Real-time EMT-Based Design and Test of Damping Control for Post-Fault Recovery in HVDC Networks

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UGM RTDS USER'S GROUP MEETING
2024 EUROPE USER'S GROUP MEETING
DELFT, NETHERLANDS
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Research Problem

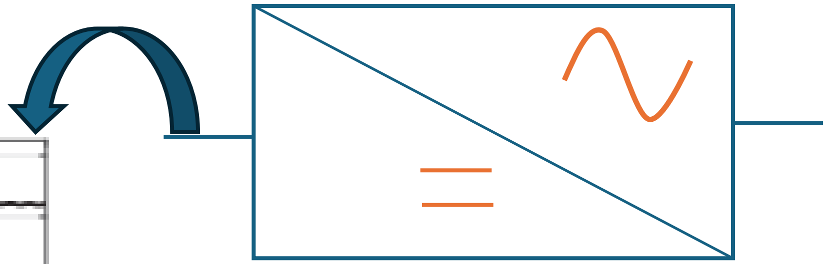
Increased adoption of power electronics interface in modern grids

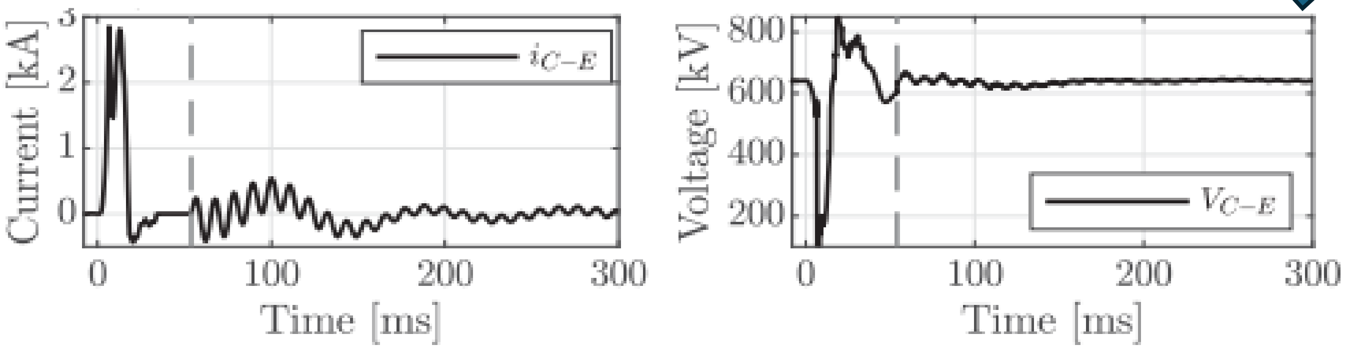
Stability challenges in HVDC networks

Research Goal

Fast & Stable DC Side Post-Fault Recovery

- Objective: To investigate and enhance the post-fault recovery of HVDC grids, which provides an insight into the interactions between the converters and the HVDC grid during the recovery process





Literature Gaps:

- Work in literature has focussed on P2P with limited consideration of meshed HVDC networks.
- Damping control methods are limited in addressing the non-linearities that exist during deblocking of converters.
- Investigating alternative CCSC method beyond the DQ type CCSC is needed to enhance damping and avoid instabilities.

[A] L.. Shi et al. ,"Enhanced control of offshore wind farms connected to MTDC network using partially selective DC fault protection", *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 9, no. 3, 2020.

