Using Distributed Energy Resources to Improve Power System Stability and Voltage Unbalance

DTU CEE **Summer School 2019**

MPEL MICHIGAN POWER & ENERGY LABORATORY UNIVERSITY OF MICHIGAN

Mengqi Yao <mqyao@umich.edu>

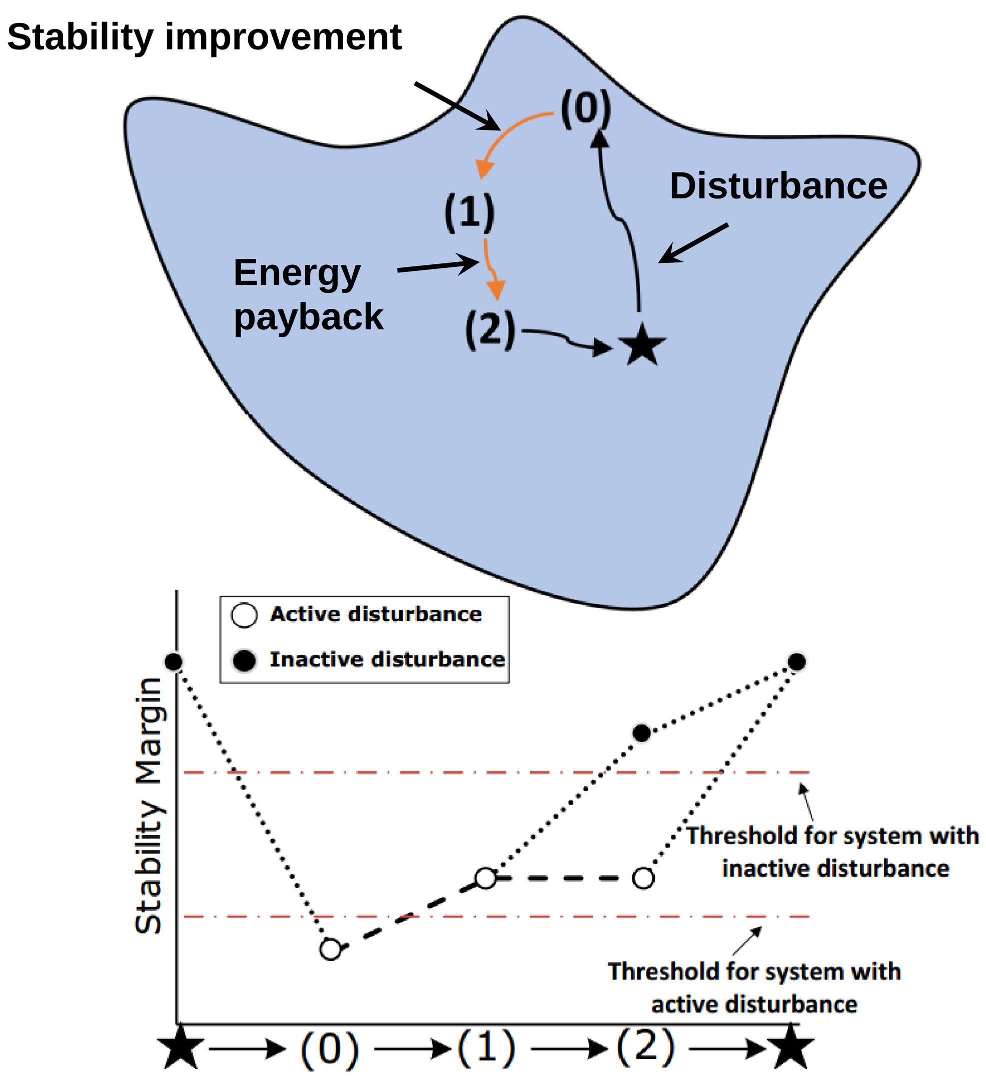
Objective

To reduce the negative impacts of renewables on the system, we need to develop proper control strategies.

