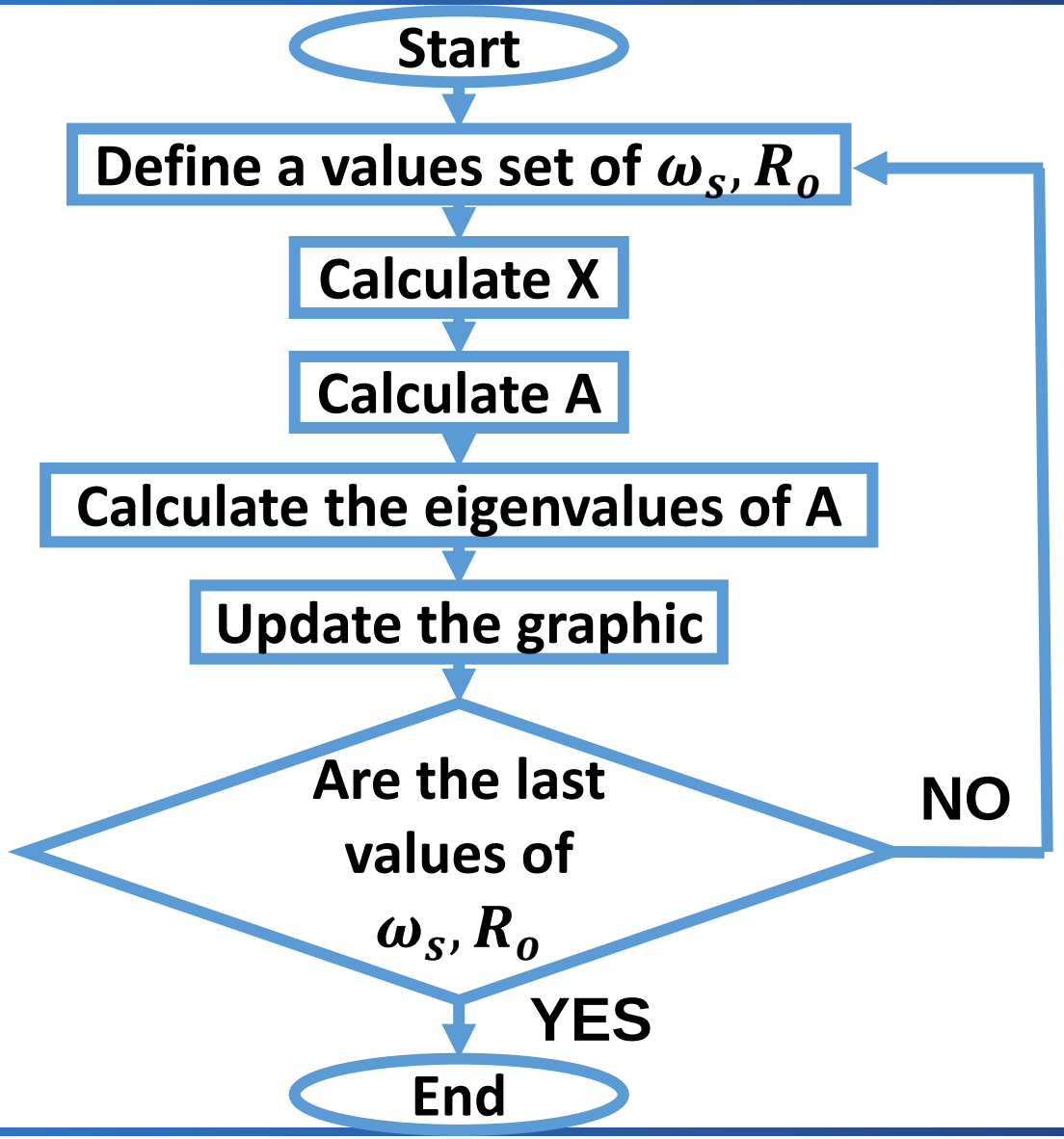
LLC Control Design

Dual-loop Control

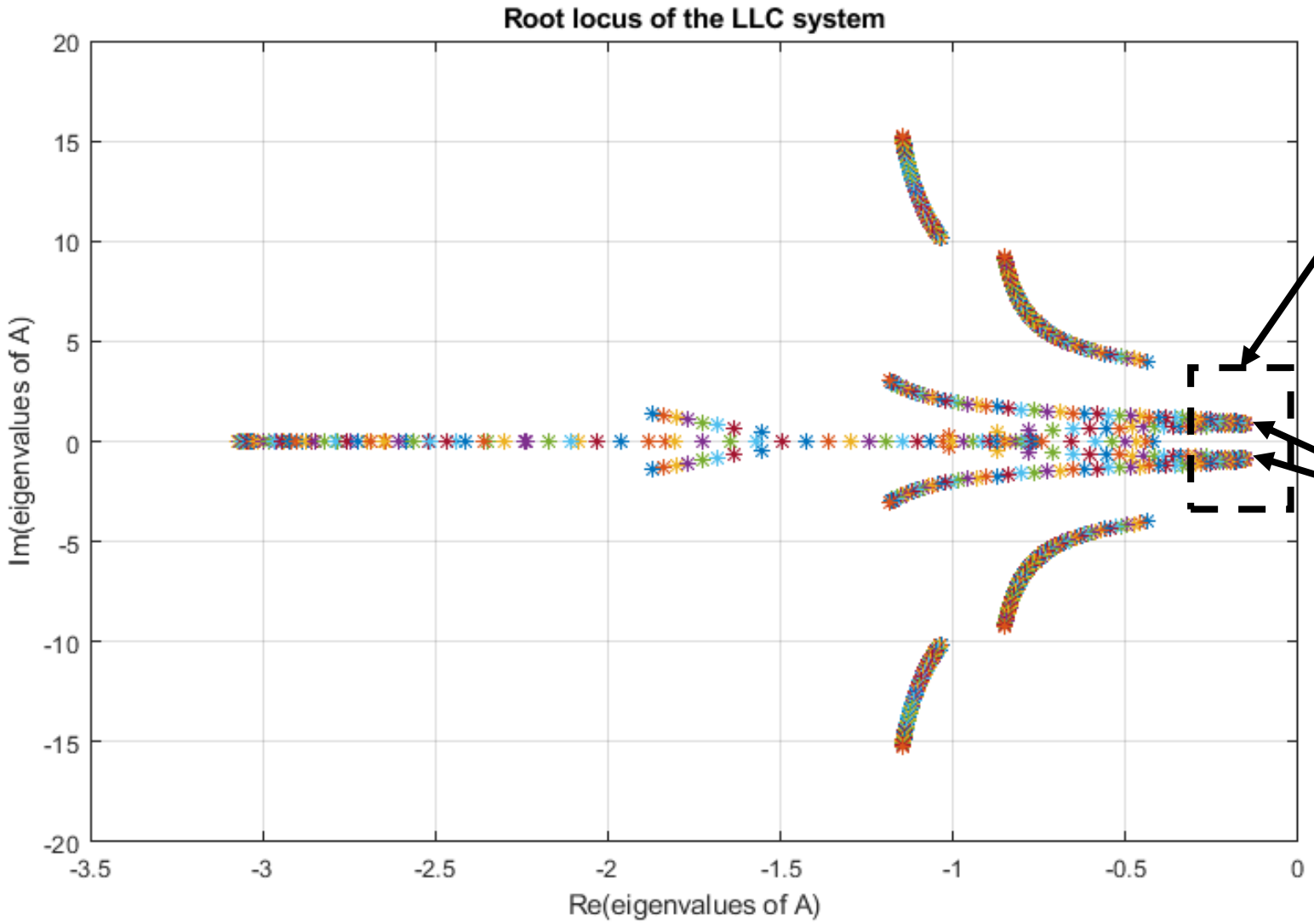




The 7^{th} order LLC system is studied for the control design



LLC Control Design – Root Locus Evaluation



