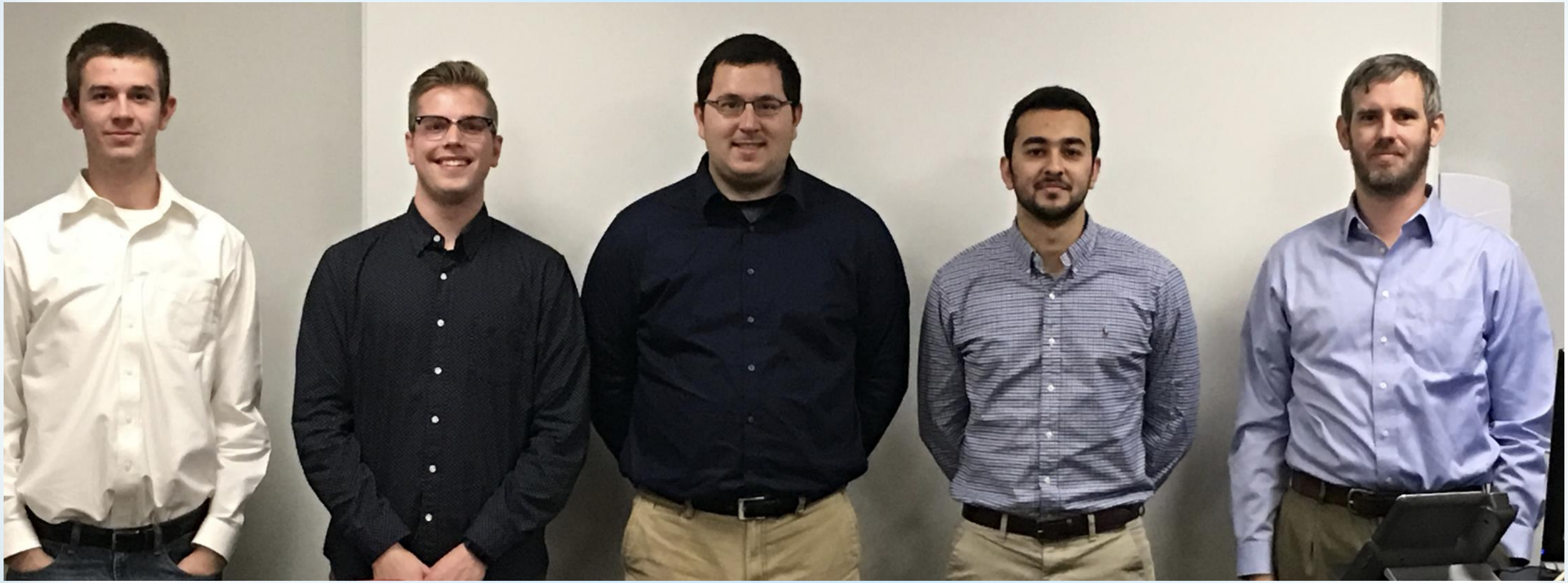
Impact of High Photo-Voltaic Penetration on Distribution Systems

Group: 1728

Advisor: Dr. Ajjarapu

Client: Alliant Energy

The Team



From left to right: Sam Searls, Wyatt Lauer, Mark Szkodyn, Abdul Waasay Mirza, Nathaniel Summitt

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

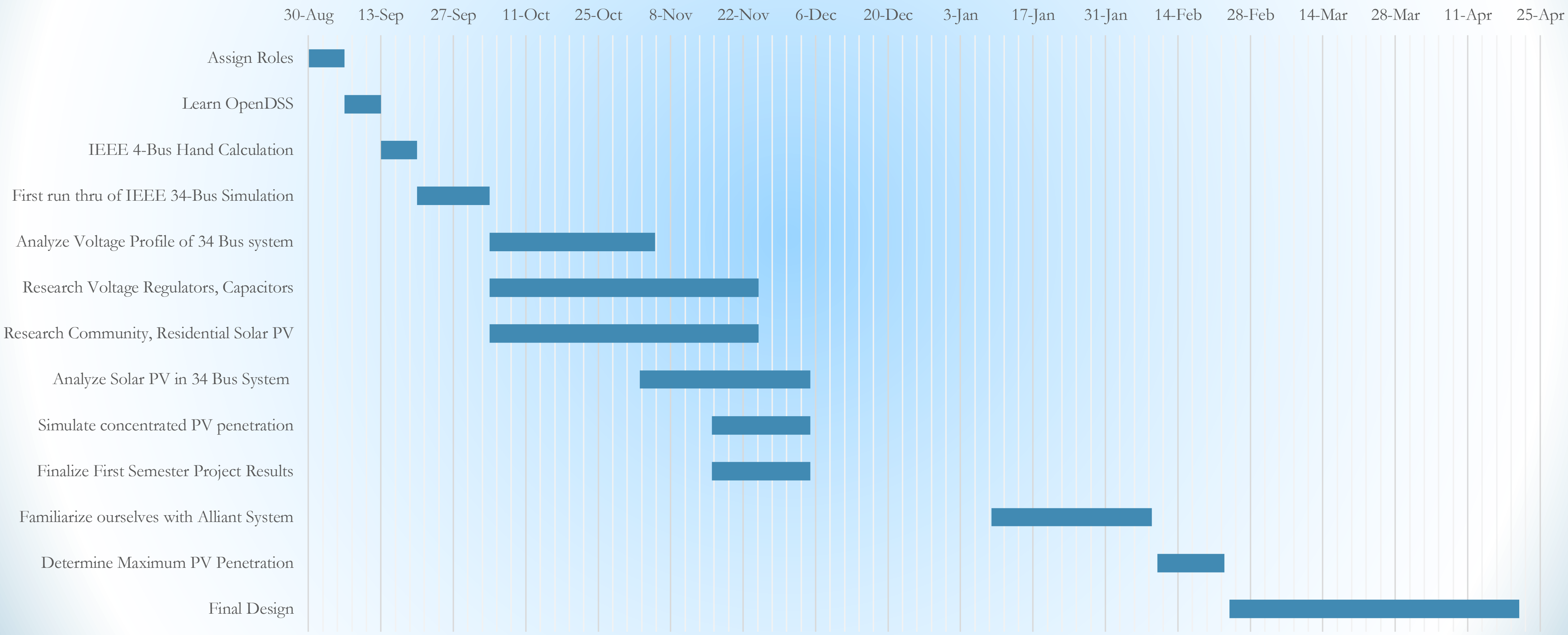
Project Goals

- Understand solar penetration trends and impacts on distribution systems
- Comparison of effects of residential versus community solar generation
- Develop model and run various real-world simulations on the Alliant Energy feeder using OpenDSS
- Use the results from the simulations to aide in the design of the distribution system to enable it to withstand maximum PV penetration
- Understand and prepare solutions to mitigate loss of generation due to cloud bank coverage and other undesirable weather conditions