Model & Tool Used

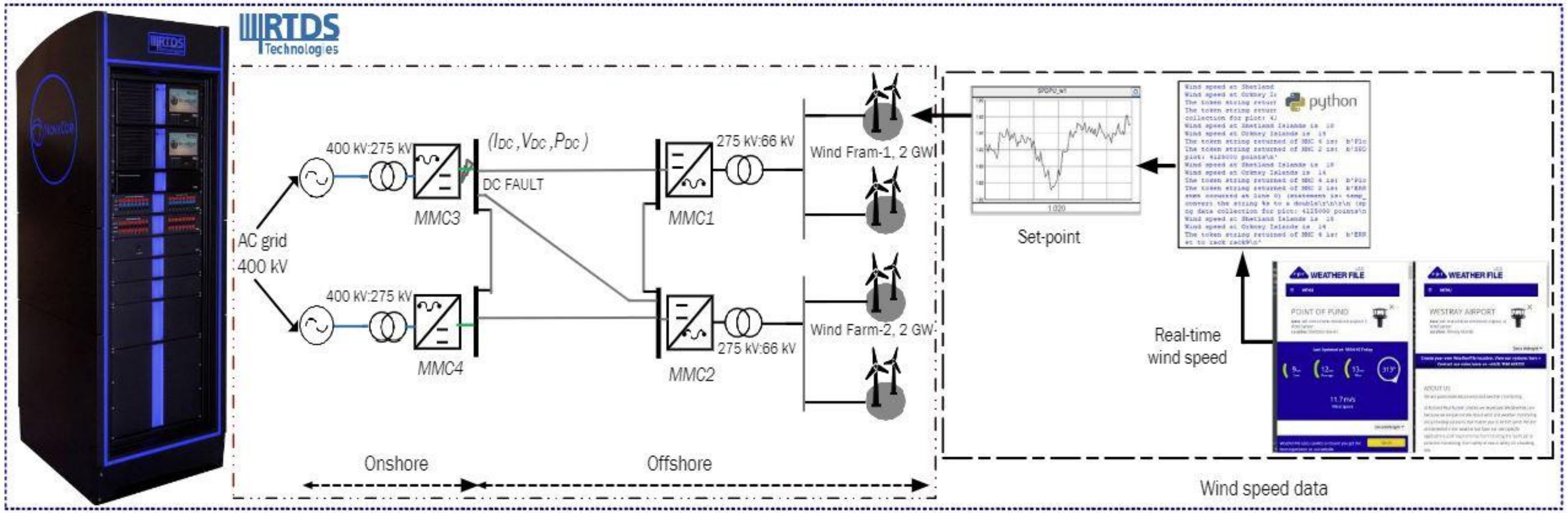


Fig. 1 A four-terminal ±525 kV bipolar half-bridge MMC-based MTDC network

Assumptions:

1) Fault: DC short circuit
2) Switch is opened at DC side during fault
3) No DCCB are considered for this study
4) Post DC fault recovery (i.e. during deblocking of converter) is studied for MMC3 converter

