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Evaluation of Communication Requirements for Voltage Regulation Control with Advanced Inverters

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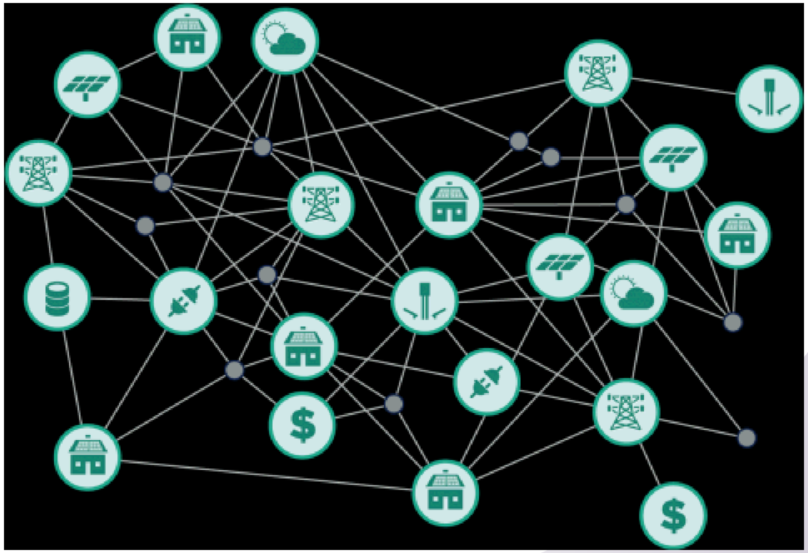
Background

- Project is intended to demonstrate advanced inverter functions in Distribution/Transmission simulations to better inform ambitious DOE SunShot Initiative communication requirements.
- Use case focused on a central control dispatch of fixed power factor(PF) or constant VAr settings to PV inverters to mitigate voltage regulator (VREG) tap operations by monitoring voltage.
- Communication variables tested:
  - Interval
  - Reliability
  - Latency
  - Bandwidth



Communications, SunShot, DOE. http://energy.gov/eere/sunshot/communications

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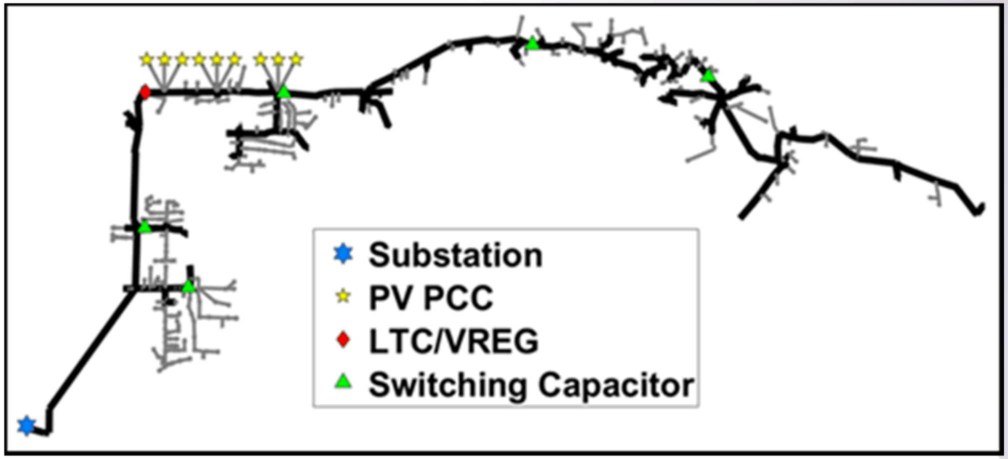
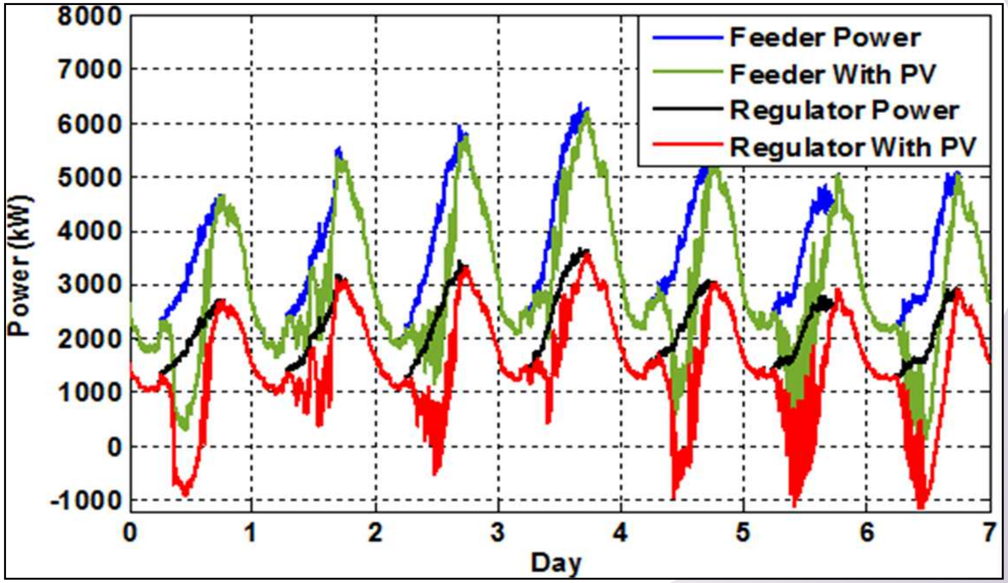
Simulation Test Setup

