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Determination of Smart Inverter Control Settings to Improve Distribution System Performance

Matthew Rylander, presenter
Jeff Smith, Huijuan Li
EPRI

CIGRE - Grid of the Future Symposium
Houston, TX
October 20, 2014

Introduction

Why smart inverters?

- 80% of PV interconnecting at distribution
- PV can impact both distribution and bulk transmission grids
- Germany retrofit

Industry adoption of smart inverters

- IEEE 1547 – recently modified to allow DER to better integrate into grid (if utility chooses)
  - Riding voltage/frequency events from bulk system
  - Regulate output to control voltage
- CA Rule 21
  - interconnection requirements for inverter-based DER
  - Adopting many of the smart inverter functions identified through the industry-wide "Common Functions" initiative
- Inverter manufacturers are onboard
  - Large 3P inverters are capable now – most functions
  - Small 1P systems are in various stages of capability
- Utilities too!

WEIL Western Electric Industry Leaders

"There is an immediate need for new solar to be fitted with "smart inverters" to provide necessary voltage support to integrate effectively and prevent costly renovations and reliability impacts"
– Western Electric Industry Leaders, Aug 2013

What is a Smart Inverter?

- Inverter that can modify it's output to better integrate into the grid

- Autonomous or communication-connected

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Objective of Presentation

1. Illustrate inverter reactive power control impact – Presentation focused on volt-var settings
2. Determining recommended settings
3. Provide results from one feeder

- Where is the research heading?
  - Developing generalized control setting recommendations based on feeder/PV characteristics and desired feeder response

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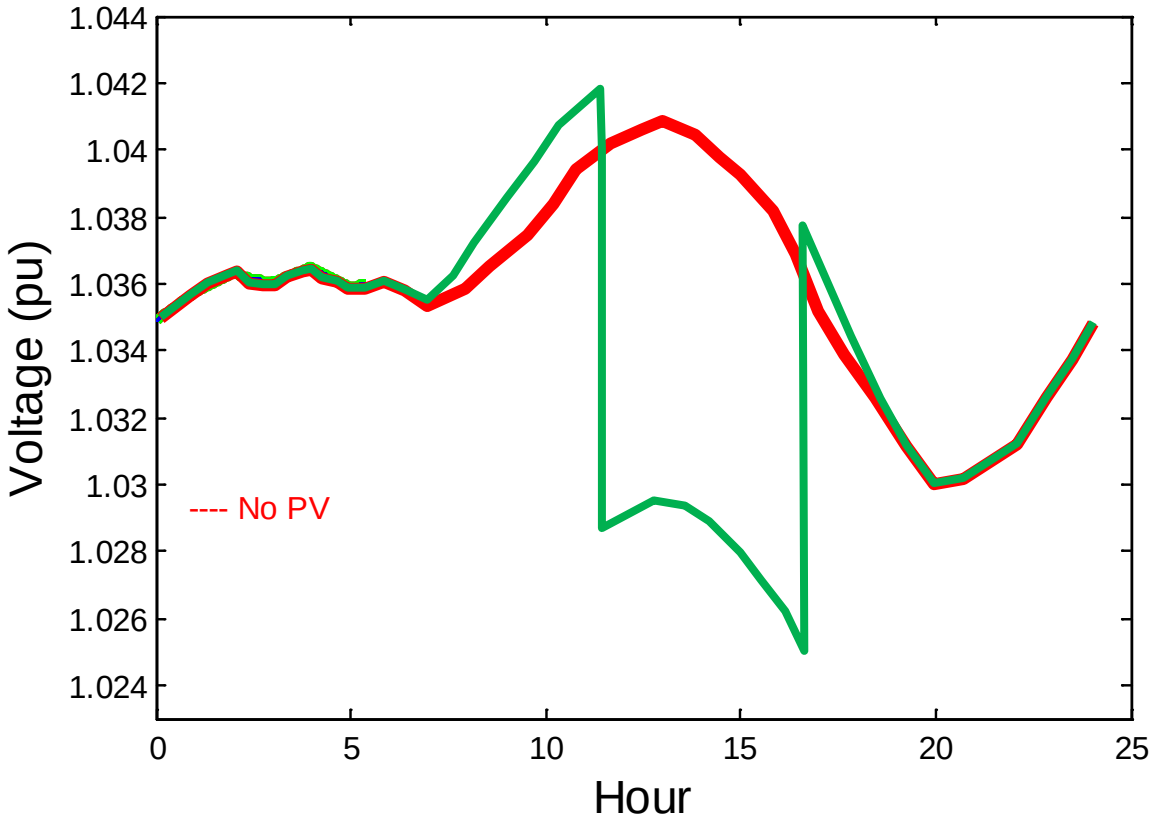
What is the best voltage response?

