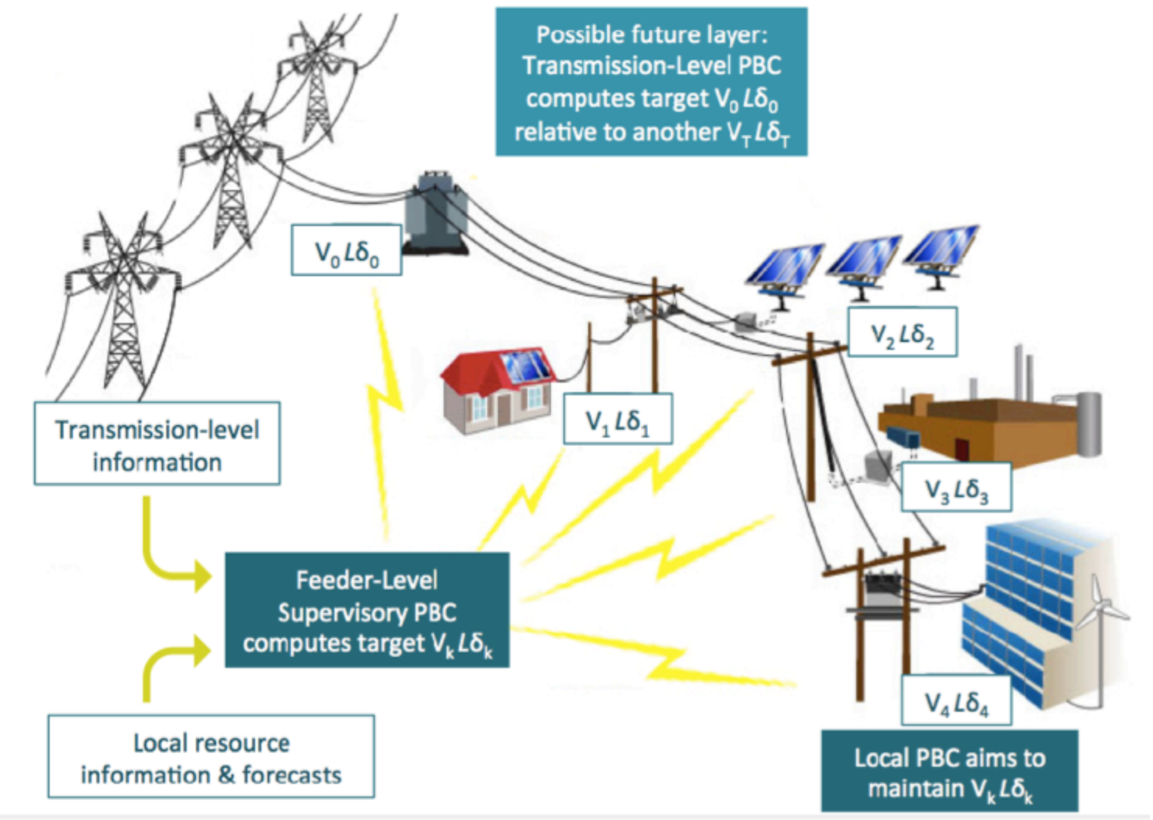
Phasor-Based Control for Scalable PV Integration



- Resources act to maintain a target voltage phasor difference (magnitude V and angle δ) 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

