Automatic AC Voltage Stabilization Using PV Inverter Control

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SYSTEMS INTEGRATION

Objective: *Utilize the Ability of PV Inverters to Generate Fast Reactive Power to Regulate Voltage on the Utility Distribution System*

Motivation & Background

Effective planning can address many of the regional and long-term impacts of PV Intermittency:

- Daily and seasonal irradiance patterns are predictable
- Geographical dispersion of PV generators has an averaging effect on sudden changes in irradiance
- Short-term forecasting can predict impending irradiance changes

At the local power distribution level, intermittency from renewables can lead to:

- Voltage variation, possibly outside ANSI-C84.1 limits
- Observable "Flicker" due to fluctuating voltage
- Increased switching operations for line regulators, tap changers, capacitors
- Transient voltage on sudden trip of DG station

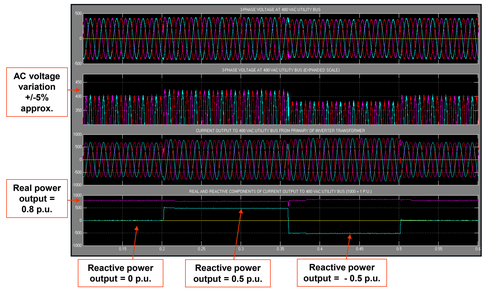
….limits reliability, performance, and availability of intermittent renewables

→ Ultimately limits the penetration of PV

PV Inverters are a nearly ideal source of reactive power which can be used to complement existing voltage regulation schemes:

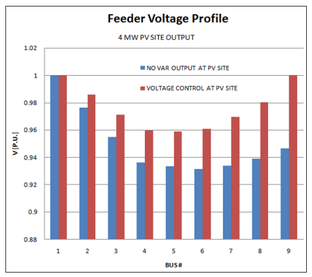
- Reactive Power response in <1 cycle
- For feeders with X/R>1, VArs can drive the local voltage to a target set point
- VAr contribution is often "free"

➢ Feeder X = 0.1 p.u. on inverter base



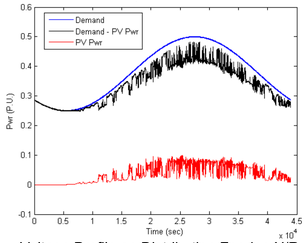
Prior and Ongoing Development:

- High Penetration of PV in California (NREL Lead)
- Direct Var injection
- Adjustable Power Factor
- Low Voltage Ride Through
- Real power curtailment and ramp rate control
- Utility dispatch
- Coordination between multiple inverters at a single site.

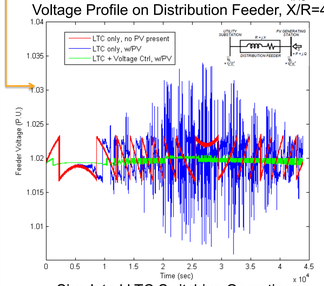


Voltage sag mitigation using inverter Var capacity

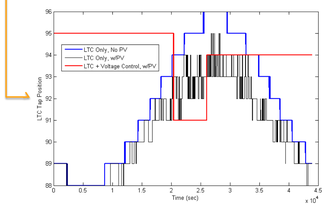
Idealized demand profile w/Intermittent PV



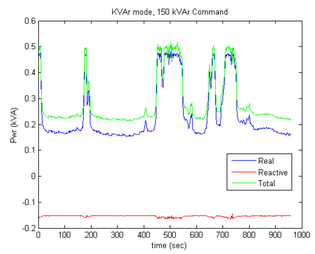
Voltage Profile on Distribution Feeder, X/R=4

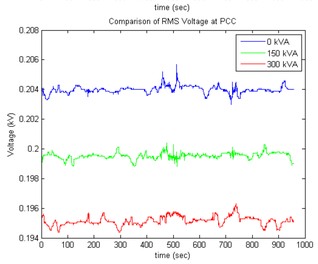


Simulated LTC Switching Operations



Inverter Testing at FSU-CAP Microgrid: Reactive Power Command Mode





Approach

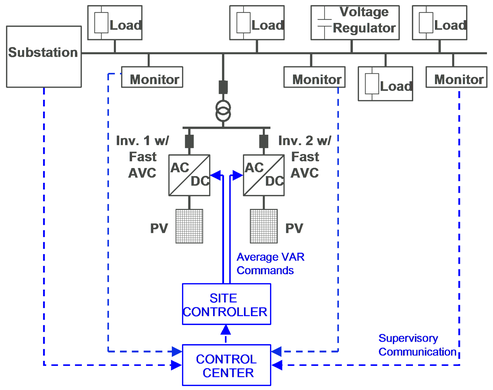
Inverter provides fast reactive power: The PV inverter acts as a dynamic voltage stabilizer by generating or absorbing reactive power while simultaneously delivering variable real power output to the grid, compensating for voltage changes that occur much more quickly than conventional regulators can respond,

Conventional regulators provide slower "bulk" voltage regulation: Conventional voltage regulators – e.g., LTCs or switched capacitor banks – act to correct voltage at time scales of tens of seconds to minutes, and provide bulk regulation of voltage.