Depends on what objective you want to achieve.



Blue lines indicate voltage response using different volt-var settings.

Discrete voltage changes are due to capacitor switching or inverter status change.

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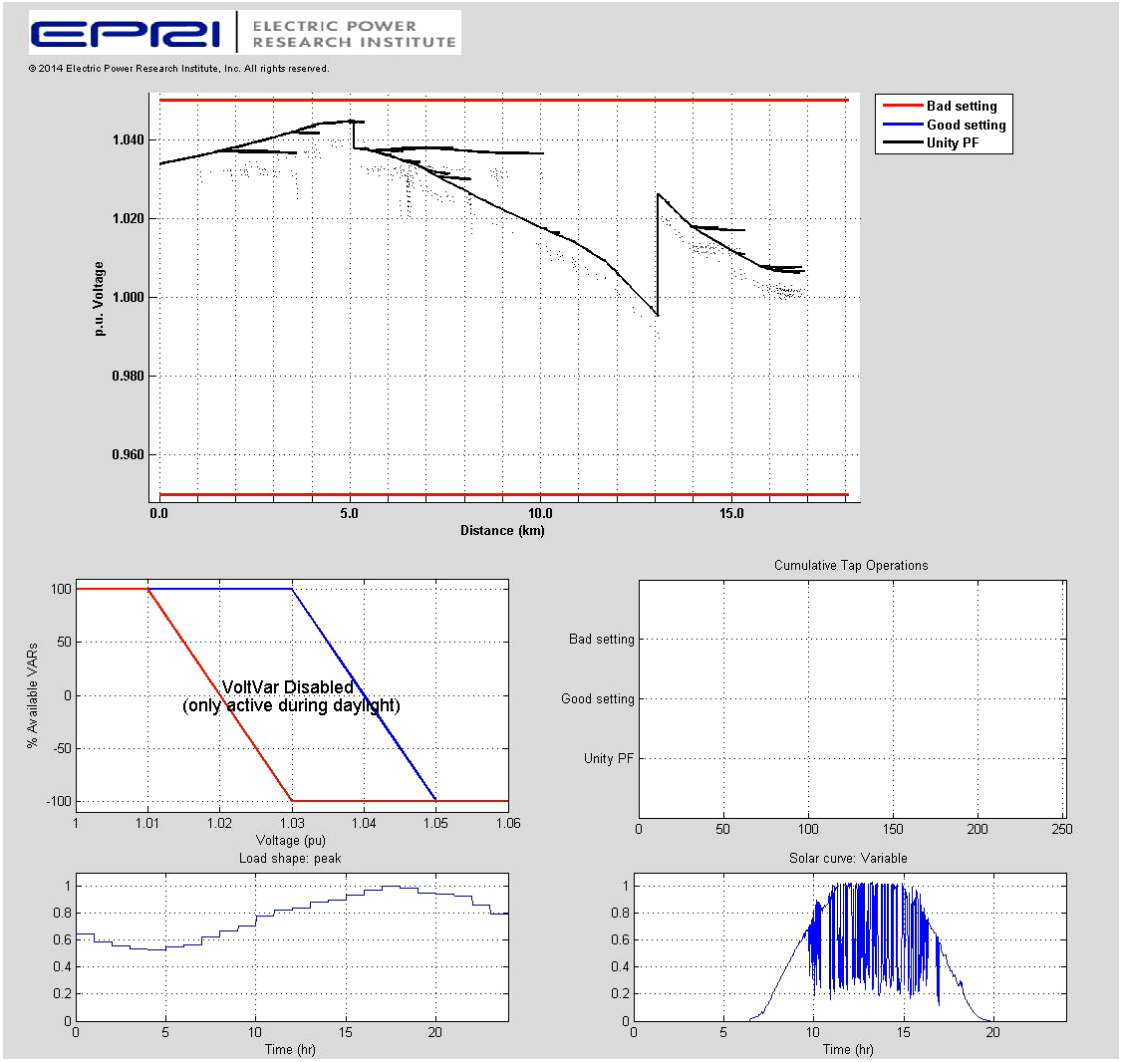
Smart Inverter Volt-var Settings Based on Tap Operation Objective – Video



