Distribution Integration Solution Cost Options (DISCO)

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Researchers Need for a Modular Tool

Distributed energy resource (DER) hosting capacity, grid impacts, and required network upgrades

Present challenges

Separate tools/platforms do not allow holistic grid analyses with DERs

Modular architecture barely exists to build up a cascaded, streamlined process

Network upgrades and their costs are not accounted for in a form of techno-economic analysis

Research Objectives

DISCO

- Conduct bottom-up analysis of distribution system planning costs associated with integrating distributed photovoltaics (DPV) while maintaining reliability and power quality
- Develop a dynamic hosting capacity methodology that provides a different perspective from static/snapshot hosting capacity
- Create a replicable pipeline/tool for evaluating PV integration costs with varying integration strategies and advanced control solutions

Current Capabilities

DISCO

- Analysis of grid impacts of DERs and hosting capacity—both snapshot and time-series (PV, electric vehicle [EV])
- Automated distribution upgrade cost analysis to accommodate DER adoption
- Modular framework with open-source Python application
- Works on stand-alone machines, servers, and high-performance computing (HPC) cluster

What Questions Can We Answer With DISCO?

?

- How much DER capacity can a community's current grid accommodate?
- What are the distribution grid impacts of integrating additional DERs (beyond current capacity) in the grid?
- What are the distribution system infrastructure upgrade costs associated with integrating additional DERs while maintaining grid reliability and power quality?
- How do these infrastructure costs compare with other grid integration technologies?
- What other considerations must be factored in to equip utilities and communities to make informed decisions about the grid's future?

DISCO Capabilities and Methodologies

Hosting Capacity and Automated
Network Upgrade Analysis

DISCO Workflow Overview

- **Setup**
  - Create power flow (OpenDSS) models
- **Config**
  - Choose analysis type
  - Customize simulation parameters
- **Run**
  - Run all simulations
  - Post-process results

Hosting Capacity Analysis Methodology

DISCO's PV or EV hosting capacity analysis aims to:

- Identify PV or EV deployment scenarios/levels likely to negatively affect grid operation
- Determine the range of PV or EV capacities that can be accommodated on the existing system

Hosting capacity calculation

Single location based

Cluster/scenario based

Hosting Capacity Analysis Methodology

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- Identify PV or EV deployment scenarios/levels likely to negatively affect grid operation
- Determine the range of PV or EV capacities that can be accommodated on the existing system

Hosting capacity calculation

Single location based – Assessing one grid node at a time

Static/snapshot—one representative time point for the season/year

Cluster/scenario based – Assessing a cluster of locations at a time

Dynamic—yearly/8760 data points to determine ranges of hosting capacity

Hosting Capacity Analysis: Single Location Based

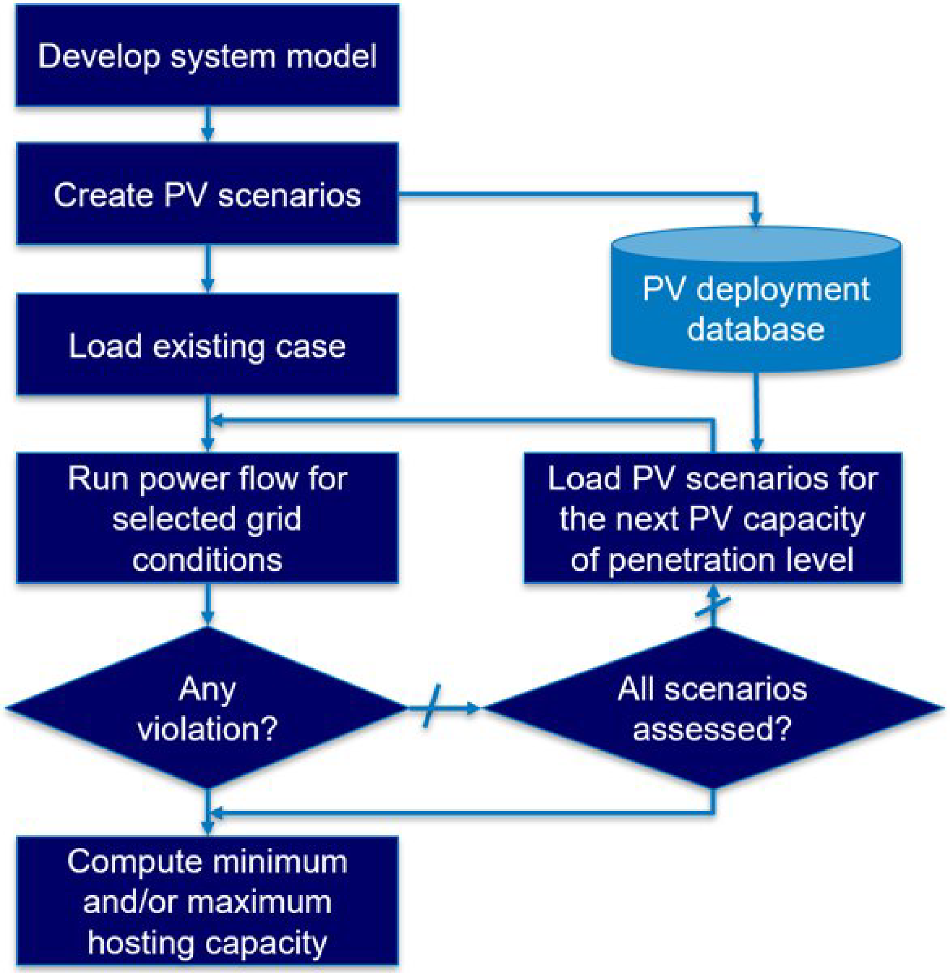
- Every grid location is assessed under this methodology (node-by-node)
- One location assumes the other grid nodes operate business as usual
- Generates a circuit heat map of varying hosting capacity levels