- 12kV distribution feeder with a 6.4 MW peak load
- VREG 6km from the substation
- Simulated peak load week of 6/27 – 7/3 in OpenDSS at 1-second resolution
- Simulated 9 PV systems at 3 locations downstream of the VREG for a total of 2.8 MW
- Used array of 7 irradiance sensors to model individual PV output propagating clouds eastward

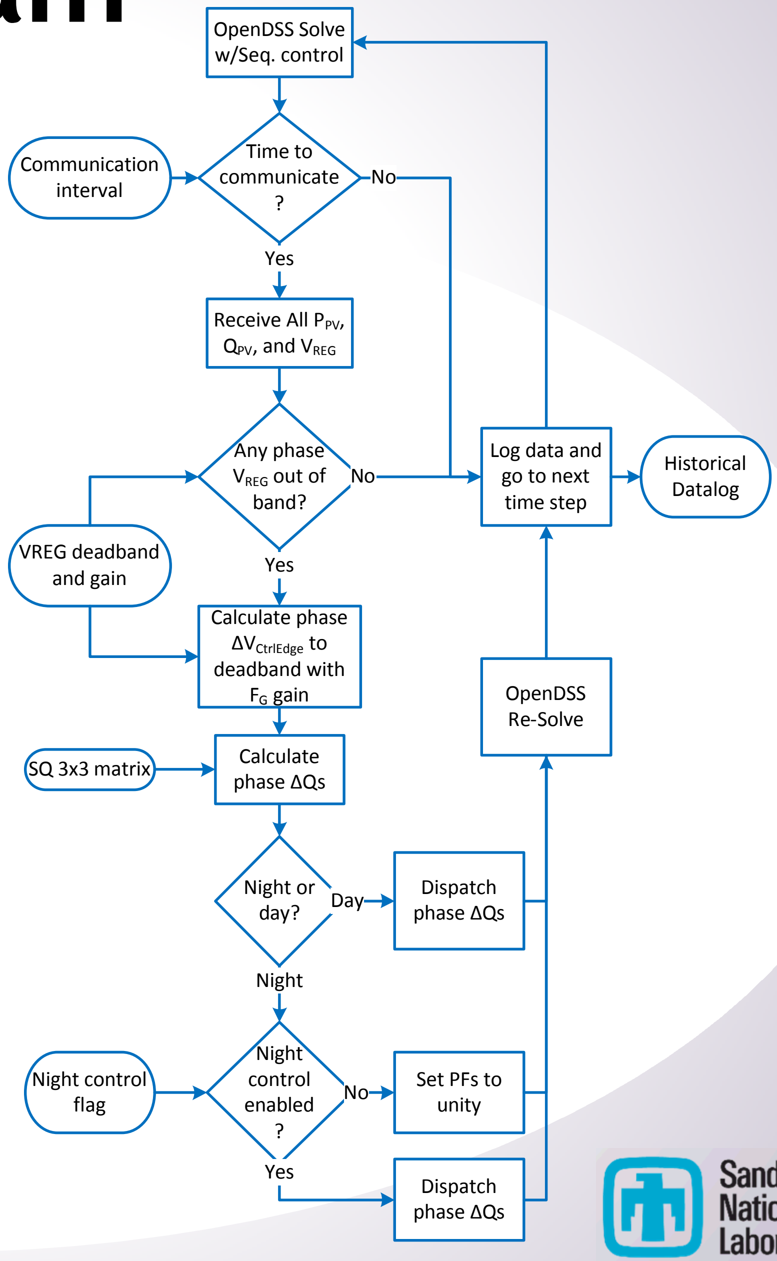




PV Control Diagram

- Communication interval determines frequency of control updates
- Controller settings based on VREG setpoint and bandwidth
- Voltage outside of deadband triggers action (80% tighter)
- $\Delta V_{CtrlEdge}$ multiplied by gain to determine ΔV needed
- Voltage sensitivities used to calculate amount of ΔQ needed