Proposed Control

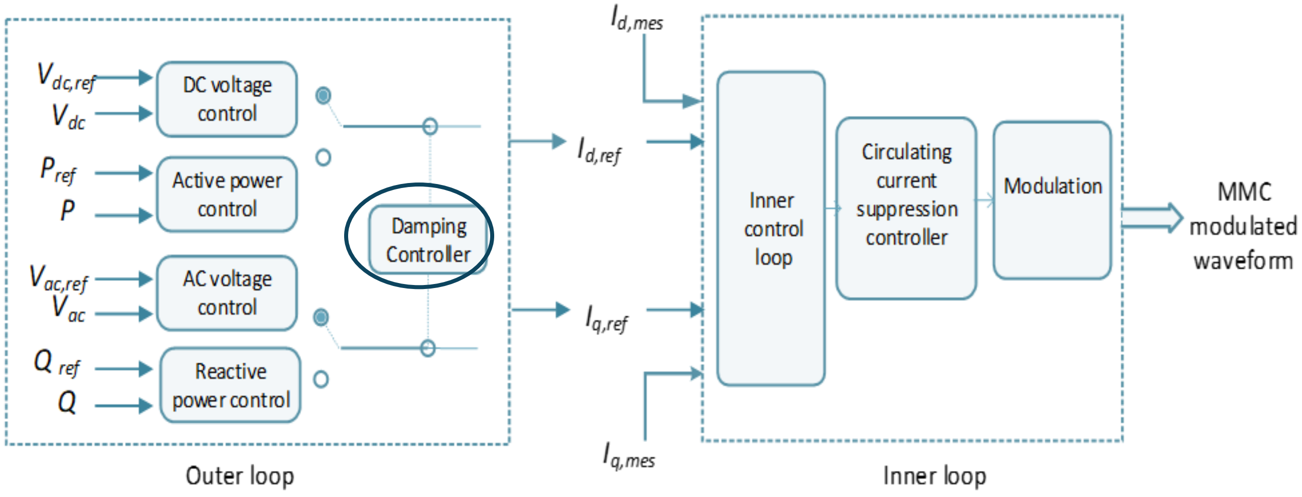


Fig. 2 Control loop structure inside MMC

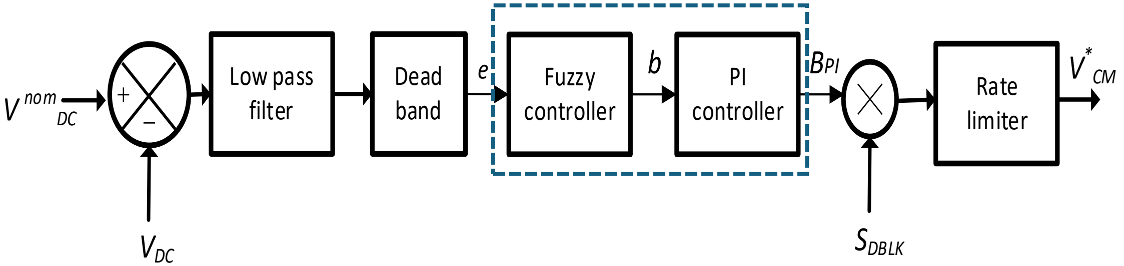


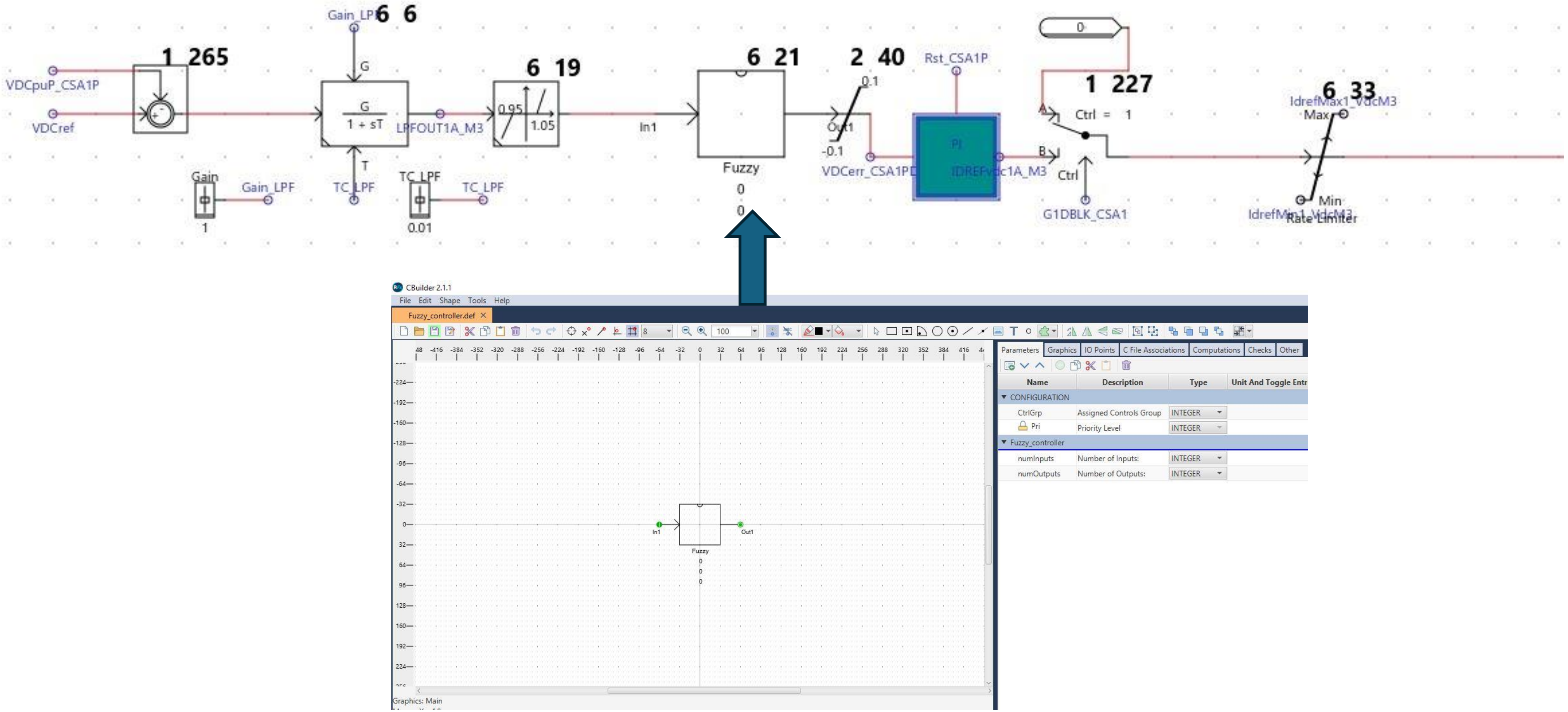
Fig. 3 Enhanced DC voltage regulation method

