Dynamic Stability of Volt-Var Controls of DER

ESIG Spring Workshop – April 2020

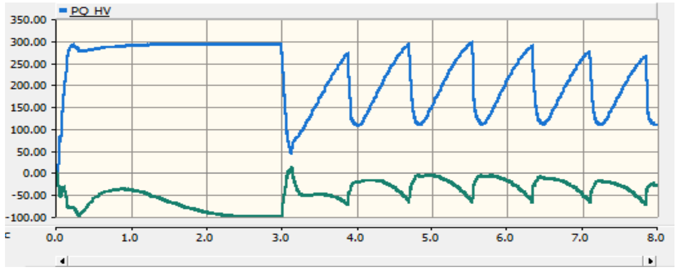
TELOS ENERGY

Outline

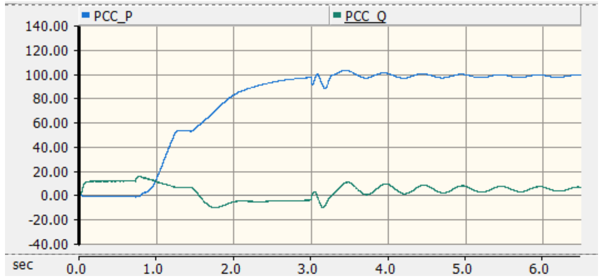
- Small-signal stability with inverter Volt/VAr controls
- What do we know from transmission system applications?
- Do these risks apply for distribution system applications?
- Conclusions

Small-Signal Instability

Example of “Large-Signal” Instability (P & Q)

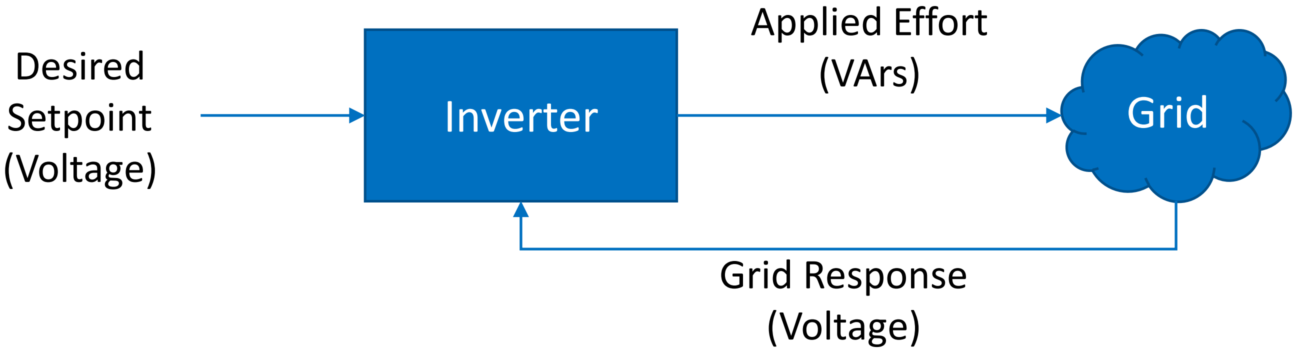


Example of “Small-Signal” Instability (P & Q)