Final Deliverables

- Voltage profiles and/or other necessary plots from simulations
- Comparison of residential and community solar PV generation on a typical sunny day
- Results of simulation with solar PV with cloud intermittency
- Possible solutions for modifications to distribution system

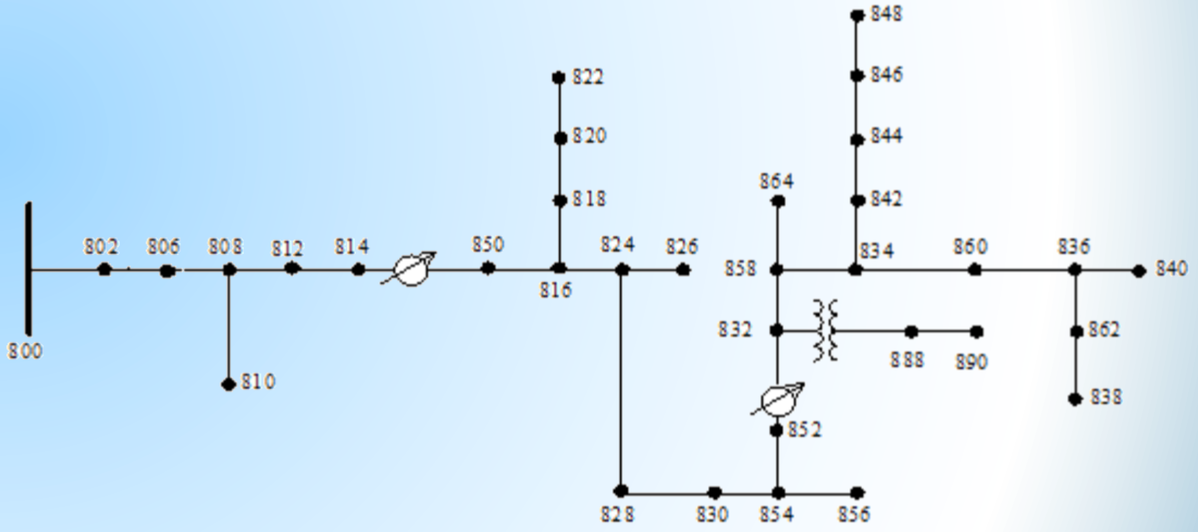
Project Timeline



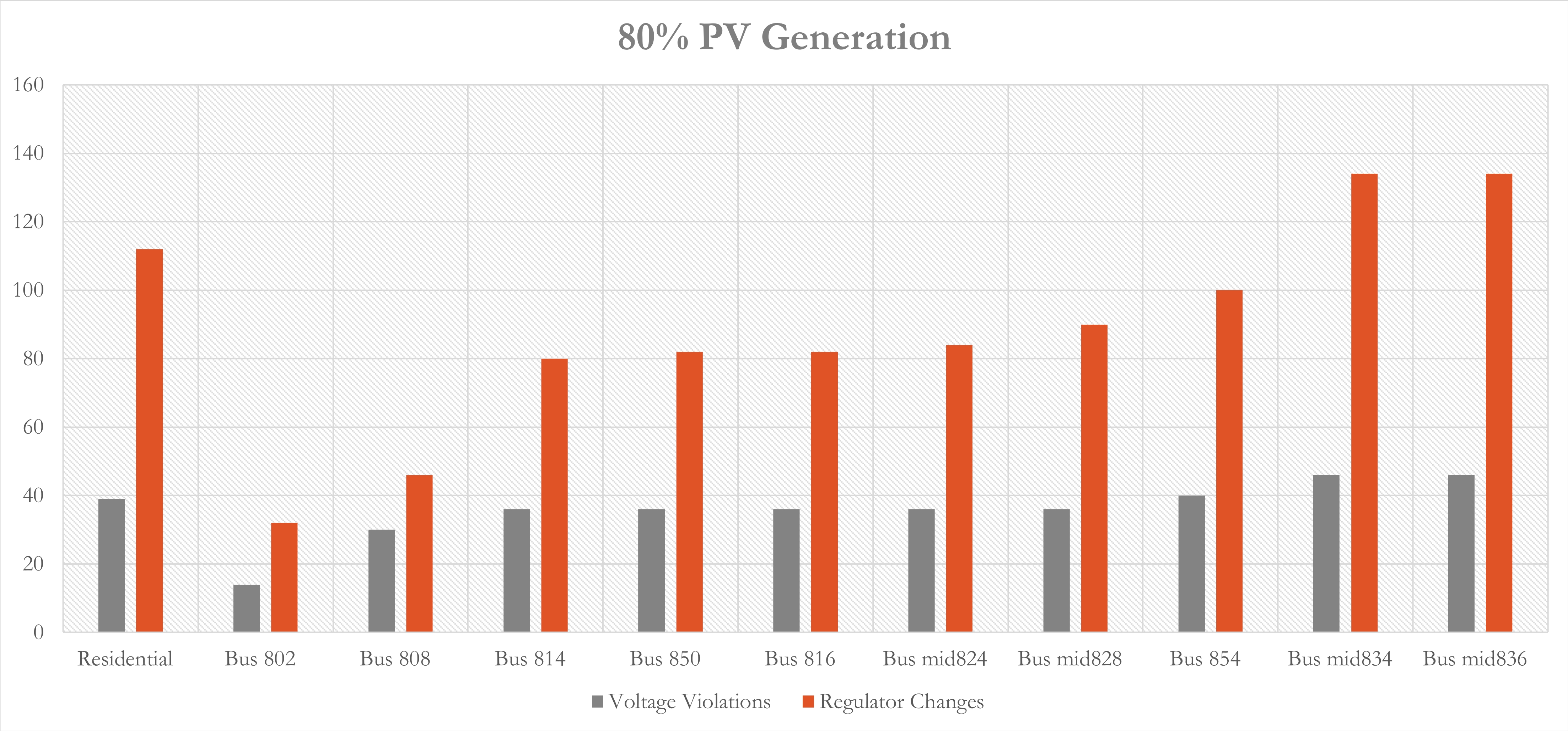
Step 1: Distribution System Concepts and OpenDSS

