Operation of MMCs with Dynamic Temperature-Dependent Current Limits

Manchester Electrical Energy and Power Systems Workshop

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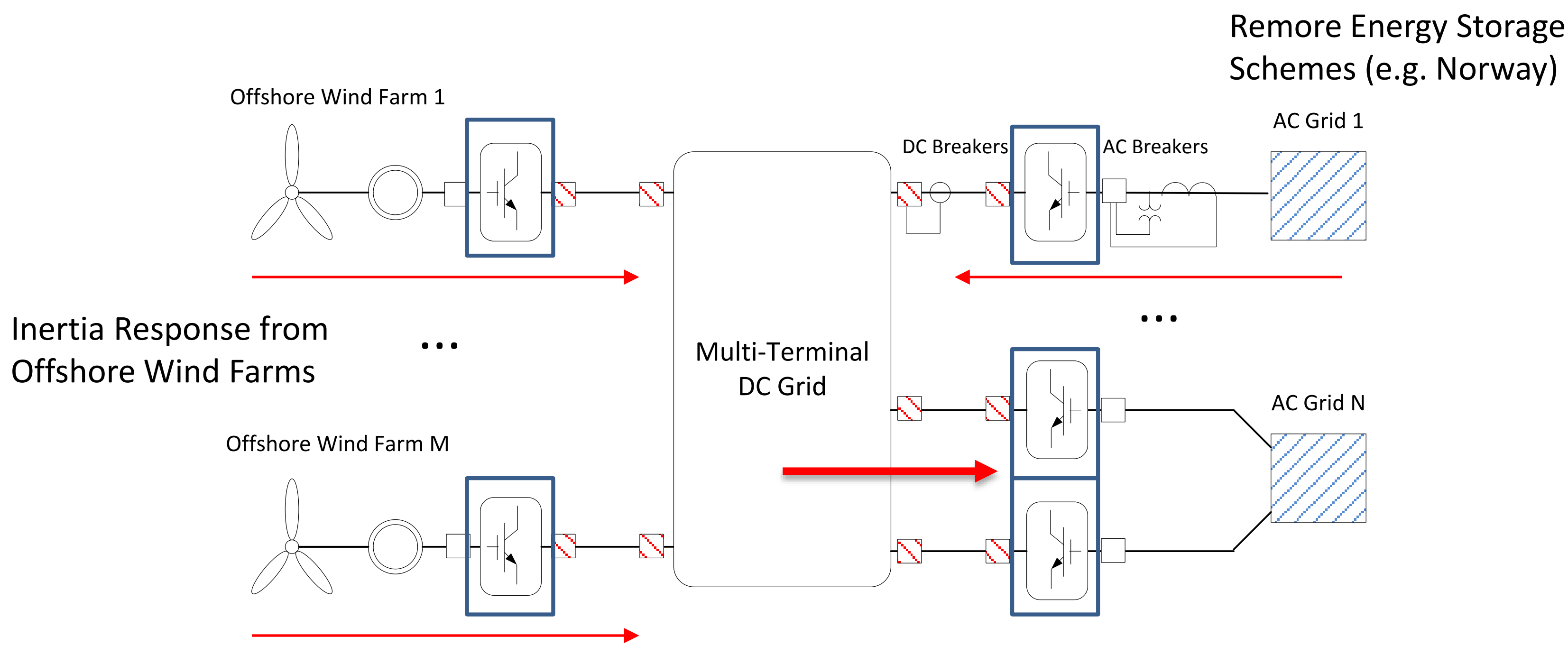
07-11-14

Outline

- Modular Multilevel Converter:
  - Structure and Control
  - Limits and Constraints
  - Electro-Thermal Model
  - Dynamic Temperature-Dependent Current Limits
- Case Study
- Results
- Conclusions & Future Work

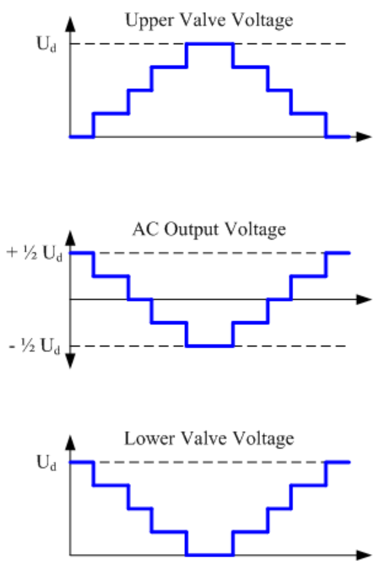
Big Picture...