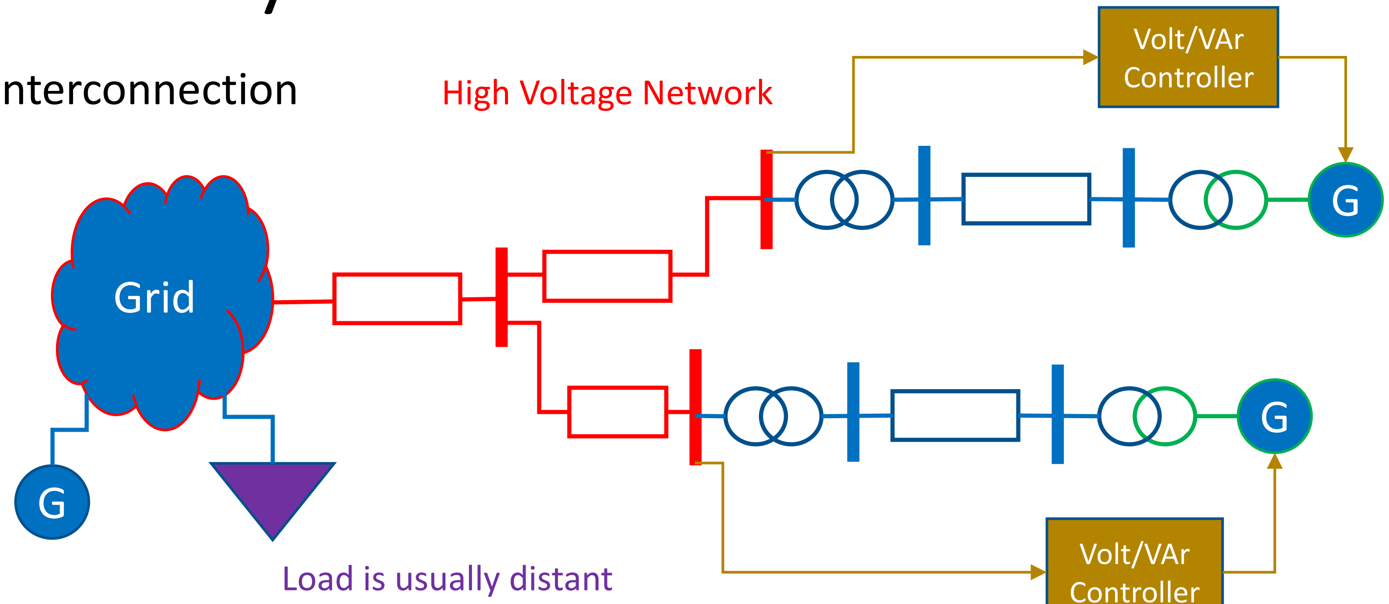
- Grid stability has many facets (small-signal, large signal, voltage, angle, frequency, etc)
- Focus: Small-signal stability… small deviation about an operating point, nominal voltage in this case
- Any closed-loop feedback control system has this risk
- Volt/Var Control utilizes feedback, therefore the response (stability) is strong function of inverter controls AND grid impedance

This **system** has **two** critical parts:
Inverter behavior
AND
Grid behavior

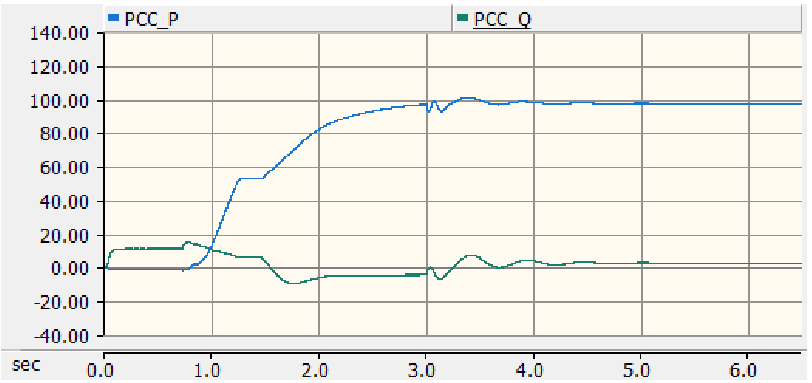


Transmission System Context

Typical Transmission Interconnection

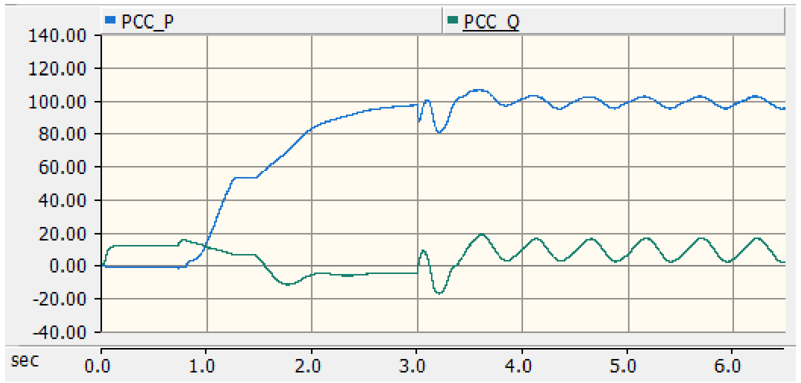


- Key factors: control structure, control gains, time constants, comm latencies
- This is relative to the grid strength… so ratings, nearby plants