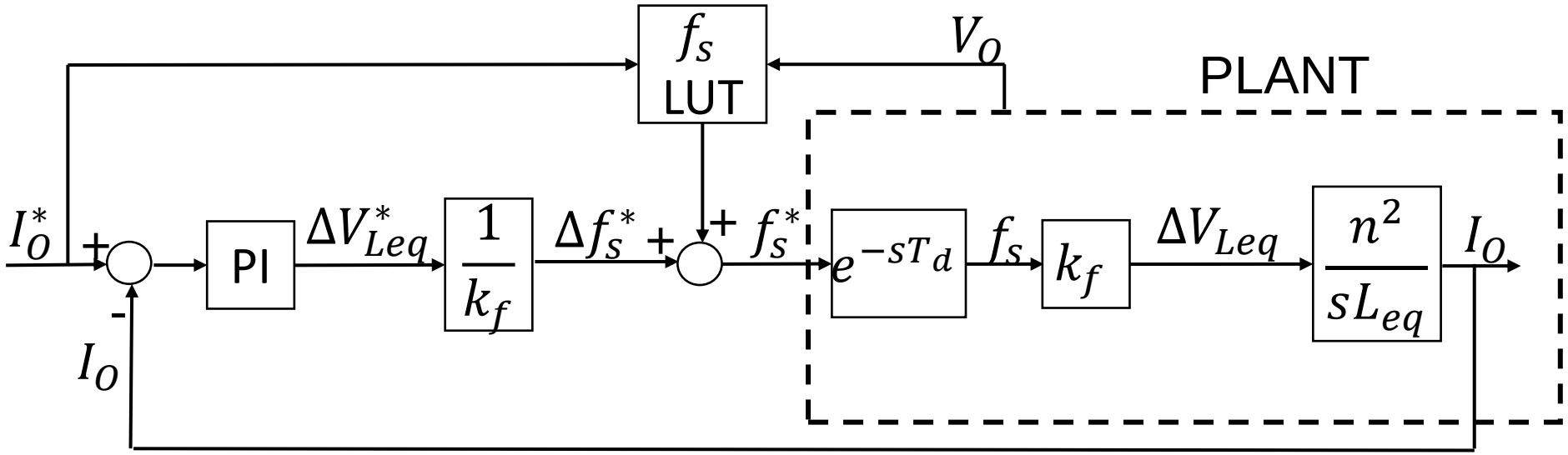
Two dominant poles can be recognized

lower damping condition

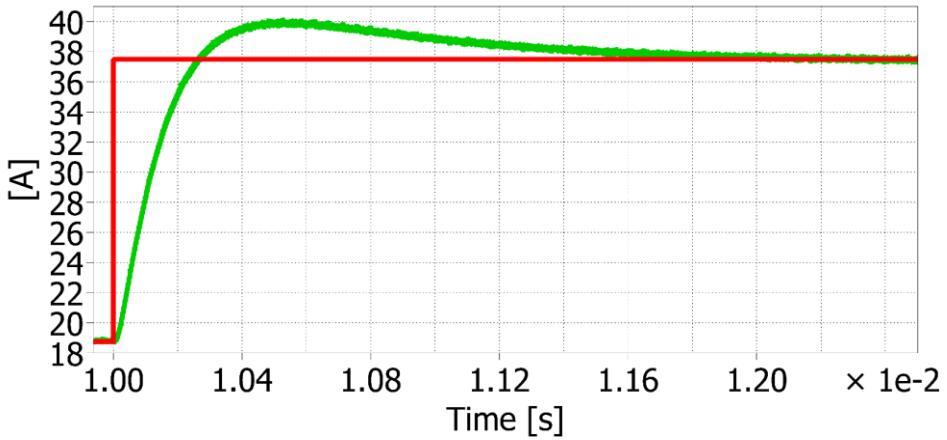
Resonant frequency

It is the control worst case operating point