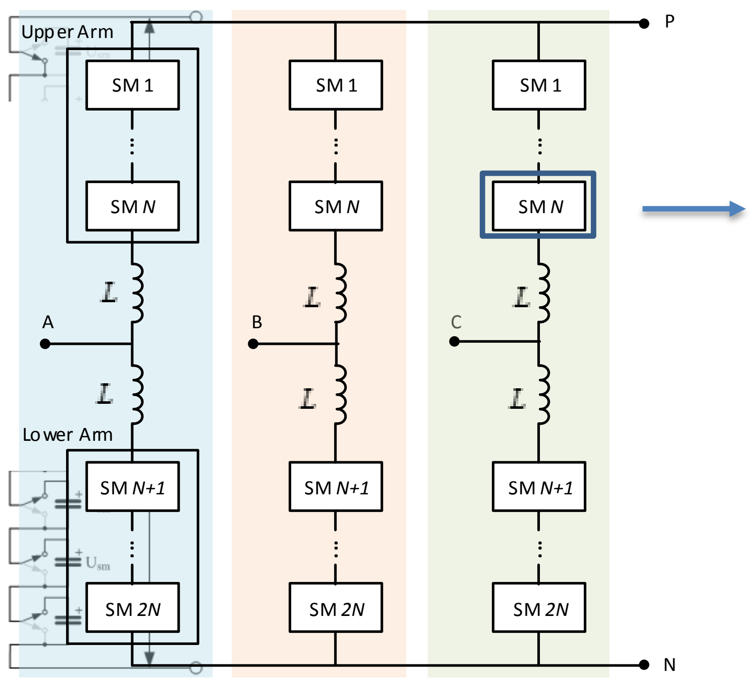


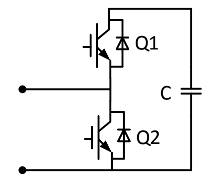
Under power unbalance conditions, additional transmision capability might be necessary.

