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Electric Vehicle Charging Impacts on Island Power Systems

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Overview

- Electric Vehicle (EV) Transition
- EV Opportunities and Challenges
- Power System Specific EV Challenges
- Hosting Capacity Simulation Explained
- Simulation Results
- Power System Mitigation Techniques
- Conclusions

Electric Vehicle Transition

- Numerous countries, cities, and territories are moving towards zero emission vehicles
  - United Nations Climate Change Conference (COP26) [1]
- Vehicle manufactures are phasing out internal combustion-only vehicles
  - Toyota (Europe by 2035), Volkswagen (2050), Hyundai (2045), GM (2035), etc. [2-6]
- Some EV adoption challenges are being reduced by technology advances
  - Battery Technology
    - Reduced cost [9]
    - Increased capacity = Increased driving range
  - Higher Powered Charging Equipment [22]
    - Allows for faster recharging
- EV adoption rates are increasing
  - Global adoption predicted to be 10-12.5% by 2025 (currently 2%) [7]

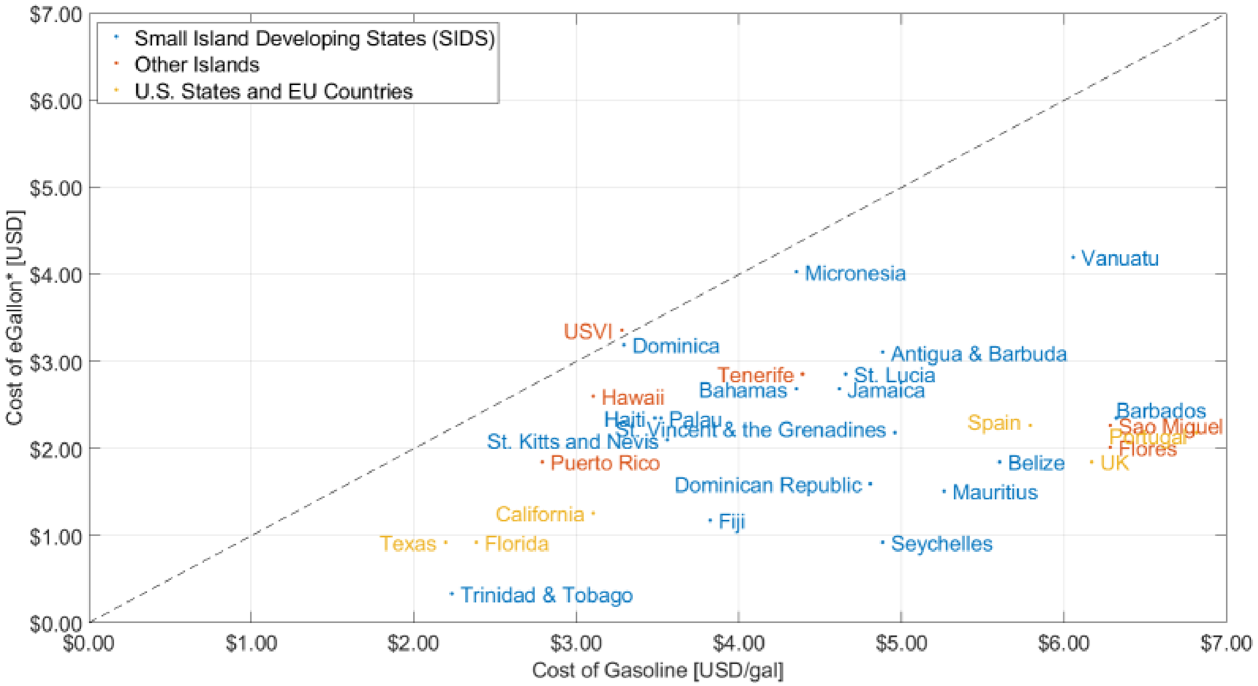
EV Opportunities and Challenges

Opportunities

- Reduction of pollution (air and noise)
  - Life-time green house gas emissions less than gasoline-powered vehicles. [15-17]
  - Climate benefit
- Future resilience benefit [11, 12]
  - Bi-directional energy flow (Vehicle to Grid) (EVs used to power services during events)
  - Repurposed old EV batteries [20]
- Efficiency
  - EVs 15%-20% vs Gasoline 64%-75% loss [14]
  - Cost of eGallon vs Gasoline [18]
  - Fleet vehicle savings [13]
- Increased utility revenue

Challenges

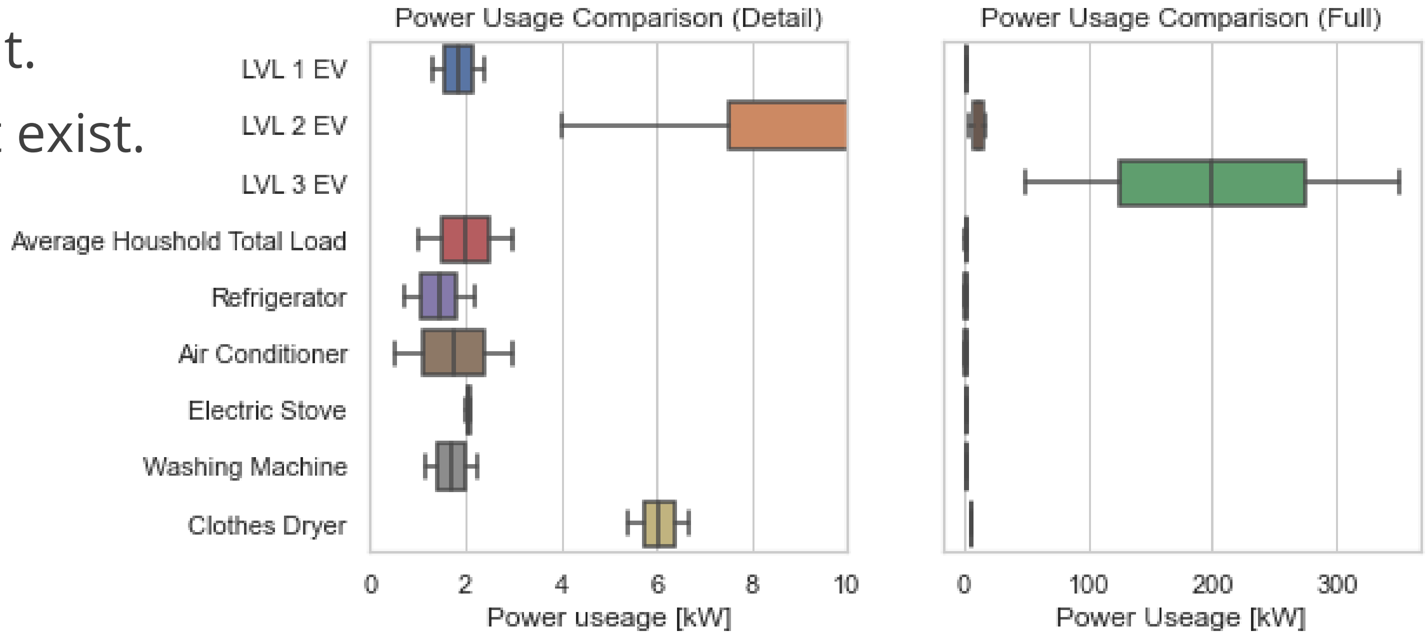
- Import tariffs [19]
- Required economic buy-in [21]
- Power system limitations
- Available charging infrastructure