- Traditional PI –simplicity & effectiveness in linear systems
- FLC offers promising alternatives for non-linear systems
- Handle imprecise data effectively
- Require less computational resources
- Coordinated approach-handles non-linearities & provides good overall performances
- Combination leads to faster settling time & reduced overshoot

[1] M. Abedrabbo, F. Z. Dejene, W. Leterme, and D. Van Hertem. "HVDC grid post-DC fault recovery enhancement." *IEEE Transactions on Power Delivery,* vol. 36, no. 2. 2020. **DOI:** 10.1109/TPWRD.2020.3002717

[2] Q. Tu, Z. Xu, & L. Xu. “Reduced switching-frequency modulation and circulating current suppression for modular multilevel converters,” *IEEE Transactions on Power Delivery*, vol. 26, no. 3, 2011. **DOI:** 10.1109/TPWRD.2011.2115258

Proposed Control



Proposed Control

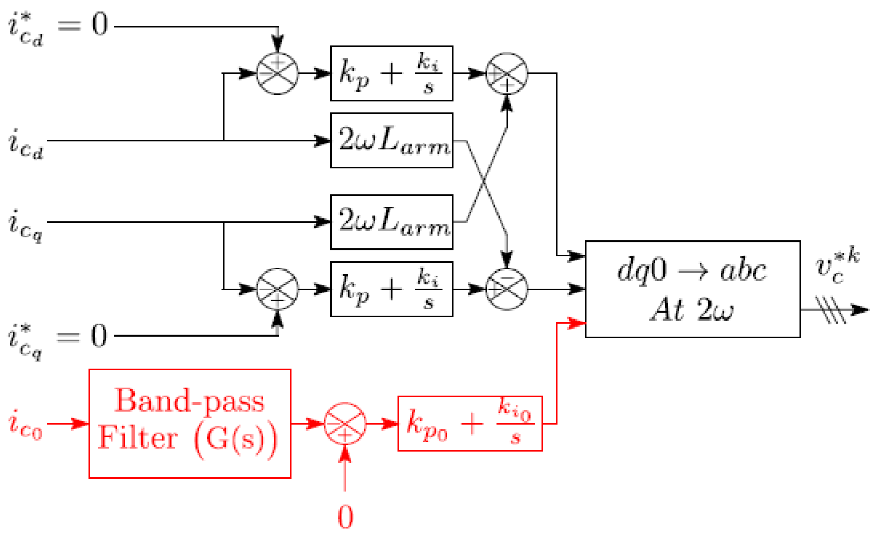
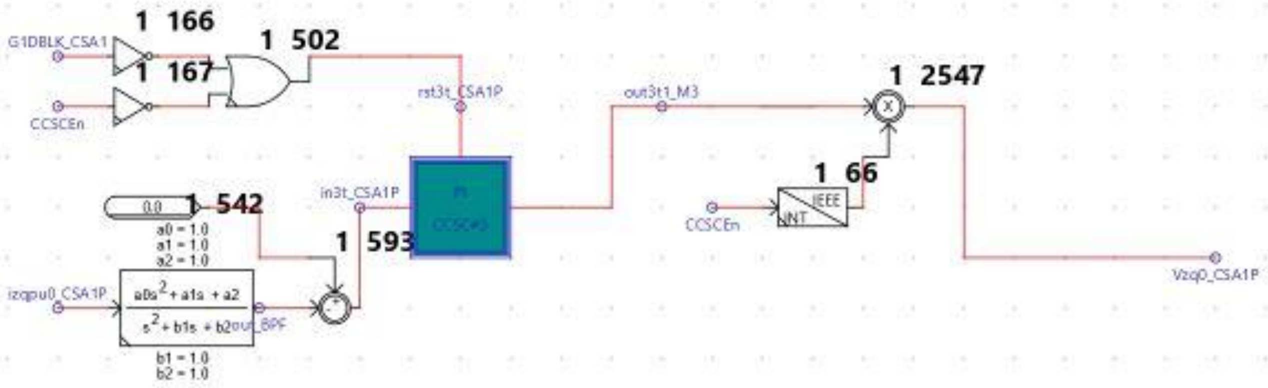
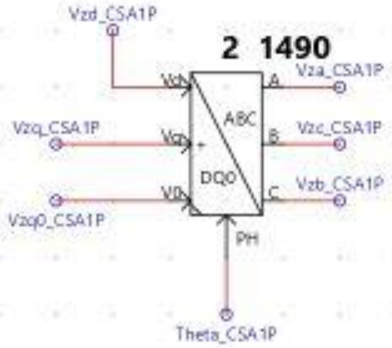
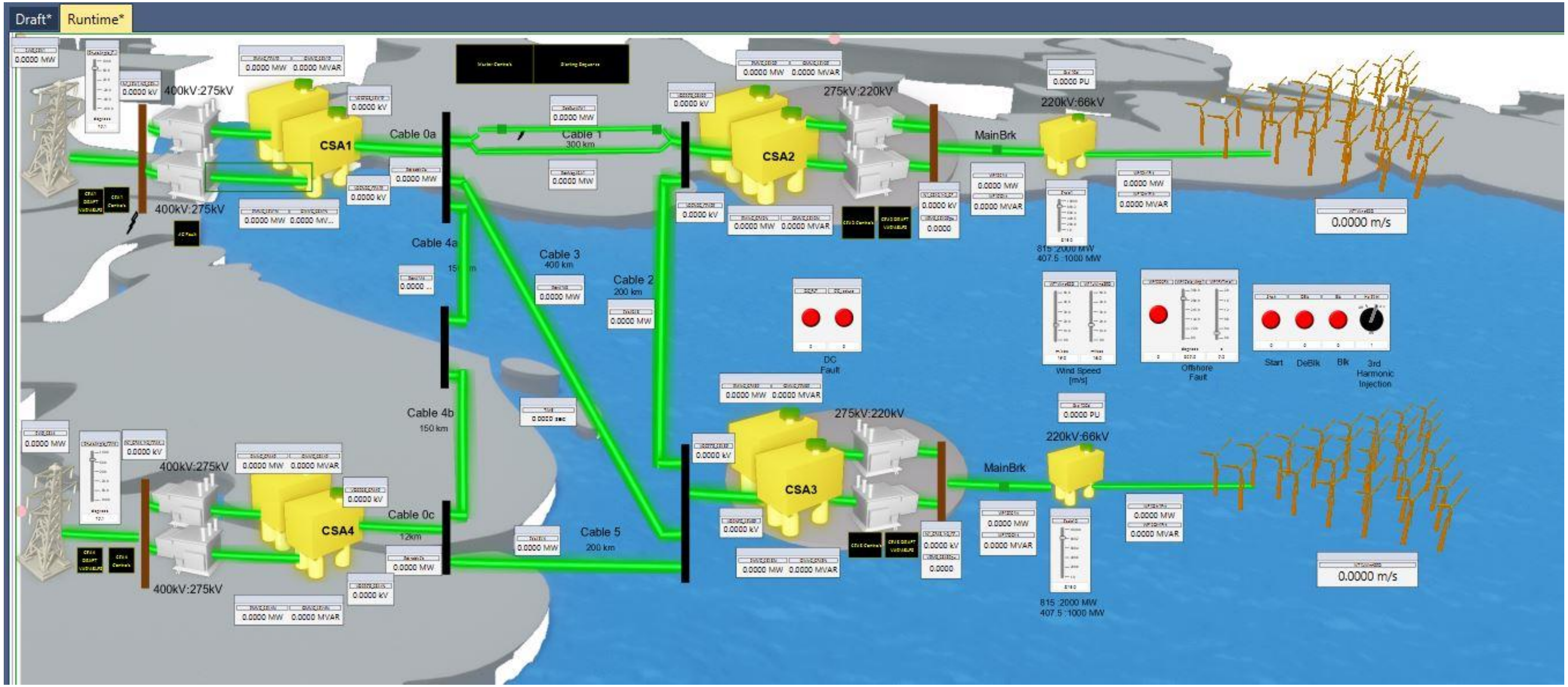