Modular Multilevel Converter

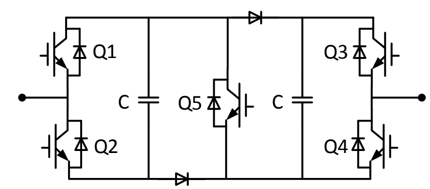
- Structure and Operation



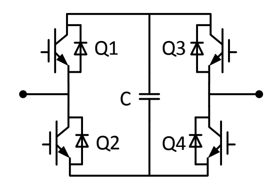




Half-Bridge



Clamp Double

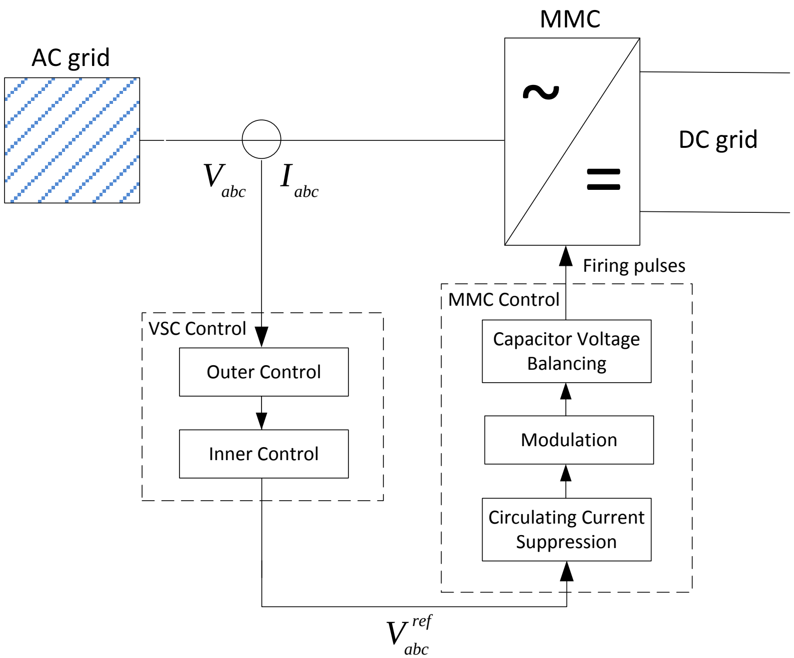


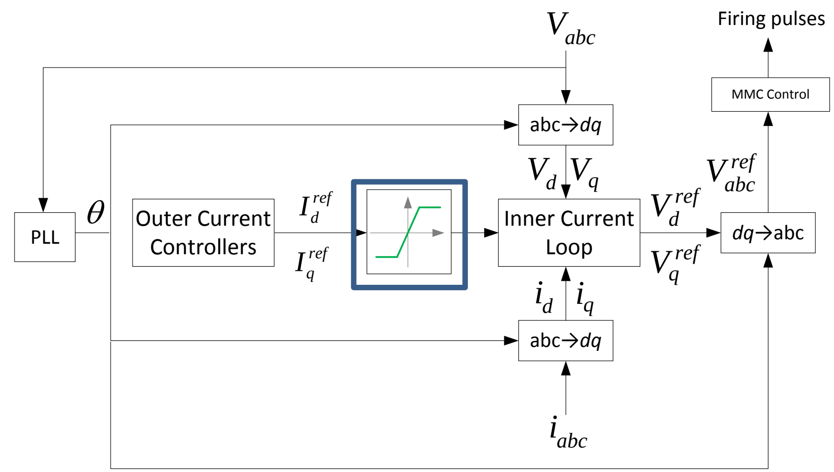
Full Bridge

PEOPLE

Modular Multilevel Converter

- Control (*dq0* reference frame)





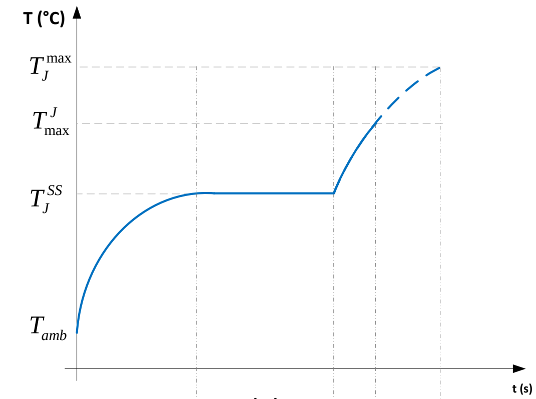
- Fixed limits set the maximum power contribution from the converter
- Must ensure that thermal limits are not exceeded

Modular Multilevel Converter

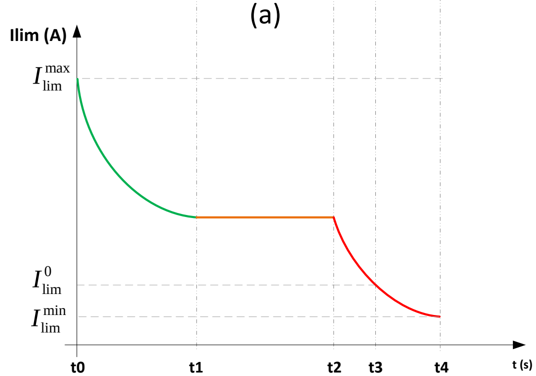
- Limits and Constraints
  - Besides electrical, semiconductors have strict thermal limits that must be respected;
  - A more robust control system must ensure that the necessary constraints are respected, **without limiting the transmission capacity**;
  - In this work a combined approach is proposed, where the current limits are sensitive to the temperature dynamics in the semiconductors.

MMC Electro-Thermal Model

Dynamic Temperature-Dependent Current Limits

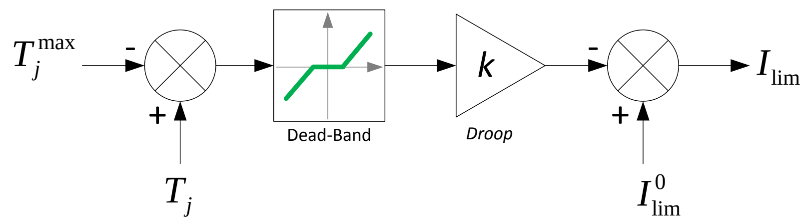


(a)

