

Blackstart Studies: Cranking Path Validation & PV Impact

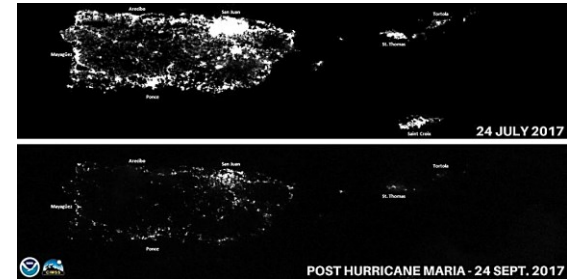
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Blackstart Background

- Blackstart: Re-energizing the grid without external power
- Localized blackstart occurred in the 2003 Northeast Blackout
 - Full scale blackstart has never happened in the mainland US
- What happens if 100% of the grid is down?
- System Restoration Plan
 - Guideline to restore power
 - Updated annually or when system changes



Times Square, August 14, 2003 [Source: The Atlantic]



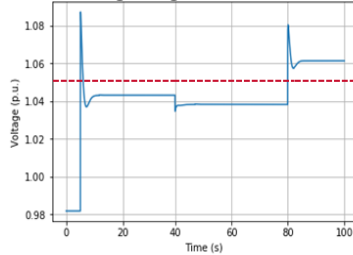
Puerto Rico Satellite Imagery [Source: NOAA]



Previous Work in 2018

- Generation Retirement

Energizing 500 kV Line



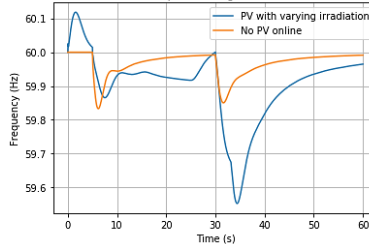
Overvoltage from
500 kV line
energization



Identified some
improvements

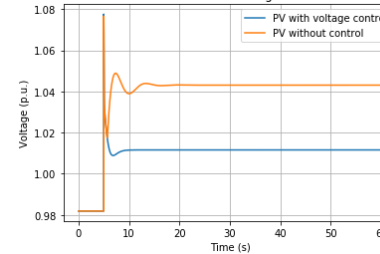
- PV Impact on Blackstart

PV Impact during Blackstart



PV(no control)
detrimental to
restoration

PV as STATCOM
500 kV Line Energized



PV(V control)
mitigates
voltage issues

Study Limitations: hypothetical PV location & size | only reactive power control



Project Overview

SRP Path Analysis

- SOC requested dynamic study of four paths
- Study voltage, frequency, generator VAR



PV Impact Study on Blackstart

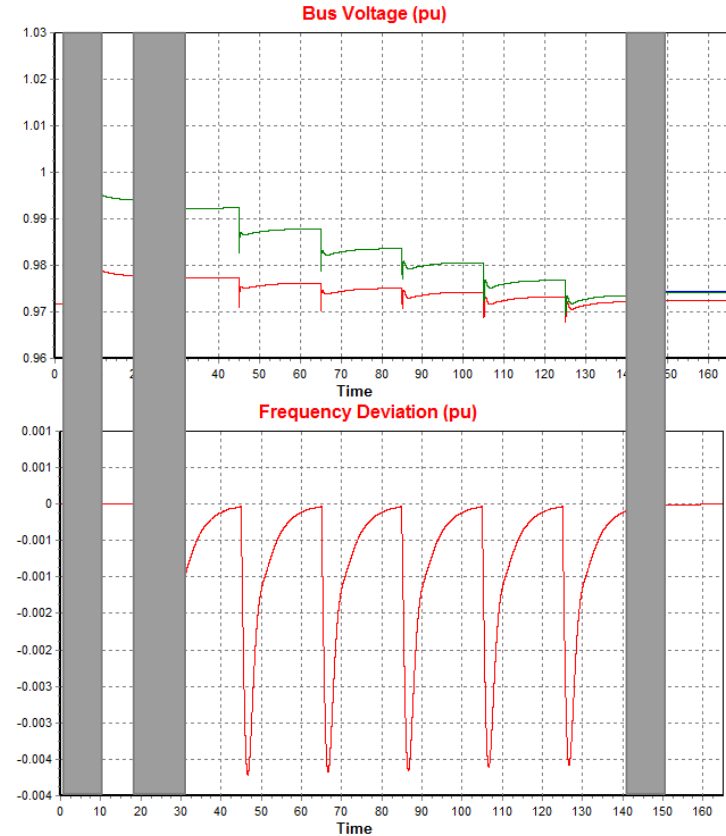
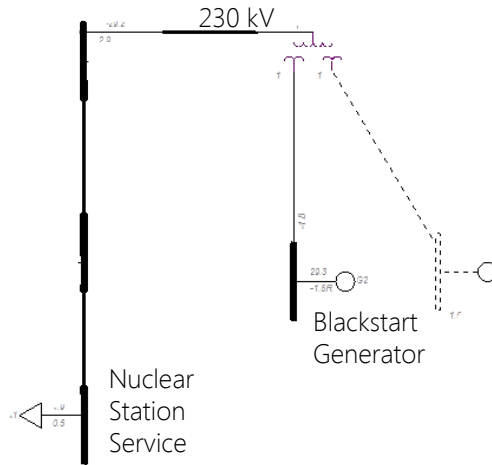
- Improve PV assumptions
- Implement active power control



