Phasor-Based Control for Scalable PV Integration

- Resources act to maintain a target voltage phasor difference (magnitude $V$ and angle $\delta$) between a pair of locations.

- As state variables, voltage phasors encapsulate all information about real and reactive power flow on the network.

Hierarchical layers:

Supervisory PBC computes phasor control targets at chosen nodes

Local PBC drives resources to meet targets

- Maintaining phasor targets rejects disturbances and prioritizes local network constraints, under arbitrarily high solar penetration levels.

Alexandra von Meier
University of California, Berkeley
Project partners: LBNL, Univ. of Michigan, OPAL-RT, GridBright, PingThings, PG&E

ENERGISE Project DE-EE0008008
Enabling Technology: µPMU

Micro - Phasor Measurement Units (µPMUs) developed through our Berkeley team’s ARPA-E OPEN 2012 project “Micro-Synchrophasors for Distribution Systems” make it possible to measure voltage magnitudes and phase angles with meaningful precision for distribution power flows.

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Motivating Intuition for Phasor-Based Control

What should Resource 1 be doing?

The desired injection $P_1, Q_1$ depends on the behavior of loads, other DER and network topology.
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Phasor profile $V_0 - V_1$

- reflects changes in $P_2, Q_2$ and $P_3, Q_3$ whereas net power $P_0, Q_0$ may not
- reflects changes in topology whereas net power $P_0, Q_0$ may not
- remains relevant to local operating constraints
- helps co-optimize real and reactive power
- allows resources to respond directly to behavior of other DERs without compromising privacy
Motivating Intuition for Phasor-Based Control

How should Resource 2 respond to a contingency?

If one transmission line fails, the network impedance between 1 and 2 will roughly double. Scheduled power flows $P_{12}, Q_{12}$ may exceed thermal or stability limits of the remaining line. Resource 2 has no way of knowing whether its scheduled $P, Q$ injection is still safe for the grid.
Motivating Intuition for Phasor-Based Control

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However: The profile $V_1 - V_2$ instantly reveals stress on the transmission path

By tracking the phasor difference, Resource 2 restores power flow on the remaining line
to the previous value of $\frac{1}{2} (P_{12}, Q_{12})$
Supervisory Phasor-Based Controller (S-PBC) assigns phasor targets

Supervisory controller performs a power flow optimization, whose results it expresses in terms of target phasors at performance nodes

- PBC is agnostic to the optimization criteria
- Optimization time step may be seconds or minutes

S-PBC uses a suitable compromise between full nonlinear and linearized power flow for computational efficiency
Local Phasor-Based Controller (L-PBC) tracks phasor targets

Local controller recruits one or multiple distributed energy resources

- actuators may include PV inverters, storage, controllable loads
- may be single- or three-phase
- may provide real and/or reactive power

Simulations show tracking phasor target, rejecting disturbances

Control time step ~ 0.5 to 1 sec

Several L-PBC algorithms are being tested
We are so excited to try this out!

Questions?
vonmeier@berkeley.edu