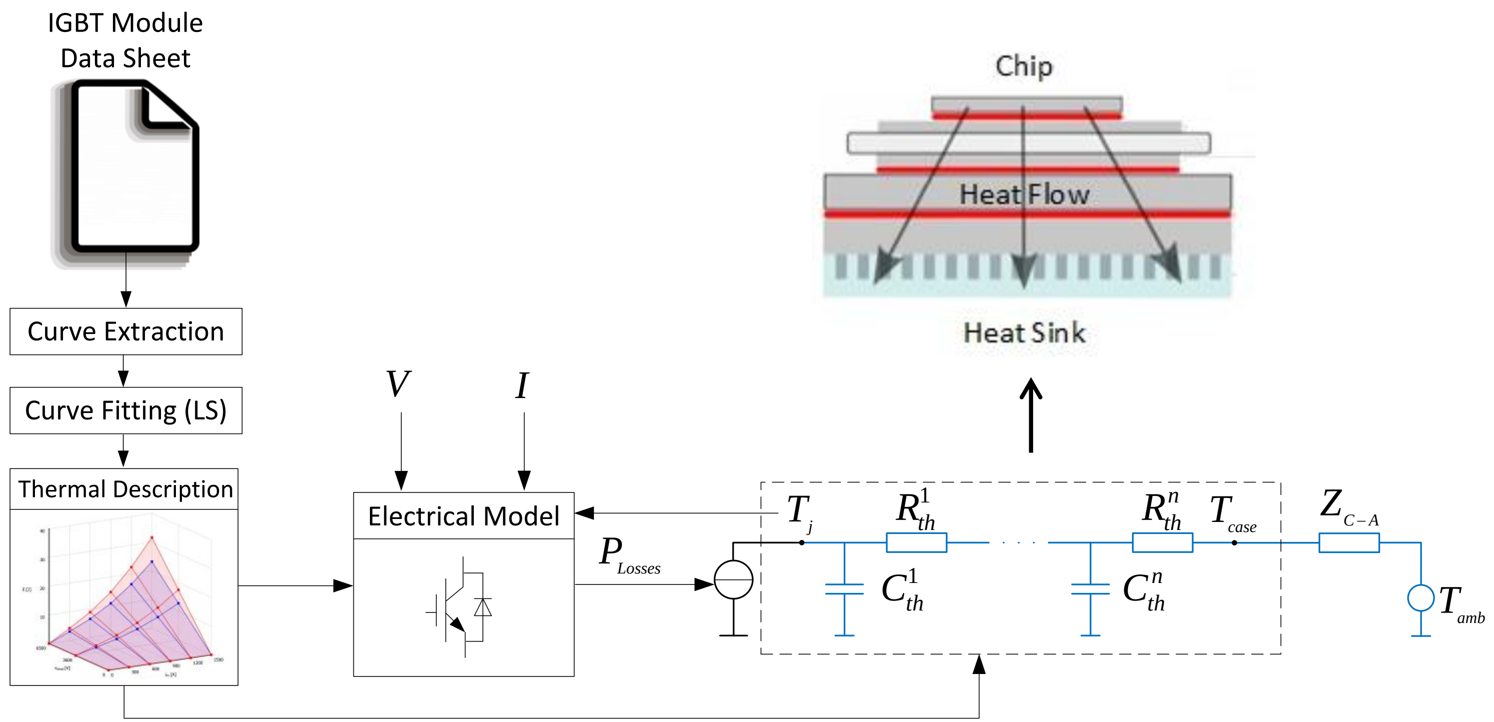


(b)