*eGallon cost based on 30 MPG for 2019 Hyundai Kona and 28 kWh/100 mi for 2019 Hyundai Kona EV, using methodology described at www.energy.gov/eGallon

Specific EV Power System Challenges

- Generation capacity may not exit.
- Charging infrastructure may not exist.
- Increased loading puts extra stress on power system leading to stability issues.
    - Leads to low voltages
    - Leads to over loading issues
        - Typical customer transformer ratings range from 10-50 kVA



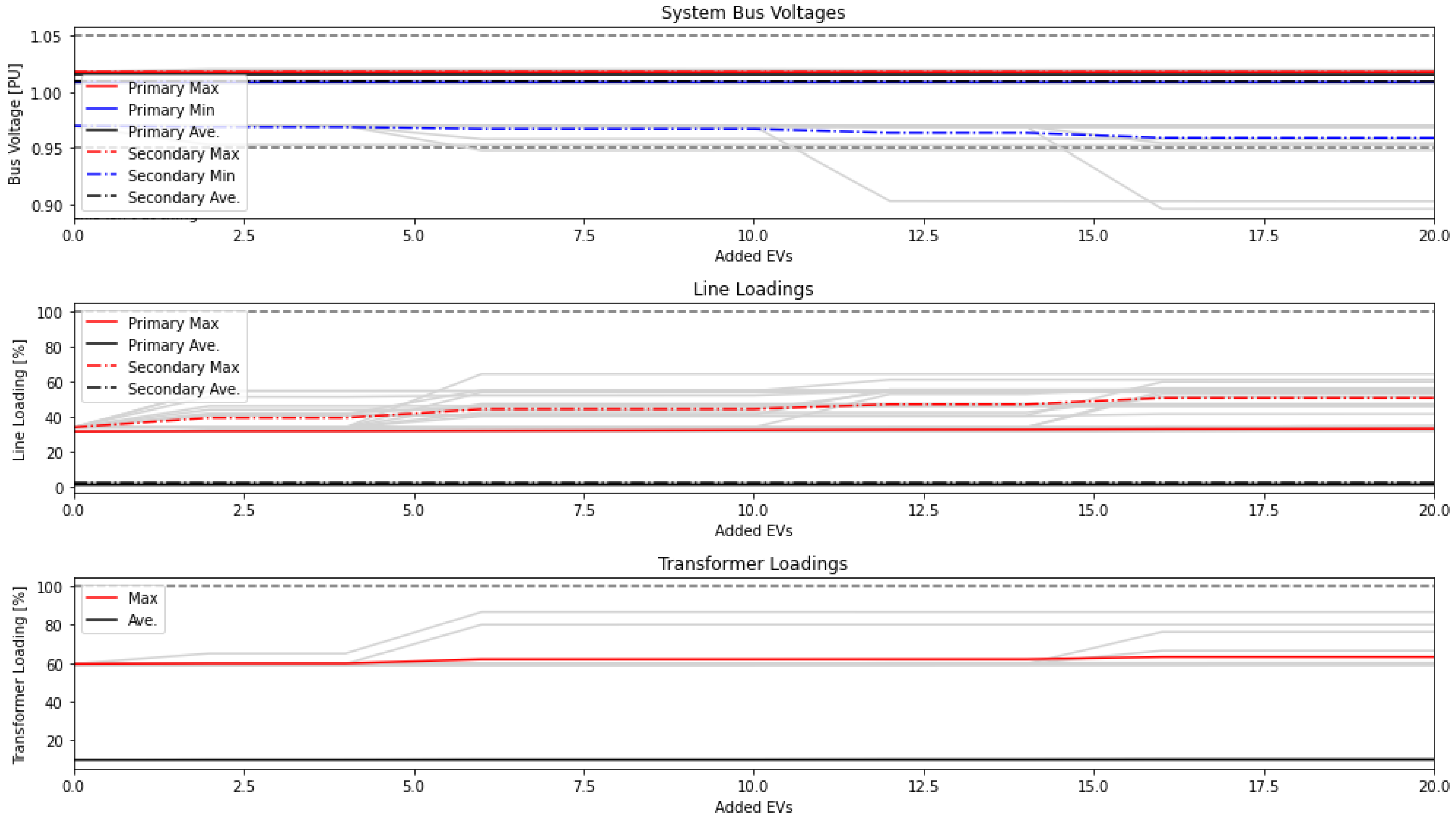
Collected from [22-25]