$$SQ_{ij} = \frac{\Delta V_i}{\Delta Q_j}$$

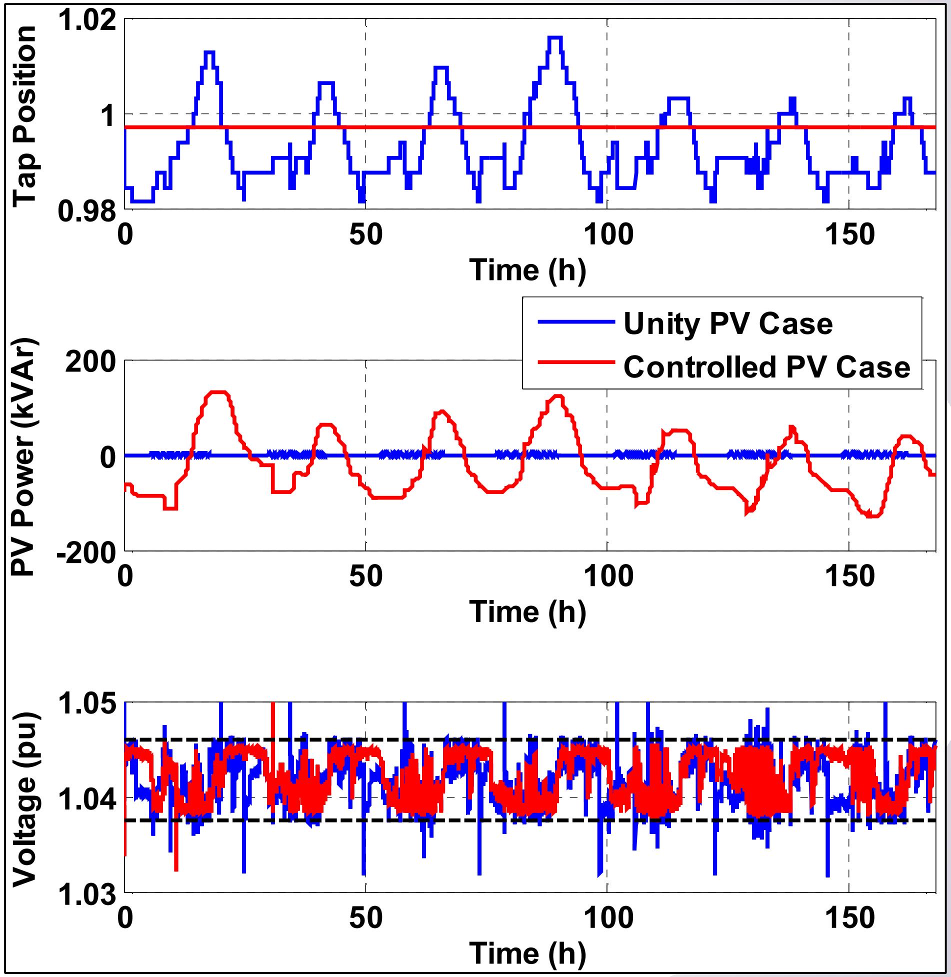


Power Factor Dispatch Results

- INV3/Fixed PF was evaluated due to popularity of function to date
- Valuable discovery: PV real power output is highly variable, proportional to irradiance. Fixed PF dispatch results in large ramps in reactive power, which can be problematic with high variability
- Since X/R ratios are generally greater than 1, the large, quick ramps in reactive power output create a larger impact on the voltage compared to solely changing the real power output. The power factor dispatched to the PV systems was appropriate