$$I_{lim}\left(T_J\right) = I_{lim}^0 + k\left(T_{max}^J - T_J\right)$$

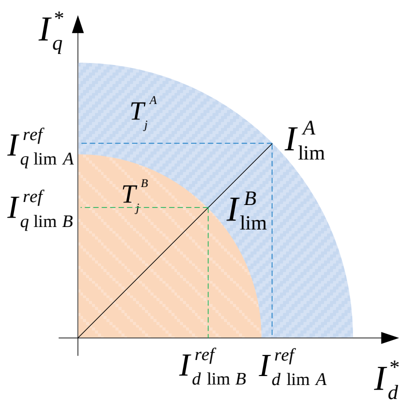


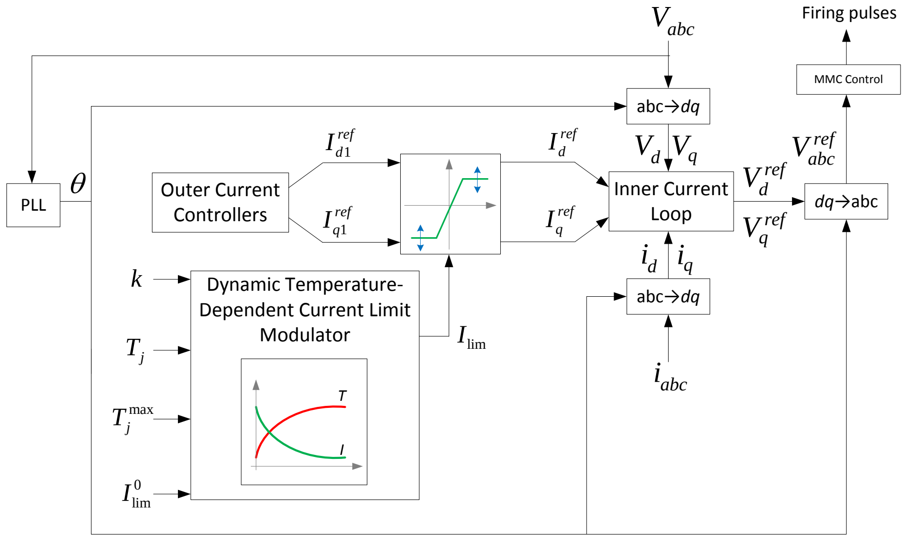
MMC Electro-Thermal Model



MMC Electro-Thermal Model

Dynamic Temperature-Dependent Current Limits

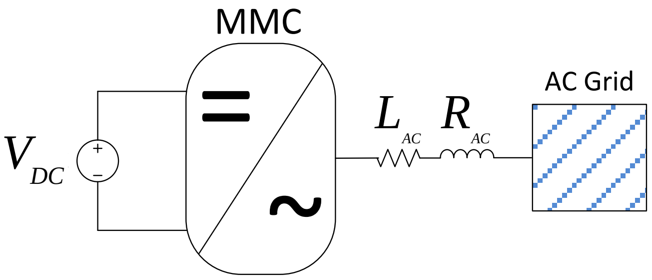




Case Study

System Data

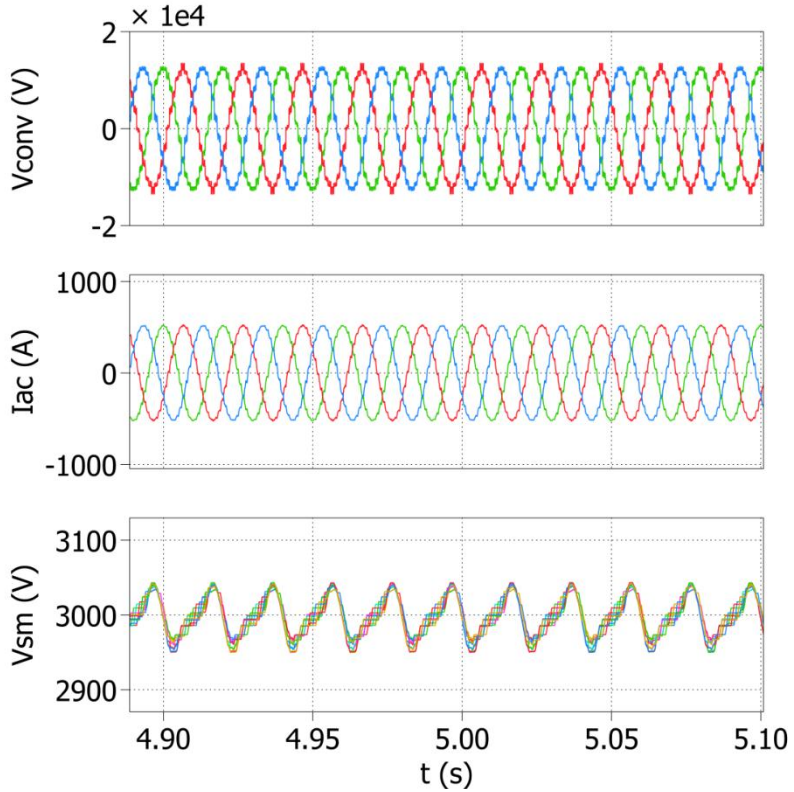
AC System Data	
V_{AC} (kV)	15
f (Hz)	50
MMC and DC System Data	
V_{DC} (kV)	30
#SM	10
V_{cap} (V)	3000
f_c (Hz)	1000
IGBT Data	
Model	ABB 5SNA 0650J450300
V_{CE} (V)	4500
I_{CE} (A)	650



$$\begin{cases} T^{J}_{\max} = 85\,°\text{C} \\ I^{0}_{\lim} = 650\ \text{A} \\ k = 16.25\ \text{A/°C} \end{cases}$$

