



Impact of High Photo-Voltaic Penetration on Distribution Systems

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Client: Alliant Energy

Our Group



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Project Statement

- Effects of increasing solar generation in Iowa
- The problems faced by current distribution systems
 - Over-voltage
 - Opposite direction power flow
 - Possibility of islanding
- Impact of high penetration solar power generation on the distribution feeders
- Quality of power delivered to the consumers





Conceptual Sketch

- We have several goals that we would like to achieve. Our goals are shown below:
 - Run simulations on an Alliant owned distribution feeder to calculate the allowable PV generation that the feeder can handle before operating outside regulated parameters
 - Compare community PV generation and residential PV generation
 - Find solutions that will prevent future problems relating to solar PV generation on the Alliant Energy systems



Requirements

- Functional Requirements

- Analyze IEEE distribution system
- Add solar PV to the distribution models
- Analyze the Alliant Energy bus system provided and determine modifications needed

- Non-functional Requirements

- Can the current Alliant Energy support high solar penetrations as it exists now?
- How much would modifications cost to the current system?



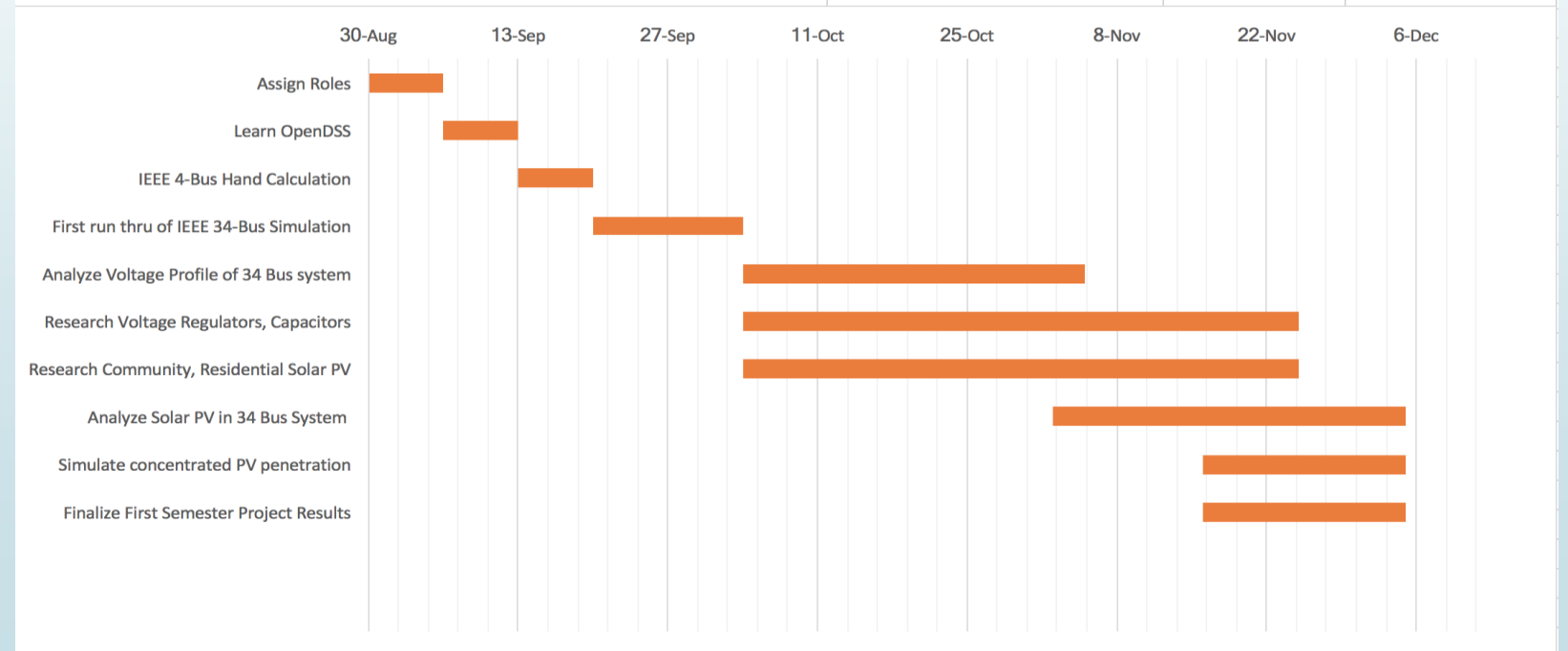
Deliverables



- ▶ Comparison of residential and community solar PV generation
- ▶ The maximum amount of generation Alliant Energy system can handle before violations occur or upgrades are made
- ▶ Voltage profile and other plots from simulations
- ▶ Cost Estimations