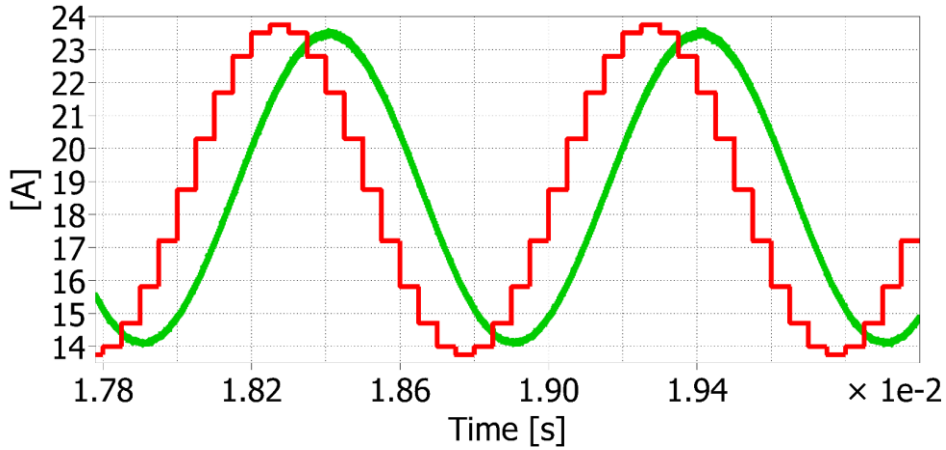
LLC Control Design – Current Loop



Step variation of the reference current

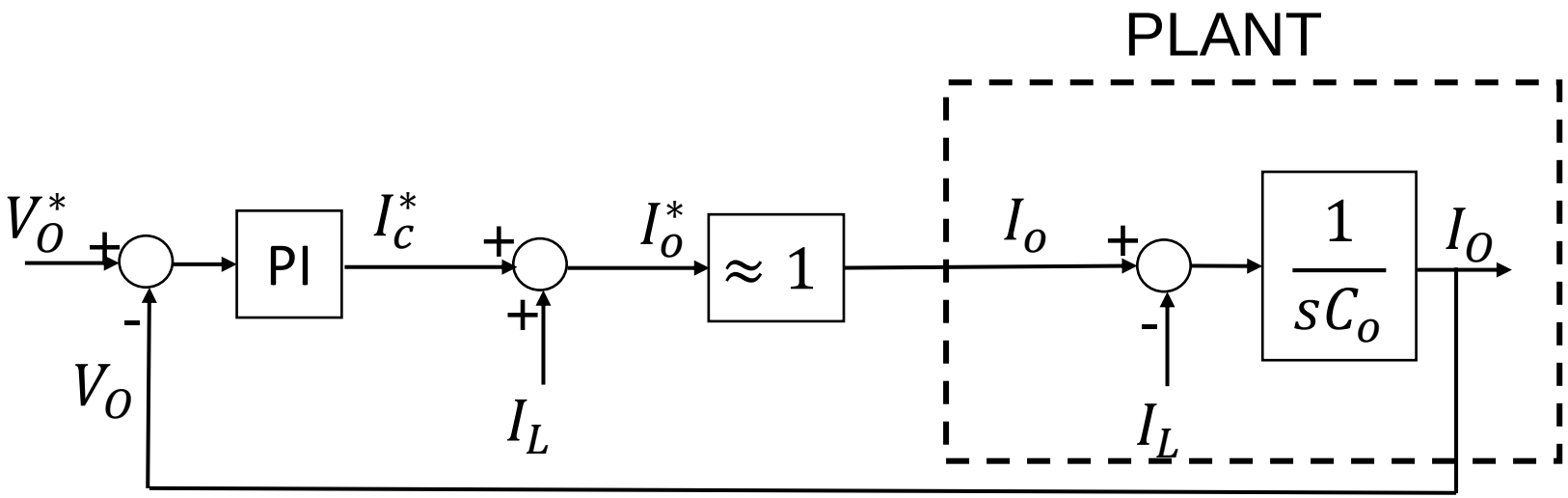


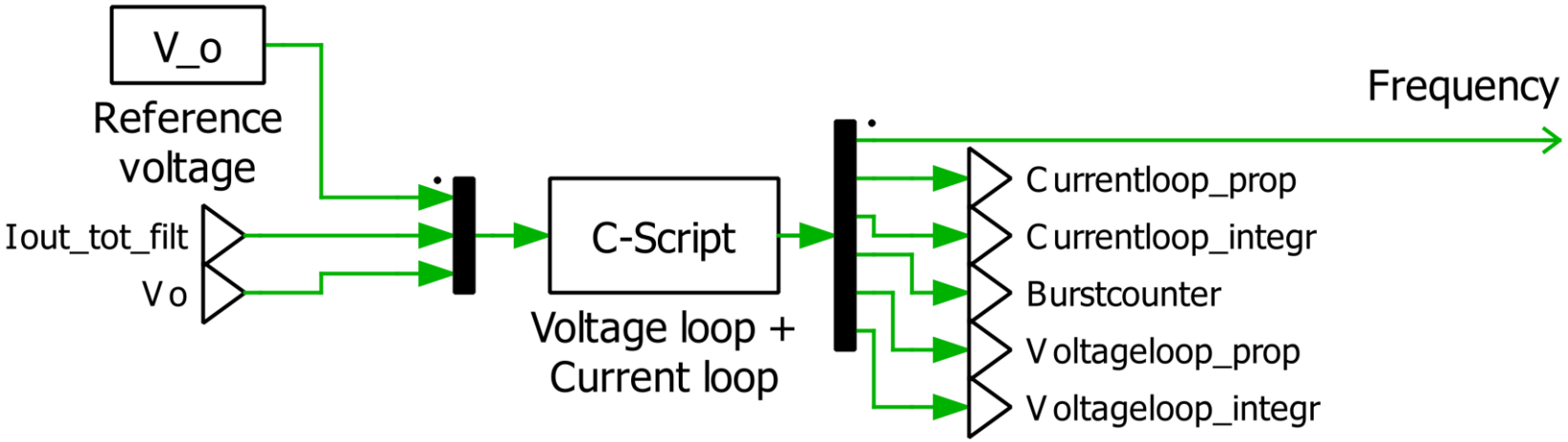
Sinusoidal variation of the reference current



