REVOLUTIONIZING MTDC NETWORKS: UNLOCKING THE POTENTIAL OF MMCS WITH GRID FORMING CONTROL THROUGH MODEL PREDICTIVE CONTROL

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TU Delft

2023 EUROPEAN RTDS TECHNOLOGIES INC. USER'S GROUP MEETING 2023

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RTDS Technologies AMETEK

Introduction

RTDS Rack Set-Up

Control Strategy

MPC Controller

Summary

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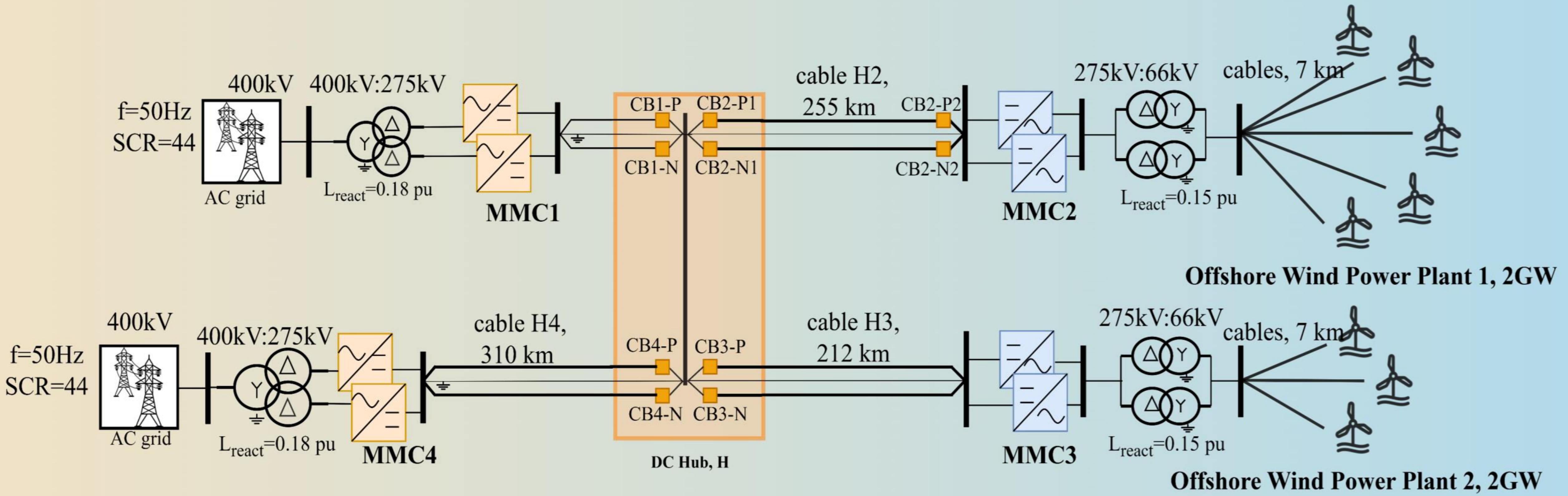
Summary

EU's 2030 target: 42.5% renewable energy.

Increase in the Power electronics-based power generation

Overall reduction in the inertia of the Grid

NETWORK SINGLE LINE DIAGRAM



Four terminal ± 525 kV bipolar metallic return HVDC Network

NETWORK SPECIFICATIONS

Onshore specifications

Onshore rating of the converter and transformer	6 GVA
MMC Submodule Voltage	2.4 kV
MMC Submodule Current	2 kA
Submodule Capacitance	25 mF
No. of submodules	240

Offshore specifications

Offshore rating of the converter and transformer	4.5 GVA
MMC Submodule Voltage	2 kV
MMC Submodule Current	1 kA
Submodule Capacitance	16 mF
No. of submodules	240