SRP Path 1

Events:

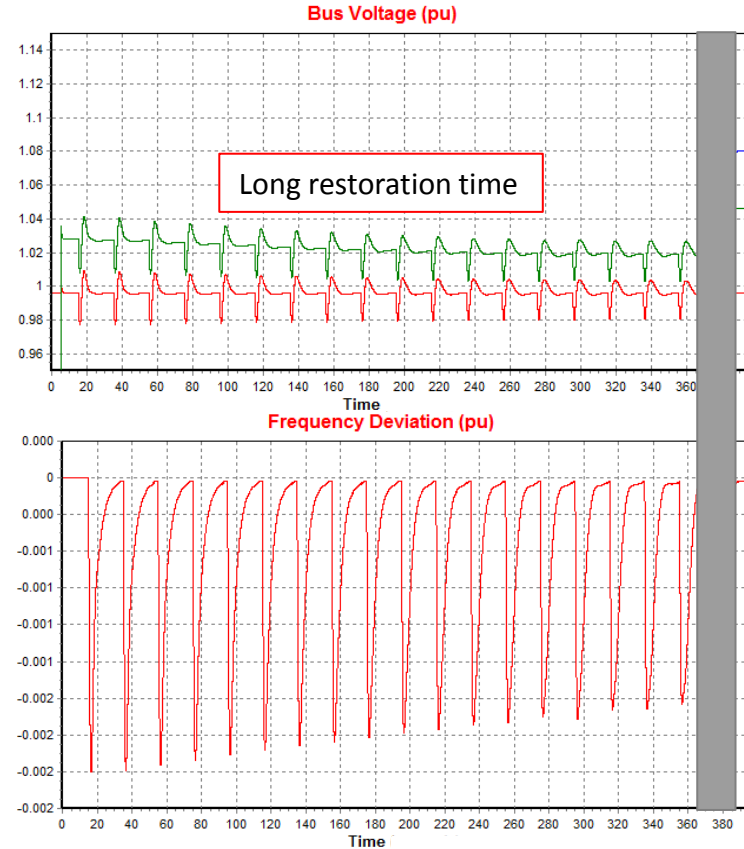
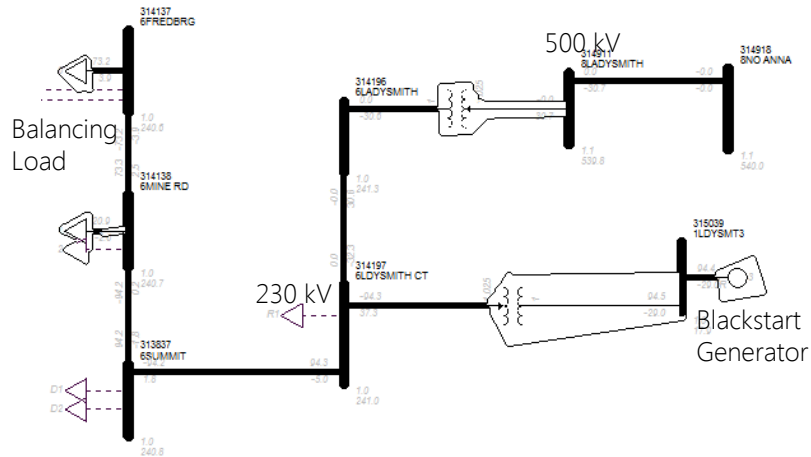
1. Energize 30.6 miles long 230 kV line
2. Pickup 30 MW load
3. Energize 1 mile long 230 kV line



SRP Path 2

Events:

1. Energize 17.3 miles long 230 kV line
2. Pickup 90 MW load
3. Energize 14.5 miles long **500 kV** line

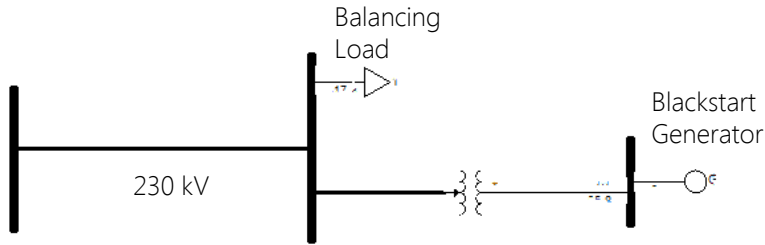


SRP Path 3

Events:

1. Energize transformer
2. Pickup 20 MW load
3. Energize 42.8 miles long 230 kV line

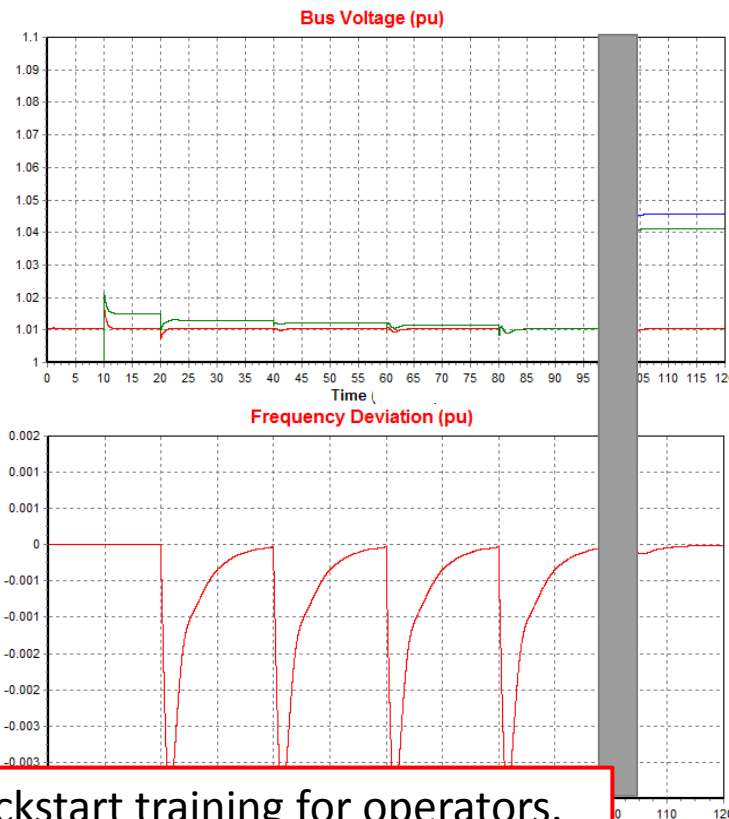
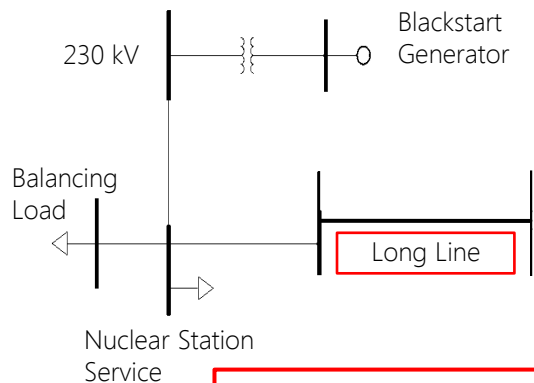
PSSE governor model is not adequate for dynamic blackstart studies.



SRP Path 4

Events:

1. Energize 0.4 miles long 230 kV line
2. Pickup 20 MW load
3. Energize 44.1 miles long 230 kV line



Path results will be used in blackstart training for operators.



SRP Path Study Concluding Remarks

- Concerns of overvoltage: long 230 kV lines and 500 kV lines
- Balancing load must be picked in increments
- Some governor models need to be updated for blackstart studies
- Need additional studies from RTDS simulation



Project Overview

SRP Path Analysis

- SOC requested dynamic study of four paths
- Study voltage, frequency, generator VAR

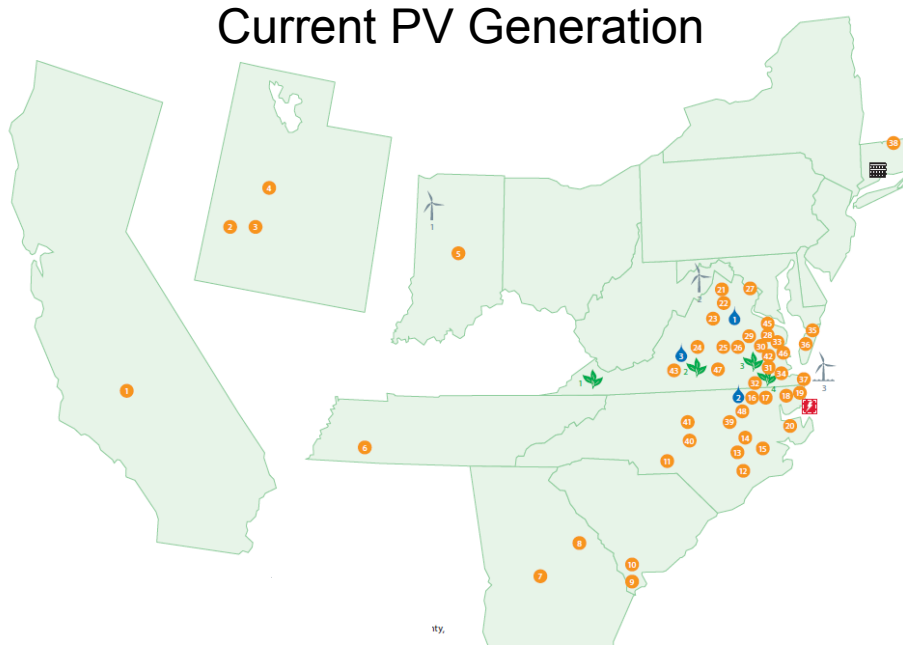


PV Impact Study on Blackstart

- Improve PV assumptions
- Implement active power control



Why Should We Study PV Impact?



