Complete Decentralized Control of AC Stacked Modular Converters as Coupled Oscillators

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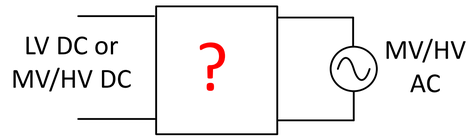
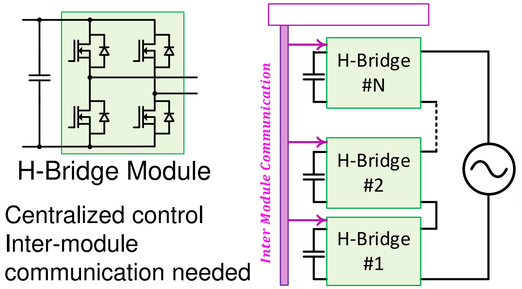
Overview

Problem statement



- MV/HV power conversion
- Modular hardware
- Communication-less complete decentralized control
- Redundant design- power stage & control

Existing Technology



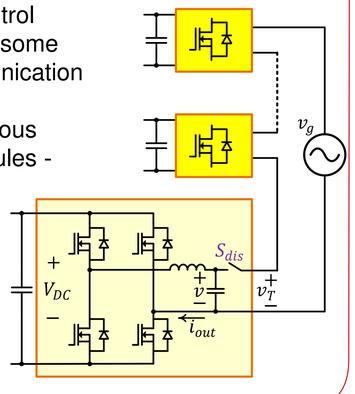
- Centralized control
- Inter-module communication needed

Modular multilevel converter (MMC)

- Modular power stage
- Centralized control with fast inter-module communication

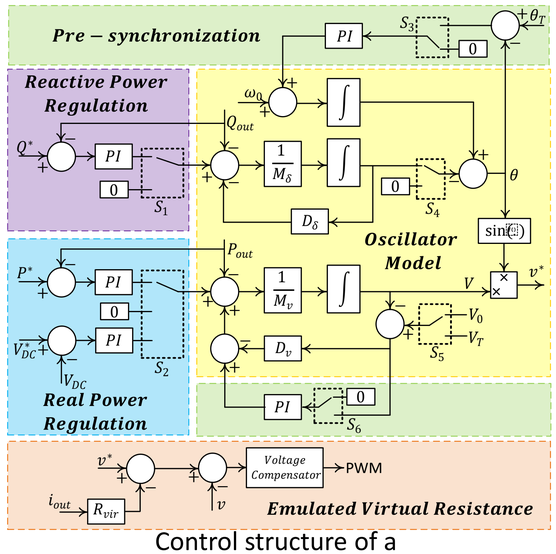
AC Stacked Solution

- All existing control methods need some form of communication [2]
- Nonhomogeneous control of modules - single point of failure [3]



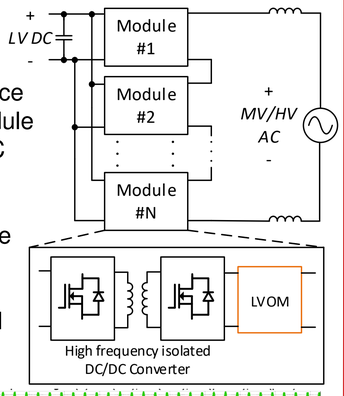
Method

Kuramoto Oscillator Control

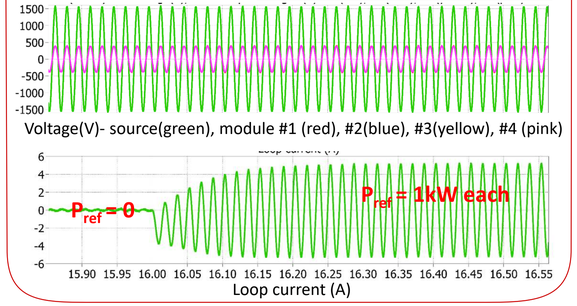


Control structure of a Low voltage oscillator module (LVOM)

Medium Voltage Application



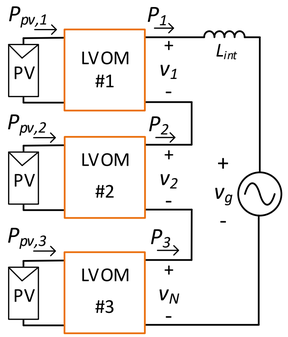
- 600V power device
- 277VAC per module
- Four modules AC stacked
- 1.1kVAC source
- LVDC bus voltage used for decentralized estimation of real power reference

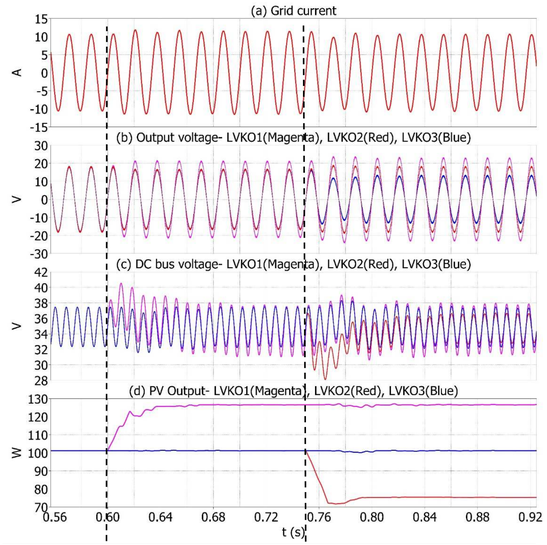


Results

AC Stacked PV Inverter

- 30VDC PV panel
- Single stage AC conversion
- Panel level MPPT using perturb & observe





#		Irradiance on Panel	
1	80%	100%	100%
2	80%	80%	60%
3	80%	80%	80%

- LVOM modules tracks step change in power injection within a few cycles
- Power output change in one module does not affect other module output

Future Work

- Switch at frequencies as high as possible leveraging wide bandgap power devices
- PCB embedded magnetics and small passives
- Single board modules integrating power stage and control

Potential Impact

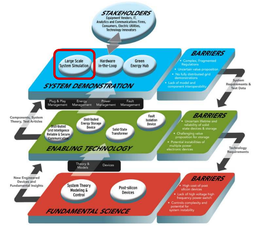
- Communication-less complete decentralized control
- No single point of failure
- Fault tolerant redundant design for MV/HV power conversion

References

[1] M. Awal, I. Husain and W. Yu, “Complete Decentralized Control of AC Stacked Modular Converters as Virtual Kuramoto Oscillators”, 2018 IEEE Energy Conversion Congress and Exposition (ECCE), 2018.

[2] P. Achanta, D. Maksimovic and M. Ilic, “Decentralized control of series stacked bidirectional DC-AC modules,” 2018 IEEE Applied Power Electronics Conference and Exposition (APEC), 2018.

[3] H. Jafarian, I. Mazhari, B. Parkhideh, S. Trivedi, D. Somayajula, R. Cox and S. Bhowmik, “Design and implementation of distributed control architecture of an AC-stacked PV inverter,” 2015 IEEE Energy Conversion Congress and Exposition (ECCE), 2015.



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