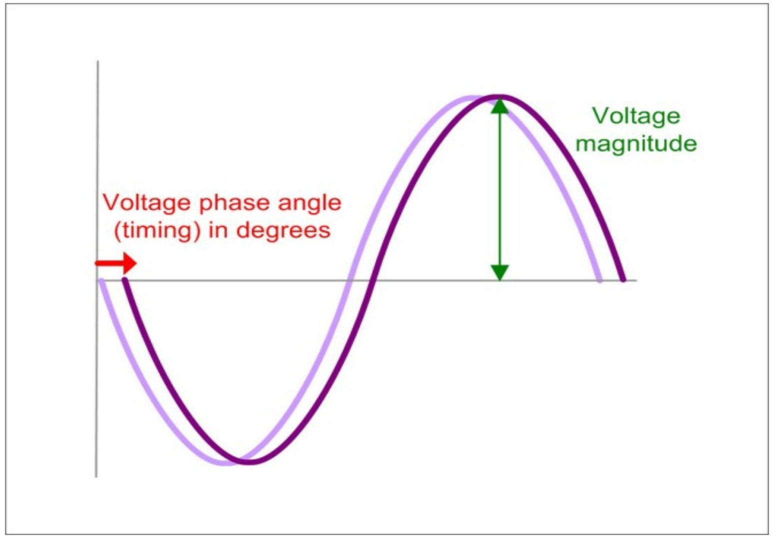
Micro - Phasor Measurement Units (µPMUs)