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Analysis Framework

1. Identify performance objective for smart inverter
2. Detailed feeder model in OpenDSS
3. Time-series simulations to determine impact combining different
   - Load levels
   - Solar variability
   - Smart inverter control settings
4. Process feeder response to determine recommended settings
   - Performance metrics
   - Voltage constraints

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Identify Performance Objective

Site \ Benefits	Efficiency		Power Quality				Asset Life			Deference of Capital Spending				Reliability		Enabling
	Reduced distribution line losses	Improve customer efficiency CVR	Flatter voltage profile	Improved harmonics	Voltage flicker	Overvoltage	Reduce LTC tap changes	Reduce line regulator tap changes	Reduce switch cap changes	Defer capacitor additions	Defer line regulators	Defer reconductoring	Defer substation upgrades	Support during momentary	Support during automation	Higher Penetration of PV
Feeder C		✓	✓					✓						✓	✓	✓
Feeder B							✓			✓				✓	✓	✓
Feeder A		✓				✓		✓						✓	✓	✓

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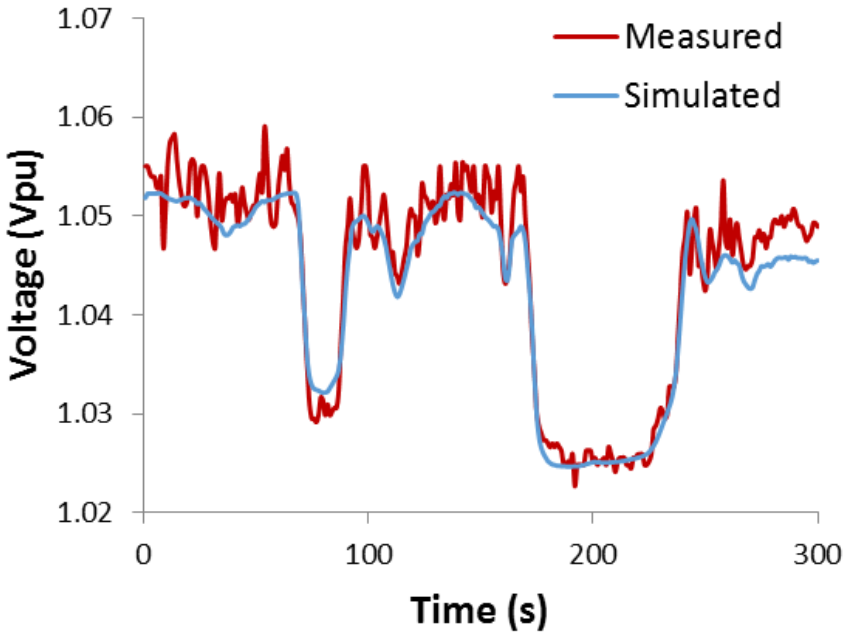
Detailed Model