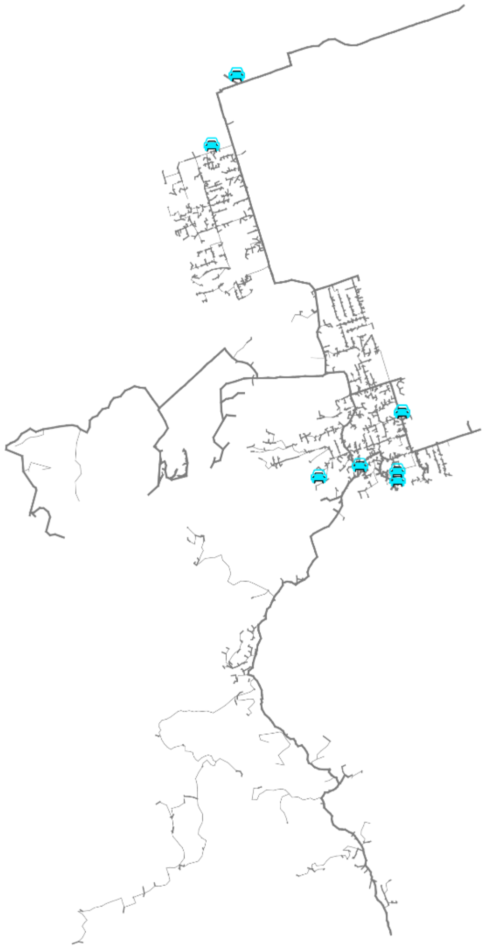
EV Charger Type	System Load	Charging Rate to Miles
Level 1	1.3 – 2.4 kW	4-6 miles per hour of charging
Level 2	4 - 18 kW	12-54 miles per hour of charging
Level 3 (DC fast Charge)	50 – 350 kW	15-45 minutes for full charge

EV Charging Hosting Capacity Simulation Explained

Hosting capacity simulation designed to predict the level at which EV charging leads to power system issues. (low voltage or equipment overloading)

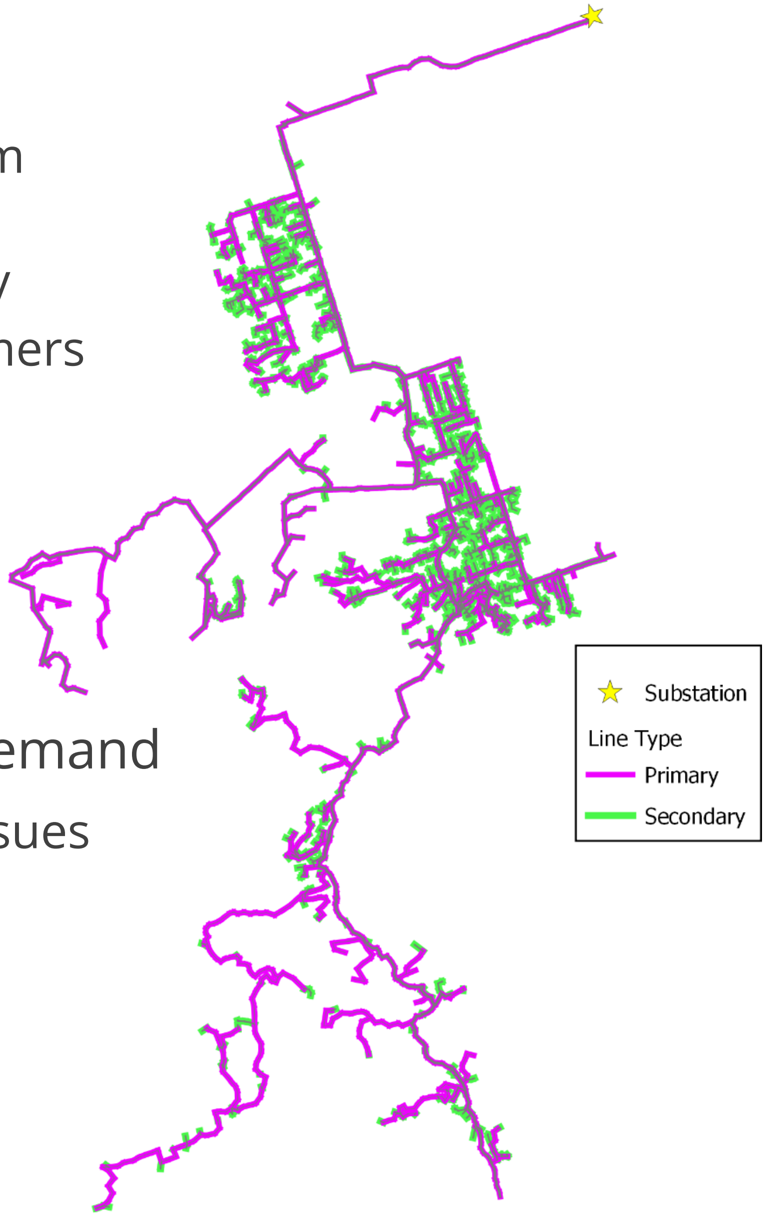
Add load representing a charging Level 2 EV (7.2 kW) at customer nodes.