Future PV Generation

Renewable Portfolio Standard:

- Virginia: 15% by 2025
- North Carolina: 12.5% by 2021

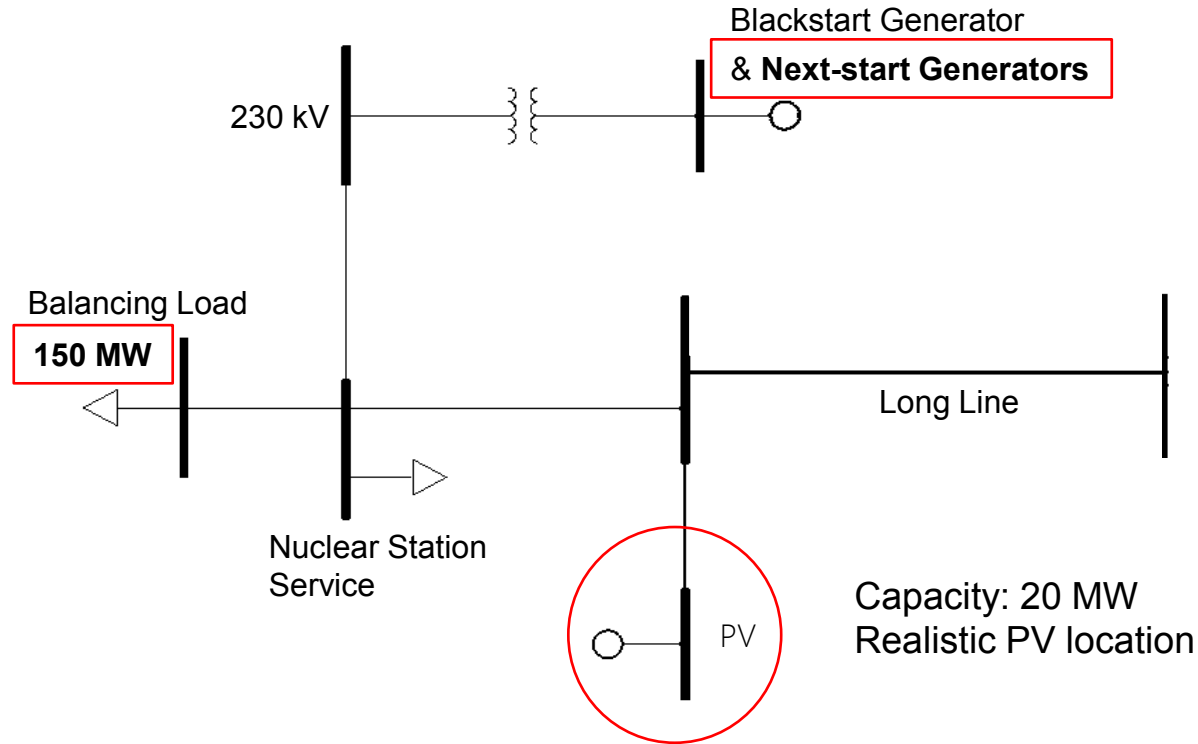
Integrated Resource Plan

- Install additional 4.7 GW of solar by 2033

Higher renewable penetration requires impact studies to normal and critical processes.



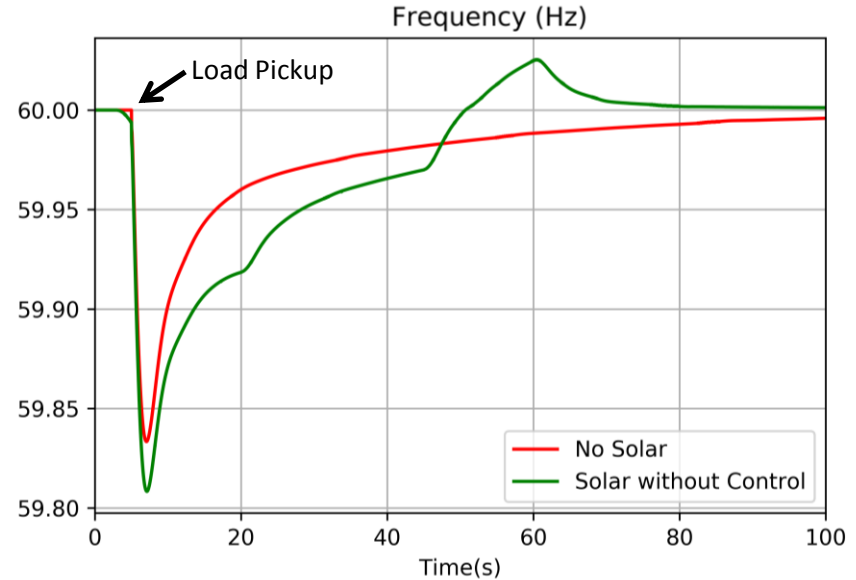
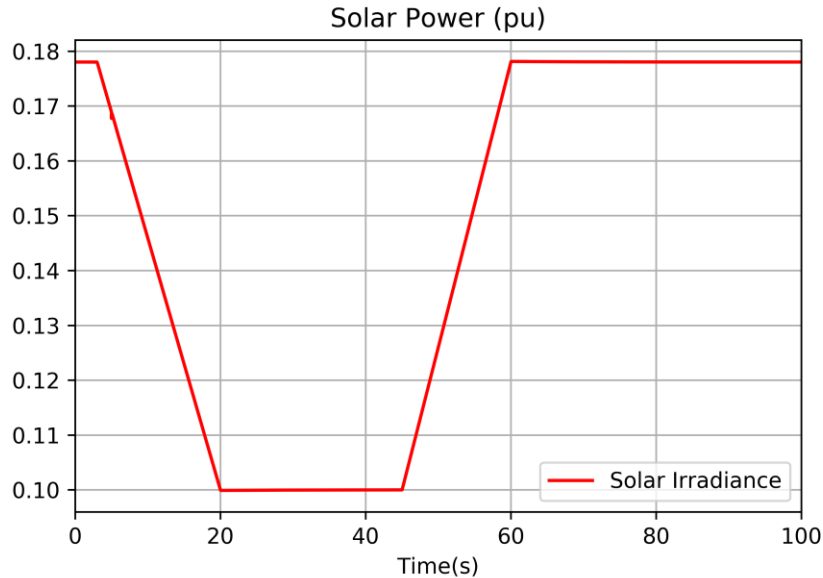
PV Site Located on Blackstart Path 4