- **Objective 1**: Developing methods to coordinate ***flexible loads*** to improve electric power transmission system stability
- **Objective 2**: Developing decentralized strategies to control reactive power of ***solar PVs*** to mitigate voltage unbalance in the distribution system

Project I

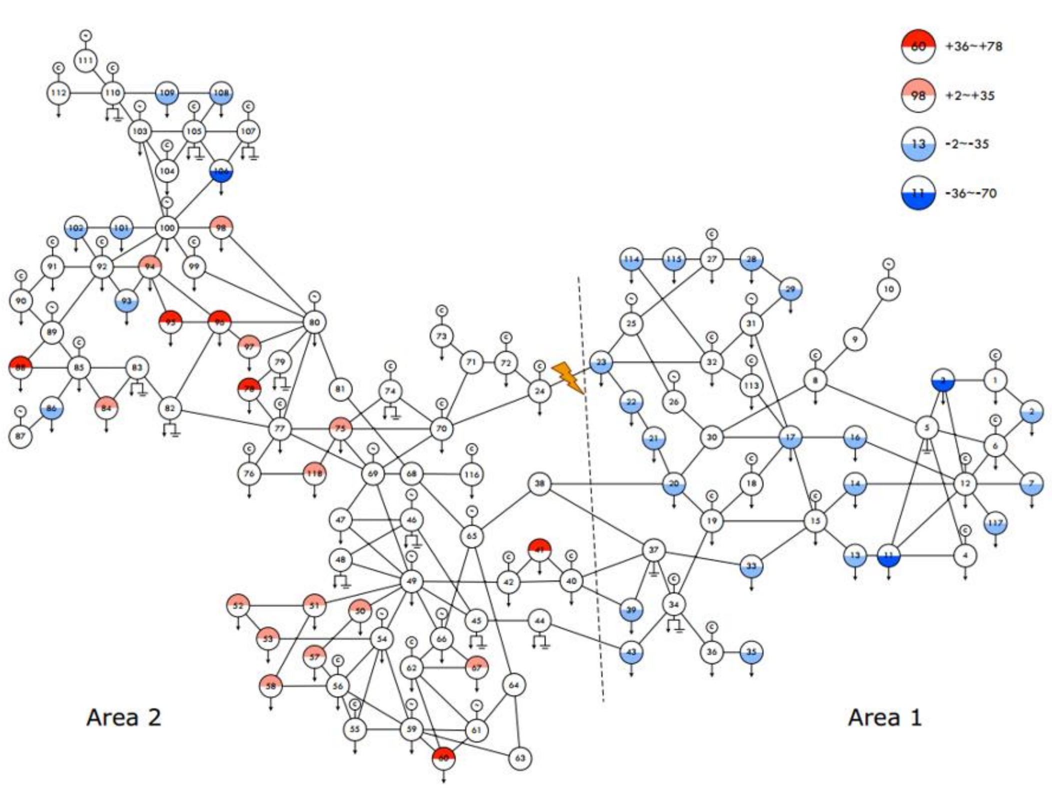
Past demand response program: 1) benefit the market 2) improve frequency stability by *time* shifting the energy consumption of flexible loads.
Our purpose and demand response strategy: Demand response based on *spatially* shifting load, *without* ***load shedding***, in order to improve voltage/small-signal stability after a disturbance.