Introduction

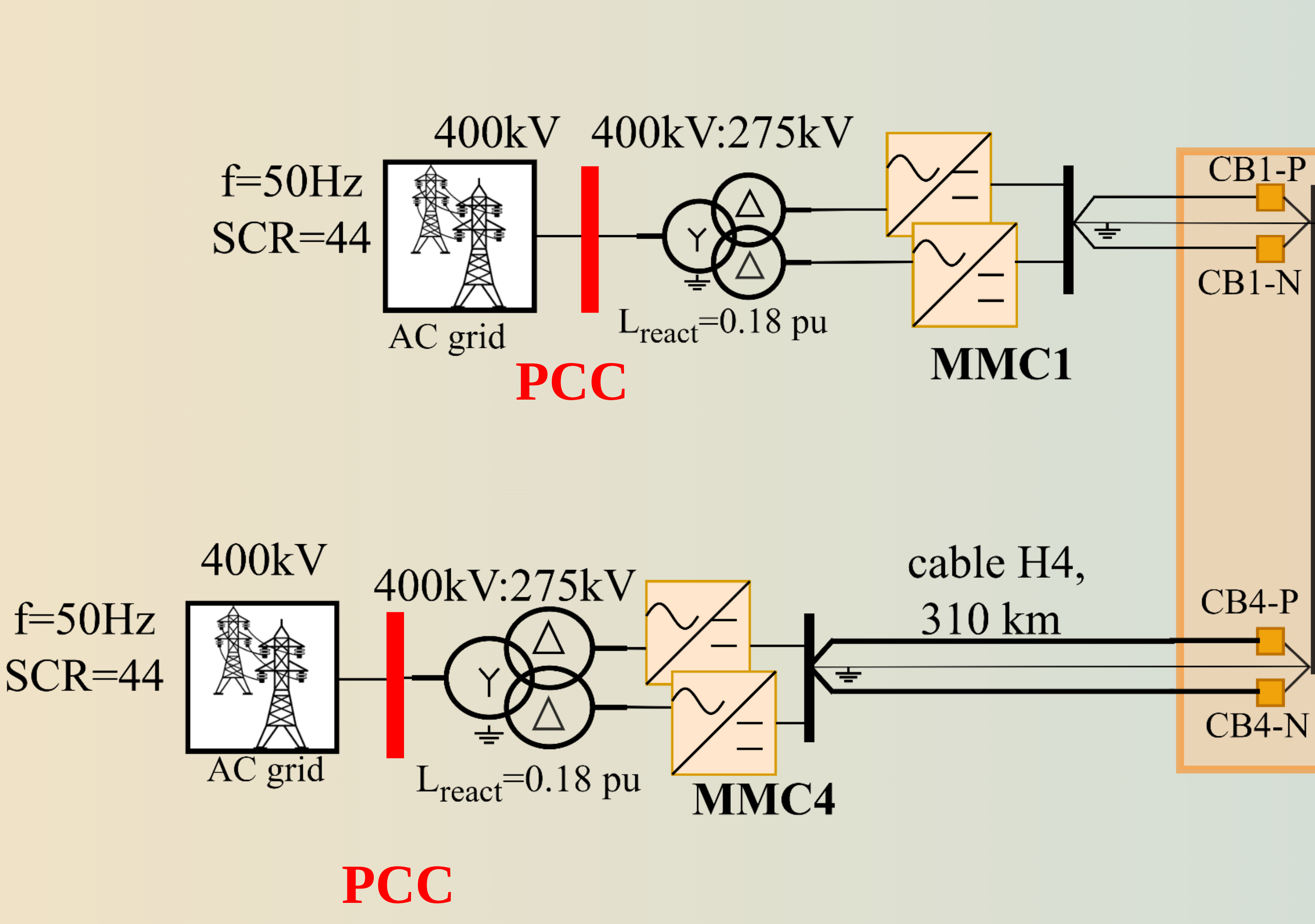
Short Circuit Ratio

IEEE 519-2014,

At Point of Common Coupling,

$$SCR = \frac{I_{\text{short circuit}}}{I_{\text{nominal}}}$$

$$SCR = \frac{1}{X_{\text{pu}}}$$



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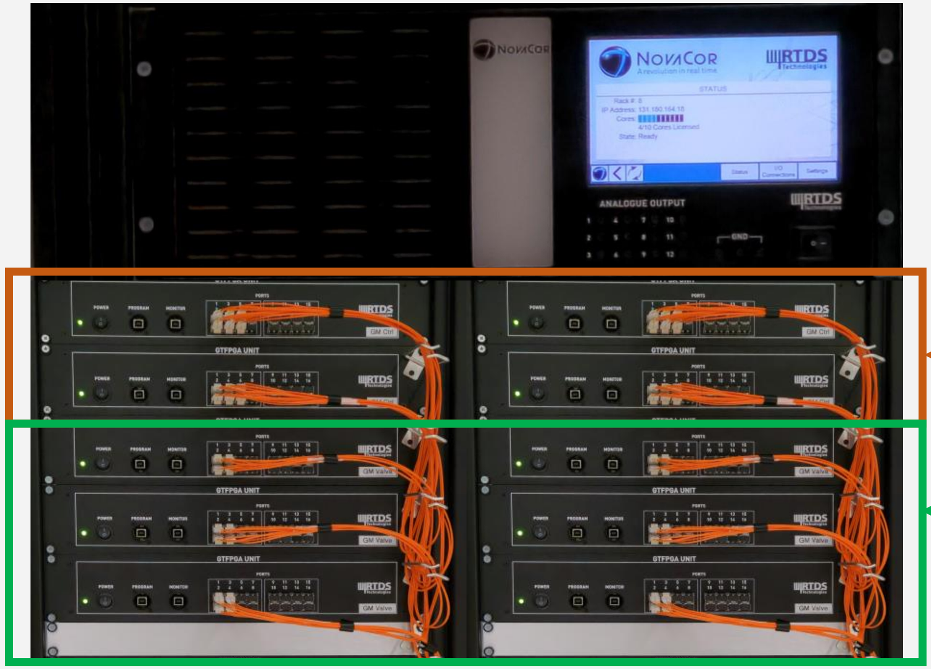


For each MMC, 5 GTFPGAs

2 for Valve controls

1 for each Phase legs (x3)