Project Timeline

Task	Start Date	Duration (days)	End Date
Assign Roles	30-Aug	7	6-Sep
Learn OpenDSS	6-Sep	7	13-Sep
IEEE 4-Bus Hand Calculation	13-Sep	7	20-Sep
First run thru of IEEE 34-Bus Simulation	20-Sep	14	4-Oct
Analyze Voltage Profile of 34 Bus system	4-Oct	32	5-Nov
Research Voltage Regulators, Capacitors	4-Oct	52	25-Nov
Research Community, Residential Solar PV	4-Oct	52	25-Nov
Analyze Solar PV in 34 Bus System	2-Nov	33	5-Dec
Simulate concentrated PV penetration	16-Nov	19	5-Dec
Finalize First Semester Project Results	16-Nov	19	5-Dec





OpenDSS

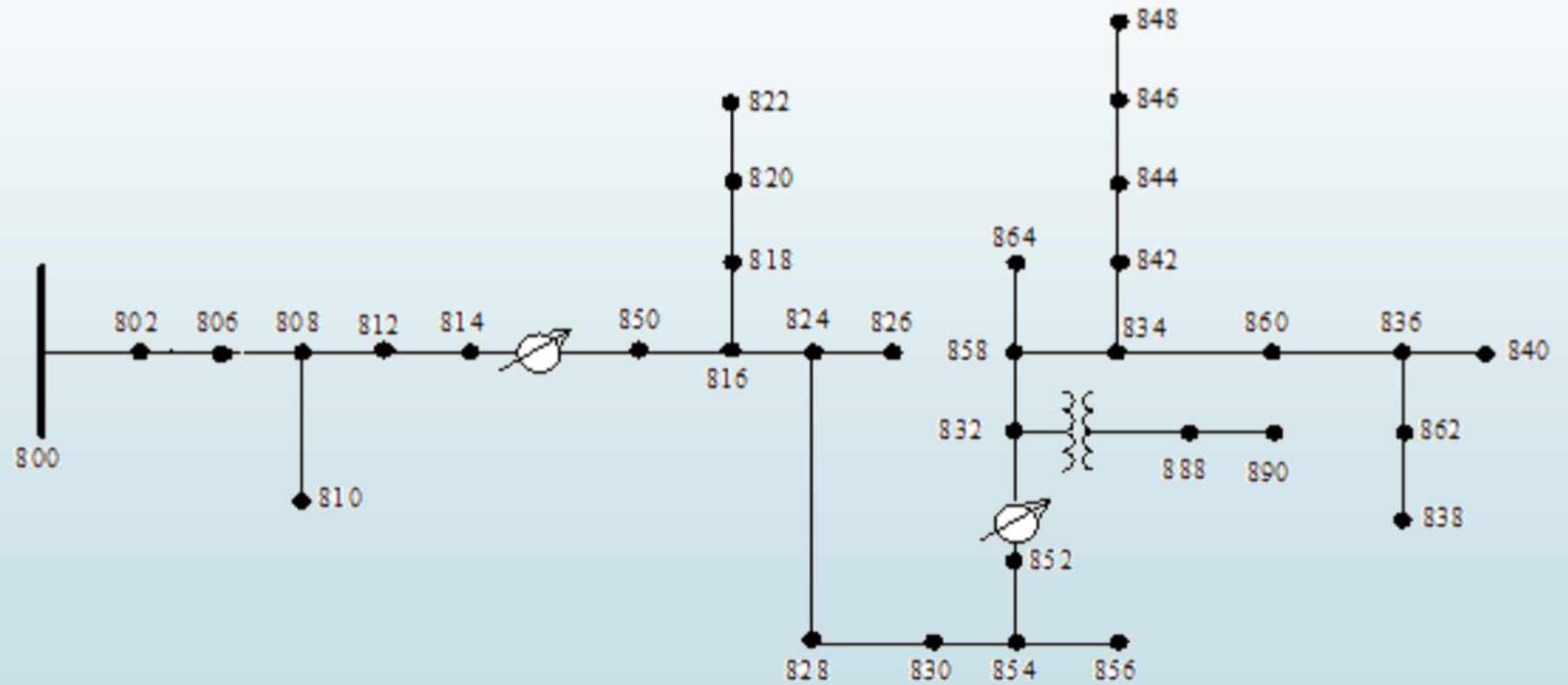
- ▶ Electric Power Distribution System Simulator
- ▶ Distribution Feeder analysis program
- ▶ Manipulate bus systems to analyze violations, losses, loads, etc
- ▶ Produce graphs of voltage profile and locations of bus violations