Consider PV Historical Data



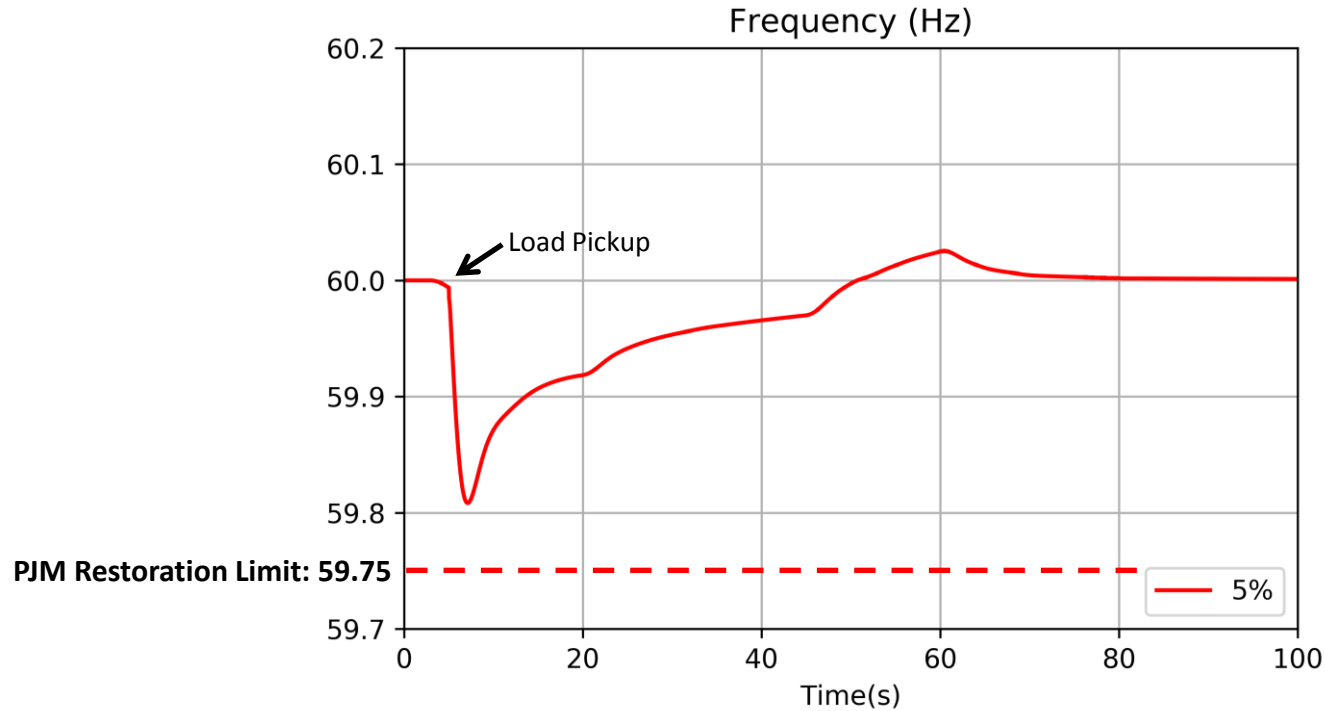
PV without Control: Impact to Frequency Response