2 MMCs in 1 terminal in Bipolar configuration

RTDS Rack Set-up

Rack #1 **Rack #2** **Rack #3** **Rack #4**

RTDS Rack Set-up

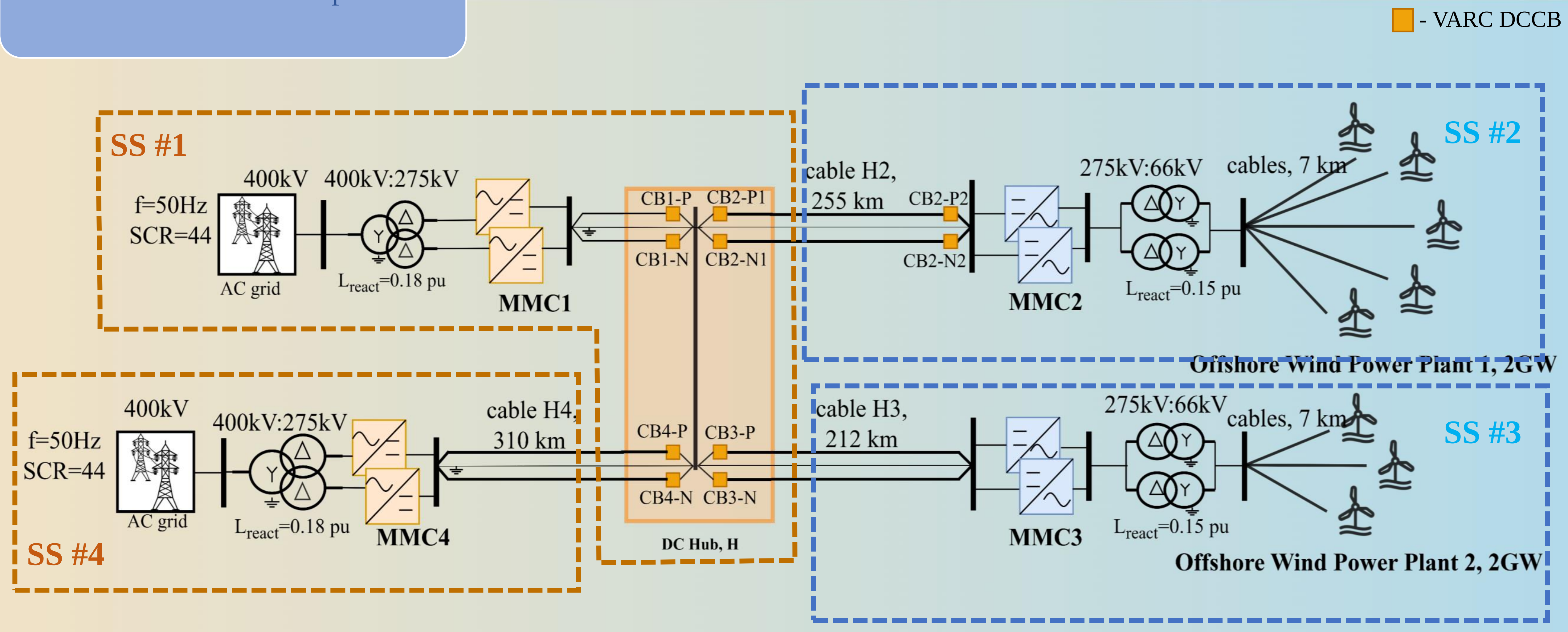
SS #1

SS #2

SS #4

SS #3

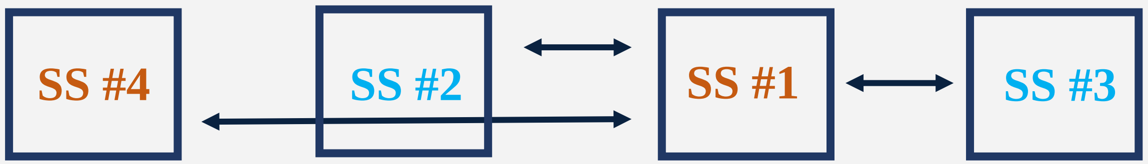
RTDS Rack Set-up