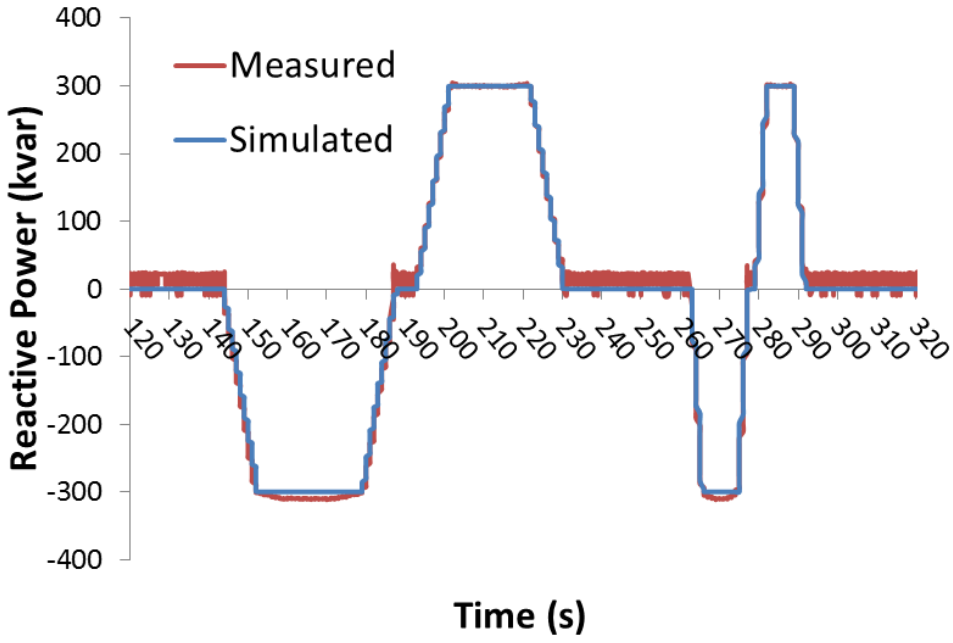
Feeder

Everything from the source to the end customer

Inverter

Key factor: Inverter capacity relative to the PV system capacity





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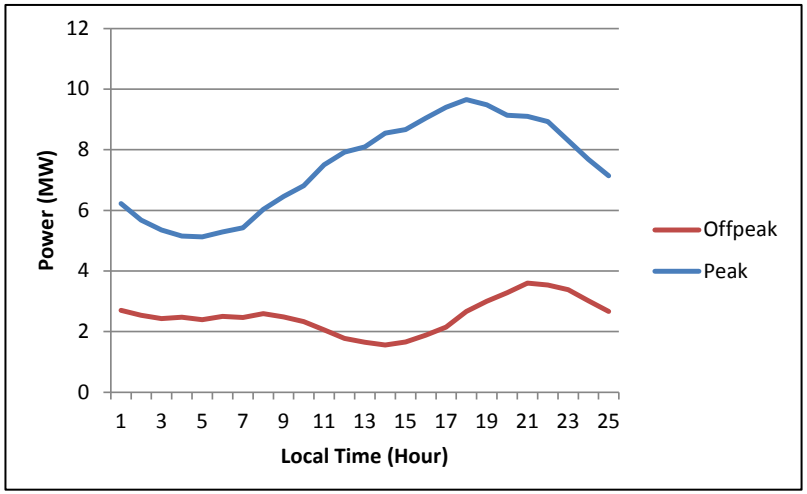
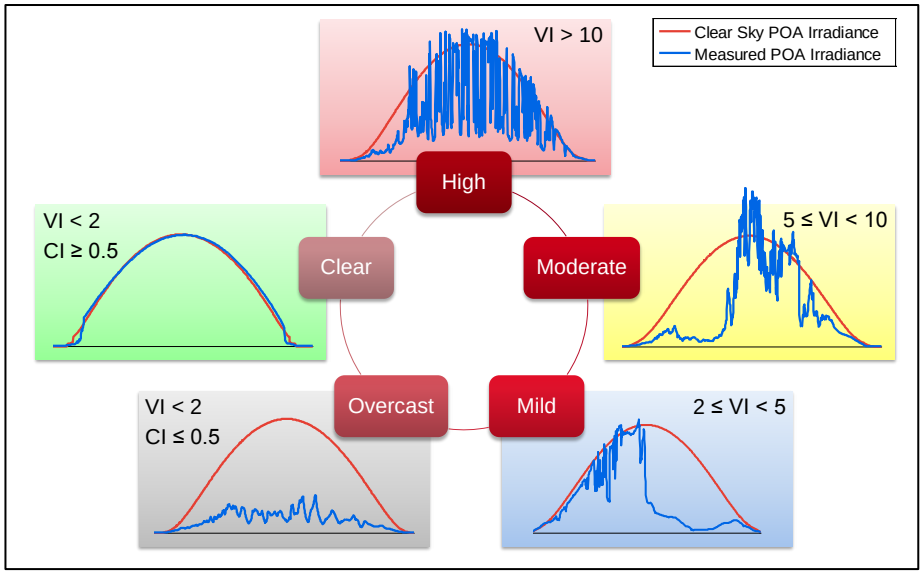
Time-series Simulations