Results

I. Operational Quantities



System Dynamics:

- P*: 9.5 → 11.4 MW (1 → 1.2 pu) @ 6s
- CLM activated @ 8s
- P*: 11.4 → 9.5 MW (1.2 → 1 pu) @ 13s

MEDOW
MULTI-TERMINAL DC GRID FOR OFFSHORE WIND

CARDIFF UNIVERSITY
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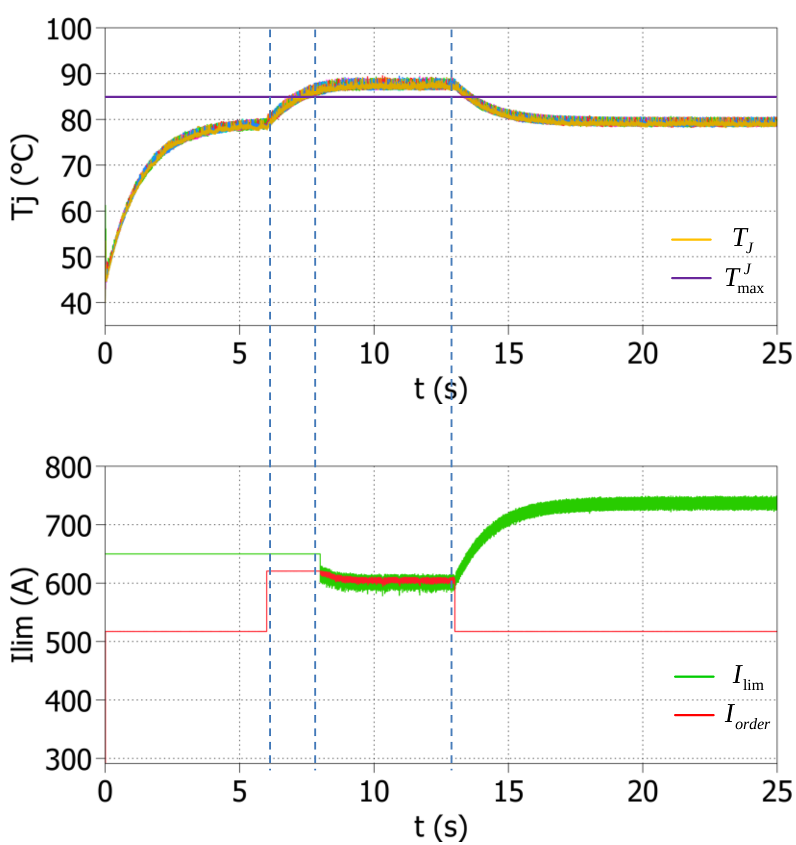
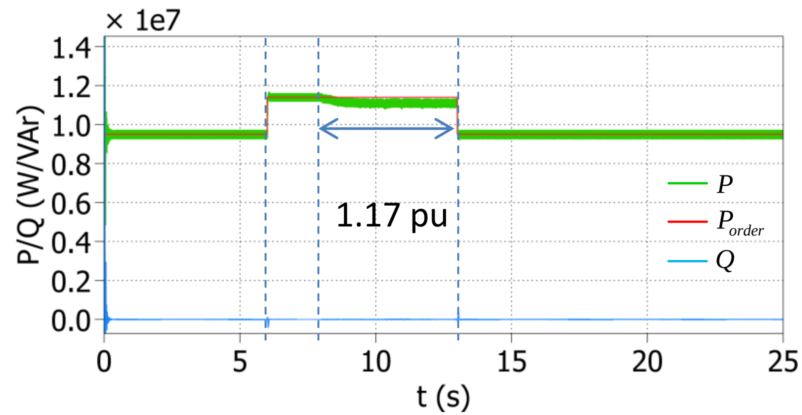
Results

II. Dynamic Temperature-Dependent Current Limits





Extension of power transmission capability

+

Respect of electrical and thermal limits

=

Seamless power support to an unbalanced grid

PEOPLE

Conclusions & Future Work

I. Proposed strategy to control the current limits with sensitivity to semiconductors junction temperature;

II. Transmission capacity can be dynamically controlled, while respecting electrical and thermal constraints, enabling the support to grids with power imbalance;

III. Operation under fault conditions (not shown) was verified and confirms the validity of the proposed control;

IV. Experimental validation is on its way.

Thank you for your attention!