LLC Control Design – Voltage Loop

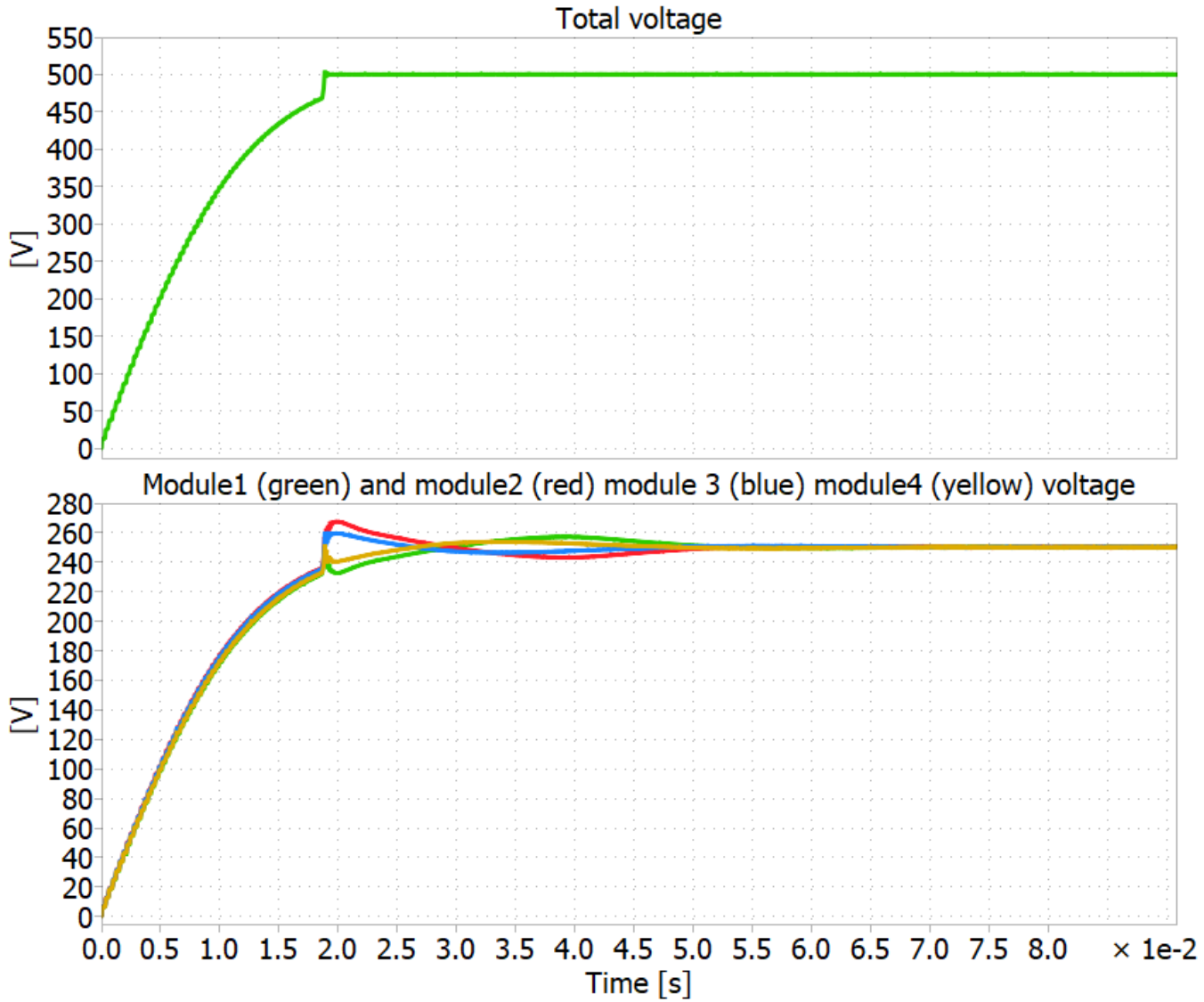
The current loop dynamics can be neglected if the bandwidth of the voltage loop is far enough