Fig. 4: Modified D-Q CCSC





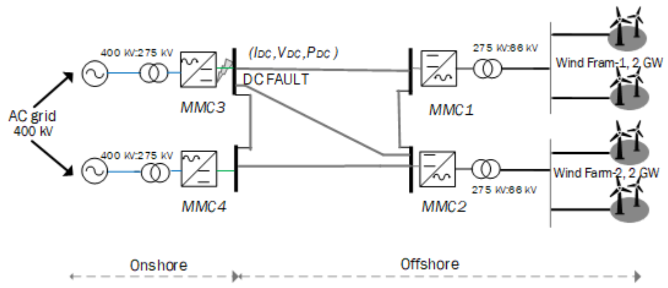
EMT Simulations



[1] A. Shetgaonkar, L. Liu, A. Lekić, M. Popov, and P. Palensky. "Model predictive control and protection of MMC-based MTDC power systems." *International Journal of Electrical Power & Energy Systems,* vol. 146, 2023. https://doi.org/10.1016/j.ijepes.2022.108710

[2] J. Pou, S. Ceballos, G. Konstantinou, G. Agelidis, R. Picas, and J. Zaragoza. "Circulating current injection methods based on instantaneous information for the modular multilevel converter." *IEEE Transactions on Industrial Electronics* 62, vol. 62, no. 2, 2014. **DOI:** 10.1109/TIE.2014.2336608

Results (Without ADC):