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

PSL

www.powerstandards.com

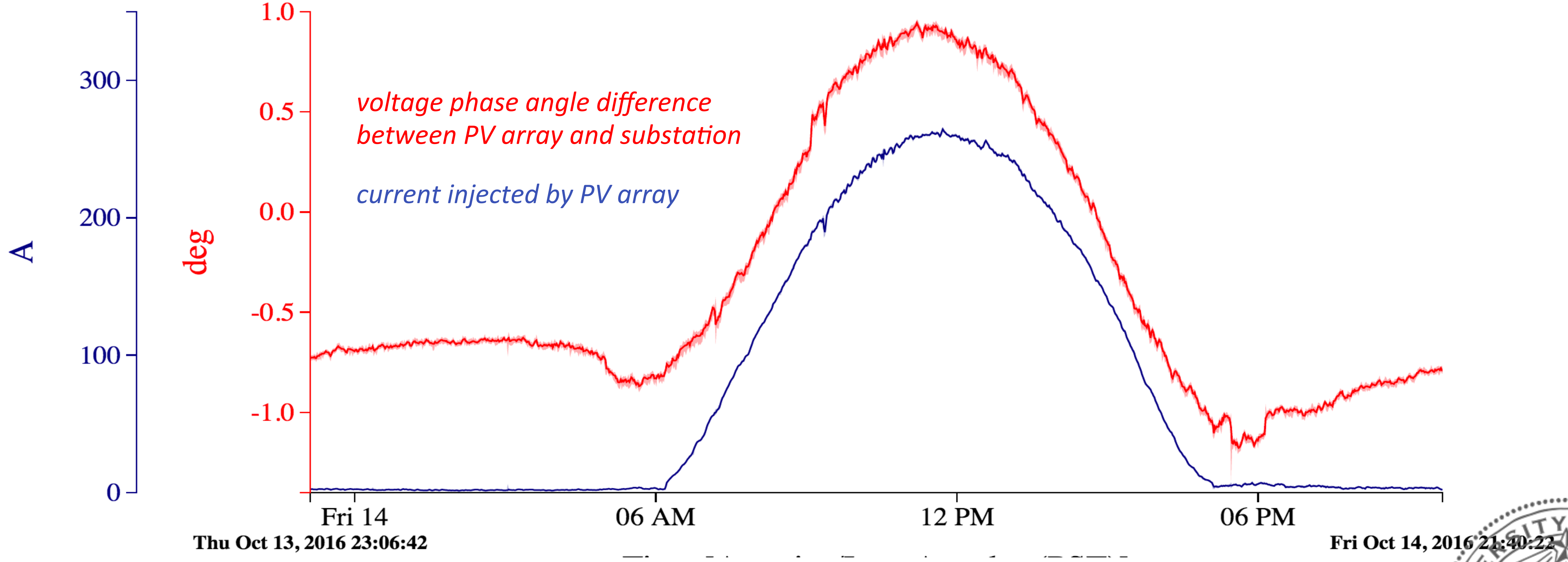


Enabling Technology: µPMU

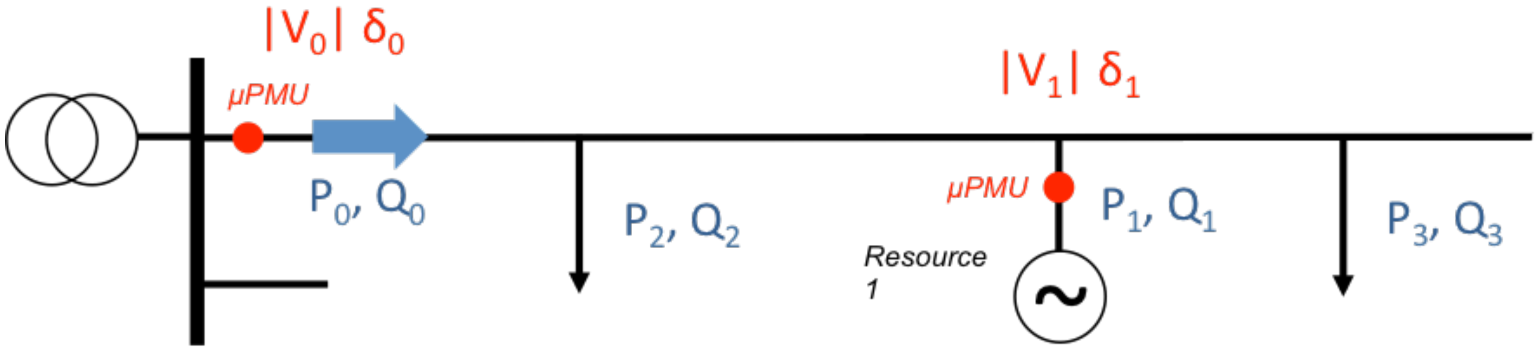
Micro - Phasor Measurement Units (µPMUs)

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



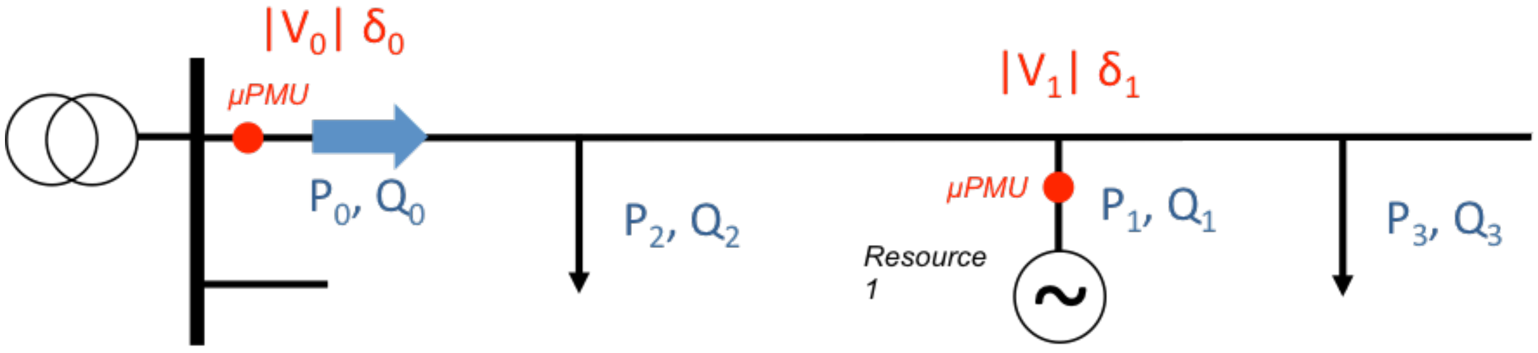
Motivating Intuition for Phasor-Based Control



What should Resource 1 be doing?

The desired injection P_1, Q_1 depends on the behavior of loads, other DER and network topology.