Implementation of the dual-loop control with a C-script

Series Configuration – PLECS Simulation

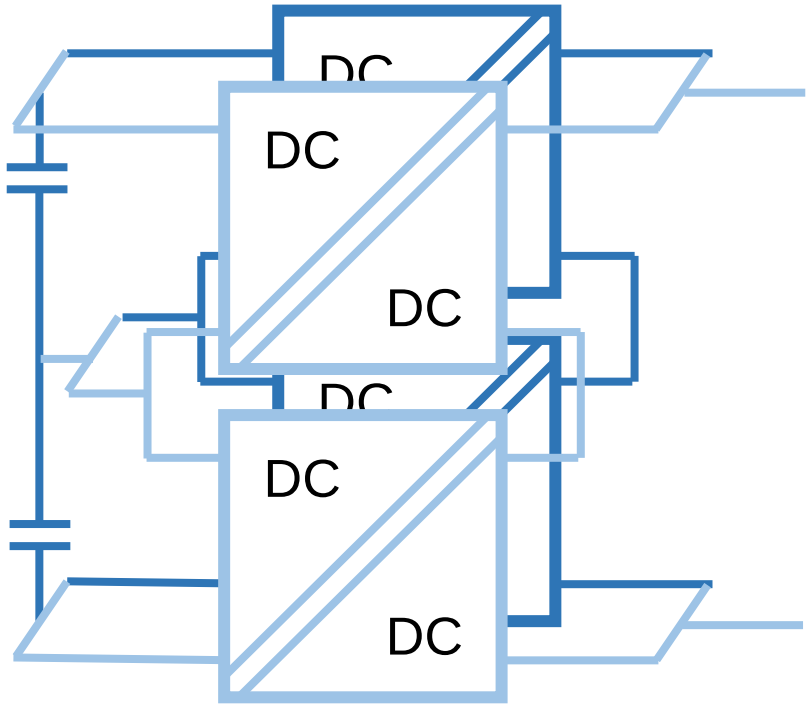


Converter output voltage range:

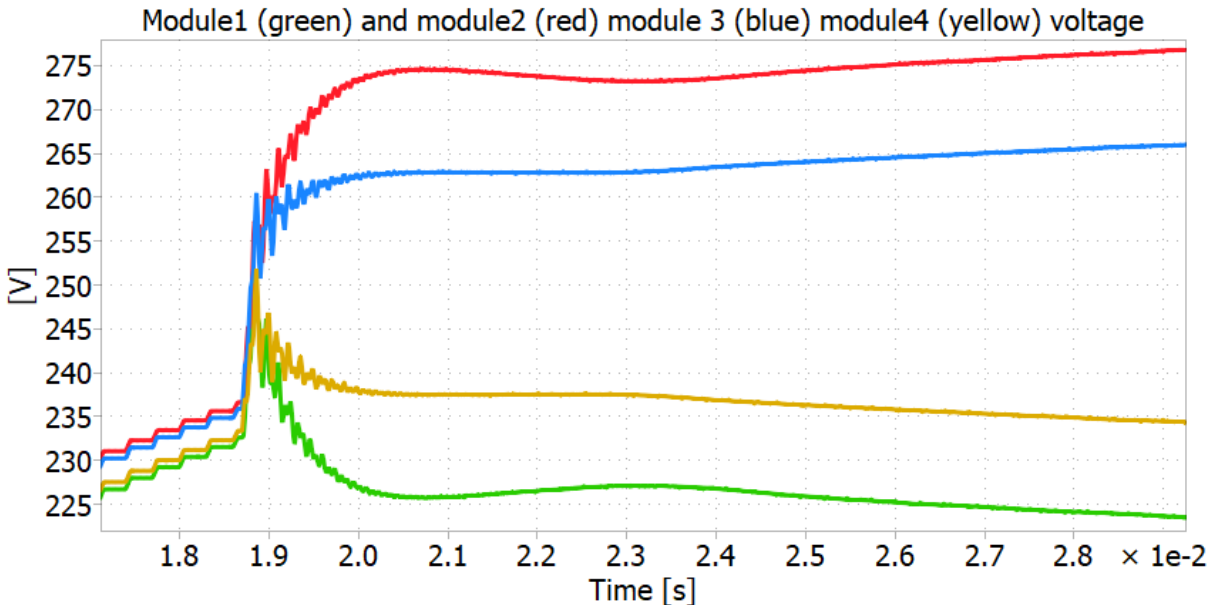
$$500 \div 1000\ V$$

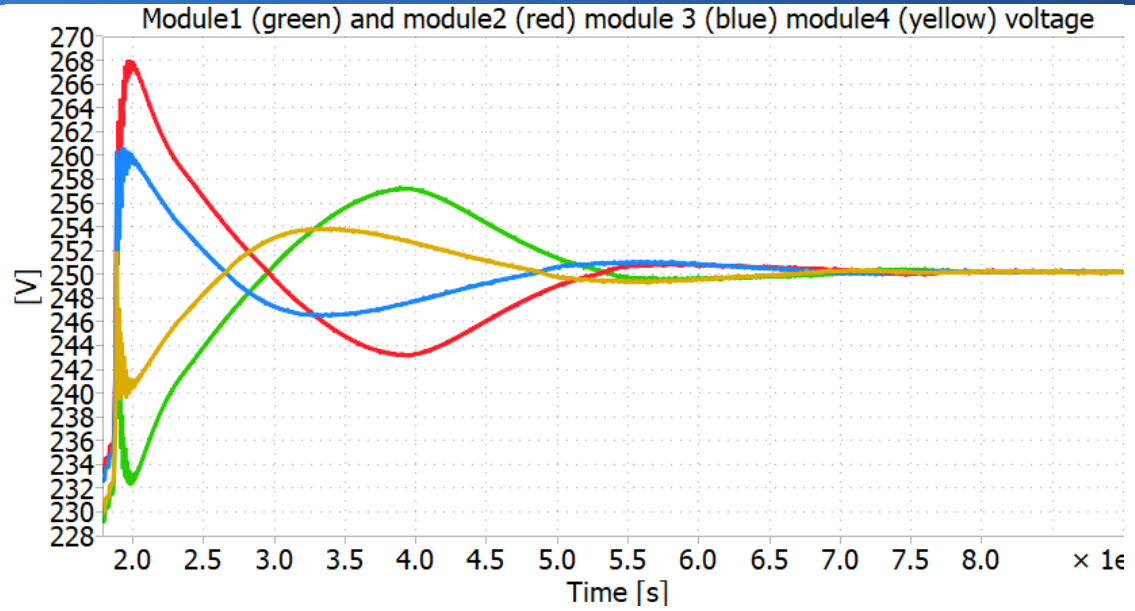
Converter maximum output current:

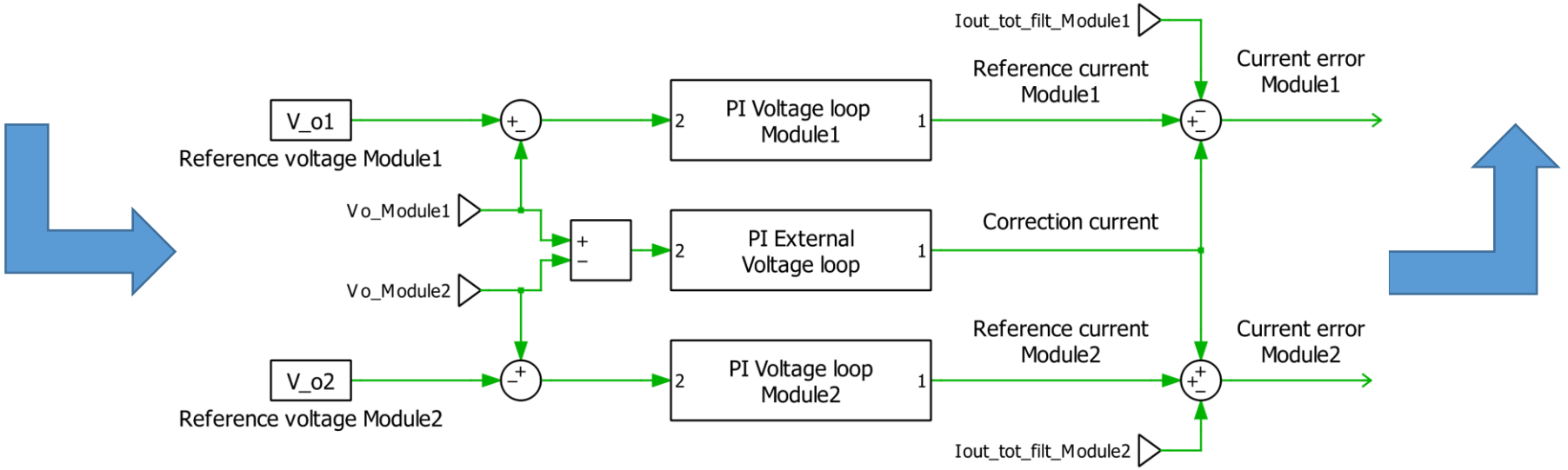
$$75\ A$$



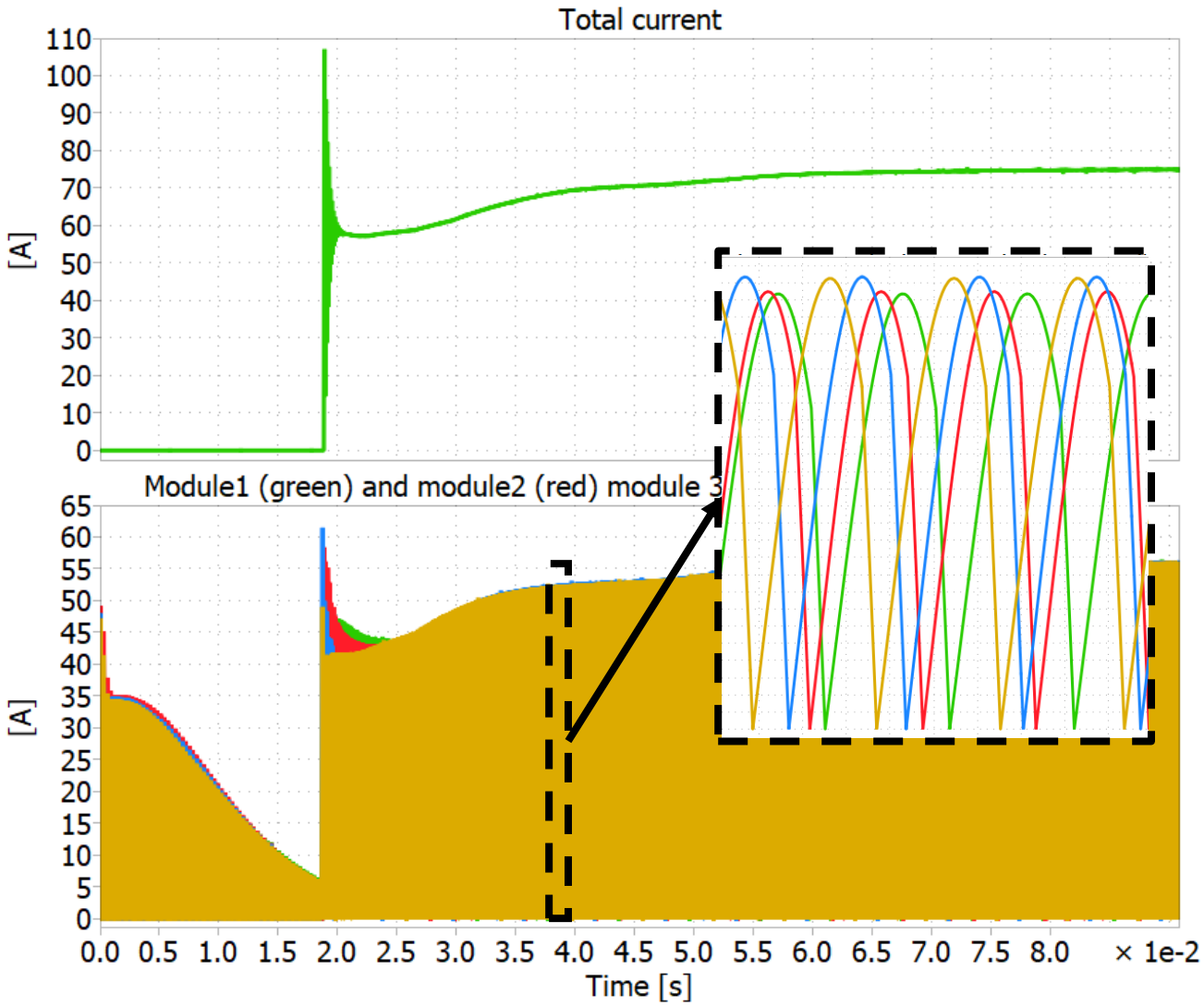
Series Configuration – External Voltage Loop