IEEE 34 Bus System Overview

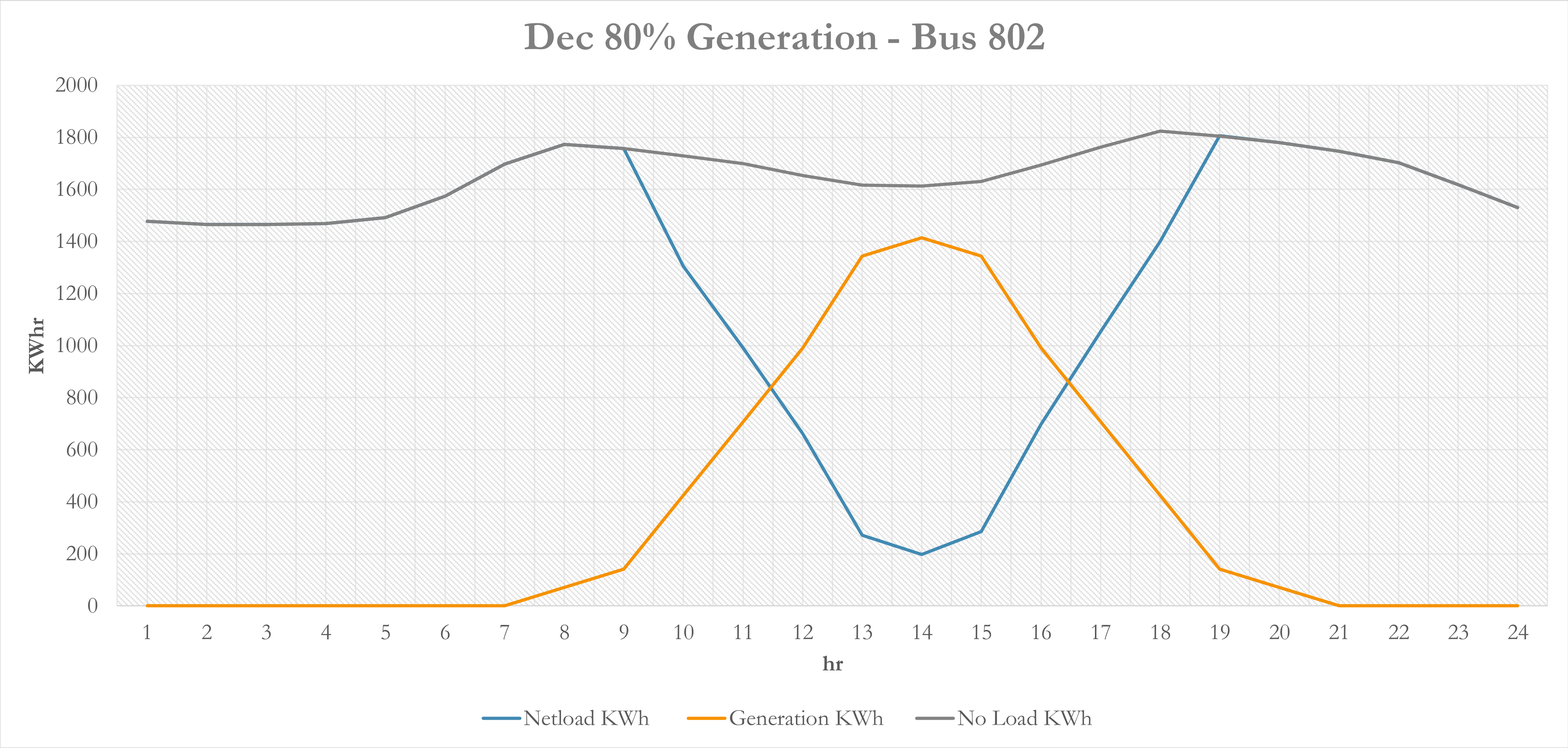
1. Testing (IEEE 34 Bus System)
2. Initial Voltage Correcting with Capacitors
3. Observe effects of system components
4. Understand Load Profiles
5. Adding Solar Generation
6. Observe effects of Solar Penetration Levels and location
    - Regulator Tap Changes
    - System Losses
    - Voltage Violations