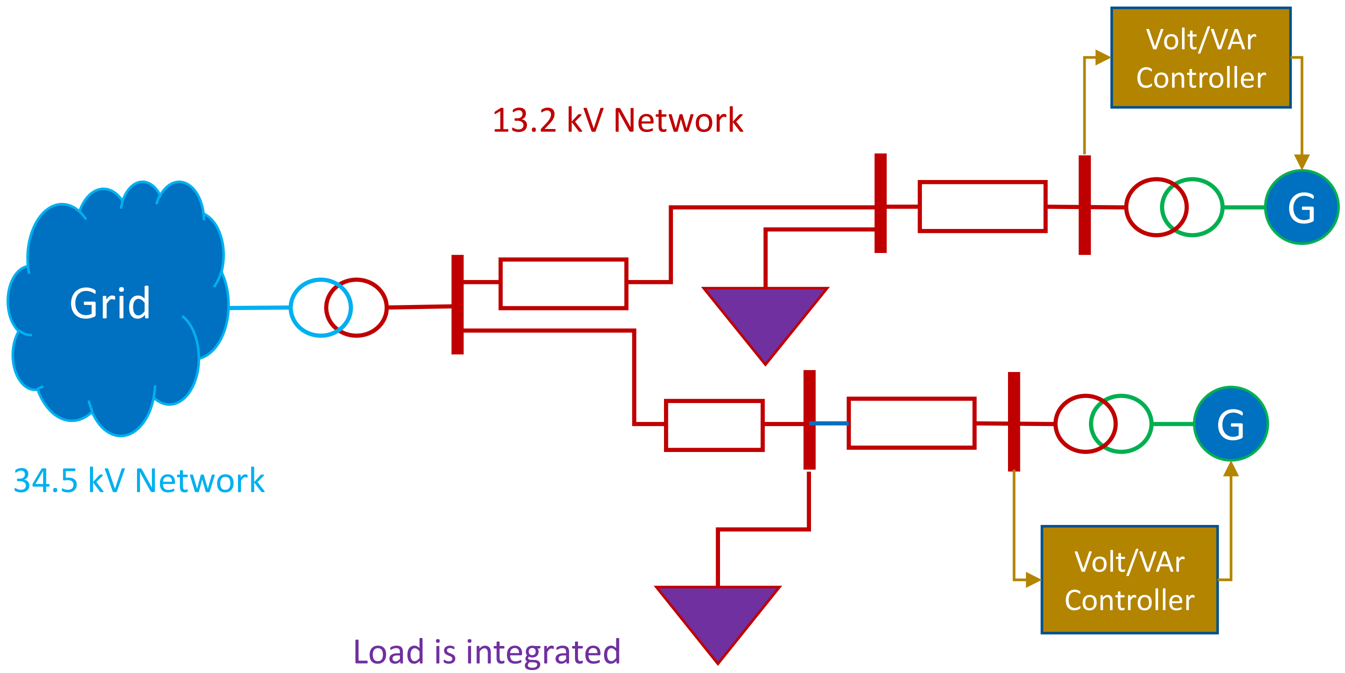
Effect of reducing grid strength on stability

(For Line Switching Events)



Distribution System Context

An Example Distribution Interconnection



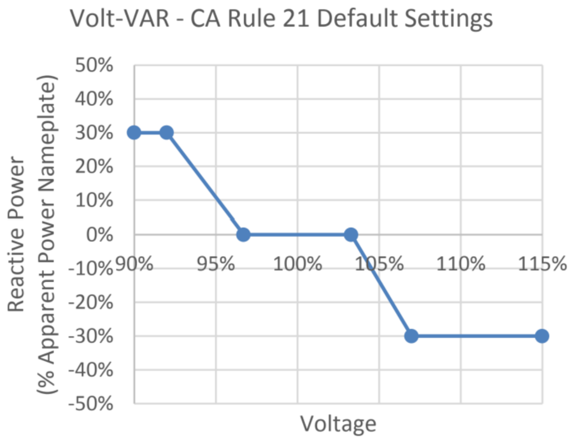
Interconnection differences between transmission & distribution:

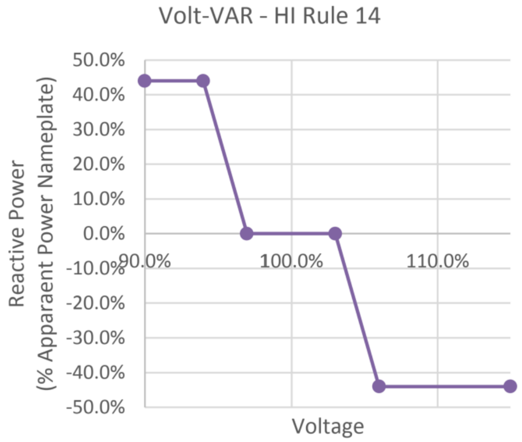
- X/R ratio
- local damping from loads
- more inverter variety

Can you still have inverter instability on the distribution system?