IEEE Test Systems Background Information

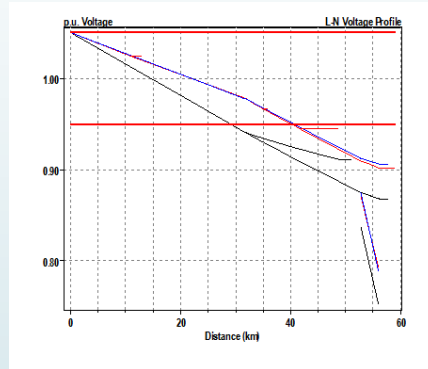
- ▶ 4-bus system
 - ▶ Used as a starting point
 - ▶ Hand calculations
 - ▶ Intro to OpenDSS
- ▶ 34-bus System
 - ▶ Monthly and Seasonal Load Analysis
 - ▶ Community Solar PV Analysis
 - ▶ Residential Solar PV Analysis

34 Bus System Analysis

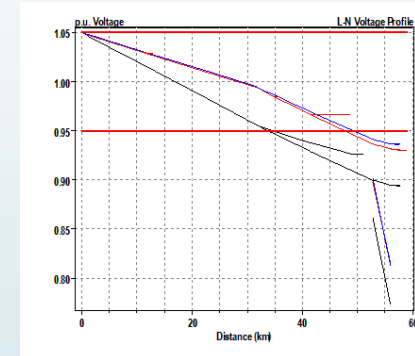


Analysis of the Effect of Capacitors and Regulators on the System

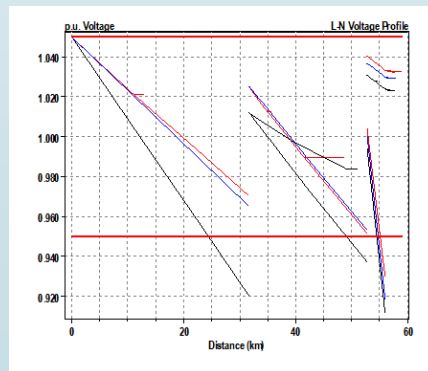
Regulator Off, Capacitor Off



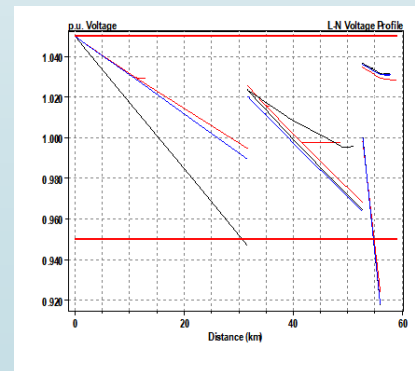