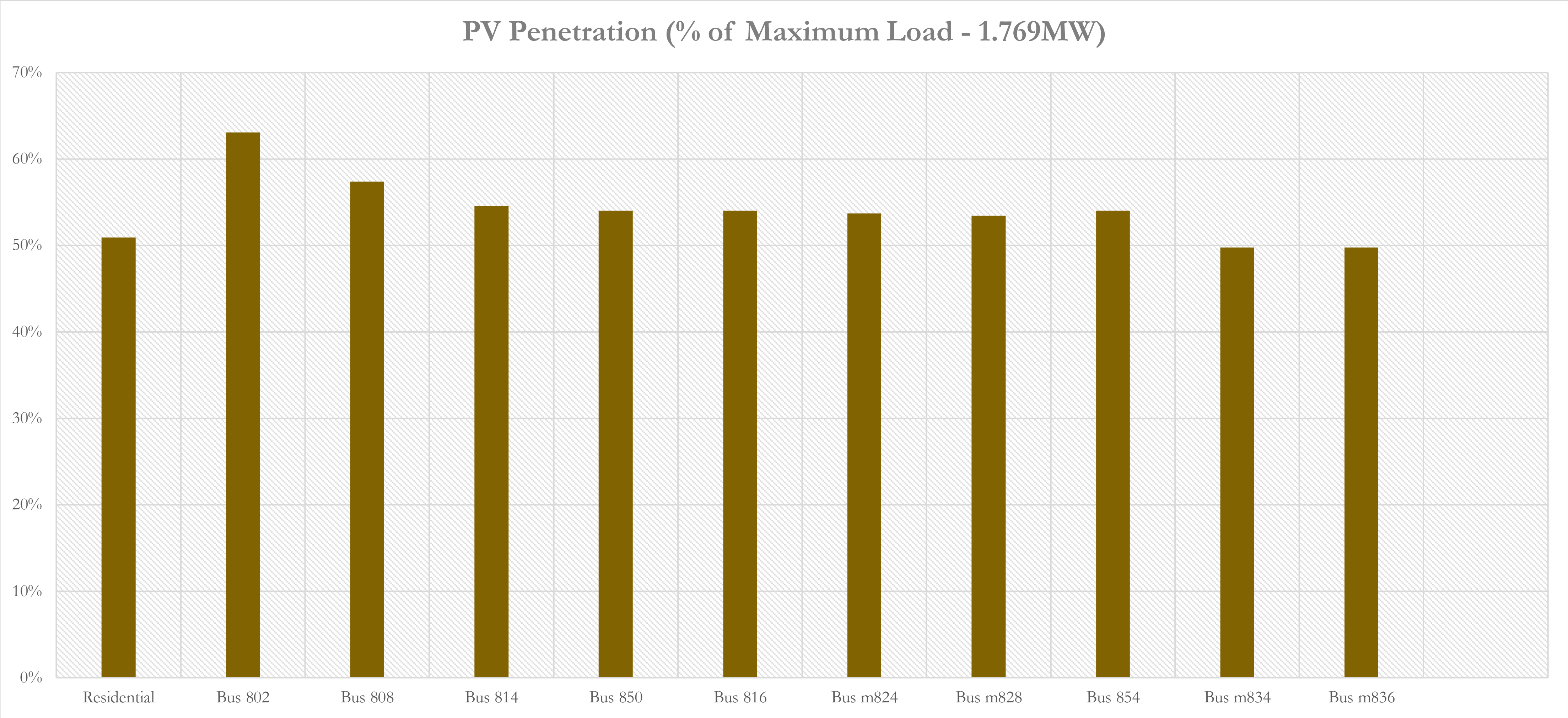
Effects of Location on PV Generation



Duck Curve Effect

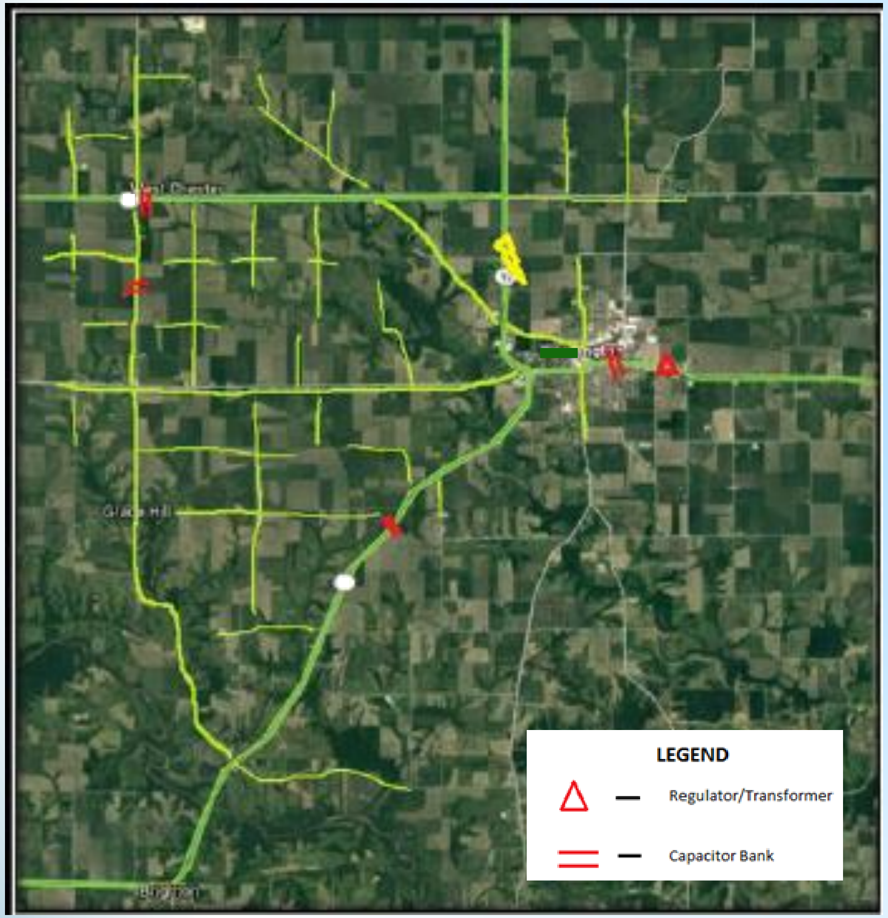


Maximum PV Penetration Without Violations



Step 2: Familiarize Ourselves with Alliant System

Alliant Distribution System



- 3,000 linear feet of distribution line
- 56 Solar Customers
- 1 Voltage Regulator
- 4 Capacitors