for that instant, but once the real power changed, the impact on the VArs became more detrimental than helpful
- With 1-second communication interval the controller removed all regulator tap changes. As the communication interval was increased, the fixed PF caused amplified voltage swings on the feeder, which conflicted with the VREG and caused thousands of tap changes

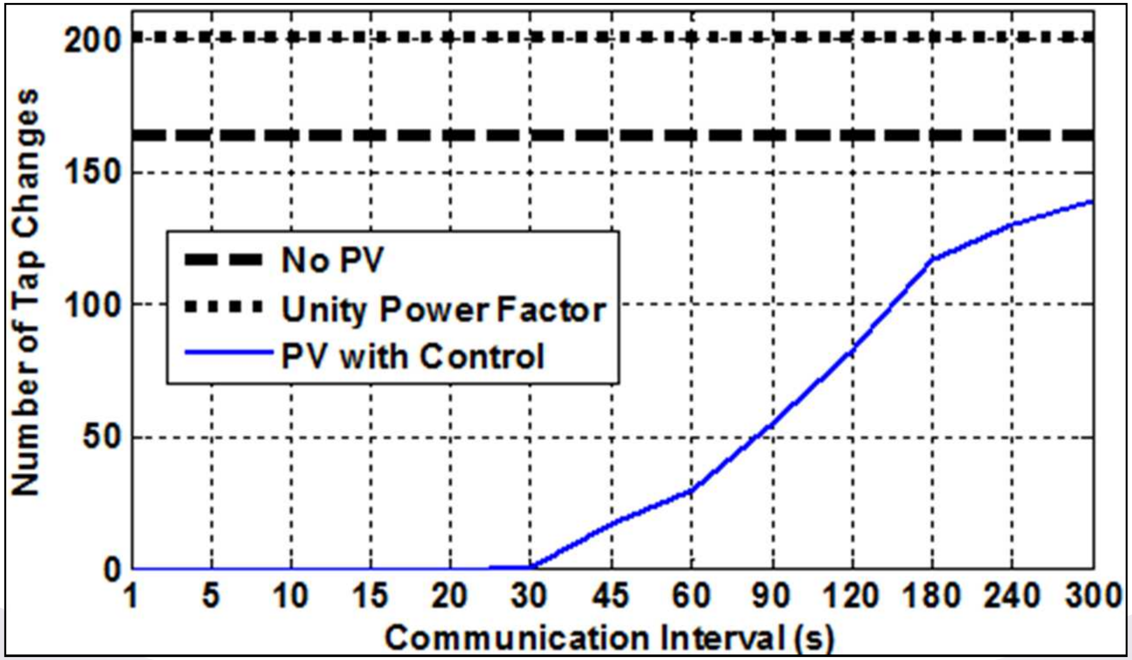
Reactive Power Dispatch Results

- VV13/Constant VAr function was evaluated
- Advantage: Reactive power output constant despite variable irradiance and real power
- 1-second communication interval results displayed