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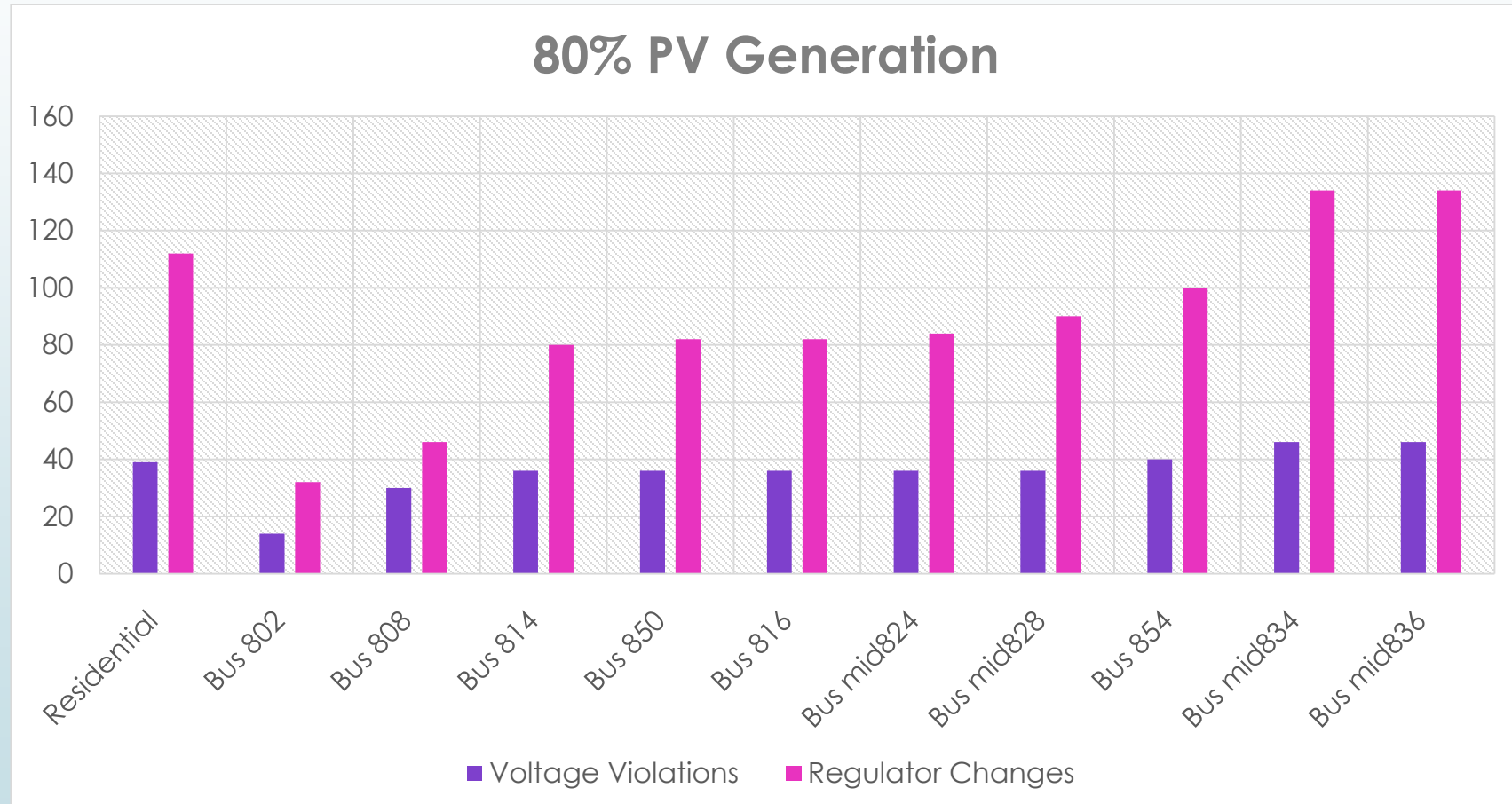
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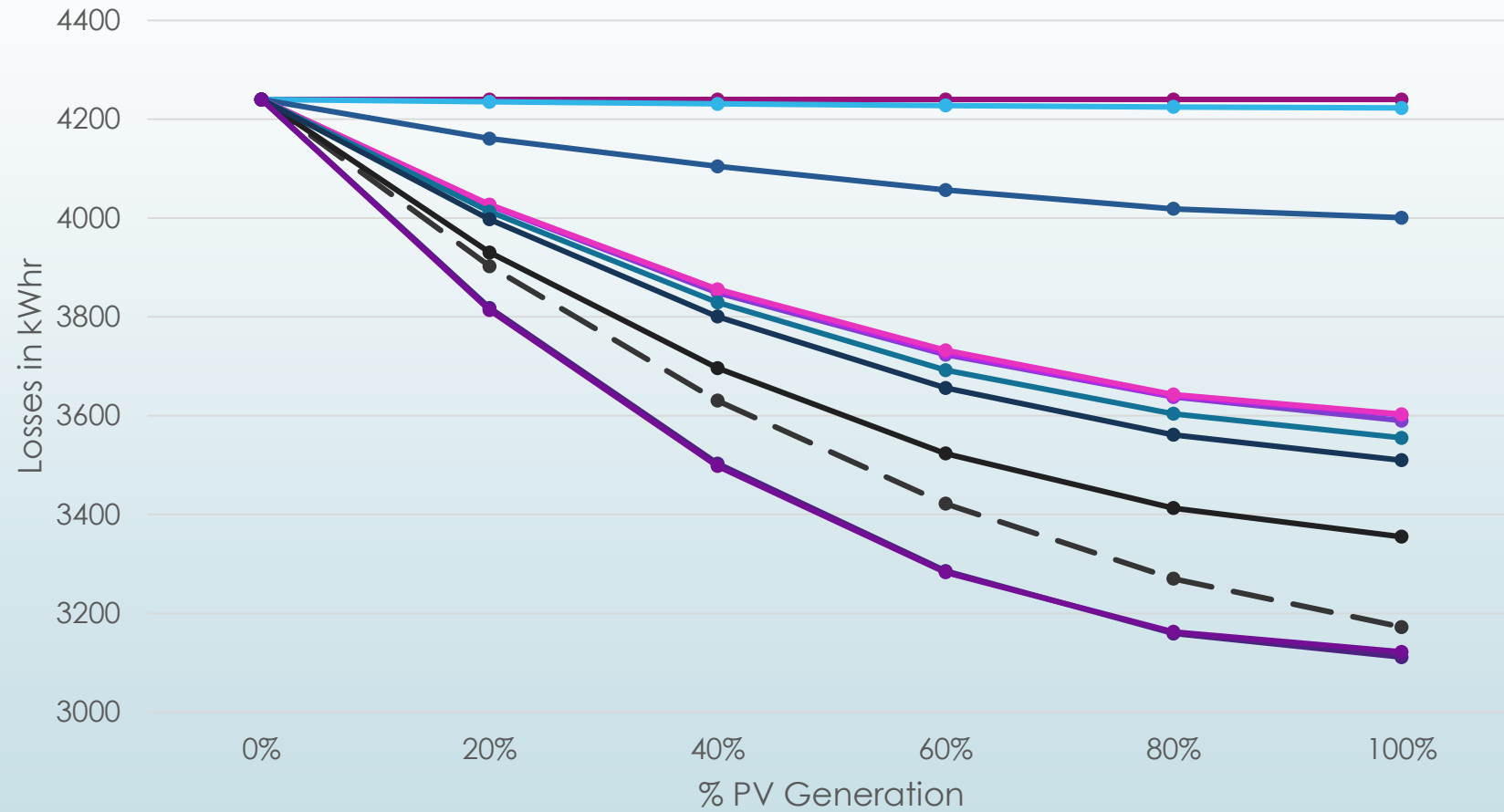
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Effects of Location on PV Generation