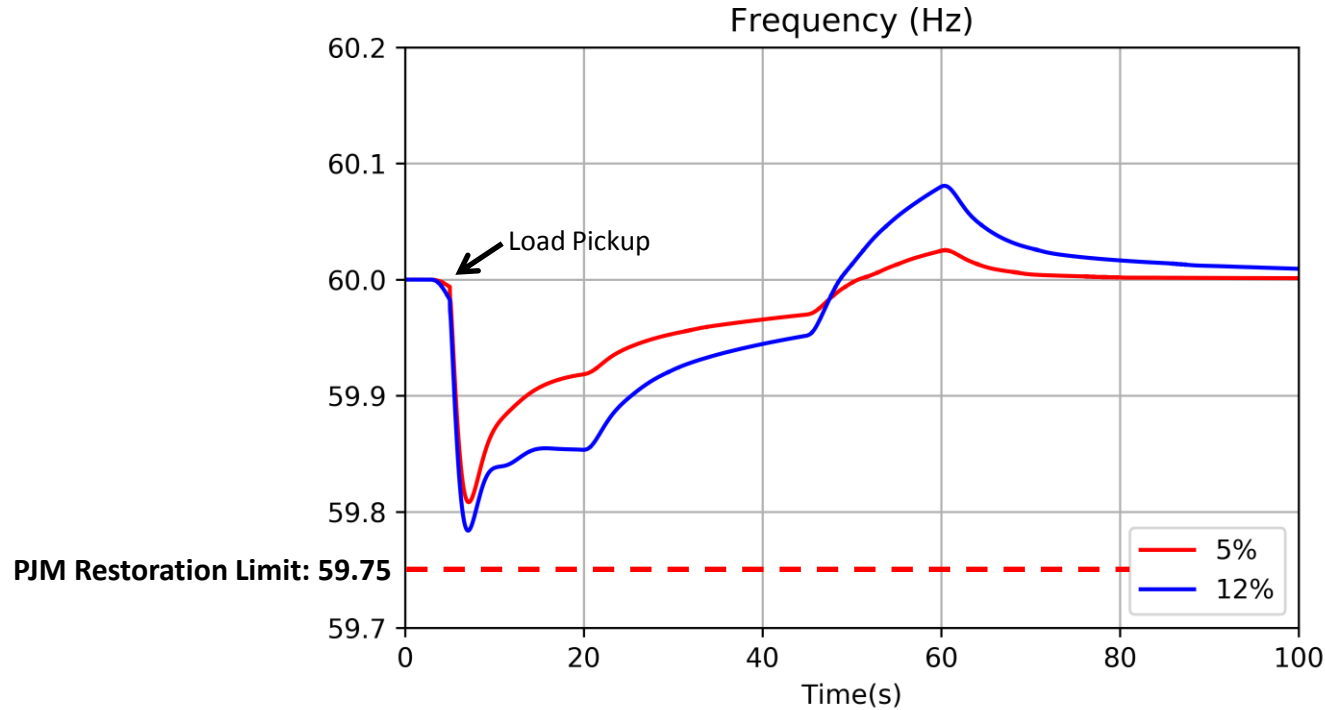
PV farm without control adds frequency variations to blackstart restoration.



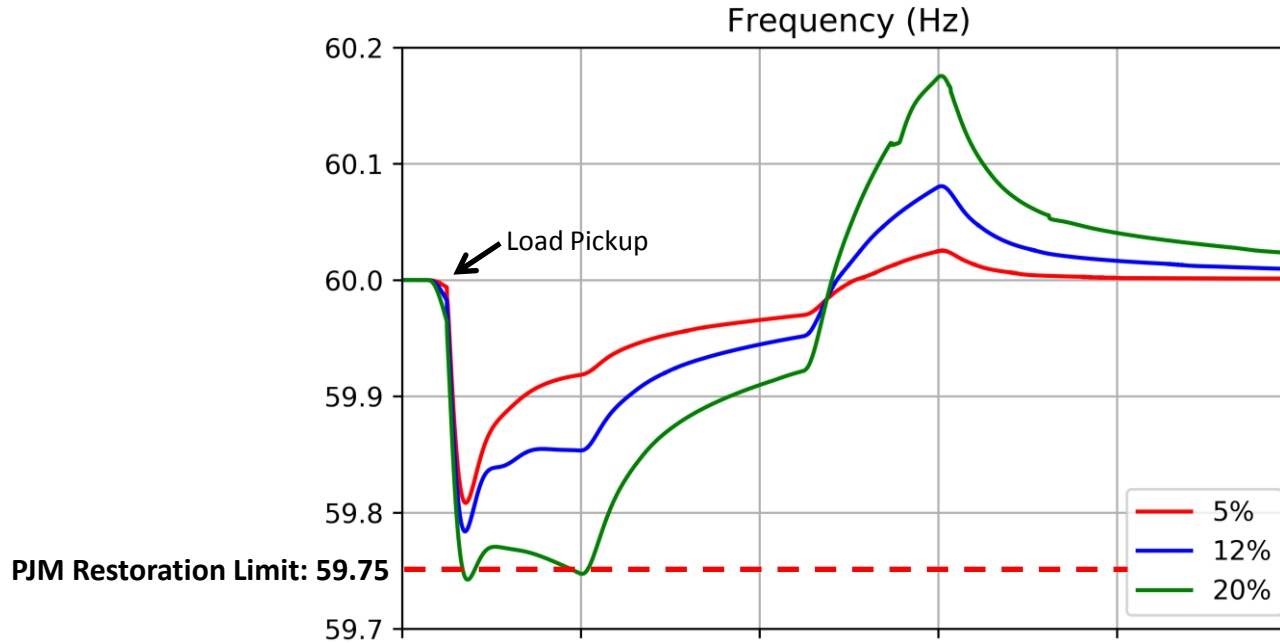
PV without Control: Impact to Frequency Response



PV without Control: Impact to Frequency Response



PV without Control: Impact to Frequency Response



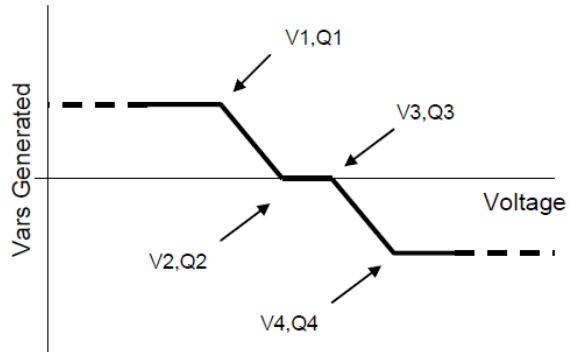
Increased PV penetration can trigger under-frequency thresholds.