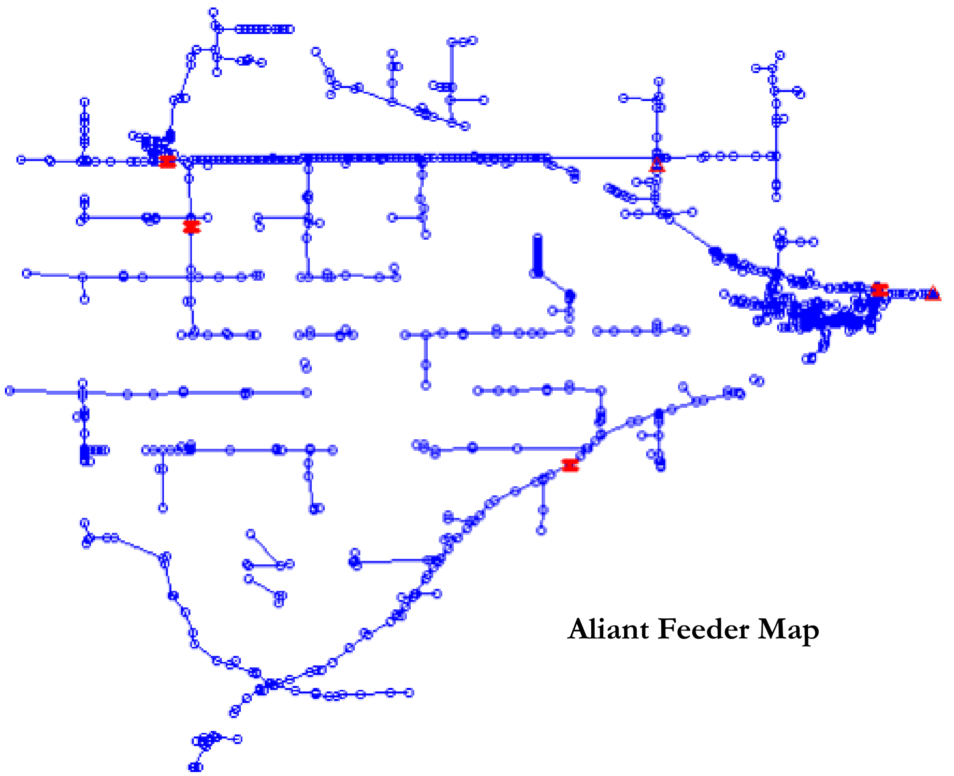
Understanding the System

1. Understand raw data of system

2. Organize raw data into separate CSV files

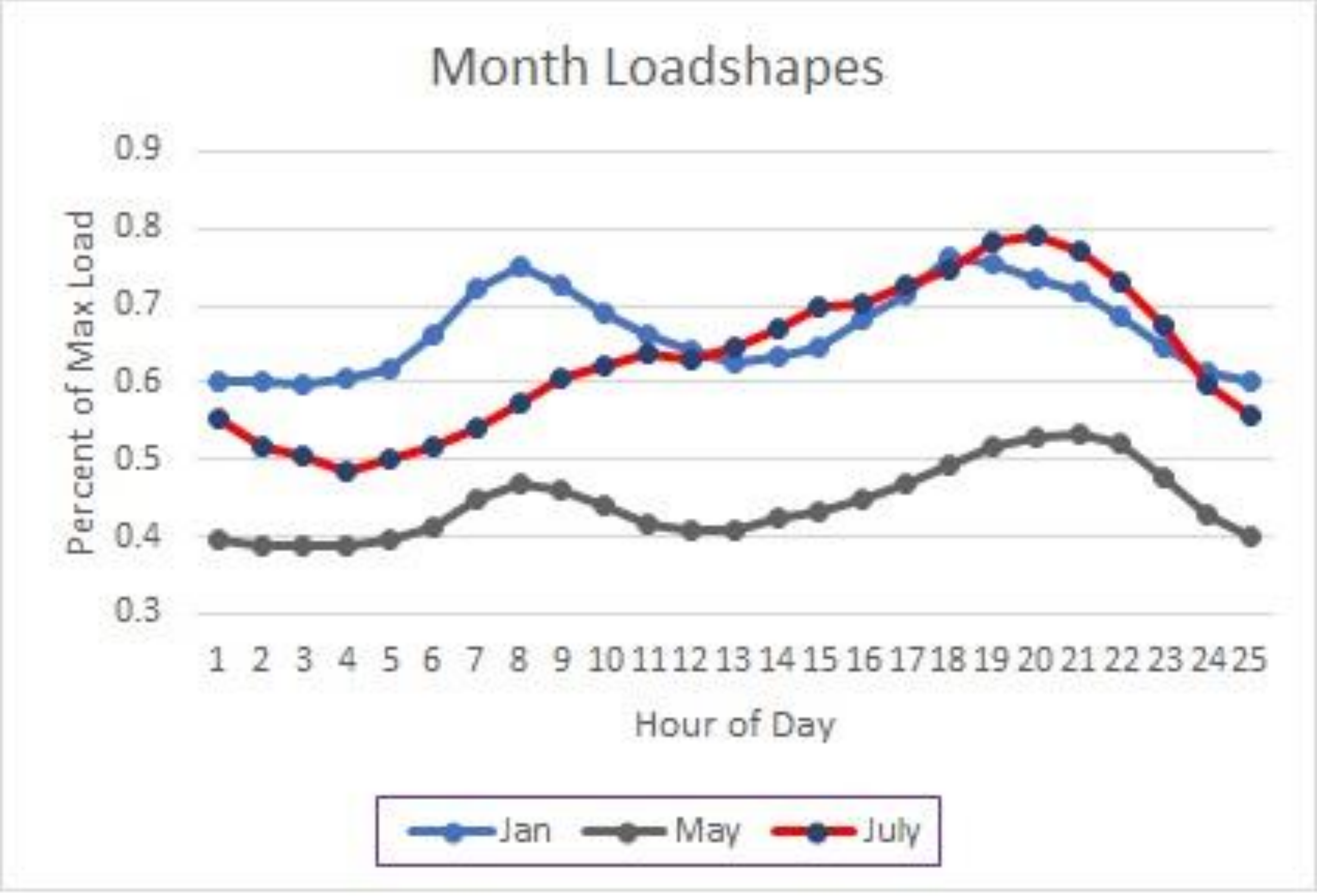
3. Import data from CSV files to OpenDSS