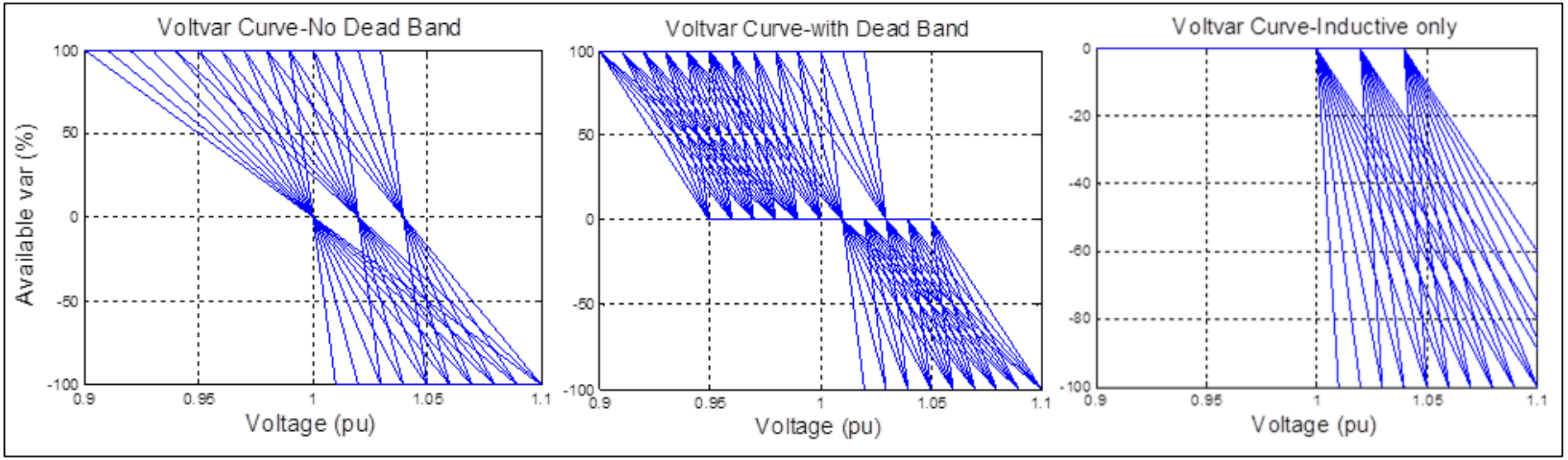
Load Profiles



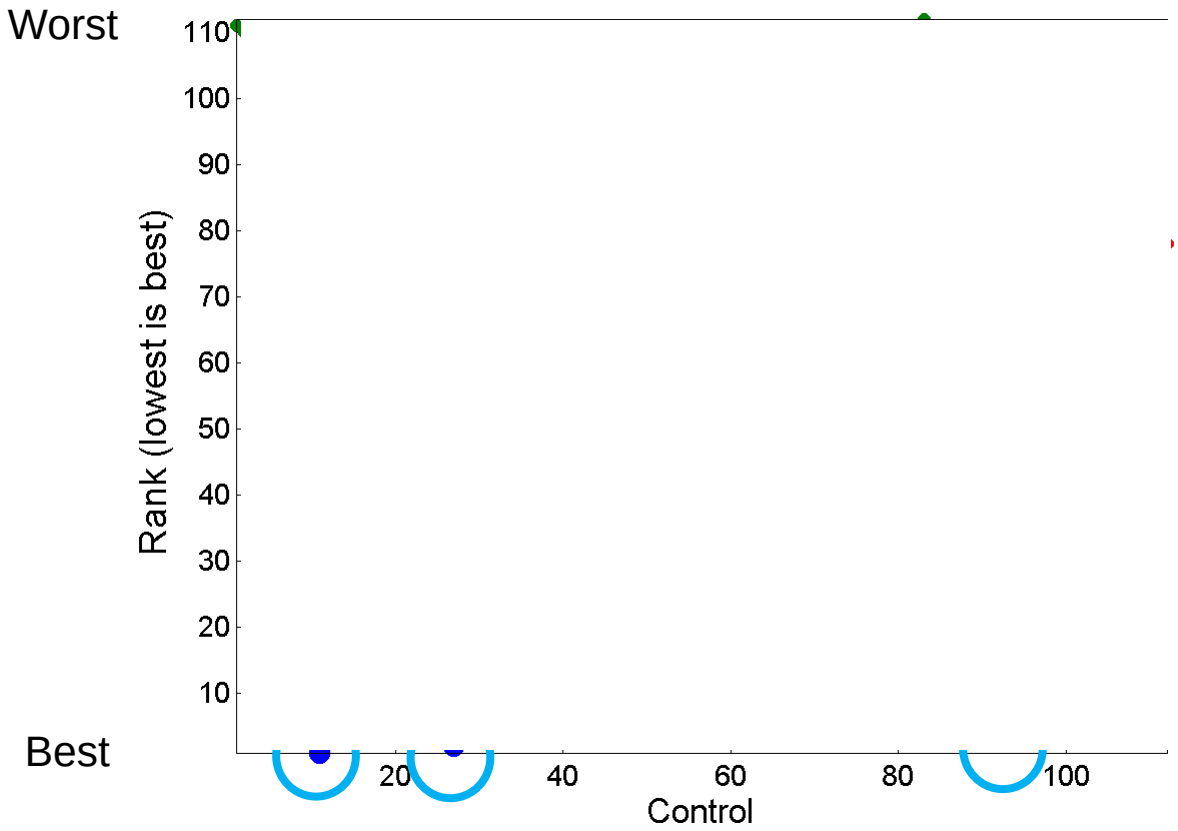
Solar Profiles



Inverter Settings



Process Feeder Response



Different Control Settings
(110 unique settings analyzed)

Optimized Performance Metric

- Black dashed line indicates rank based on performance metric

Voltage Constraints

- Blue circles indicate no ANSI voltage violations
- Green circles indicate improvement in voltage but still has some ANSI violations
- Red circles indicate additional ANSI voltage violations

