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Department of Electrical and Electronic Engineering

Control of Point-to-Point MMC-HVDC Transmission to Provide Synthetic Inertia to Weak Grids

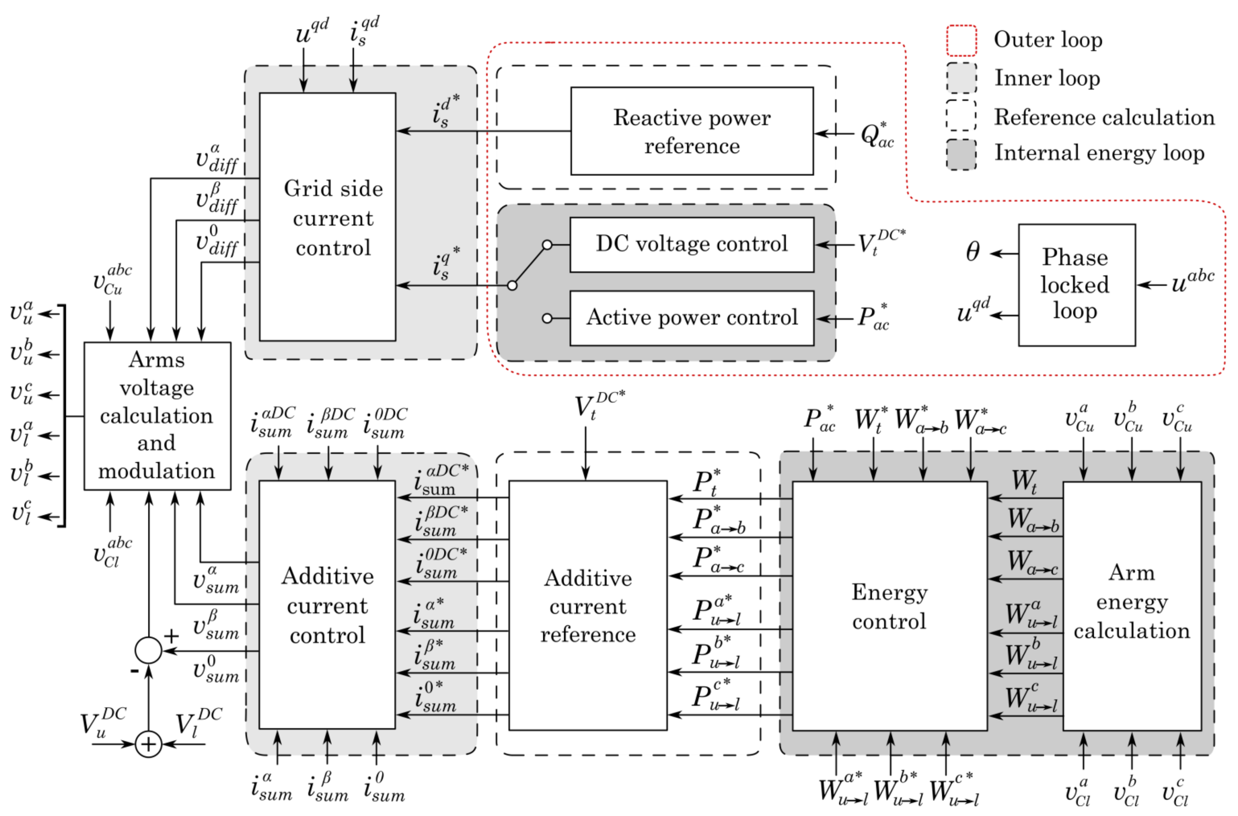
Jintao Wang,
Adria Junyent-Ferre,
Bikash Pal

MMC–HVDC control strategies

From the perspective of **DC-link voltage regulation**, MMC–HVDC control strategies for transmitting offshore wind power to the onshore AC grid can be classified into

1. Centralized leader–follower control

- The **leader station** regulates the DC-link voltage.
- The **follower station** controls the transmitted power and controls the fixed offshore AC voltage and frequency.
- Offshore wind generation is decoupled from the main AC grid.



Source: Sánchez-Sánchez et al., 2018 [1]

2. Decentralized DC voltage droop control

- Commonly used in **multi-terminal DC grids**.
- Multiple converters share DC voltage regulation through coordinated droop control.