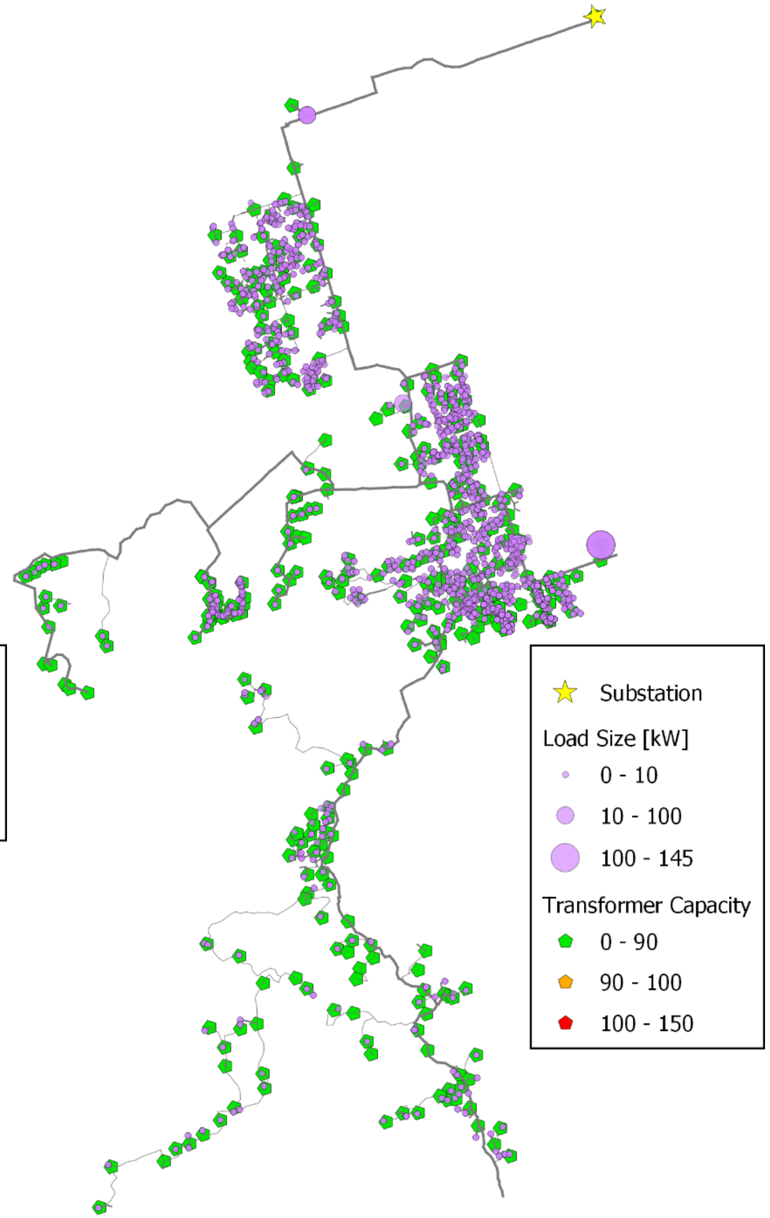




Distribution System Feeder Model Overview

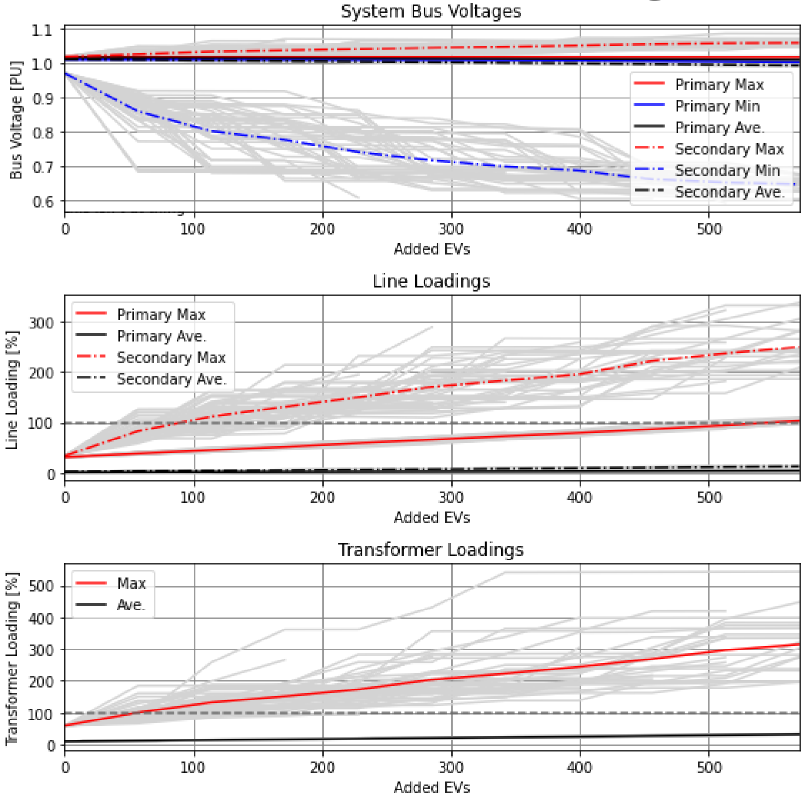
- 18 km (11 mile) Island System
  - 14.4 kV primary
  - 120/240/480 V secondary
  - ~400 customer transformers
- Initial Loading: 1,605 kW
- Total Customers: 570
  - Average ~3 kW/Customer
- Scenario is during peak demand
- No overloading or voltage issues