4. Build OpenDSS code to model the system



Aliant Feeder Map

Monthly Loadshapes

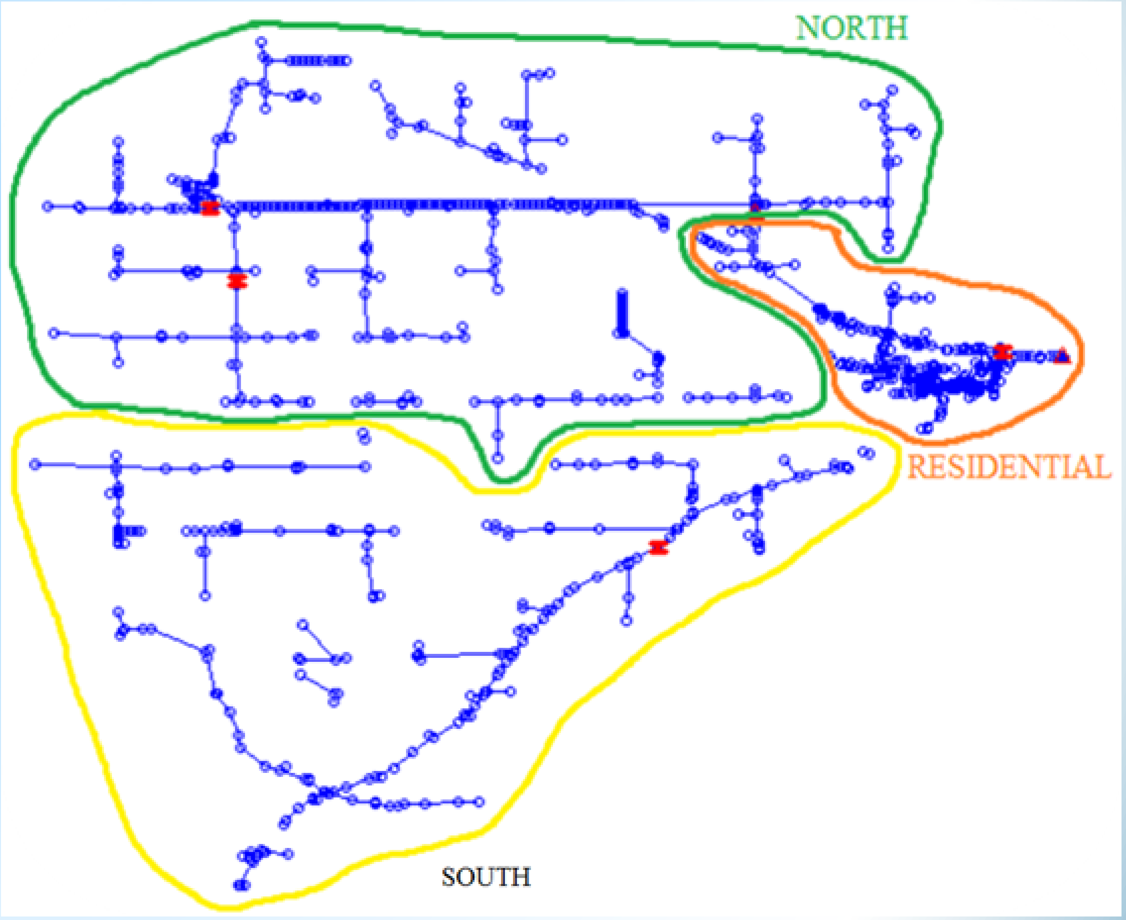


- Understanding Months of Interest
  - January: Largest Duck Curve Effect
  - May: Lowest Load Values
  - July: Largest Peak Load Value

Step 3: Determine Maximum PV Penetration on Alliant System

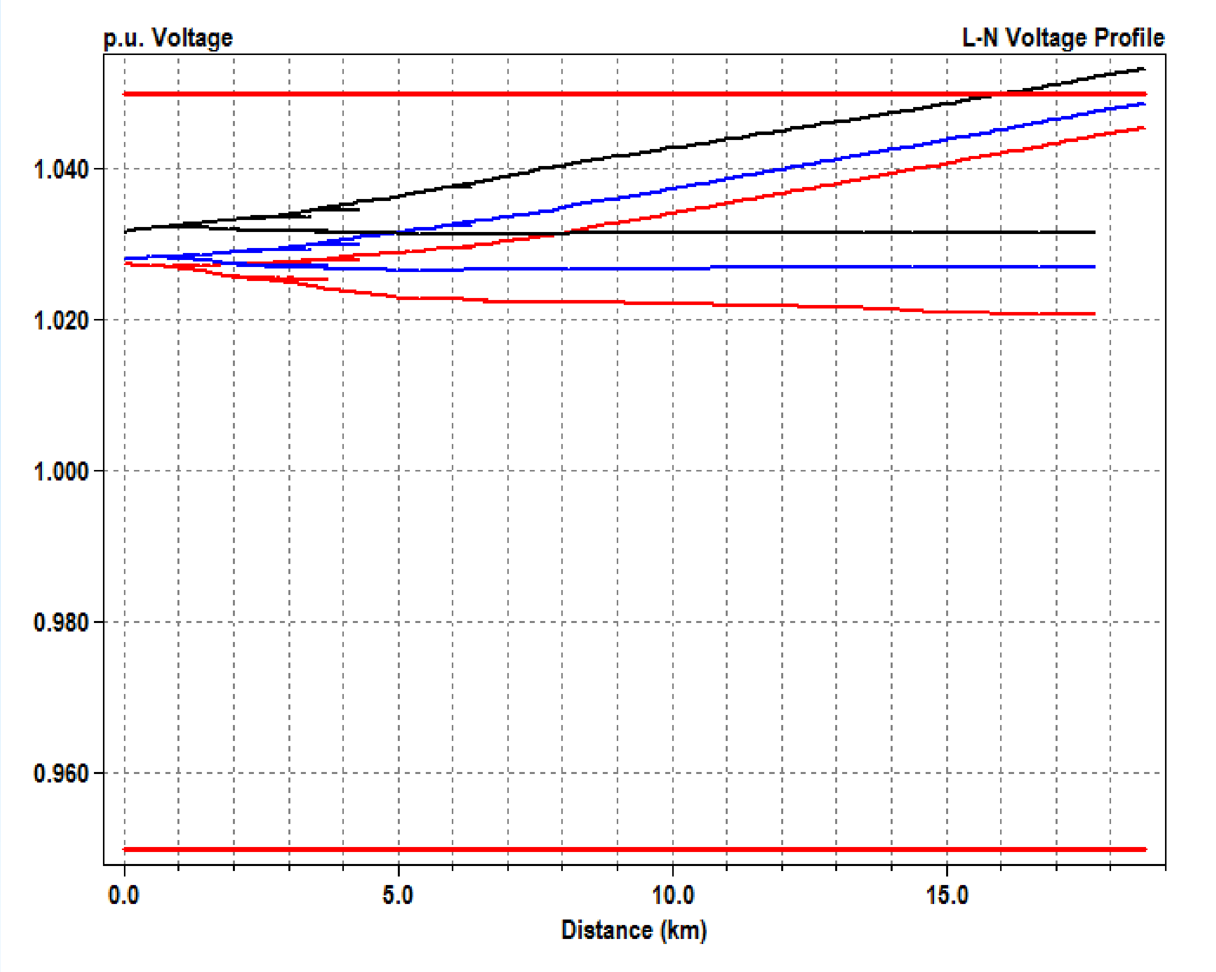
Plan for Analysis

1. Break System into three parts
2. Add Solar
3. Use techniques
   from 34 bus system to
   analyze results
4. Determine Max PV Penetration
5. Repeat for next part