Communication Interval Results

- Communication interval – frequency of communication between controller and inverters, e.g. every 5 seconds
- Varied from 1 second to 5 minutes
- VAr-based controller simulations with night control enabled for 100% reliable communication, no network delays, and enough bandwidth to communicate with every PV system simultaneously



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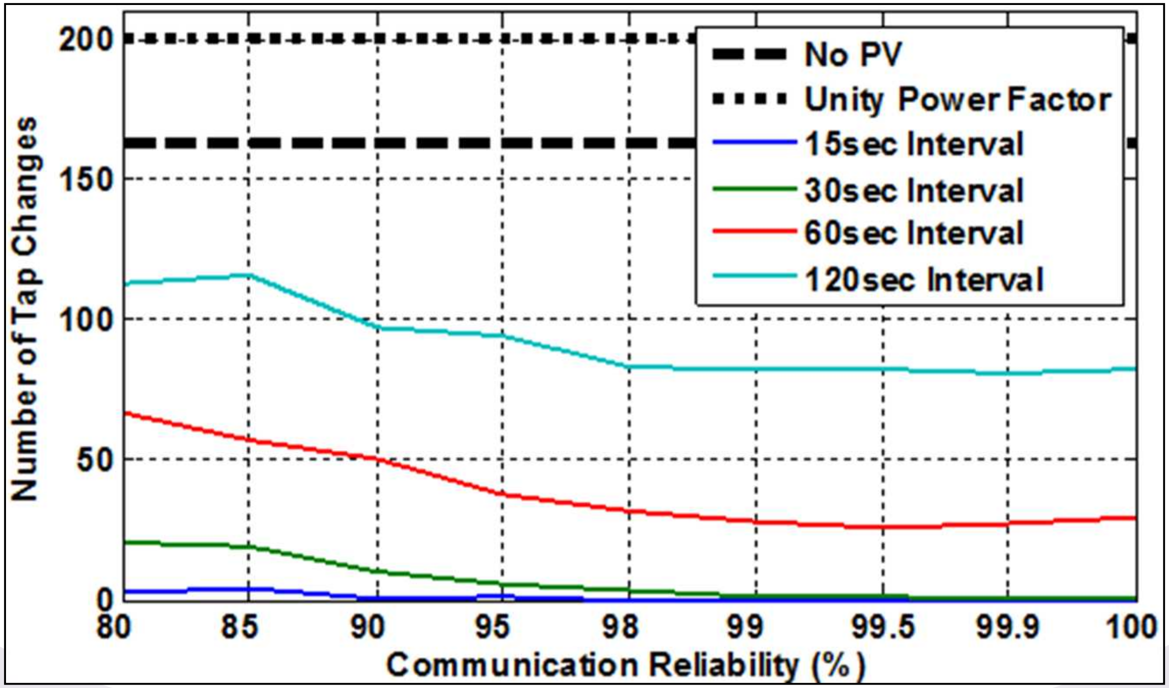
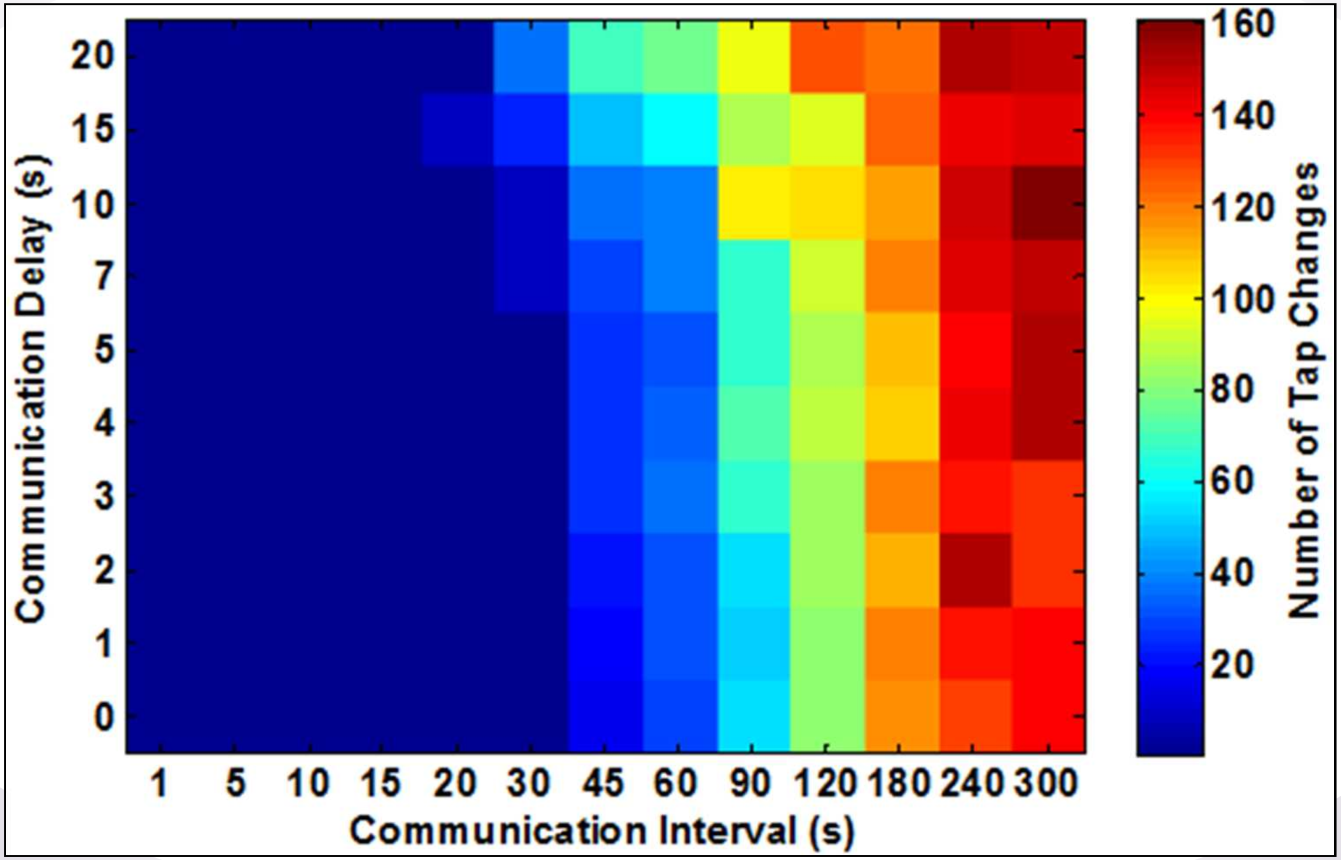
Communication Reliability Results