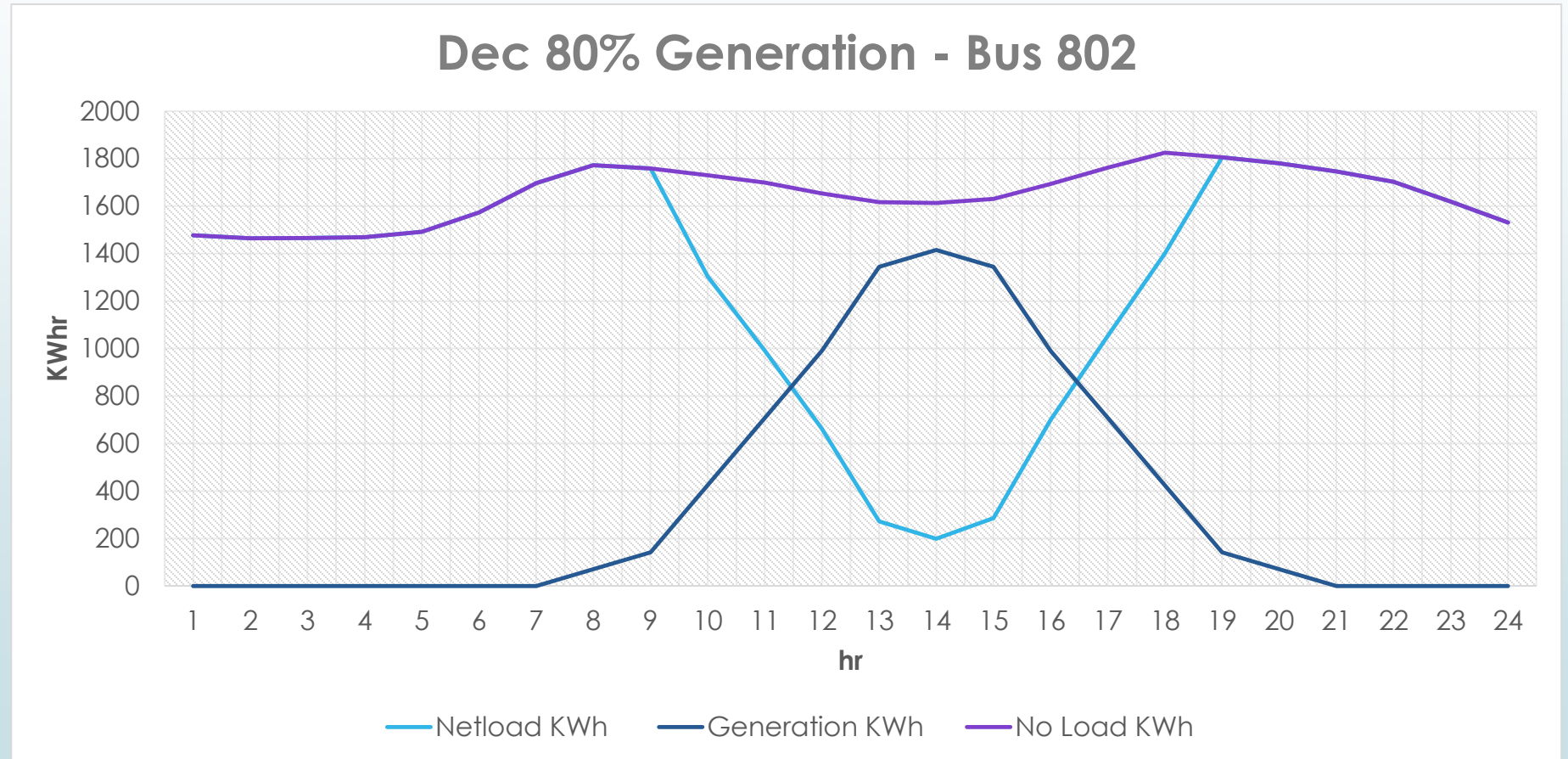


Line Losses as PV Penetration Increases

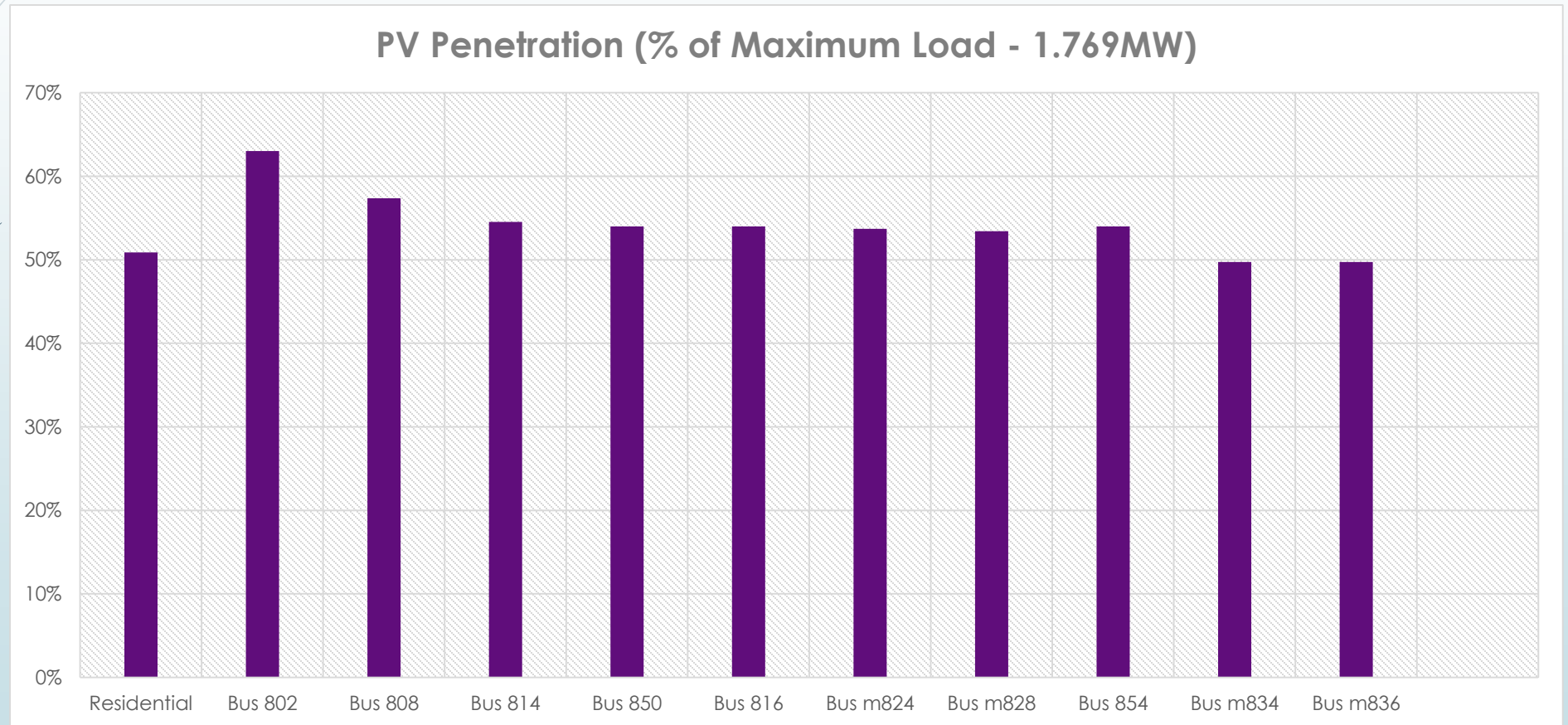


- No Generation
- Residential
- Bus 802
- Bus 808
- Bus 814
- Bus 816
- Bus 850
- Bus 854
- Bus MID824
- Bus MID828
- Bus MID834
- Bus MID836

Impact of Location and Amount of Solar Generation on the System



Maximum PV Penetration System Can Handle Without Violations



A dark blue arrow points to the right at the top left. Below it, several thin, curved lines in shades of blue and grey sweep across the left side of the slide.

Takeaways

- ▶ Regulators are more effective as they are more variable than capacitors
- ▶ As the location of generation moves further away from the sub-station:
 - ▶ Voltage Violations increase
 - ▶ Regulator position changes increase
 - ▶ Losses decrease
- ▶ Solar is difficult due to peak generation is not always occurring at peak load
- ▶ Closer to sub-station, more PV penetrations we can have before upgrading or seeing violation



Current Project Status

- Completed analysis on 34-bus test system
- Prepared to analyze Alliant Energy System (next semester)
- Communicate with previous group to continue their work on Alliant Energy system
- Cost Estimation (next semester)



Looking Forward



- ▶ Plan for Next Semester:
 - ▶ Analysis of Alliant's System
 - ▶ Cost Analysis of Residential vs Community Solar Generation
 - ▶ More In-Depth Analysis
 - ▶ Regulator Settings
 - ▶ Realistic Conditions



References



- ▶ “EPRI | Simulation Tool – OpenDSS.” *EPRI | Simulation Tool – OpenDSS*, Electric Power Research Institute, Inc., 1 Jan. 2011, smartgrid.epri.com/SimulationTool.aspx.
- ▶ Kersting, William H. *Distribution System Modeling and Analysis*. Boca Raton: Taylor & Francis, 2012. Print.
- ▶ Singhal, Ankit, and Venkataramana Ajjarapu. “Impact Assessment and Sensitivity Analysis of Distribution Systems with DG.” *2015 North American Power Symposium (NAPS)*, 23 Nov. 2015, *IEEE*, doi:10.1109/naps.2015.7335218.



Thank You!