Volt-VAr Control Specifications

- IEEE 1547-2018 provides the framework for response, and a range of values
- Key parameters include droop curves and response time tuning
- California Rule 21 and Hawaii Rule 14H provide specific parameters





A critical footnote from IEEE, c:

[a] The DER reactive power capability may be reduced at lower voltage
[b] If needed DER may reduce active power output to meet this requirement
[c] Improper selection of these values may cause system instability

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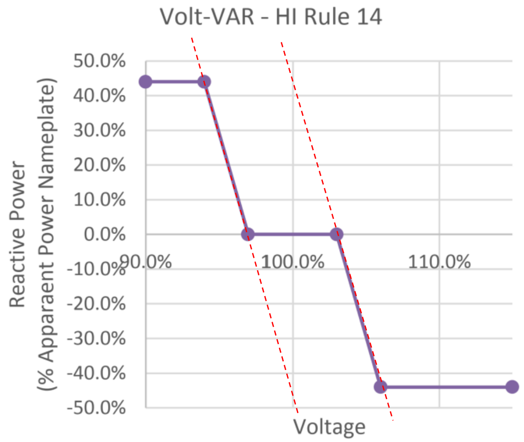
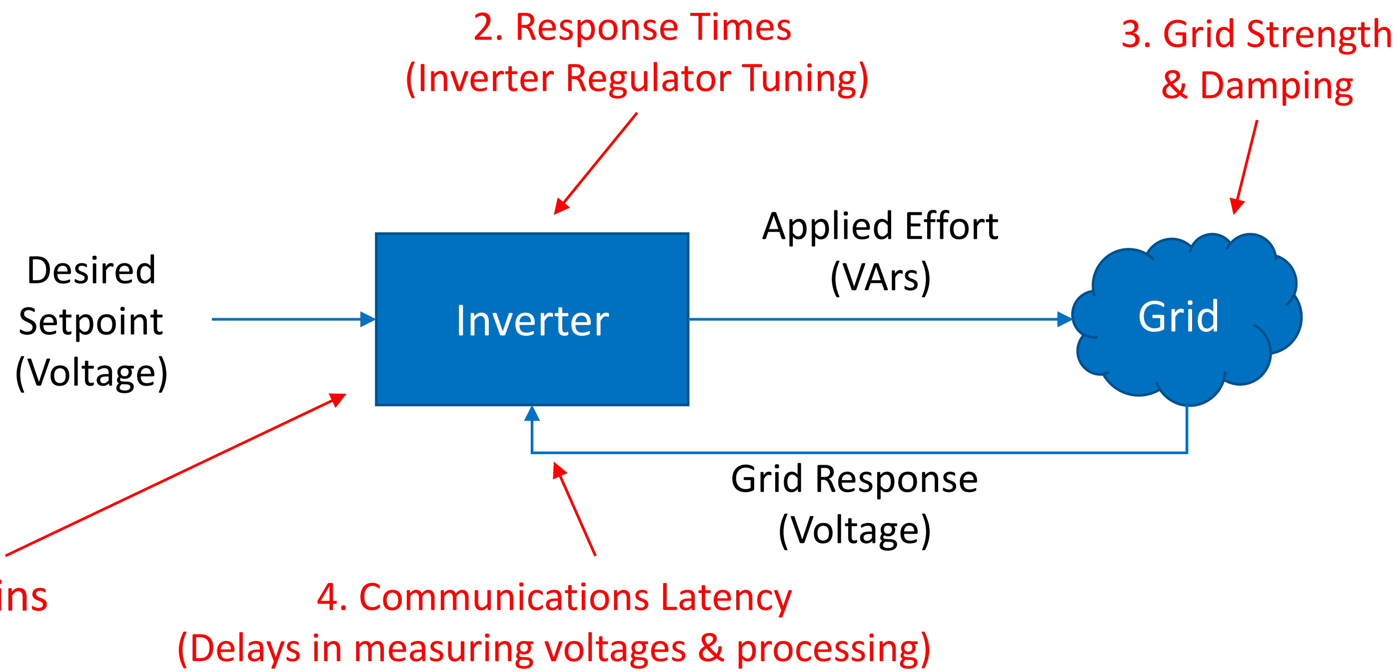
Distribution System Stability