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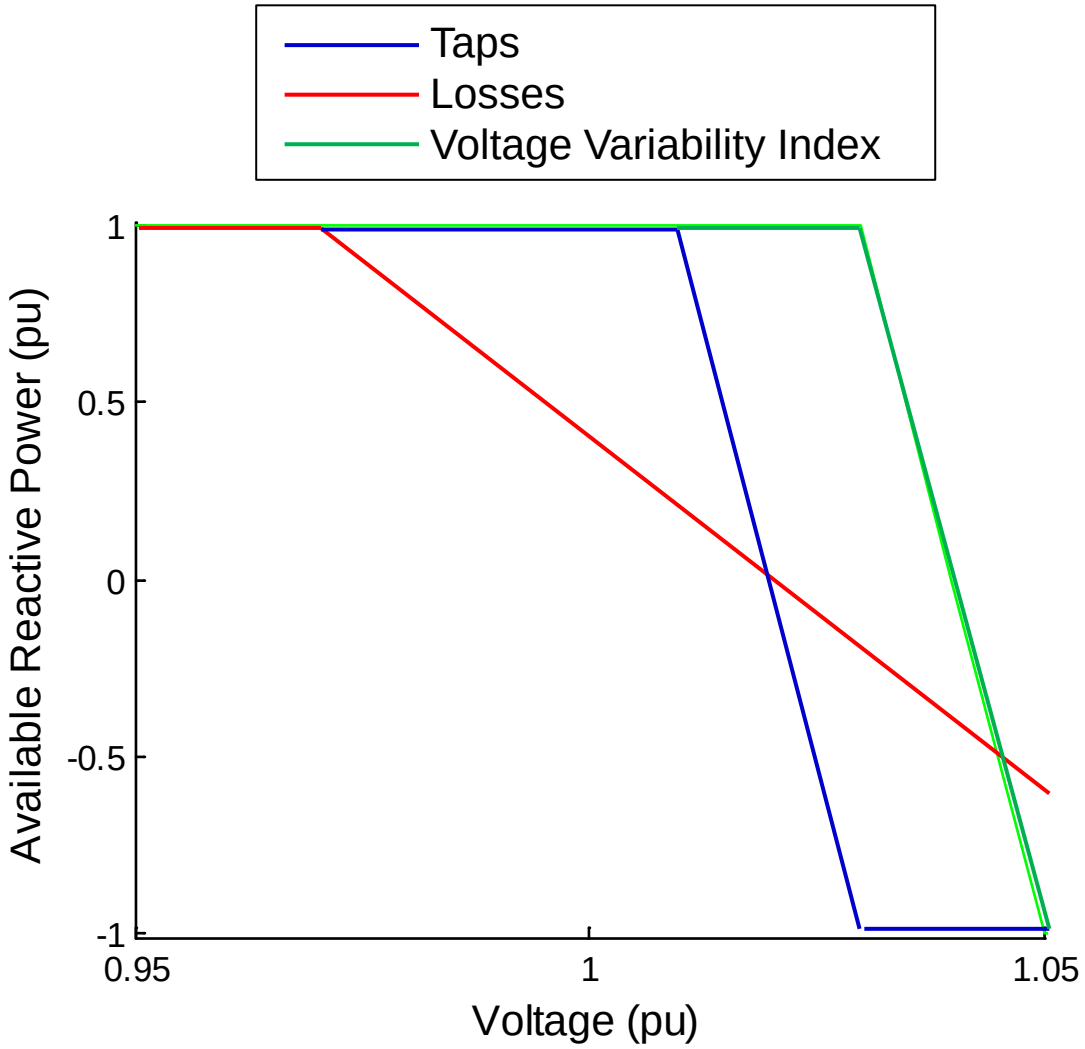
Recommended Control Settings