Four terminal ± 525 kV bipolar metallic return HVDC Network

RTDS Rack Set-up

SUBSYSTEM CONFIGURATION



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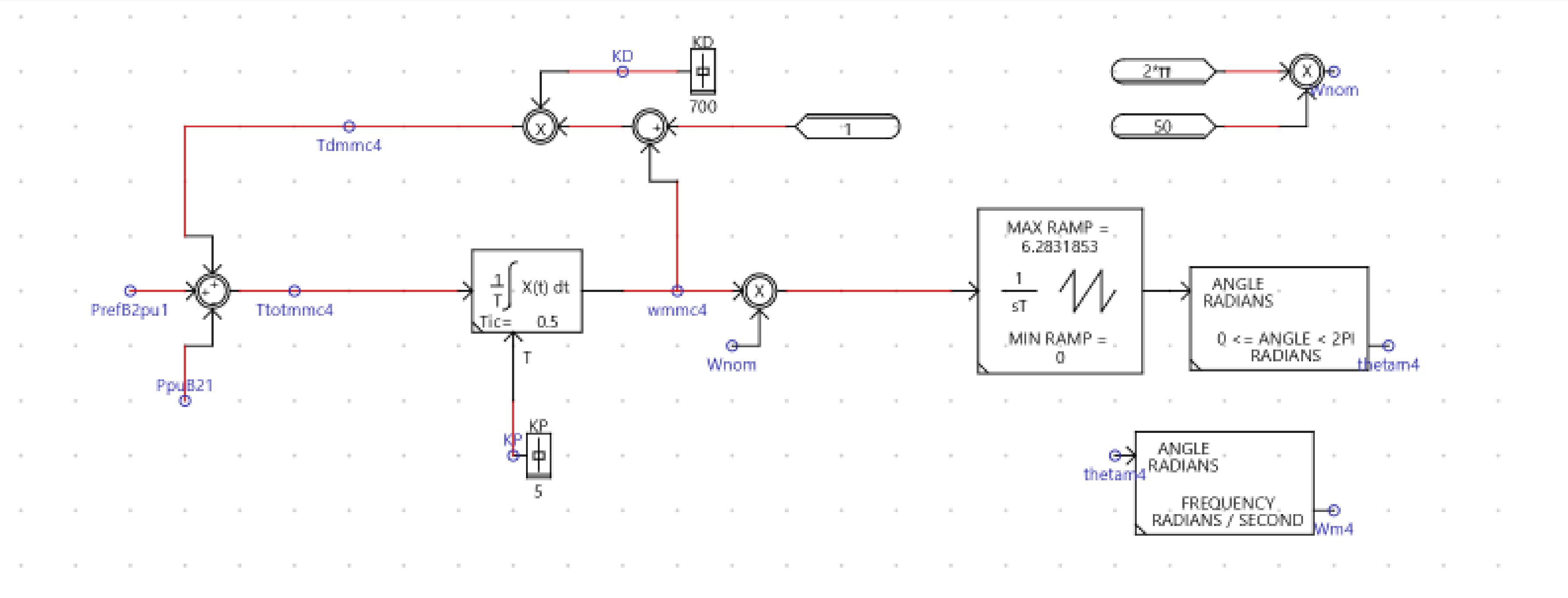
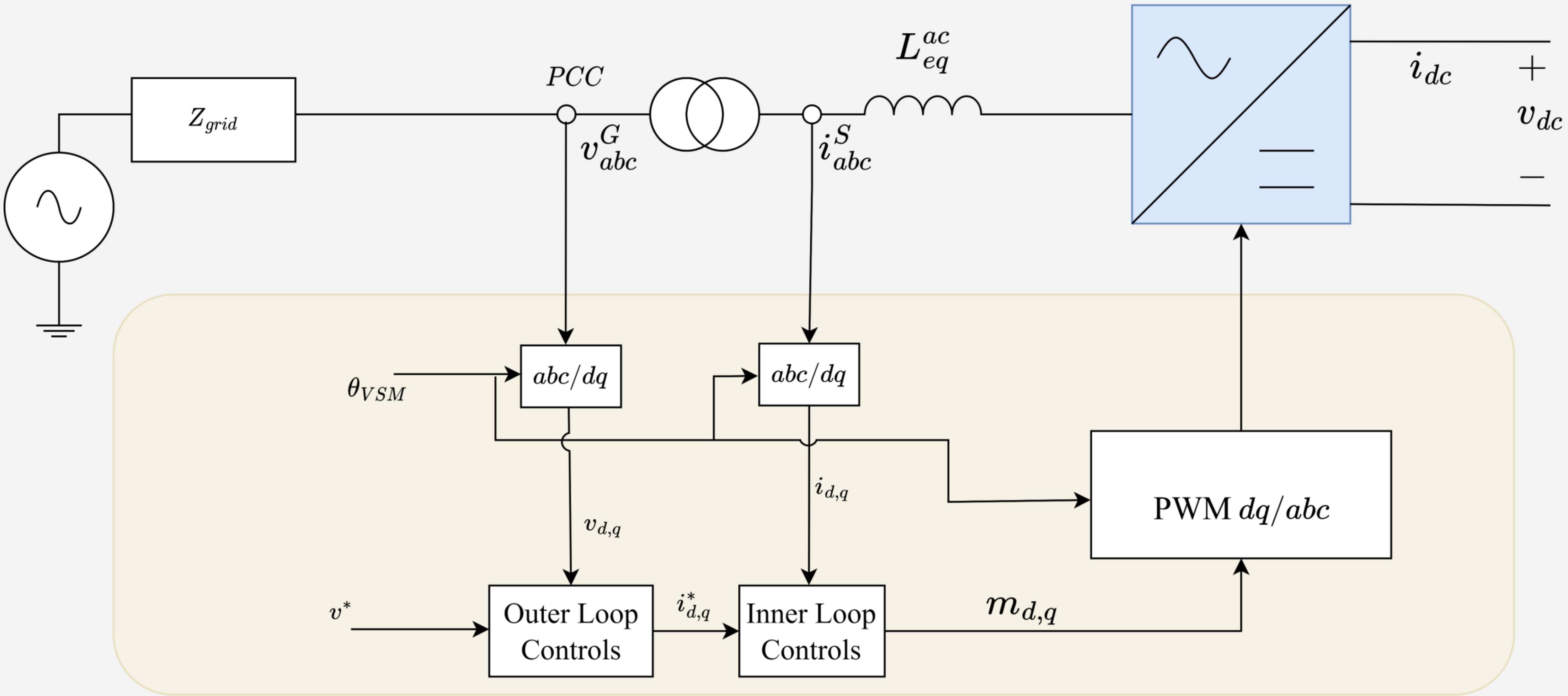
Phase Angle Generation for GFM