- These are NOT load flow (steady-state or quasi steady-state) simulations
- The intent is to look at dynamic behavior, stability over seconds of operation

Four Key Factors for Stability:





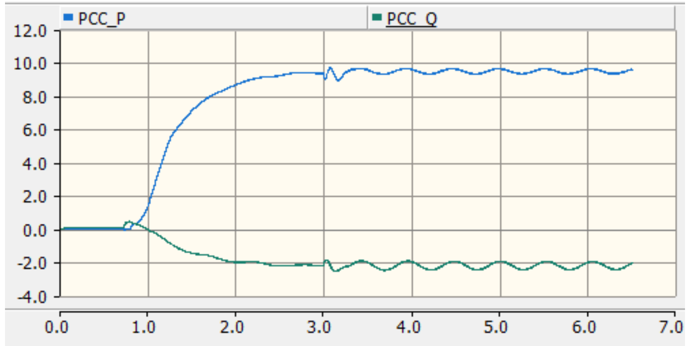
1. Slopes of curves are effectively controller gains

Distribution System - Dynamic Simulations

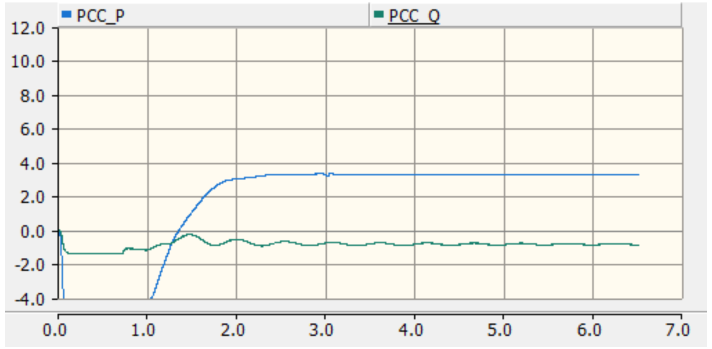
No Local Load

Presence of Local Load (7MW)

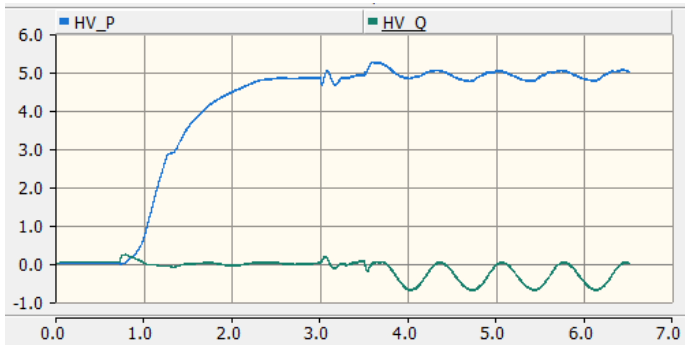
Inverter Controls (Low Latency 90msec)



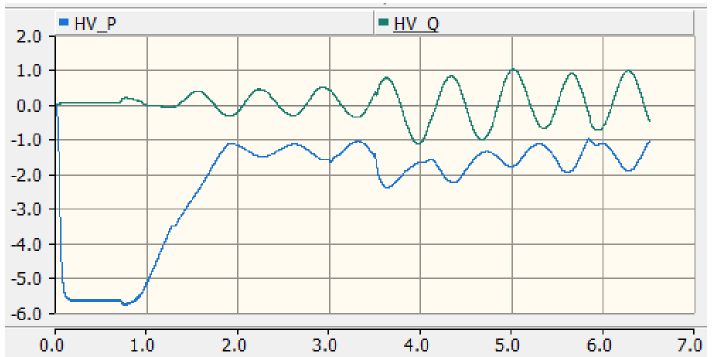
Local load helps stability



Inverter Controls (Higher Latency 140msec)



Local load hurts stability



Detailed PSCAD simulations

- Simple distribution network (shown previously)
- 10MW of inverters with volt/VAr controls
- 7MW of resistive load

Many factors impact dynamic stability at the distribution level – more to be understood here

Conclusions

- Known stability risks on the transmission system
- Stability concepts apply to distribution system, but with more complexity
- The distribution system is evolving from the supply side AND the load side
- Be aware of new risks from a confluence of factors

Questions?

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