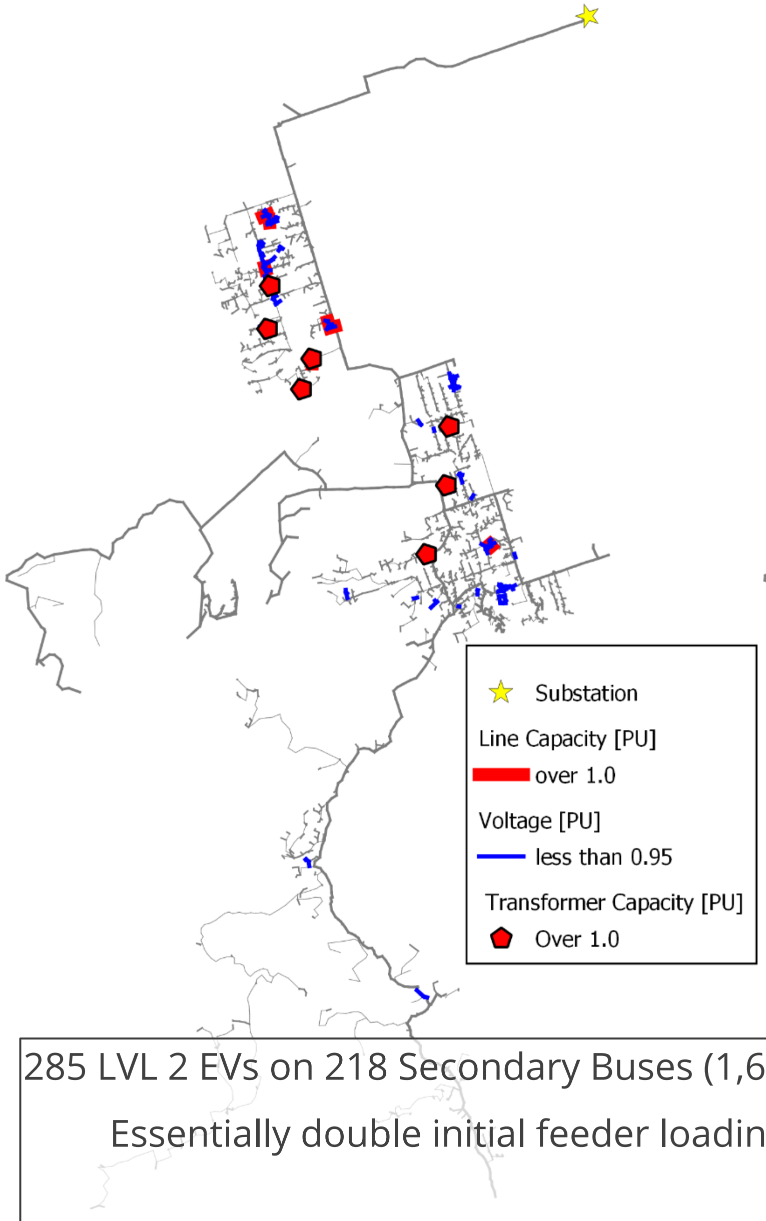


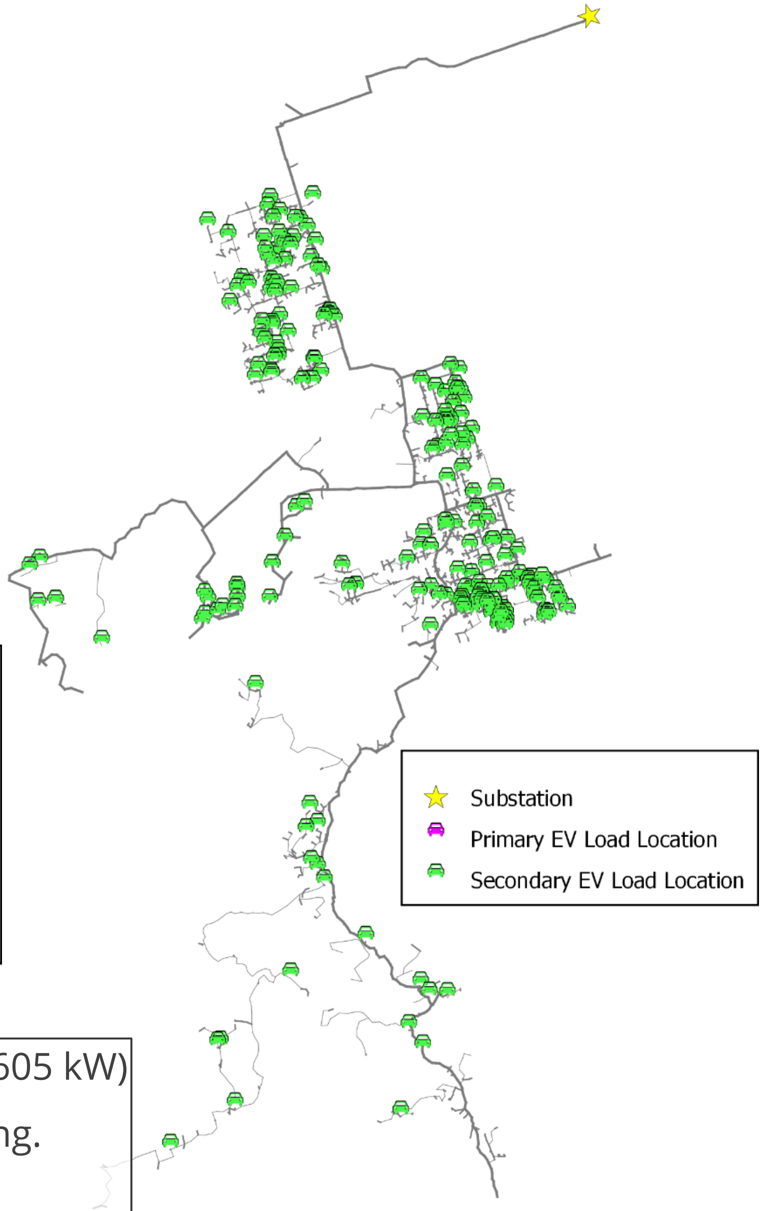


EV Charging Simulation Results – Secondary Charging Only

- 'Do Nothing' Case
- All residential charging leads to line and transformer overloading, as well as low voltages.