Motivating Intuition for Phasor-Based Control



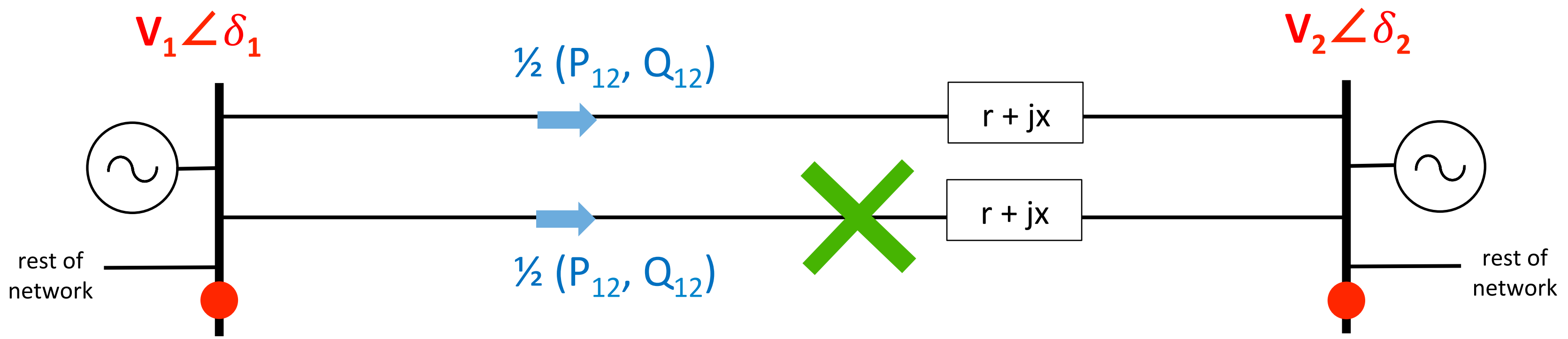
What should Resource 1 be doing?

The desired injection P_1, Q_1 depends on the behavior of loads, other DER and network topology.

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



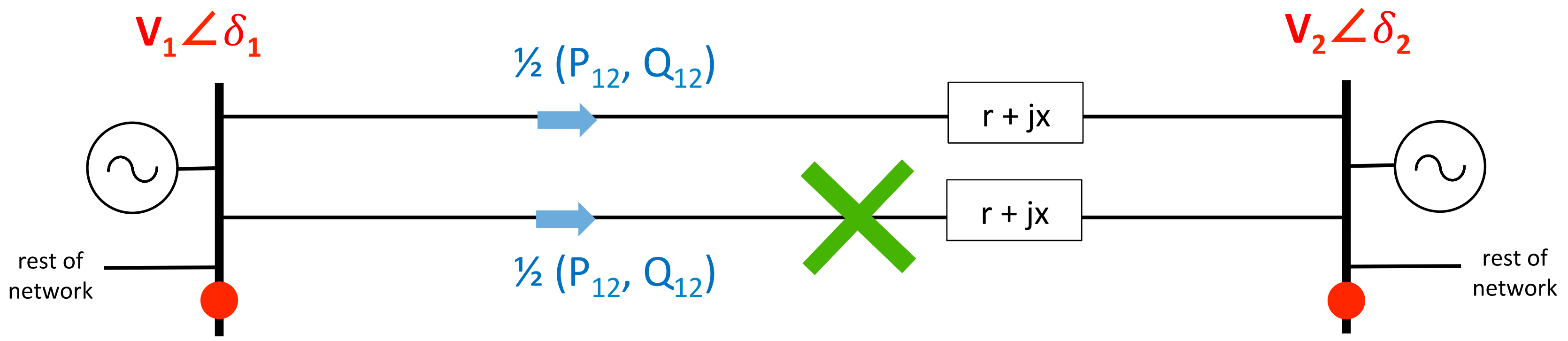
How should Resource 2 respond to a contingency?