Possible Ways PV Can Help

Reactive power control:

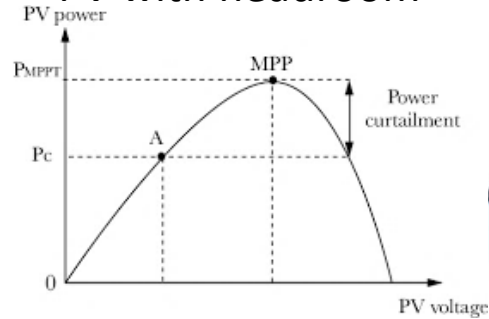
- Assist with voltage regulation



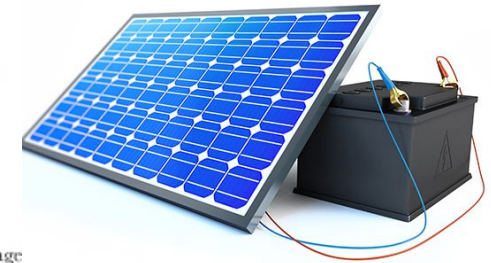
Active power control:

- Assist with frequency regulation

PV with headroom



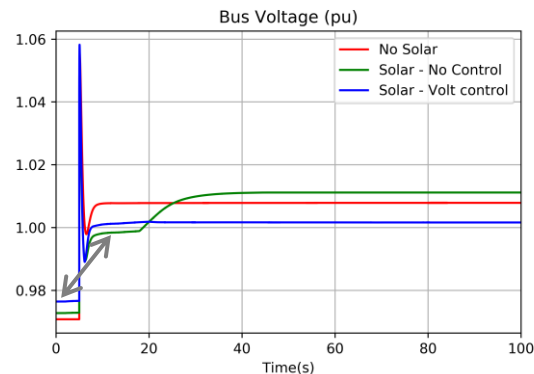
PV with battery



PV Reactive Power Control

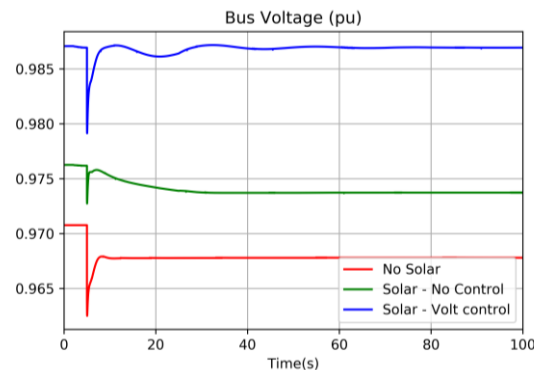
Energize 500 kV

Solar Scenario	Δ Voltage (Pre- & Post-Event) (%)
No Solar	
No Control	
Volt Control	

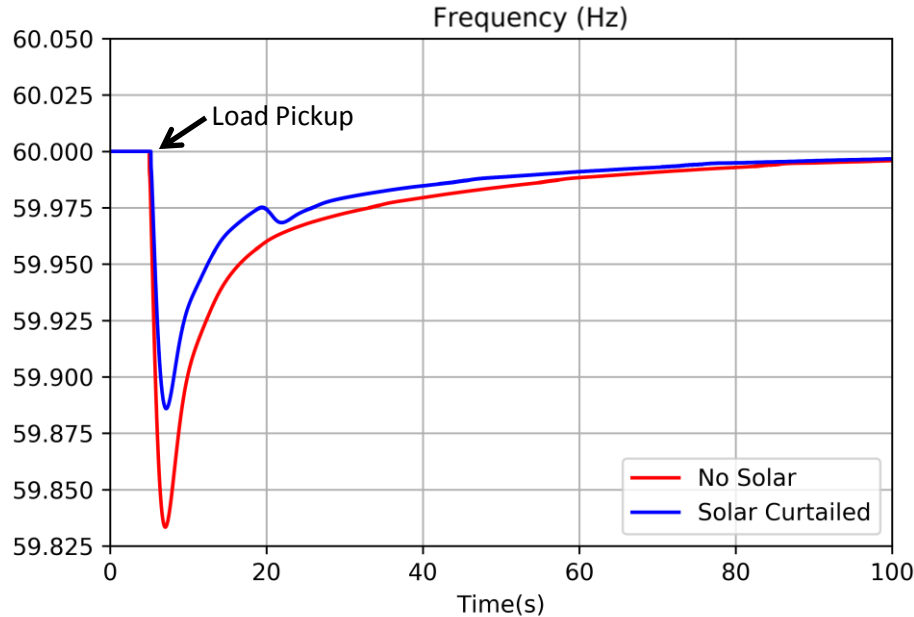


Pickup 10 MW

Solar Scenario	Δ Voltage (Pre- & Post-Event) (%)
No Solar	
No Control	
Volt Control	



PV Active Power Control: PV Curtailment



Assumptions:

- Pickup 10 MW load
- PV has ramping capability
- PV with dynamic headroom

Result:

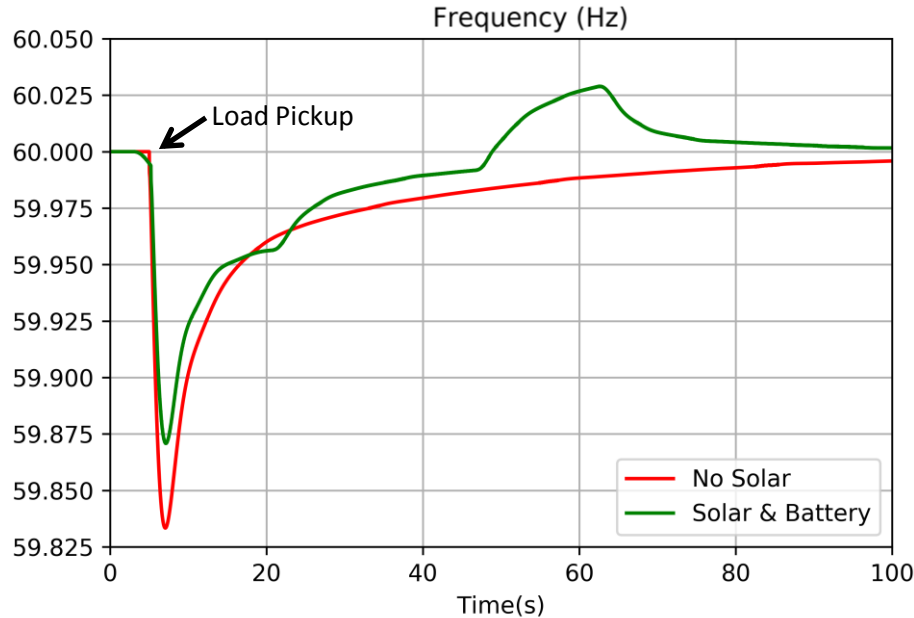
- Minimum frequency improved by **29.4%**

Possible challenge:

- May not eliminate all fluctuations
- Not very popular



PV Active Power Control: Battery + No Control PV



Assumptions:

- Pickup 10 MW load
- Battery provides ~8MW support at peak
- PV operates with MPPT

Result:

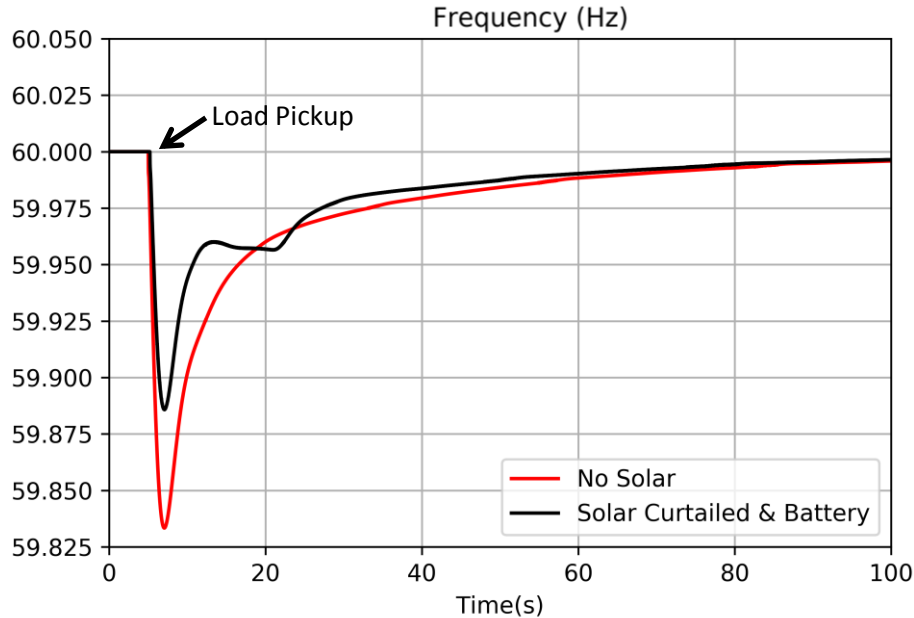
- Minimum frequency improved by **23.5%**

Possible challenge:

- High cost



PV Active Power Control: Hybrid Approach



Assumptions:

- Pickup 10 MW load
- Smaller dynamic headroom
- Less support from battery

Result:

- Minimum frequency improved by **29.4%**
- Two methods to improve frequency



PV Blackstart Study Concluding Remarks

- Reactive power control helps with voltage
 - Mitigate overvoltage from line energization
 - Mitigates undervoltage from load pickup
- Active power control helps with frequency
 - Curtailment can mitigate upward frequency fluctuations
 - Battery can mitigate upward & downward fluctuations
 - Hybrid battery-curtailed provides two regulation methods



Contributions

- Studied the dynamic response of blackstart cranking paths
 - For future training of system operators
 - Identified necessary modeling improvements for blackstart
- Continued studying the impact of PV on blackstart restoration
 - Achieved a more realistic scenario
 - Developed active power control algorithm for frequency regulation



Future Works

- PV adaptable control scheme
- Study the impact of PV on protection system settings
- Study more paths with nearby PV
- PV optimal size sensitivity on blackstart
- Microgrid blackstart with PV & BESS



Acknowledgements

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ET Operations Engineering-Special Studies



Thank you!