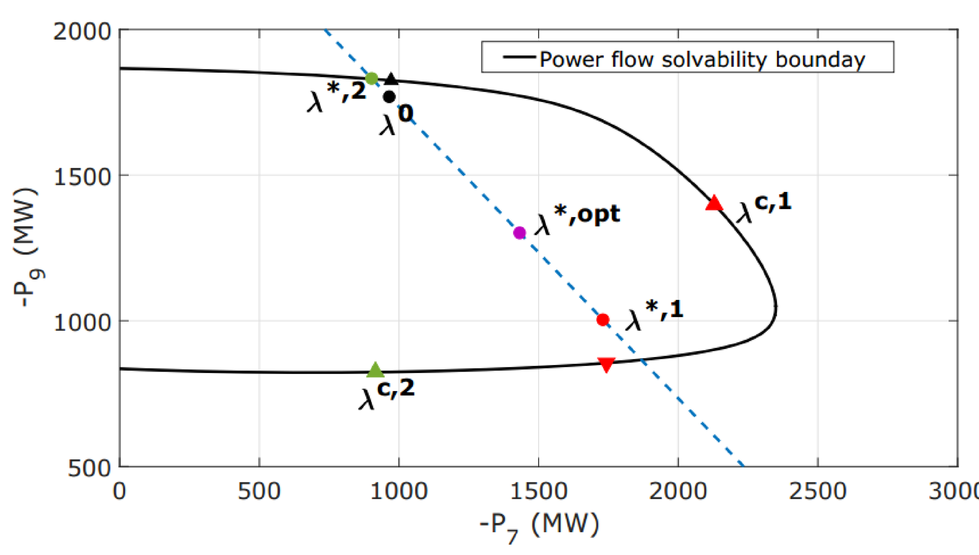


Results

Voltage Stability $\min_{x(t)} -\alpha\sigma_0(1) + \mathcal{C}(\boldsymbol{P}_{\rm g}(2))$

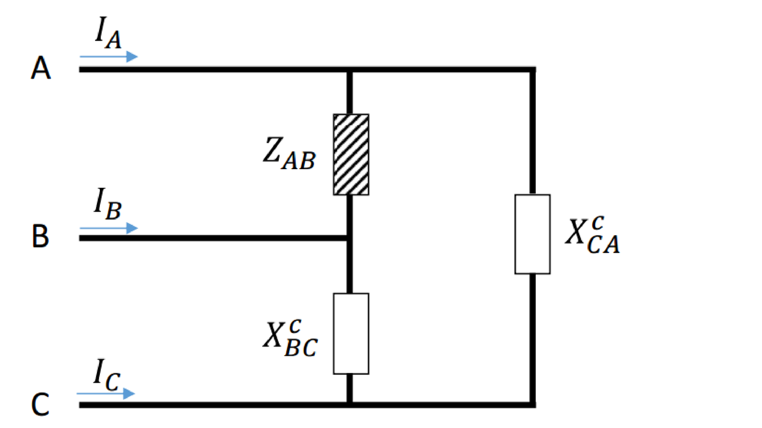
Stability margin : loading margin, SSV, distance to closest SNB