GRID FORMING CONTROL STRATEGY



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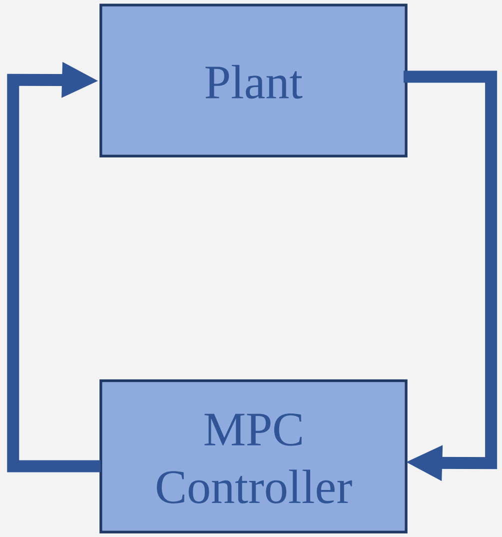
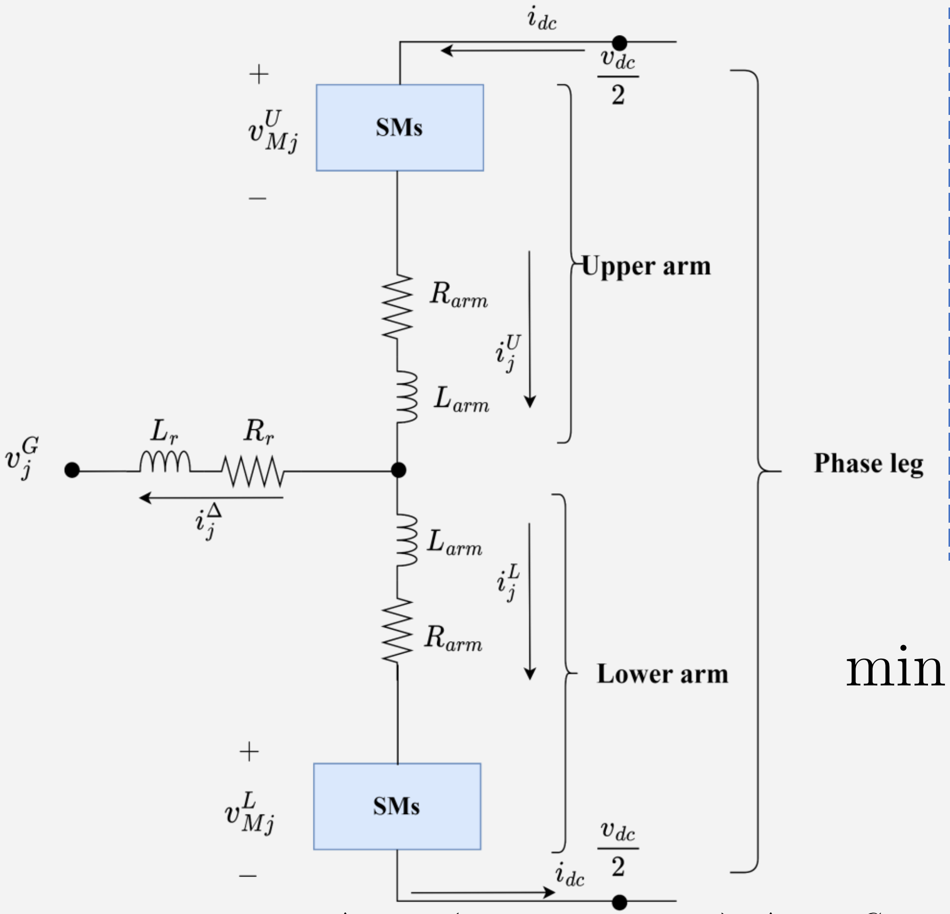
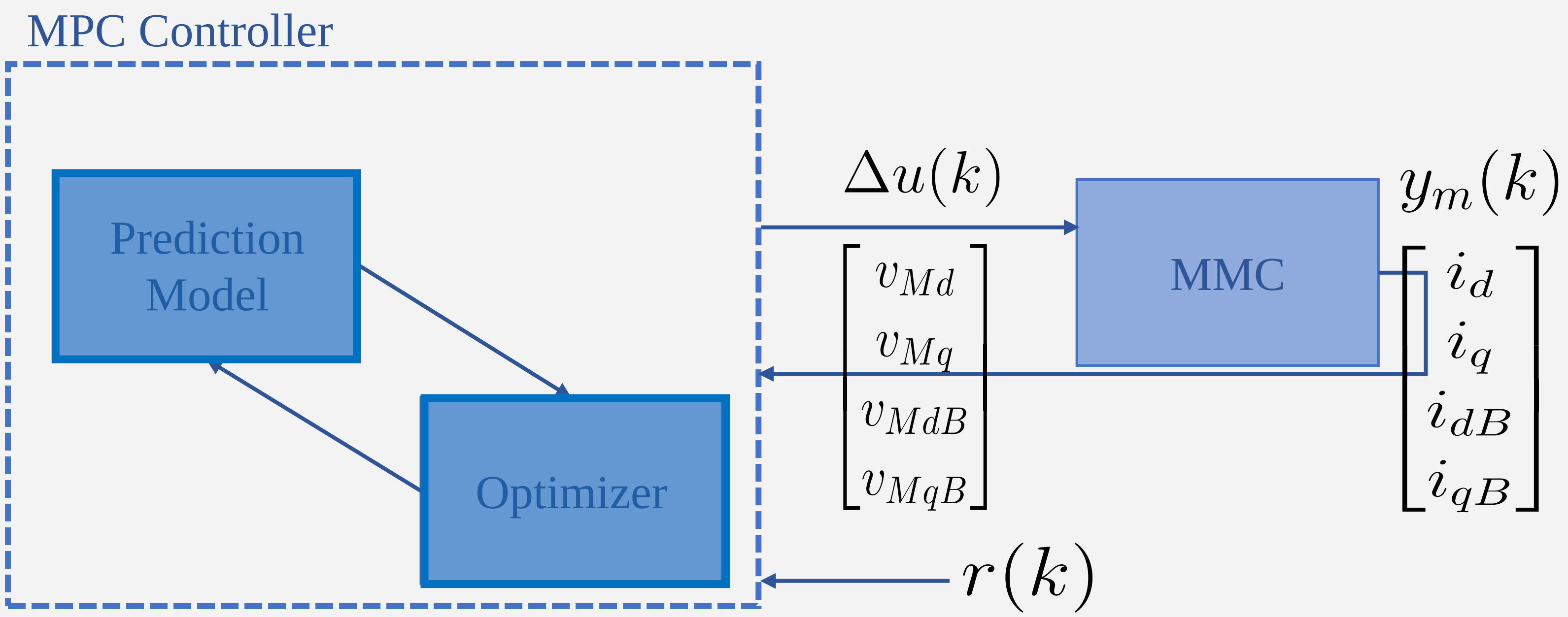


MPC Controller



$$\frac{d}{dt}\left(i_{dq}^{\Delta}\right) = \frac{v_{Mdq}^{\Delta} - \left(\omega L_{eq}^{ac} J_2 + R_{eq}^{ac} I_2\right) i_{dq}^{\Delta} - v_{dq}^{G}}{L_{eq}^{ac}}$$