Background

The increasing penetration of **inverter-based renewable generation (IBRs)** is changing power system dynamics. Replacing **synchronous generators (SGs)** with IBRs raises stability concerns due to:

- lower **system inertia**
- lower **short-circuit ratio (SCR)**
- weaker grid strength and poorer **frequency stability**

Features of traditional MMC–HVDC

- **Large-scale power transmission** (typically around or above 1 GW)
- **No frequency support** under onshore **grid-following (GFL)** control
- A converter trip may **worsen frequency excursions**
- Available stored energy comes from:
  - **MMC submodules** (not sufficient)
  - **HVDC cable capacitance** (not sufficient)
  - **wind turbine rotor inertia** (rotor speed recovery may cause a secondary frequency dip

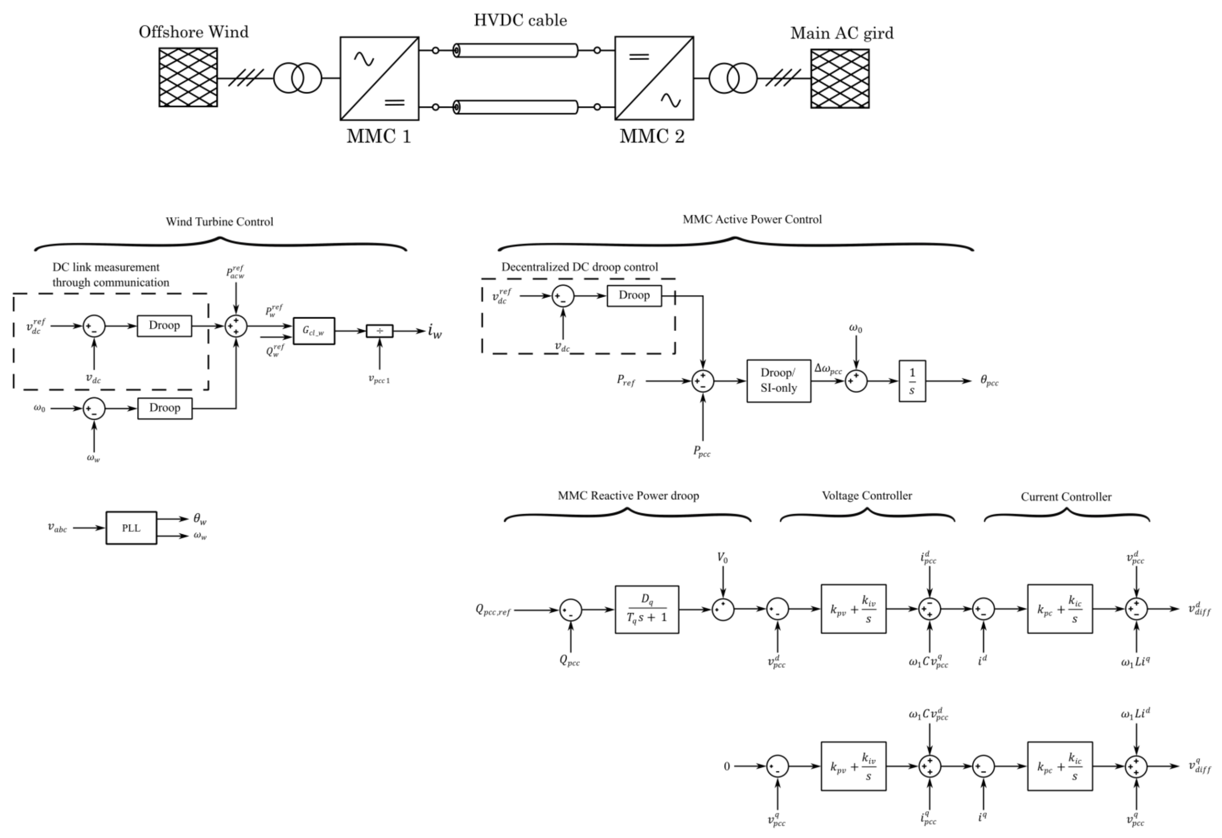
In **weak grids** with low inertia and low SCR:

- reliable **RoCoF** measurement is difficult
- sudden changes of the power will challenge the stability of the PLL.

How could we utilize rotor inertia?
Could we get rid of the PLL?

Proposed Control Scheme

The offshore wind turbine stored energy is utilized by coupling **onshore AC frequency**, **DC-link voltage**, and **wind turbine power**.