- Communication reliability– probability of successful communication
- Varied from 100% to 80%
- Communication failure could occur during times the voltage was within band or a voltage issue being missed, resulting in VREG tap
- Run twice for each test condition, averaging results



Communication Latency Results

- Communication latency – delay time from measurement to implementation of new setting (previously assumed to be within 1 second)
- Varied from 1 second to 20 seconds



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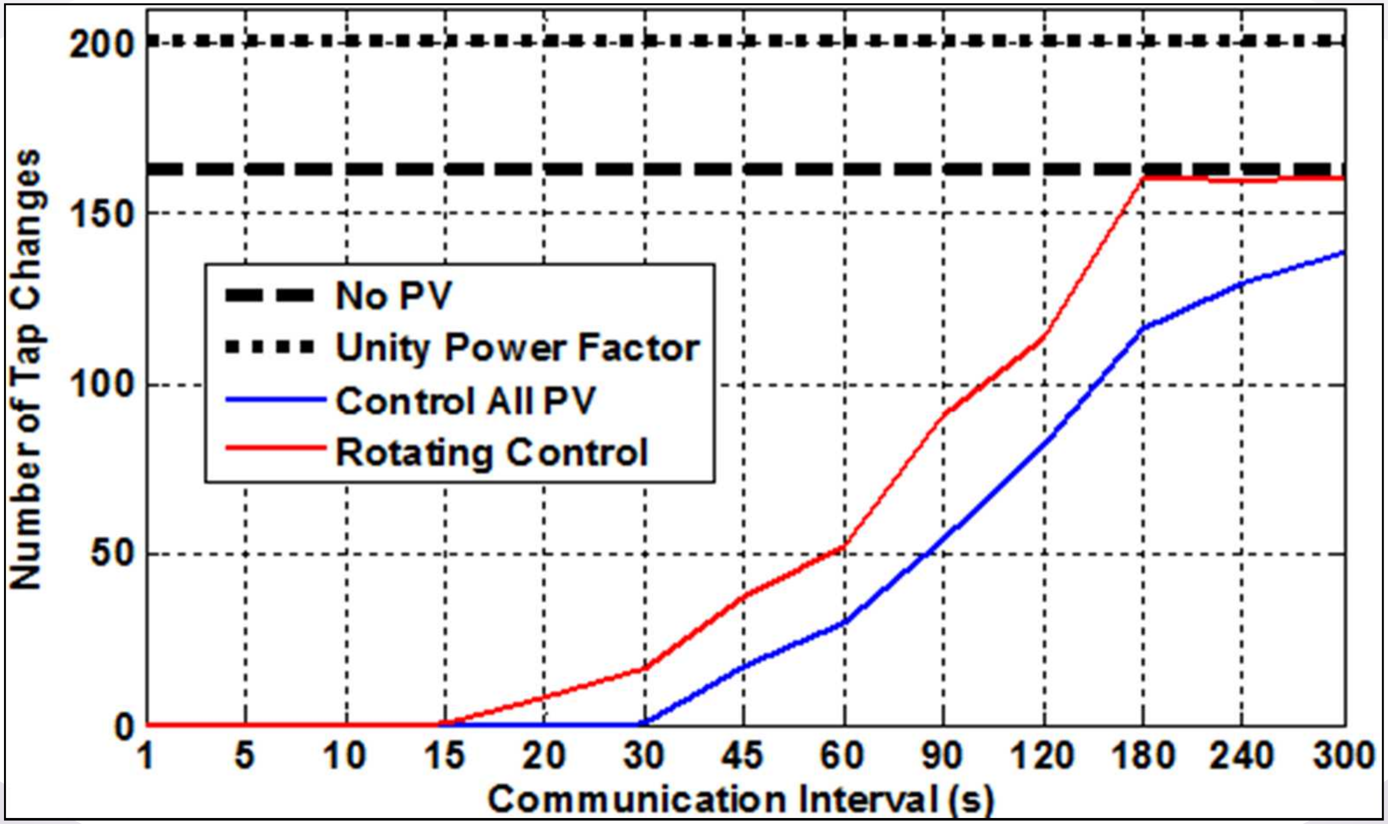
Communication Bandwidth Results

- Communication bandwidth – the number of inverters the controller can communicate with at a time
- Rotating control was developed to control 1/3 of the PV systems at a time



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Conclusions

- PF-based dispatch introduced complications under high-variability
- Constant VAr-based control mitigated all tap changes up to 30 seconds and remained below basecase and unity PF thresholds up to 300-second intervals
- Reliability did not have a noticeable impact as long as it was at least 98%
- Communication latencies of 10 seconds or greater had a noticeable impact on the system controller
- For bandwidth-limited communication networks, a rotating control improved the results from communicating less frequently
- Experiments with a reduced AC-to-DC ratio limiting the amount of VAr capacity would produce different results
- Impacts such as thermal limitations, ANSI voltage compliance, and increased losses could be monitored

Thank you!

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