Performance Parameters	Voltage and thermal limitations Thresholds are user defined
↓	
Feeder Data/Models	Planning models can be used with worst-case load representations Account for some uncertainties and assumptions
↓	
DER Hosting Capacity	Nodal hosting capacity Hosting capacity of existing grid nodes is accessed

Hosting Capacity Analysis: Cluster Based

Grid conditions considered:

- Snapshot
  - Min daytime load
  - Max base load
  - Max EV load
- Timeseries
  - Year-long load conditions

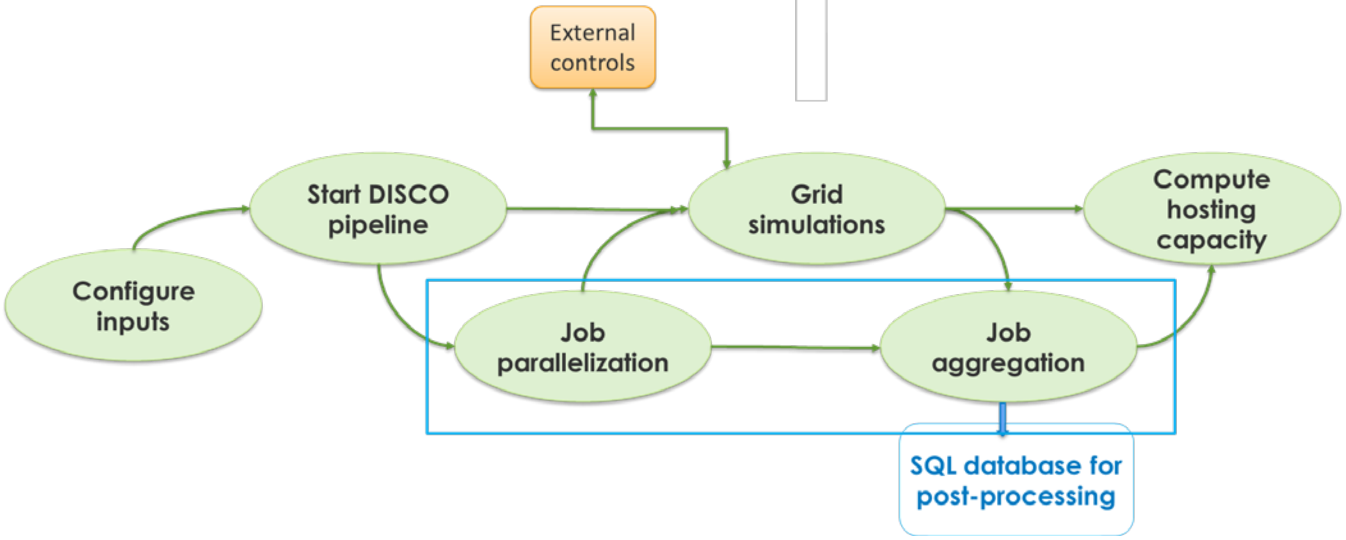


EV Hosting Capacity

(work in progress)

Computing hosting capacity at scale

Conducts EV hosting capacity for N number of feeders using the same iterative process



Performance Parameters

- Voltage and thermal limitations
- Thresholds: 0.95–1.05 voltage per unit; >100% loading on rated capacity

Feeder Data/Models

- Planning models can be used with worst-case load representations
- Account for some uncertainties and assumptions

EV Hosting Capacity

- Nodal hosting capacity
- EV hosting capacity of existing load nodes is accessed

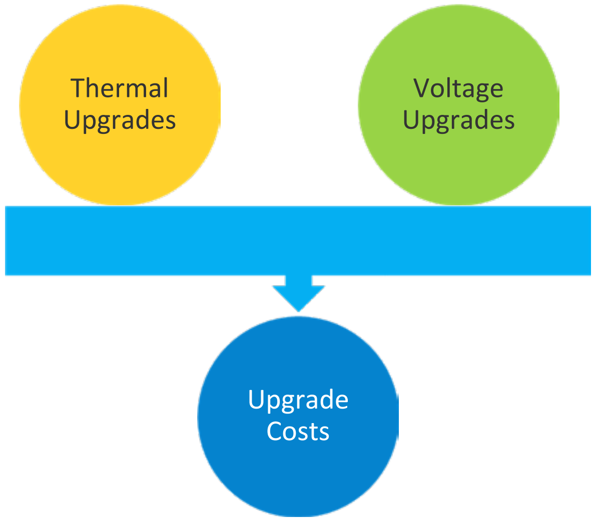
Automated Upgrade Cost Analysis

To integrate more DERs, new technologies must be identified and grid infrastructure upgraded.