Conclusions

- Single PV site saw most violations
- Residential can handle 100% of system load
- North can handle 70% of system load
- South can handle 50% of system load

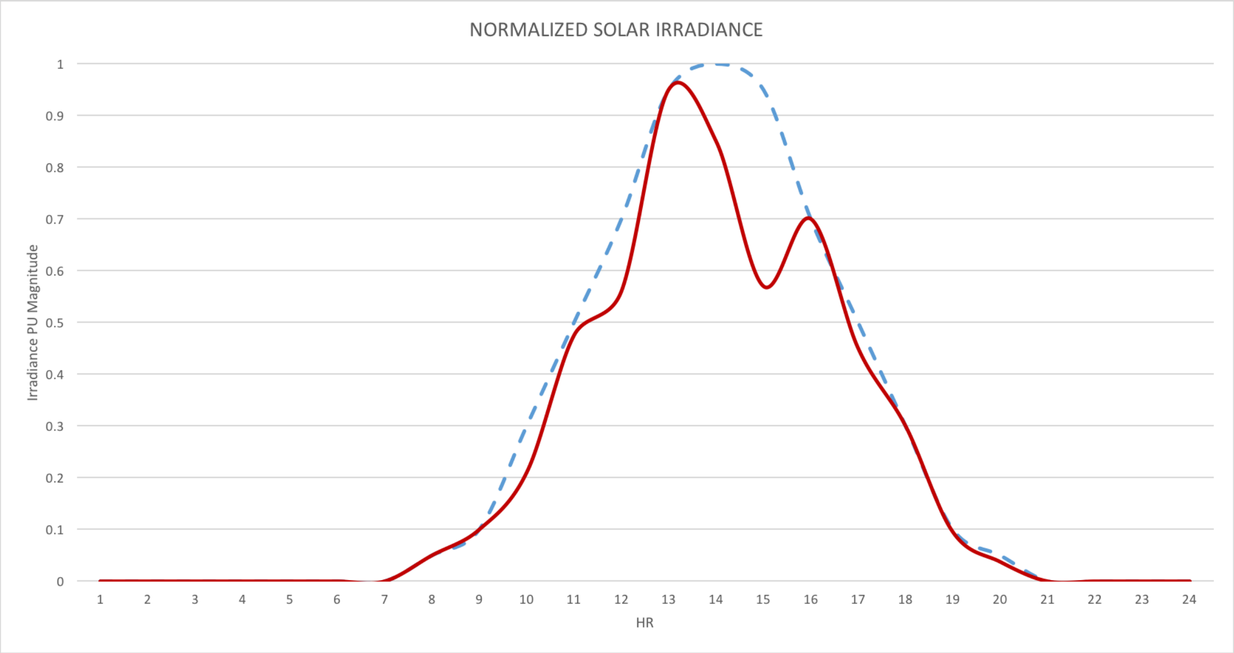


Step 4: Final Design

Design System That Can Sustain High PV Penetration During Cloud Intermittency

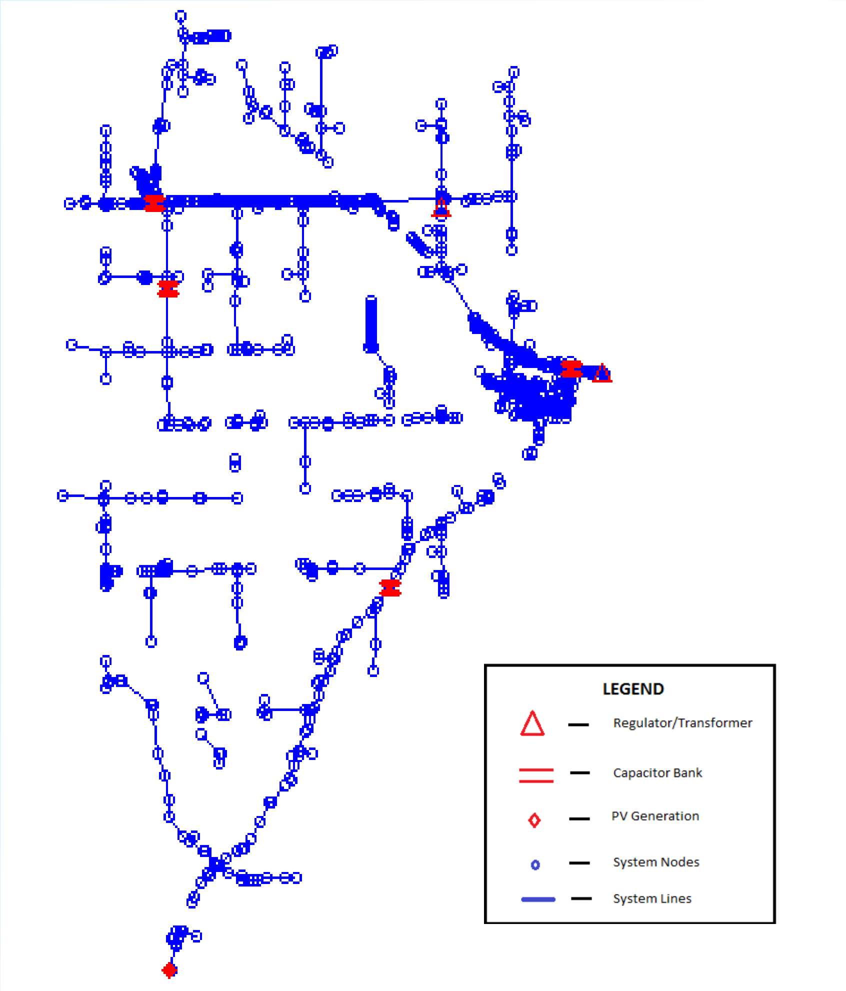
Design Plan

1. Design for worst case scenario in south region
2. Use modified solar waveform
3. Compare community and residential solar
4. Analyze data of both scenarios
5. Determine solutions for maximum PV penetration with cloud coverage