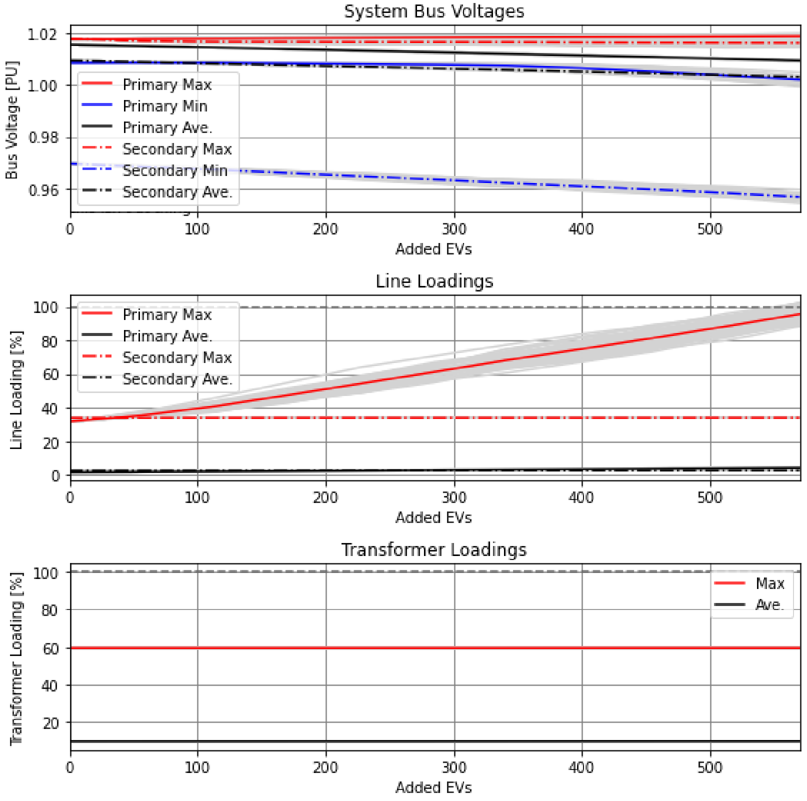


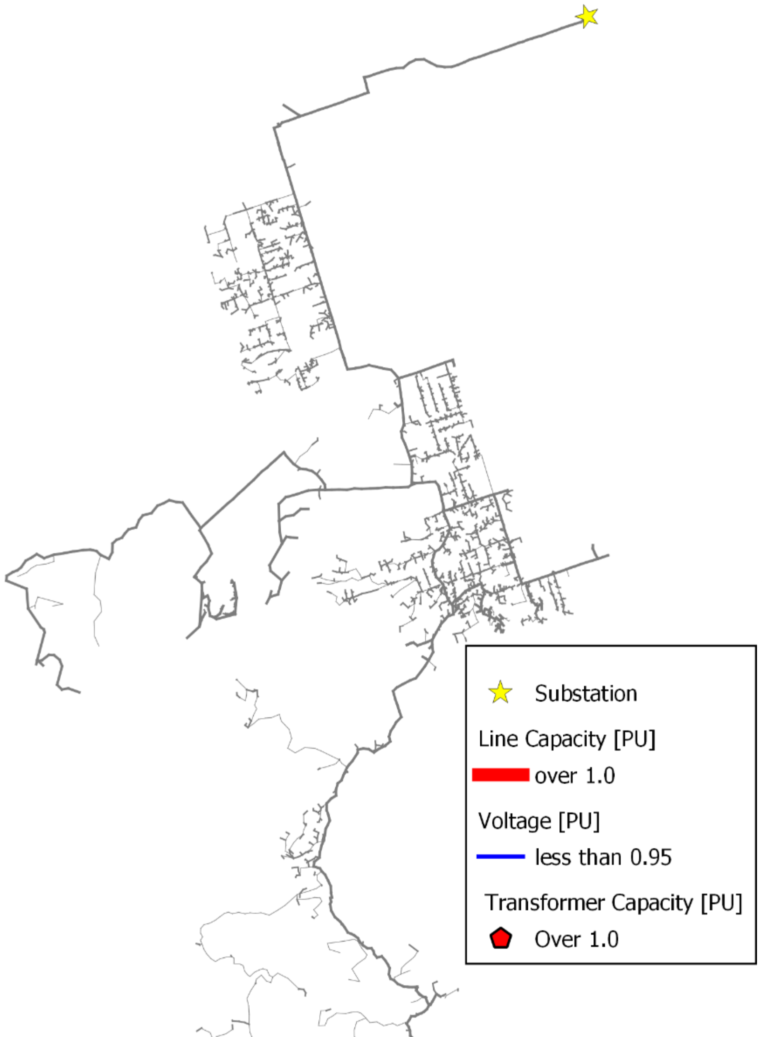
285 LVL 2 EVs on 218 Secondary Buses (1,605 kW)

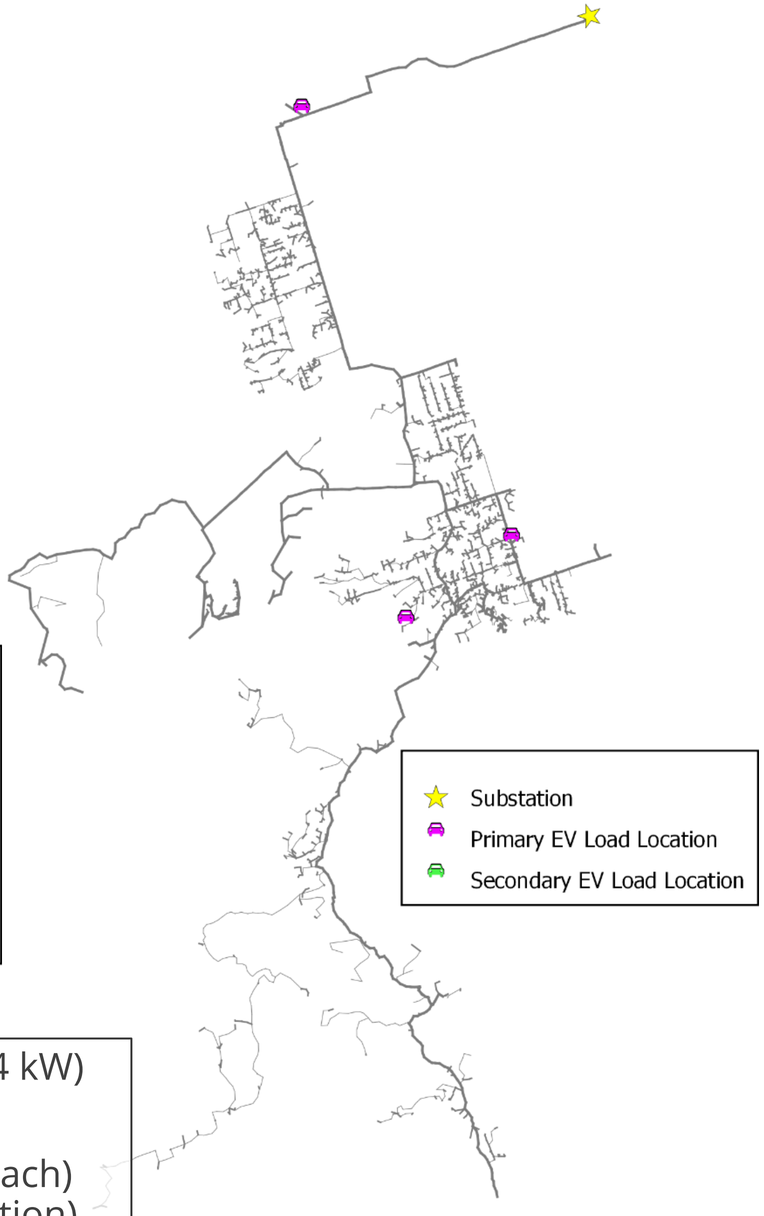
Essentially double initial feeder loading.

Mitigation Technique – High Powered Charger Locations

- If all charging on primary, system has no issues.
- Somewhat unrealistic due to expected user convenience, etc.