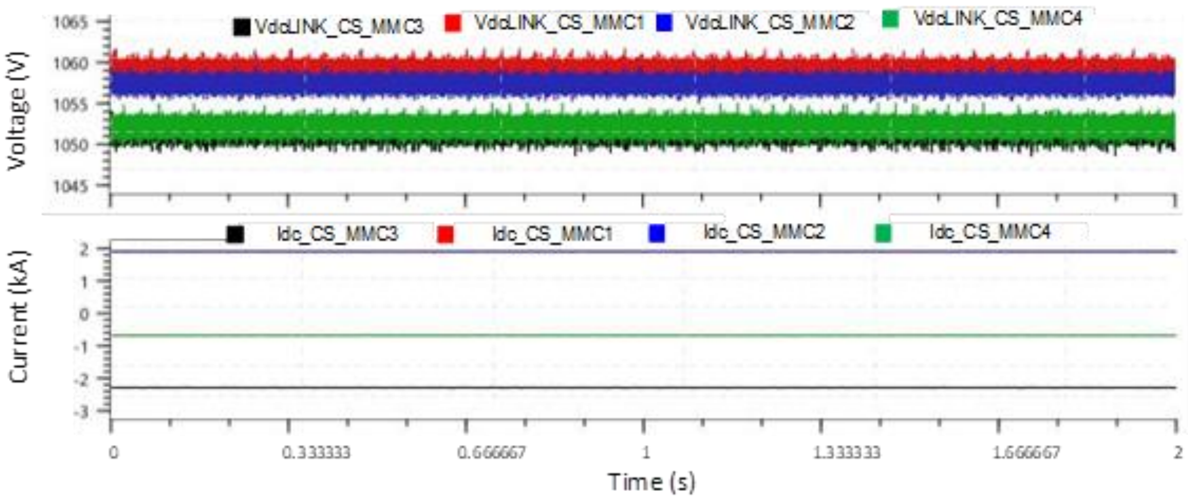


Fig. 5: Initial currents and voltages at DC side of MTDC network

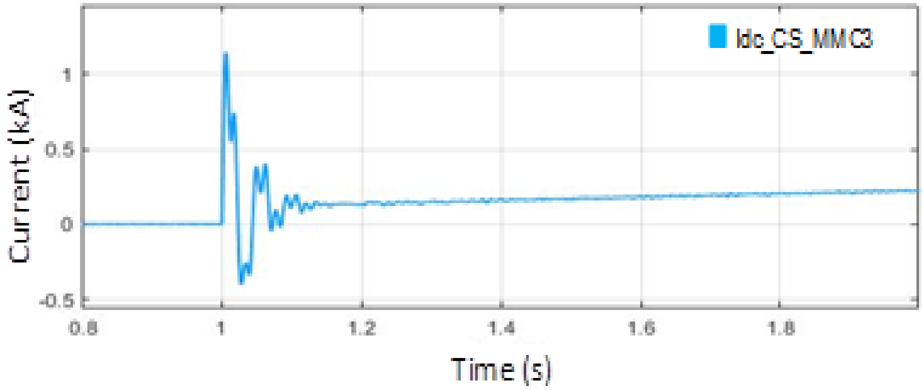


Fig. 7: Current at PCC during deblocking of MMC3 converter

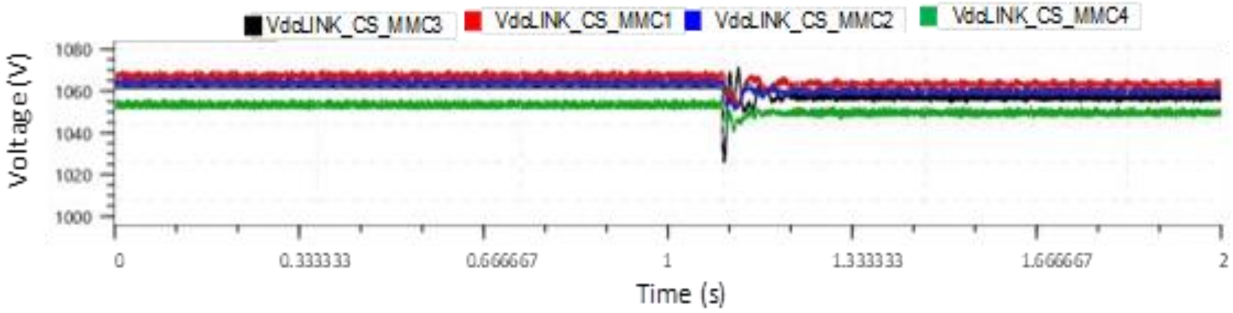
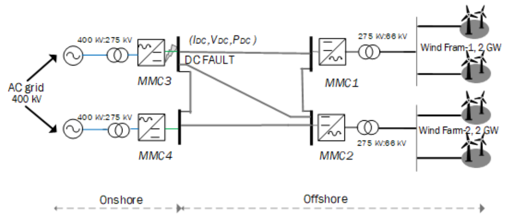