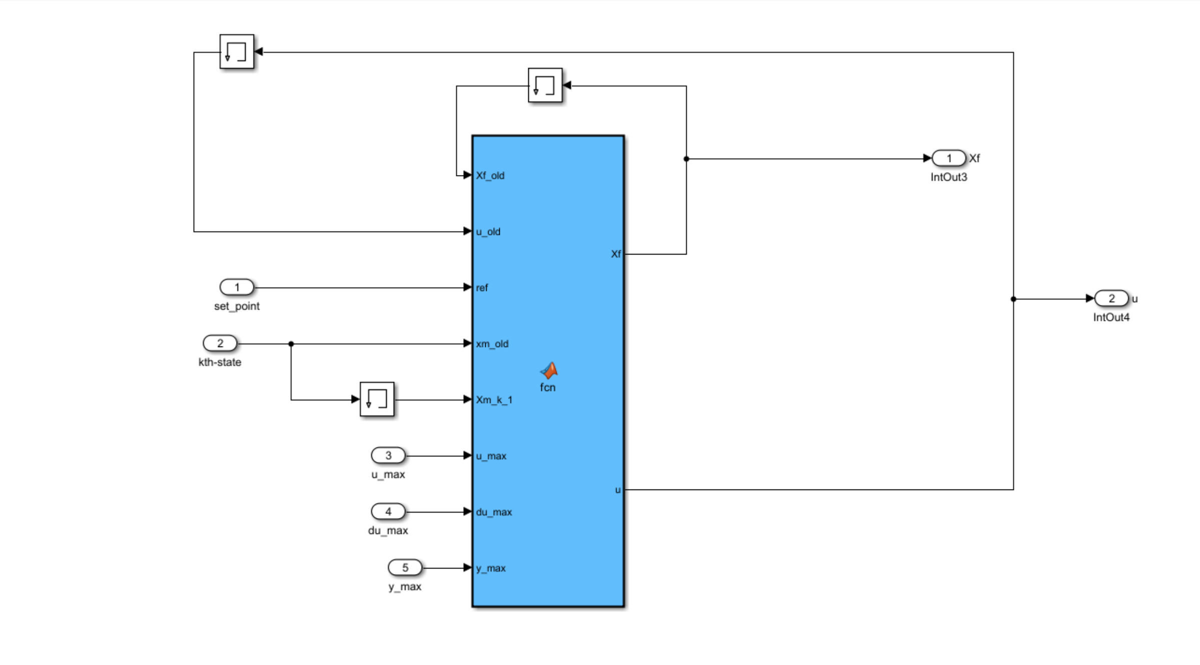
$$\min J = \sum_{i=1}^{N_p} x_m(k+i \mid k)^T Q x_m(k+i \mid k) + \Delta u(k)^T R \Delta u(k)$$

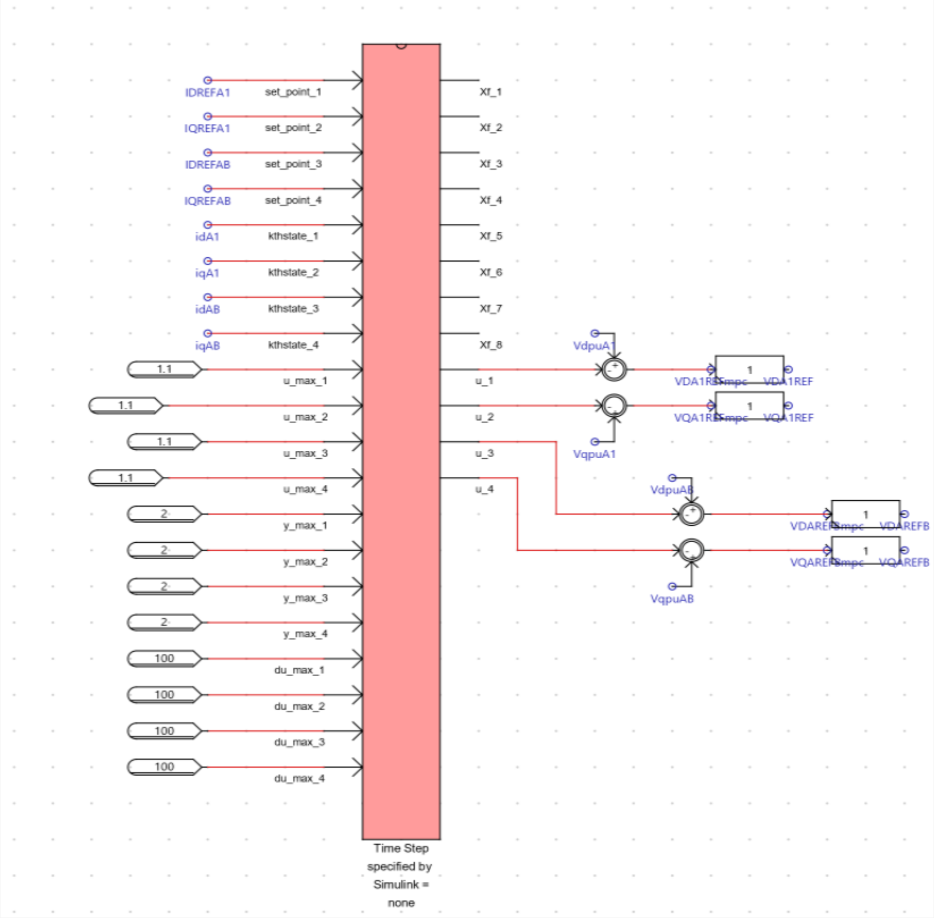
$$x_m(k) = r(k) - y_m(k)$$

$$-1.1 \text{ pu} < I_d < 1.1 \text{ pu}$$
$$-1.1 \text{ pu} < I_q < 1.1 \text{ pu}$$