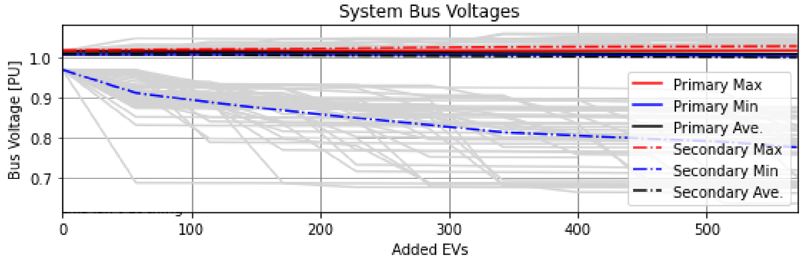
570 LVL 2 EVs on 3 Primary Buses (4,104 kW)

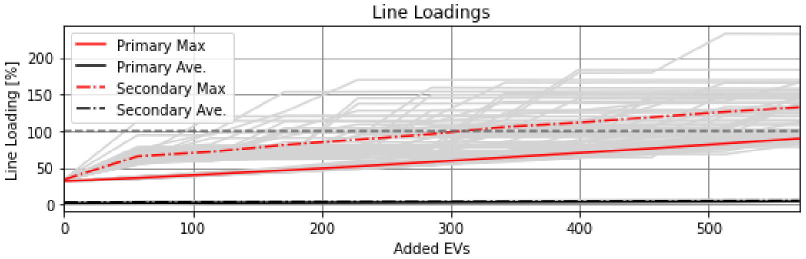
OR

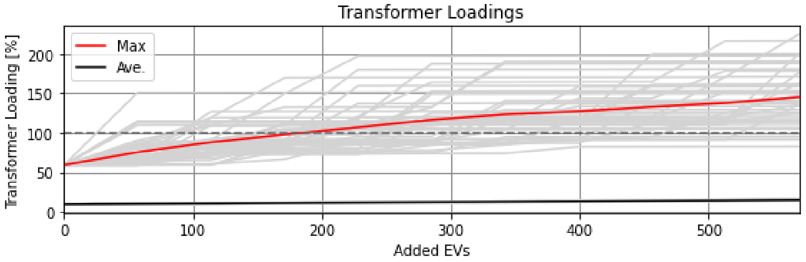
about 41 LVL 3 Fast chargers (100 kW each)
(approximately 13 EVs per Primary location)

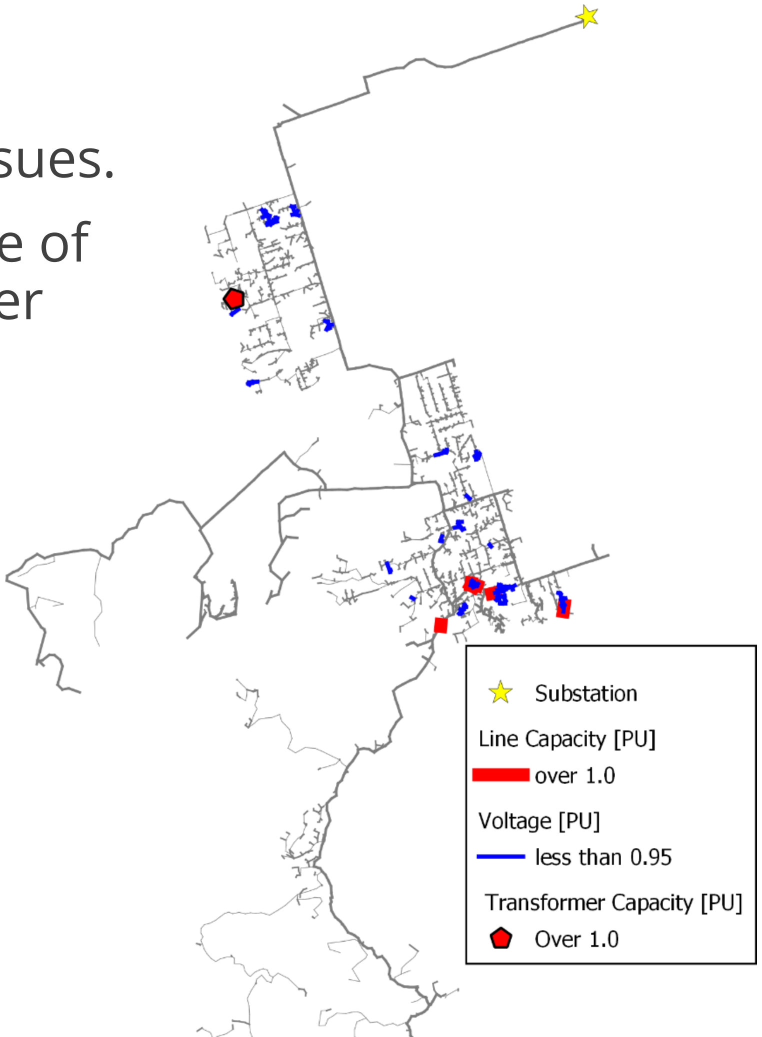
EV Charging Simulation Results – 75% Primary Charging