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



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

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 ½ (P_{12} , Q_{12})

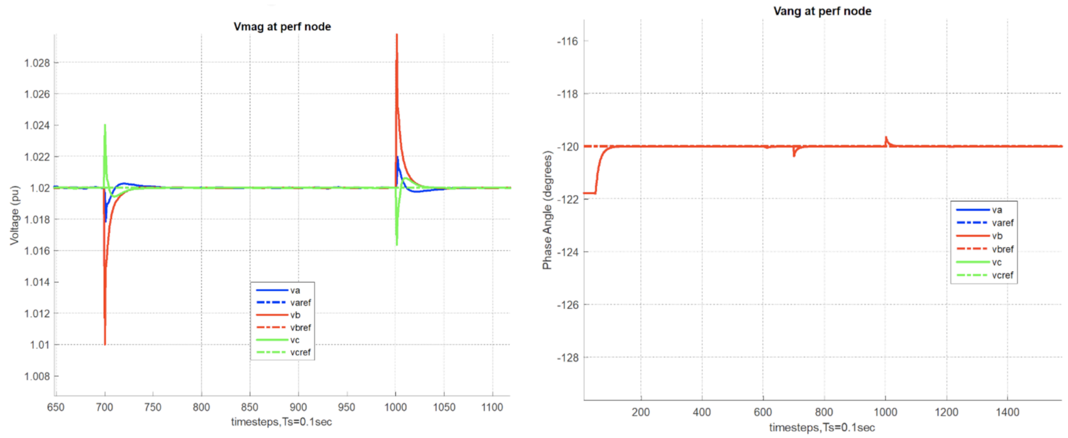
Supervisory Phasor-Based Controller (S-PBC) assigns phasor targets

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

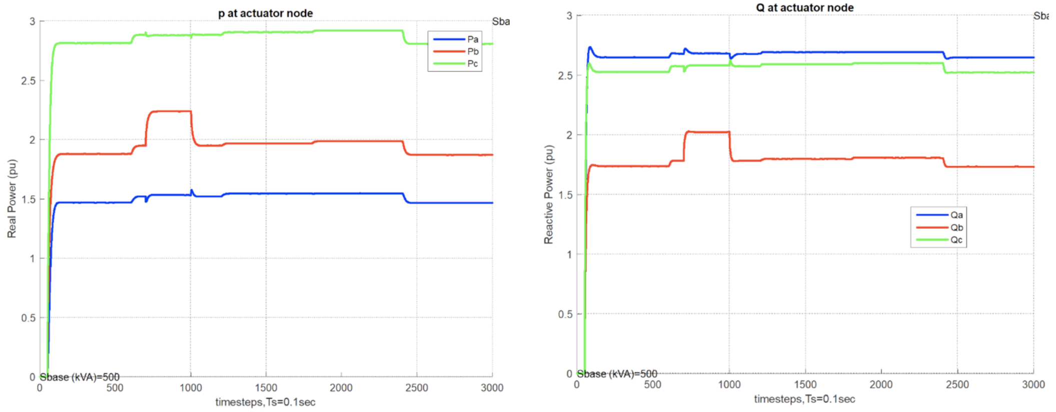
- PBC is agnostic to the optimization criteria
- Optimization time step may be seconds or minutes

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



Voltage magnitude (left) and phase angle (right) tracking by a three-phase local controller in response to a large step change in load elsewhere on the same distribution circuit



Actuation effort in real (left) and reactive (right) power to produce above results under PI control
Note different time scales in the two sets of graphs.

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!

BERKELEY LAB
Lawrence Berkeley National Laboratory

LBNL FLEXLAB

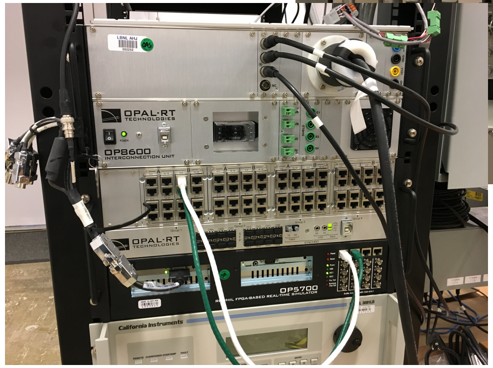
OPAL-RT

PG&E

UNIVERSITY OF MICHIGAN

PingThings

GRIDBRIGHT



Questions?
vonmeier@berkeley.edu

ENERGISE Project DE-EE0008008 UC Berkeley