Proposed control scheme of MMC-HVDC to provide frequency support

Onshore MMC

- DC voltage control (in the outer loop) is replaced by **SI-only control** [2]
- **Decentralized DC voltage droop control** is added to couple AC frequency with DC-link voltage

Offshore MMC

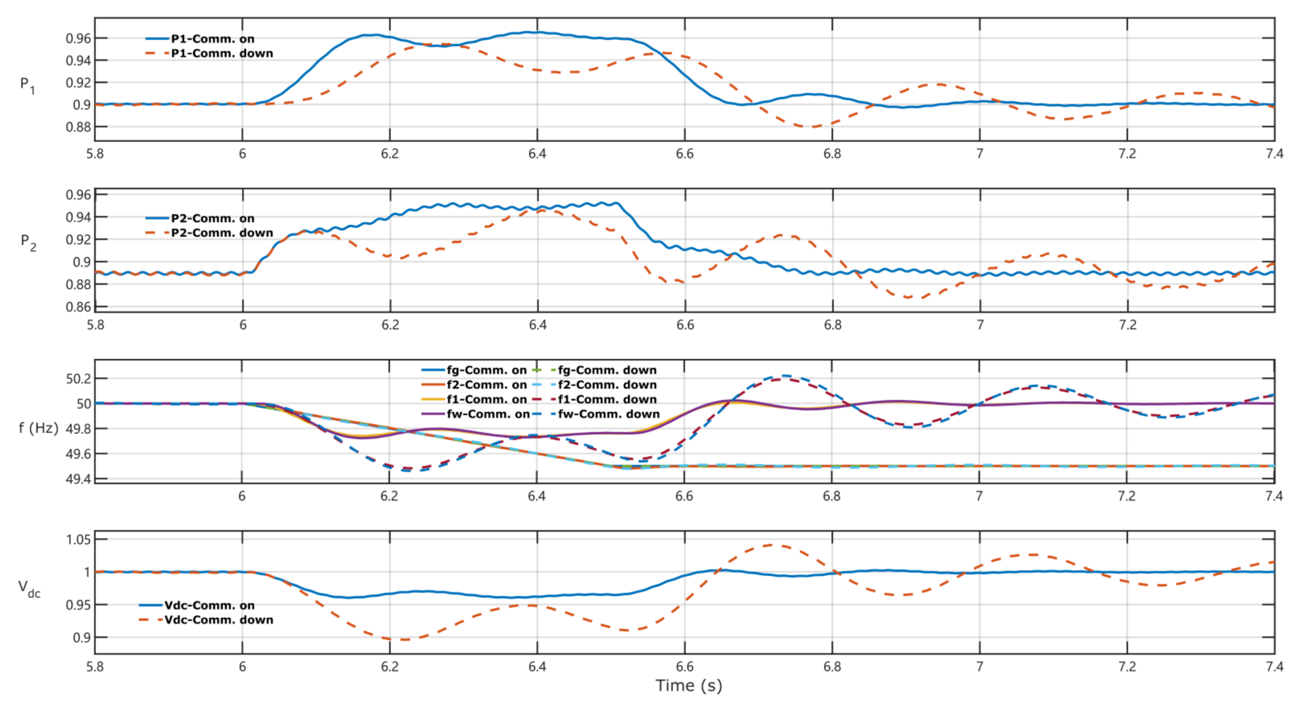
- Supports the DC-link voltage through **decentralized droop control**
- **P/f droop control** to establishes coupling between **DC-link voltage** and **offshore AC frequency**

Wind turbine

- Additional **DC-link voltage support** and **frequency support** are introduced
- Enable **fast response** through communicated DC voltage measurement

Simulation Studies

1. The DC-link voltage is **jointly supported** and serves as an **internal communication signal** to convey onshore grid frequency information to offshore wind generation
2. Case studies evaluate the **impact of communication availability.** Two scenarios are considered:
   - with communication: direct DC-link voltage support from wind turbines
   - without communication: DC link voltage and offshore AC frequency transmit information



Transient response of MMC-HVDC (H = 2, SCR=2, Communication on versus down)

Conclusion

- A **coordinated** MMC–HVDC frequency support framework is proposed for coupling offshore wind generation with onshore grid frequency.
- Direct DC-link voltage support from offshore wind turbines **improves system damping**.
- Retains frequency support capability under **communication-limited conditions**

References

[1] E. Sánchez-Sánchez, E. Prieto-Araujo, A. Junyent-Ferré and O. Gomis-Bellmunt, "Analysis of MMC Energy-Based Control Structures for VSC-HVDC Links," in *IEEE Journal of Emerging and Selected Topics in Power Electronics*, vol. 6, no. 3, pp. 1065-1076, Sept. 2018
[2] J. Wang, A. Junyent-Ferre and B. Pal, "Grid Forming Control with Decoupled Droop Gain and Synthetic Inertia," *2024 IEEE Power & Energy Society General Meeting (PESGM)*, Seattle, WA, USA, 2024, pp. 1-5