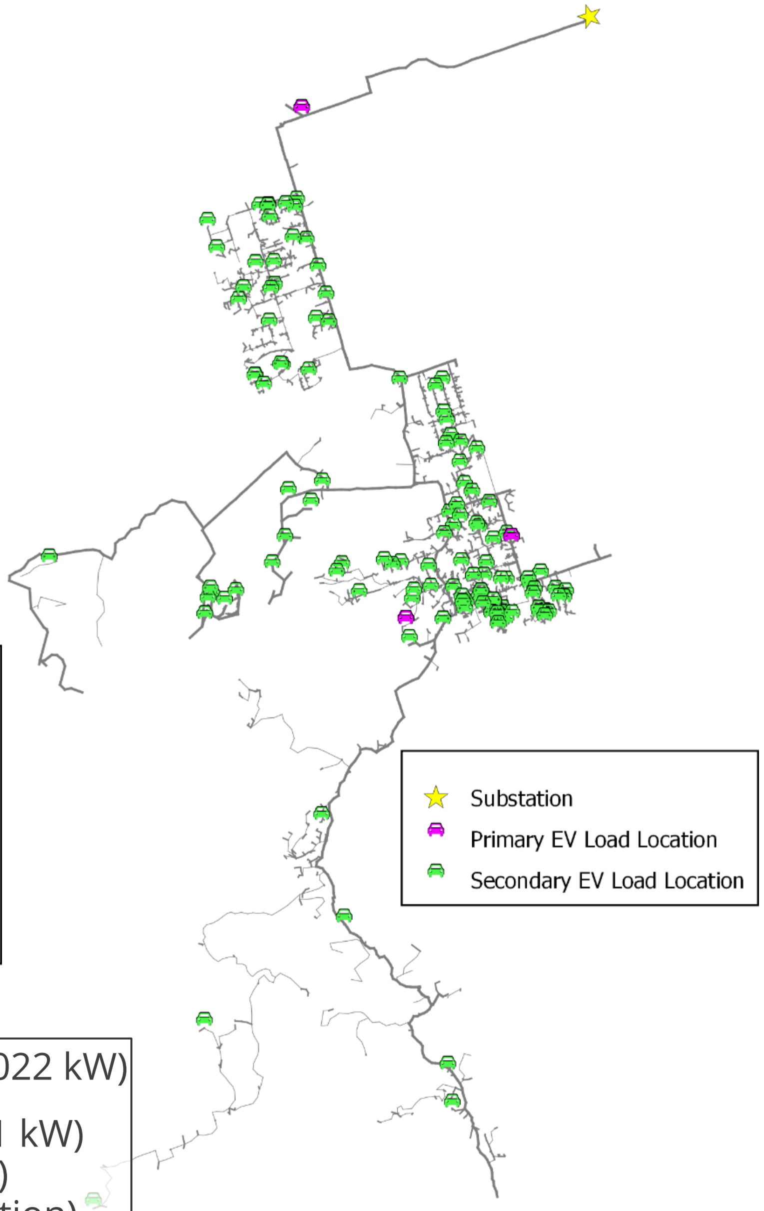
- More realistic – still has issues.
- Location, density, and time of EV charging all affect power system impacts.











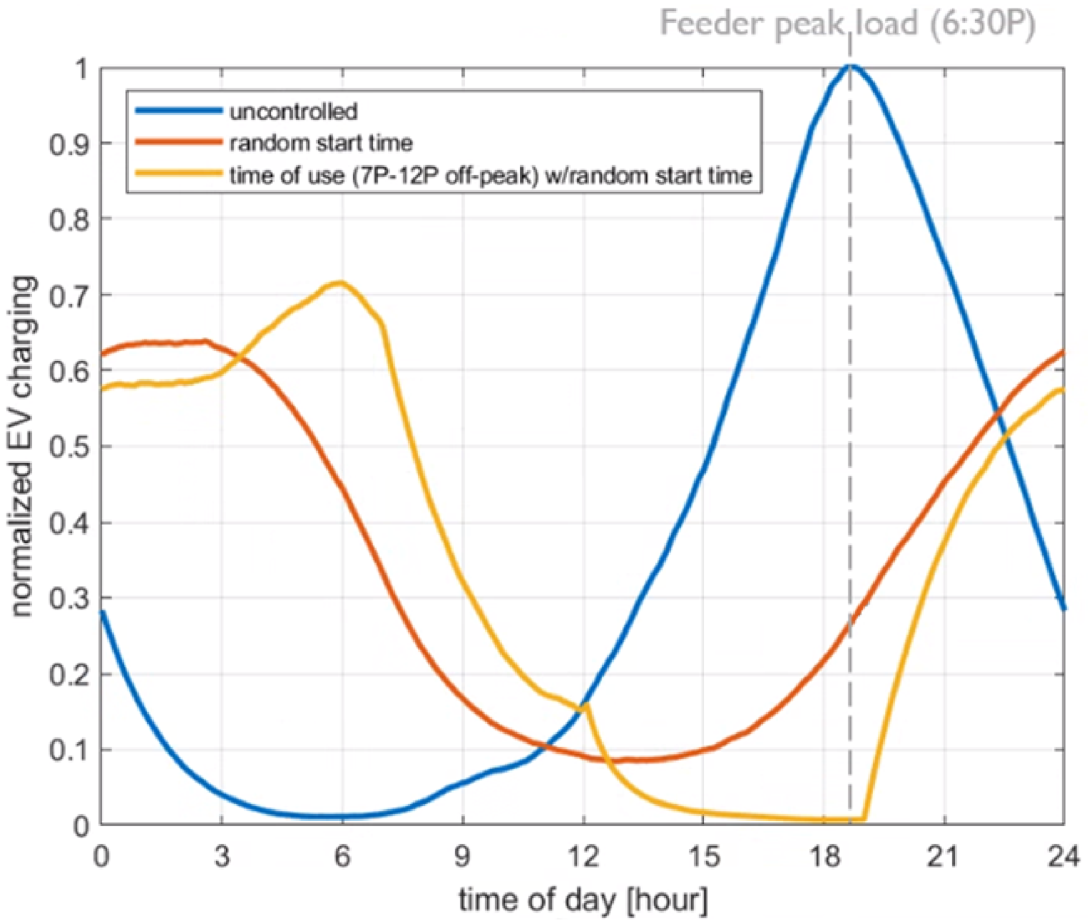
142 LVL 2 EVs on 122 Secondary Buses (1,022 kW)

428 LVL 2 EVs on 3 Primary Buses (3,081 kW)
OR 31 LVL 3 chargers (100 kW each)
(approximately 10 EVs per Primary location)

Mitigation Technique – Controlled Charging

Time-of-Use: Incentivize customers to charge during non-peak demand hours to shift EV charging away from system peak loading times.

- Benefits:
  - Reduces system stress
  - Could utilize solar energy during day
- Disadvantages:
  - Technology requirements
  - Requires public education
  - Variable user participation



Conclusions

- EV technology is advancing, widespread use coming 'soon'.
- Benefits do not come without challenges and costs.
- Without preparation for increased demand, power system issues likely to occur.
    - Low voltages, overloading of lines and transformers
- New or updated infrastructure should account for EV charging impact and possible mitigation actions.
    - Strategically placed fast charging locations, controlled charging methods
- Any solution will depend on local circumstances and need.
- Communication between communities, utilities, local government, and industry should be utilized to develop and guide an appropriate course of action.

Thank you!

Questions?

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