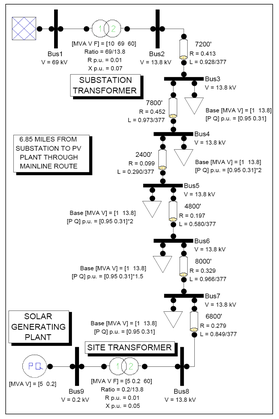
Inverter maintains a dynamic VAr reserve: The inverter responds to a sudden change in voltage by quickly deploying reactive power, and then slowly backing off its reactive power generation to maintain a predetermined reserve capacity. At its core, the inverter's role is to *slow* the rate of change of voltage on the feeder until conventional regulators can react.

Utility SCADA network can be used to dispatch local VArs from the inverter: The inverter may be used to optimize the voltage profile along a feeder by providing a local, distributed source of bulk reactive power.

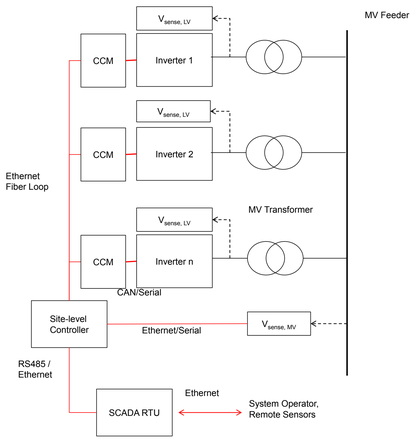
Regional Communication & Control



Distribution Feeder Modeling



Intra-Site Control & Communications



Next Generation Control Platforms:

- Site Controller
- Inverter Control & Communications

Goals: *Precision and Response*

Speed: Reduced latency at all levels of communication is critical

- Inter-site (regional supervisory control, SCADA interface) → Slow (seconds to minutes)
- Intra-site (between inverters)
- nverter → Fast (sub-cycle)

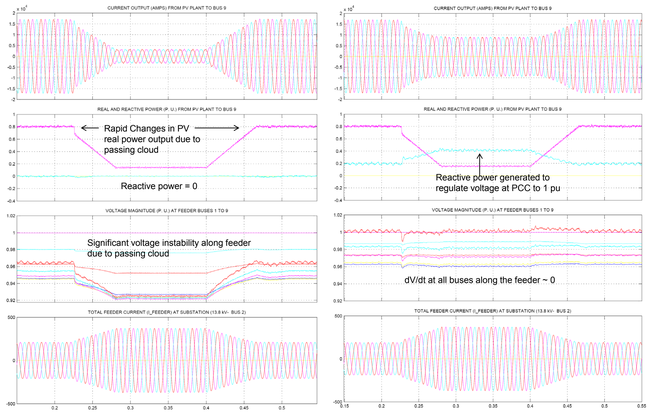
Flexibility: Adaptable to multiple utility systems, site specifications, etc.

Improved Control & Communication Functionality:

- New protocols: CAN, broadcast modes,
- Additional I/O, larger installations
- Configurable firmware, robust data handling capability

Initial Results

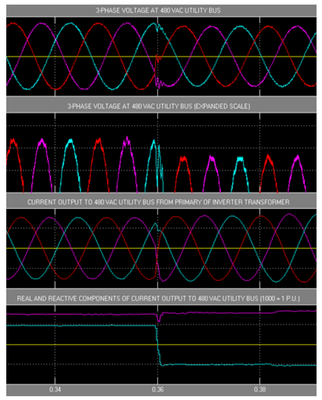
Transient Simulation – Closed loop solution

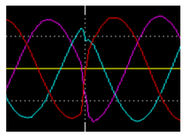


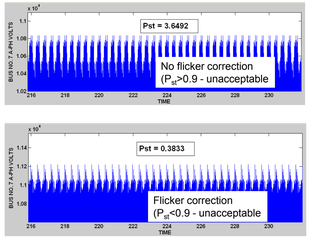
No Voltage Control

w/Voltage Control

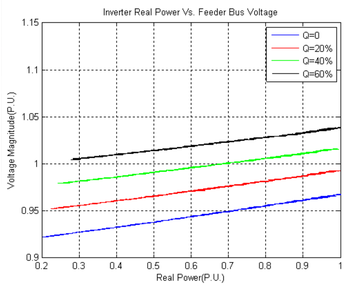
➢ **No tap changers, line regulators, or capacitors**
➢ **Balanced feeder, balanced three-phase loads**
➢ **9 buses - 7.5 MVA 0.95 p.f. constant power loads**
➢ **PV plant output, P = 4 MW**







Open Loop Controls for Localized Correction



Project Team

SunShot U.S. Department of Energy