Fig. 6: Voltages at DC side of converters during deblocking event

Peak overshoot = 1.1431
Settling time = 0.15842

Result: Enhanced Controller



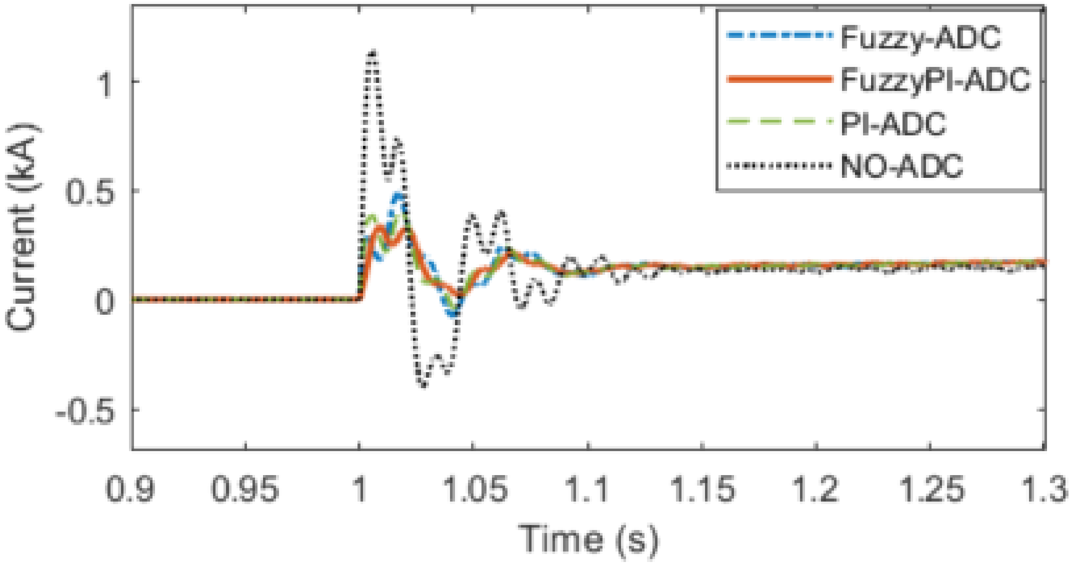


Fig. 8 Performance of ADC using fuzzy controller, PI controller, enhanced controller and without ADC

Table I

Controller Performance Comparison: (ADC vs No ADC)

Controller	Peak-overshoot reduction	Settling time
PI	64%	29.47%
Fuzzy	62.40%	21.57%
Fuzzy +PI	71.05%	36.78%

Table II

Performance Evaluation of Enhanced Controller with Different ADCs

Method	Reference	Reduction in Overshoot (%)	Reduction in Settling Time (%)
Enhanced Fuzzy + PI Controller	-	19.56	10.36
D-Q CCSC with Modulated Signal	[1]	2.59	3.57
CCSC with MPC	[2]	---	13.6 (compared to PI)
Modified D-Q CCSC (FCCC)	[3]	7	12

[1] M. Abedrabbo, F. Z. Dejene, W. Leterme, and D. Van Hertem. "HVDC grid post-DC fault recovery enhancement." *IEEE Transactions on Power Delivery,* vol. 36, no. 2. 2020. **DOI:** 10.1109/TPWRD.2020.3002717

Impact on R&R

- Significant improvements in post-fault recovery have been demonstrated, resulting in 19.56% reduction in current overshoot and 10.36% faster settling time, which is important to prevent outages at DC side of the converter

Thank you