MPC Controller

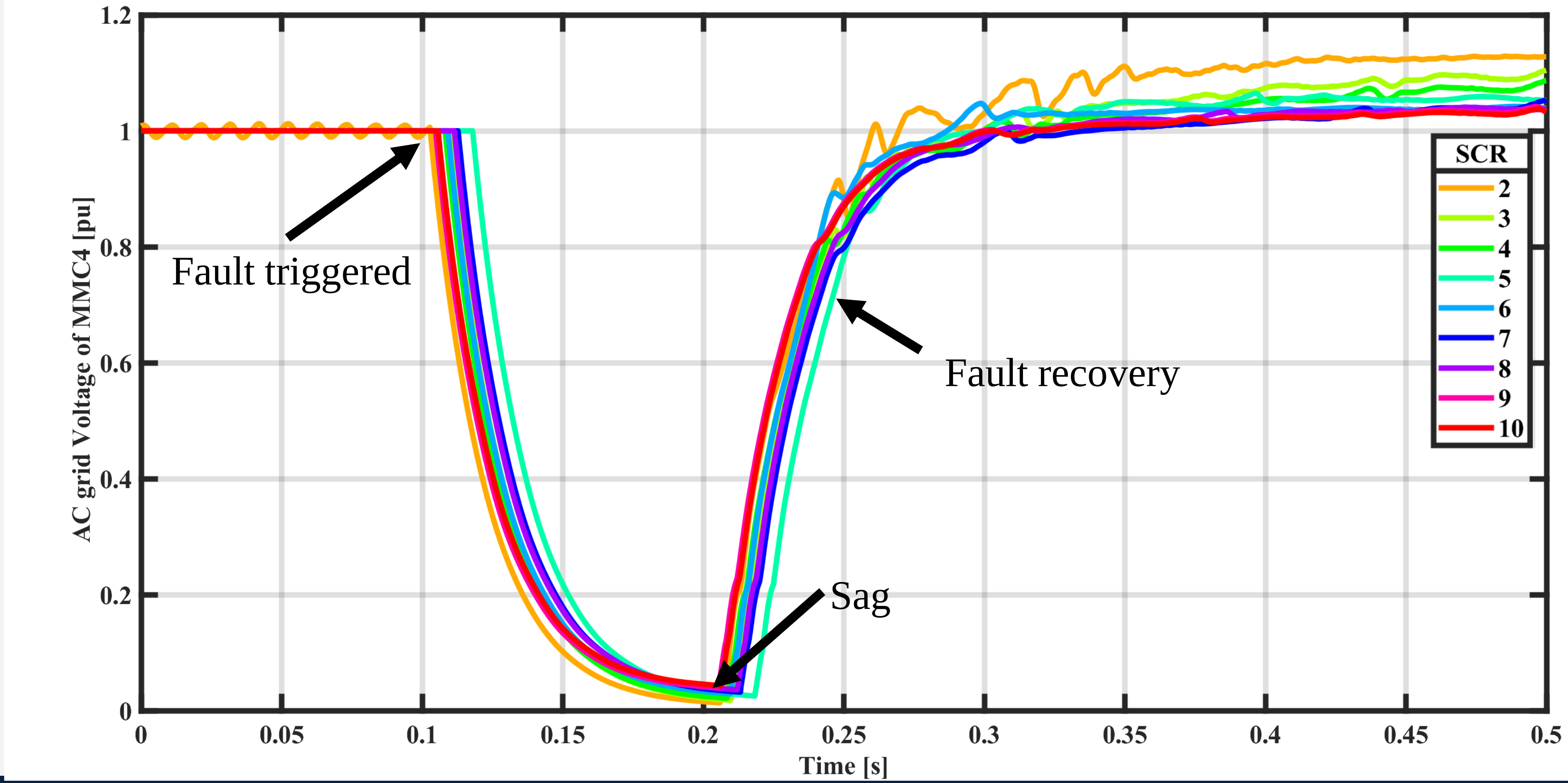
CUSTOM MPC COMPONENT USING SIMULINK



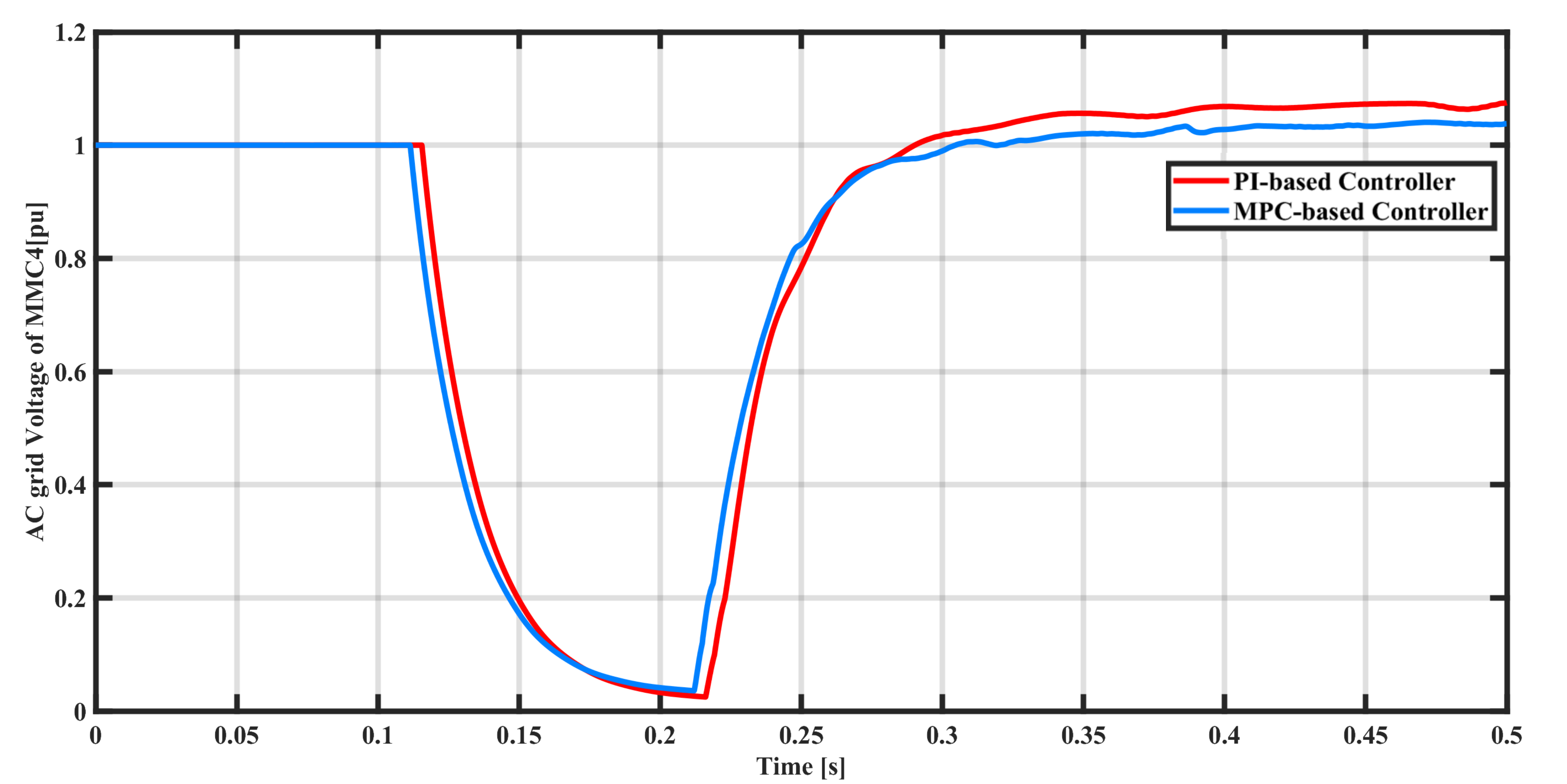


MPC Controller

Three-phase AC fault (with MPC controller)



Comparison of MPC and PI-based Controllers



MPC Controller

Comparison of MPC and PI-based Controllers

Settling time(s)	
MPC	PI
0.359	0.38
0.3679	0.384
0.3684	0.384
0.3797	0.385
0.3878	0.387
0.3897	0.387
0.3948	0.39
0.3979	0.40
0.42	0.42

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- Low SCR capability of Grid forming Converters
- Speed of response of MPC controllers

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MPC	PI
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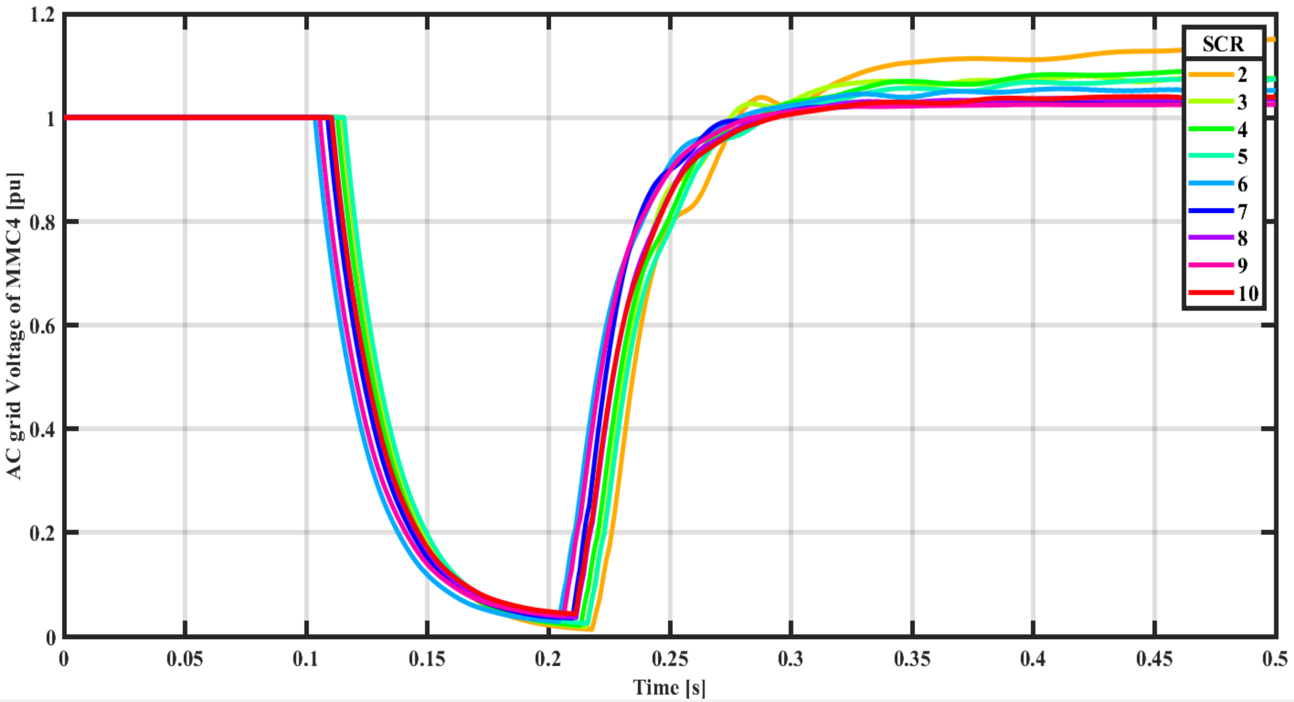

THANK YOU FOR YOUR ATTENTION

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1. Ebrahim Rokrok et al. *Effect of Using PLL-Based Grid-Forming Control on Active Power Dynamics Under Various SCR.*
2. Ajay Shetgaonkar et al. “Model predictive control and protection of MMC-based MTDC power systems”. In: *International Journal of Electrical Power & Energy Systems* 146 (2023), p. 108710
3. Taoufik Qoria et al. “Grid-Forming Control With Decoupled Functionalities for High-Power Transmission System Applications”. In: *IEEE Access* 8 (2020), pp. 197363–197378. doi: 10.1109/ access.2020.3034149Ãŕ. url: https://hal.archives-ouvertes.fr/hal-03703440.
4. Yiming Wang et al. “Transient Stability Analysis and Improvement for the Grid-Connected VSC System with Multi-Limiters”. In: *IEEE Transactions on Power Systems* (2023), pp. 1–16. issn: 0885-8950, 1558-0679. doi: 10.1109/TPWRS.2023.3245806. url: https://ieeexplore.ieee.org/ document/10045813/