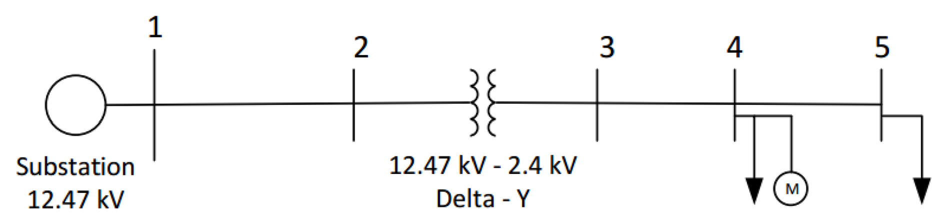


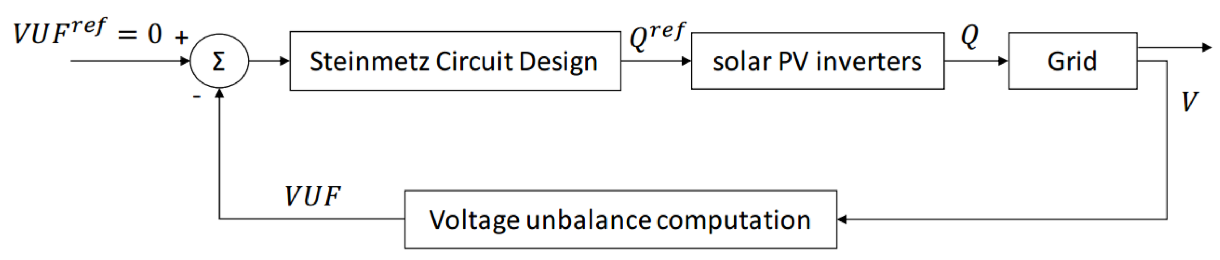
Project II

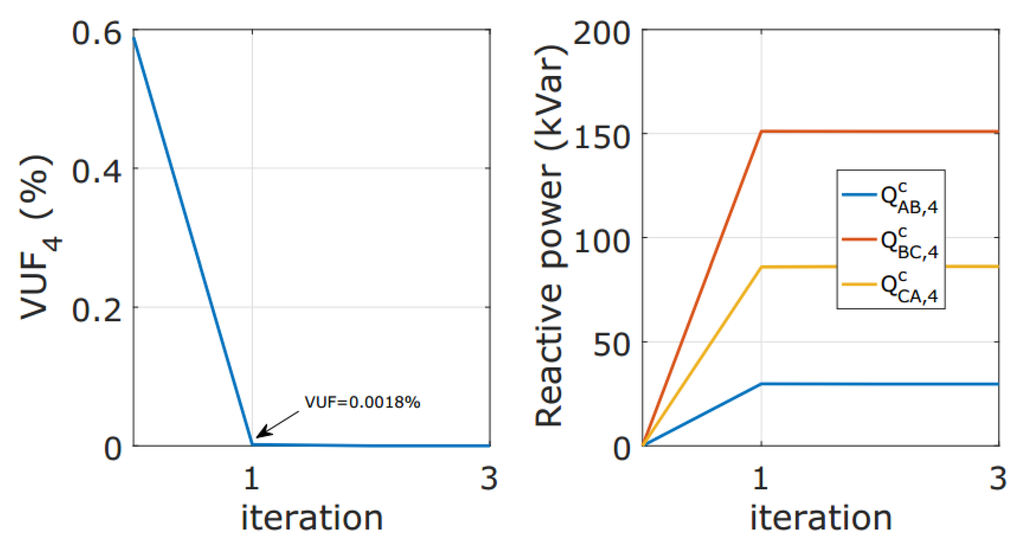
Steinmetz circuit design [1,2]: it aims to achieve voltage balance by controlling the reactances of three-phase delta-connected constant-impedance loads. The method is **simple**, **open-loop**, and **decentralized**, and so inexpensive to implement.



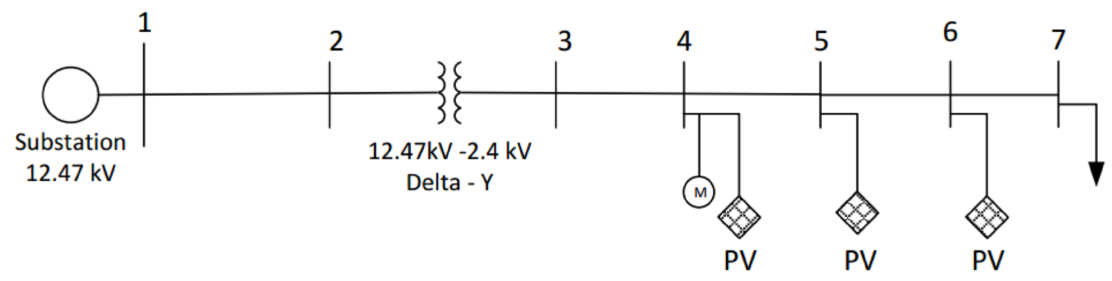
$$Q^c_{AB} = \frac{P_{BC}}{\sqrt{3}} + Q_{BC} - \frac{P_{CA}}{\sqrt{3}} + Q_{CA}$$
$$Q^c_{BC} = \frac{P_{CA}}{\sqrt{3}} + Q_{CA} - \frac{P_{AB}}{\sqrt{3}} + Q_{AB}$$
$$Q^c_{CA} = \frac{P_{AB}}{\sqrt{3}} + Q_{AB} - \frac{P_{BC}}{\sqrt{3}} + Q_{BC}$$







Distributed solar PV case



Initial $VUF_4 = 1.4755\%$

- Strategy #1 (decentralized controller): No communication between PV systems. Each system computes three-phase Q but only inject into the phase in which it is connected
  Final $VUF_4 = 0.1986\%$
- Strategy #2 (group controller):Communication is available. PV at bus 4 computes three-phase Q and communicates to other PV systems
  Final $VUF_4 = 0.0659\%$

Future Work

Project I:

- Gain a better understanding of why the loading patterns change in the way they do.
- Develop a formulation that incorporates both the voltage stability metrics and the small signal stability metrics and determines how different metrics impact the control of resources.

Project II:

- Test these approaches on realistic distribution feeders with high penetrations of distributed PV systems.
- Prove the convergence of the feedback controller.
- Benchmark the performance of these decentralized strategies against a centralized optimal control strategy.

Acknowledgement

Project I was funded by NSF Grant #ECCS-1549670
Project II was funded by DOE SETO Agreement # 34235