Optimal setting depends on the feeder performance objective

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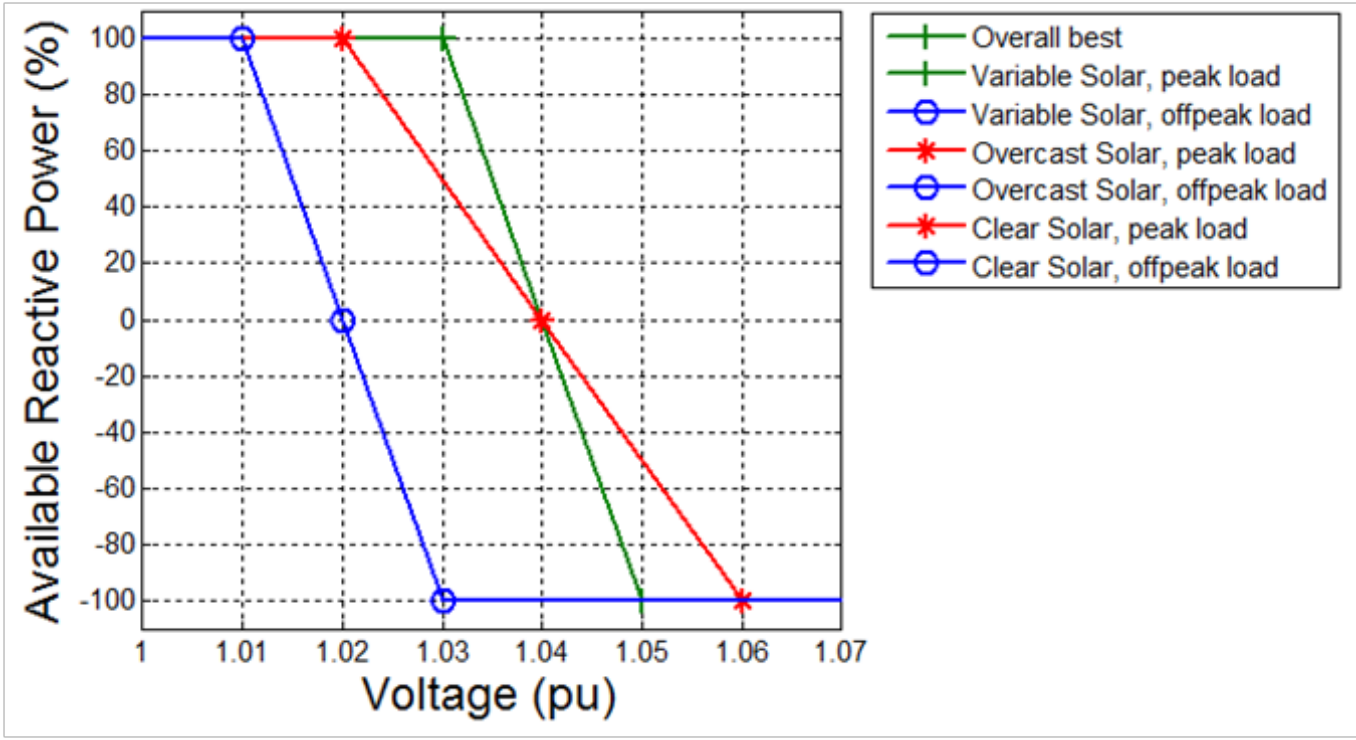
Integrated Control of Inverter Settings

- 'Overall Best' setting assumes there is no capability to periodically update settings, **one setting for all conditions**
- Specific solar/load condition assumes **the settings can be periodically updated with Integrated Control**



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Summary

- Smart inverters can have impact on feeder performance
- Methodology can be applied to determine recommended inverter control settings
- Best inverter settings are dependent on
  - Performance metric
  - Feeder/PV details
    - Load level
    - Solar characteristics
    - Inverter rating

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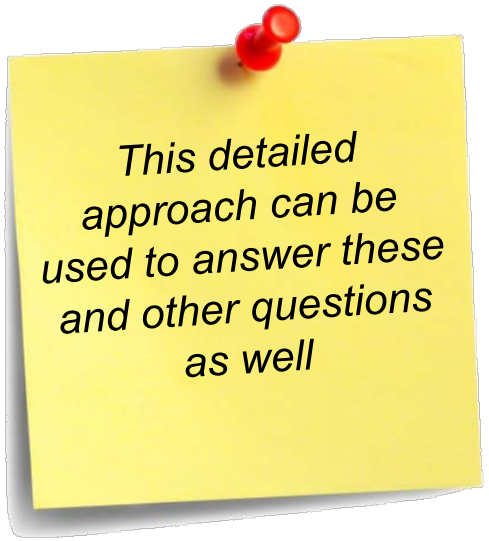
More Work to be Done

- How can I use simplified metrics for determining appropriate settings, without detailed analysis? (Similar to detailed hosting capacity work, which is foundation for more simplified hosting capacity screening techniques being developed this year)
- What about combined functions (volt-var with volt-watt)
- What about non-linear volt/var curves?
- What about multiple PV systems throughout a feeder?
- How effective are smart inverters when the inverter is undersized? What setpoints need to be used then?



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