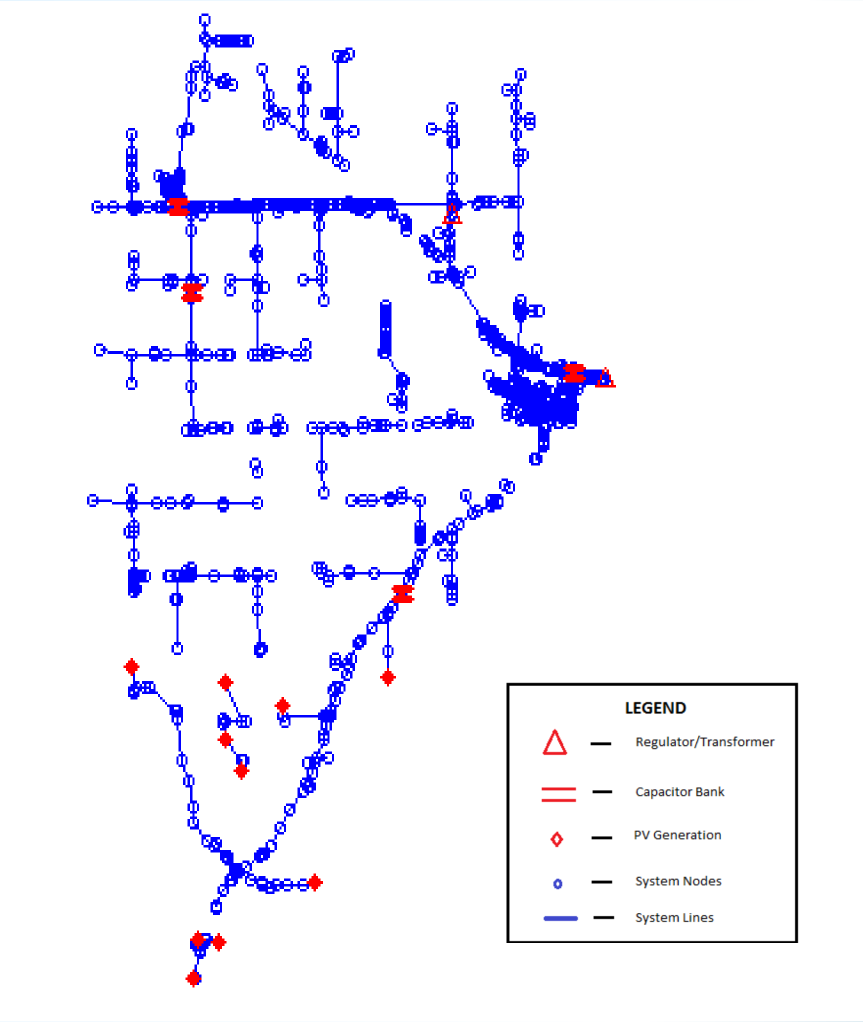
Results: Single Site Solar

- Violations at 50% of maximum load with cloud coverage
- Smart Inverters are unable to rectify the problem



Results: Distributed Solar

- No violations at 50% of maximum load with cloud coverage
- Smart inverters would increase voltage quality



Results: Future Planning

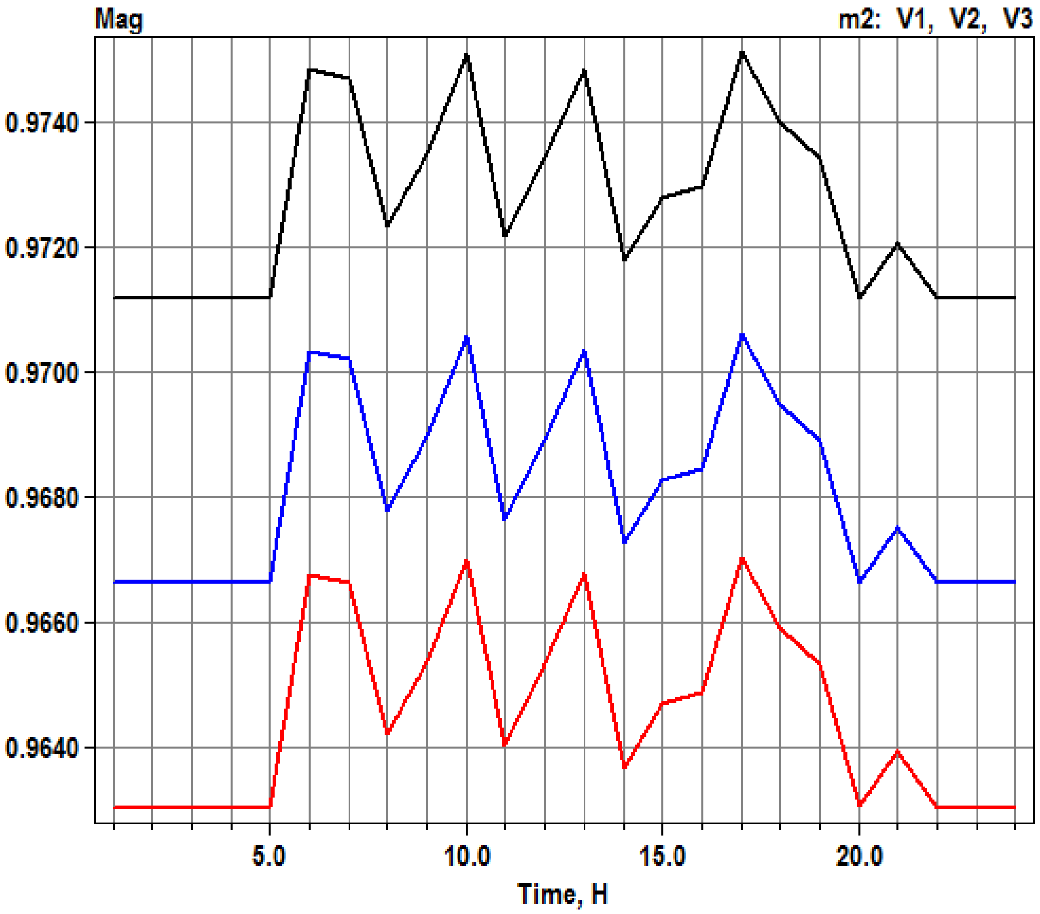
If Desired Generation is closer to 100% of the Maximum Load:

- Single Solar Site
  - Place closer to substation
- Distributed Solar Sites
  - Distribute across entire system
  - Size of solar site based on load in area

Thank You

Smart Inverter Effect

Voltage at Solar Site without Smart Inverter (per unit)



Voltage at Solar Site with Smart Inverter (per unit)