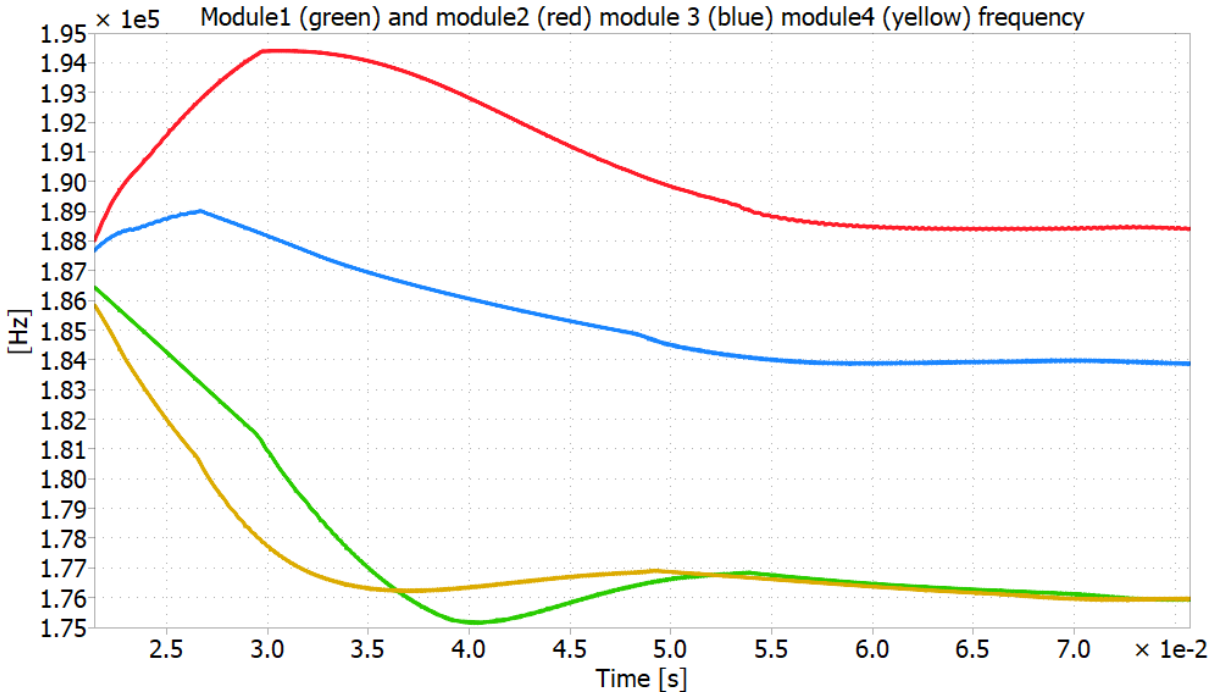






Series Configuration – PLECS Simulation





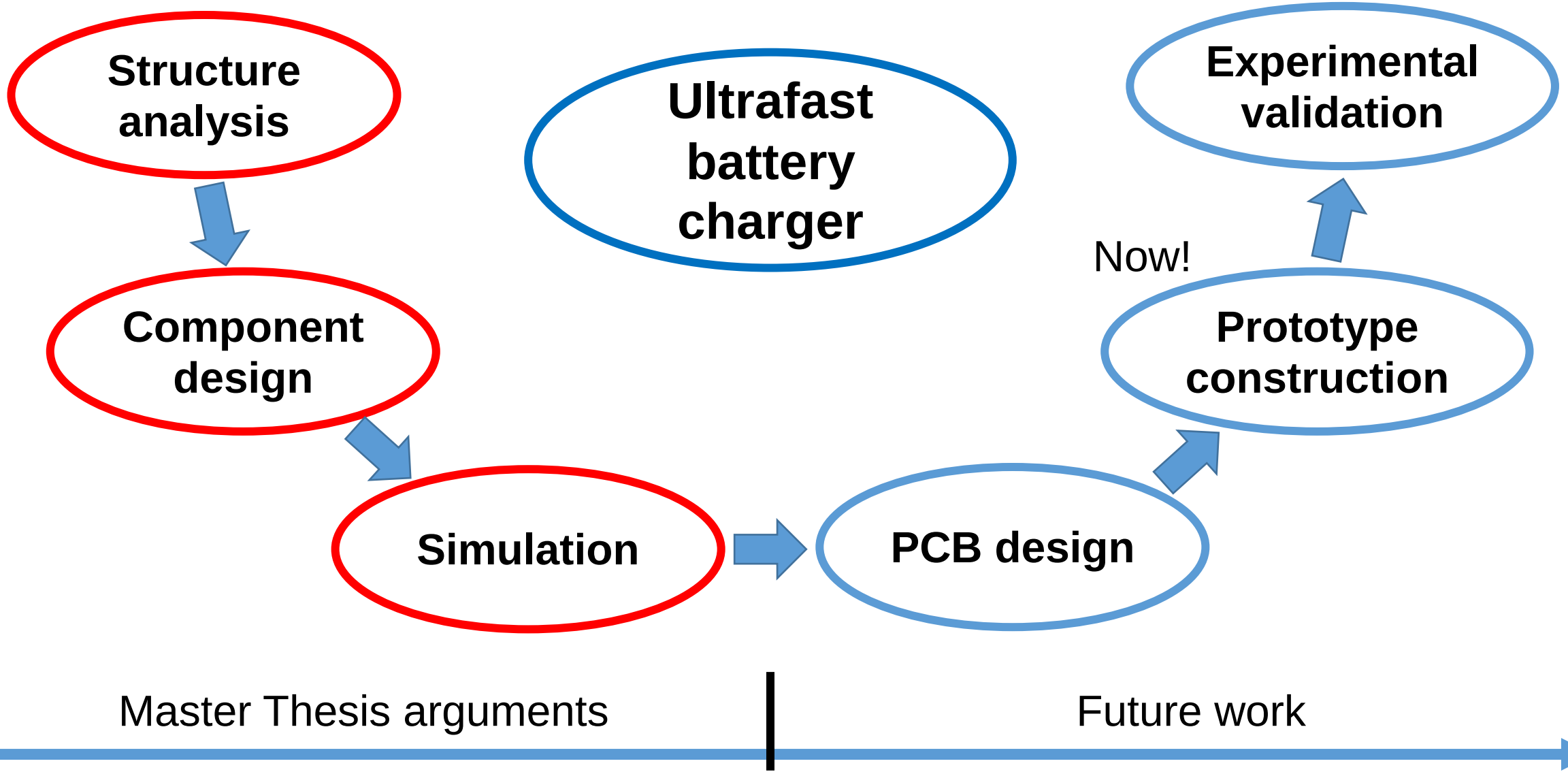
The switching frequencies are different in order to compensate the parametric variations

Personal Contributions

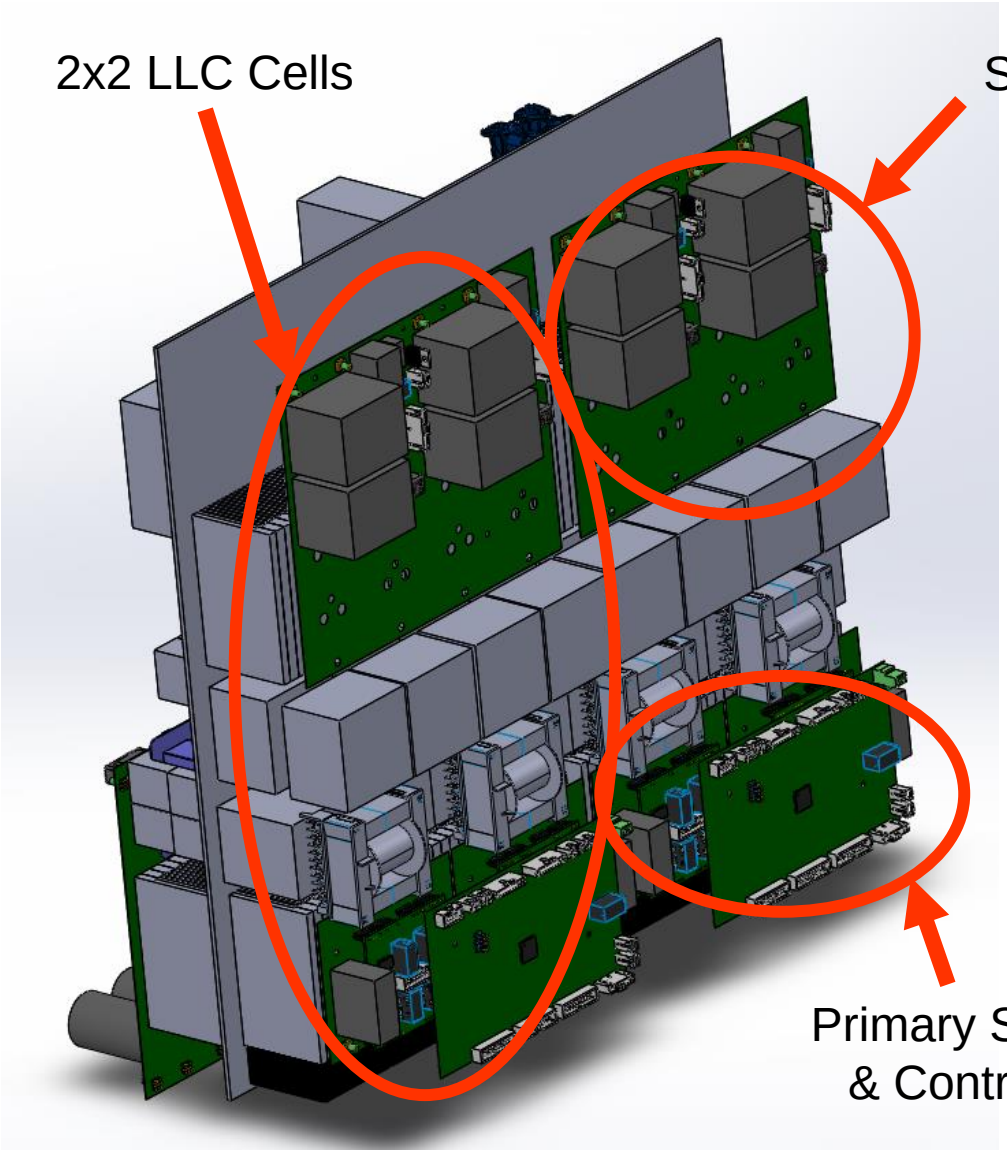
My personal contributions in this master thesis are:

- The development of a circuit design methodology
- The design of the dual-loop control
- Validation through simulations

Multilevel team project



Conclusion



Thanks for the attention!