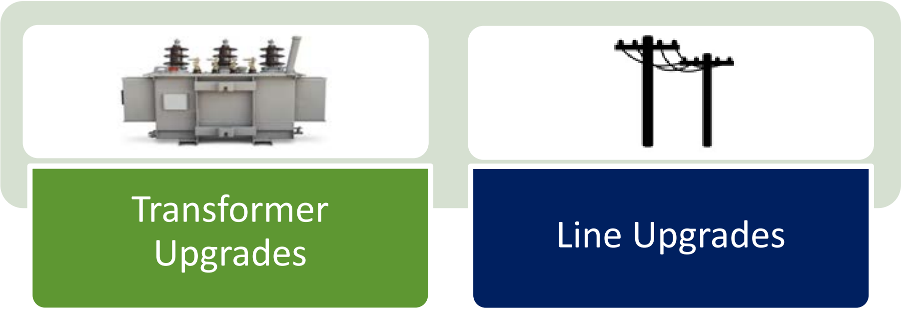
– Determining upgrades is challenging because of many design considerations.
– Automated scalable open-source tools to determine distribution grid upgrades are not available.

DISCO can be used to perform comparative analysis of various grid integration technologies.

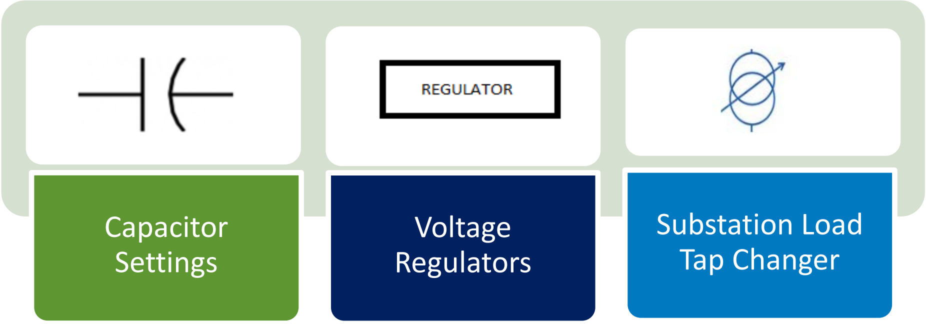
Automated Upgrade Cost Module



THERMAL UPGRADES



VOLTAGE UPGRADES



Automated Upgrade Cost Analysis: Inputs

- Electric distribution system feeder scenarios in **OpenDSS** format
- **Equipment unit cost database** including unit costs for different types of grid infrastructure
- **Technical catalog** containing possible upgrade options for transformers and lines
- Power quality and design
  - **Thresholds** →

Parameter	Value
line_upper_limit (p.u.)	1.0
transformer_upper_limit (p.u.)	1.0
voltage_upper_limit (p.u.)	1.05
voltage_lower_limit	0.95
transformer_design_pu	0.75
line_design_pu	0.75

Automated Upgrade Cost Analysis: Sample Outputs

- Power quality metrics; number of violations before and after upgrades
- Costs per equipment upgrade

Example metrics

Parameter
Max. bus voltage (p.u.)
Min. bus voltage (p.u.)
Max line loading (p.u.)
Max transformer loading (p.u.)
Number of overvoltage violation buses (p.u.)
Number of undervoltage violation buses (p.u.)
Number of transformer violations (p.u.)
Number of line violations (p.u.)

Note: Total costs are equal to the count of each upgrade multiplied by the unit cost of that upgrade. These include equipment costs only. Additional costs such as those for replacement, permitting/approval, and other siting costs can be included if available.

More details on outputs and inputs can be found here: https://nrel.github.io/disco/analysis-workflows/upgrade-cost-analysis.html

DISCO Use Cases

Use Cases/Applications

San Francisco Region
- Smart-DS dataset with 2,000+ distribution feeders
- Used to compare snapshot and time-series hosting capacity with DERMS application

Los Angeles 100% Renewable Energy Study
- Determined distribution grid impacts and costs on 1,500+ feeders to achieve 100% renewable energy pathways

Los Angeles 100% Renewable Energy Study: Equity Strategies
- Determined distribution grid impacts and costs on 500+ feeders to compute grid equity score and identify equitable strategies

Hawaii (HECO)
- Selected feeders in Oahu island
- Assessed advanced inverter functionalities

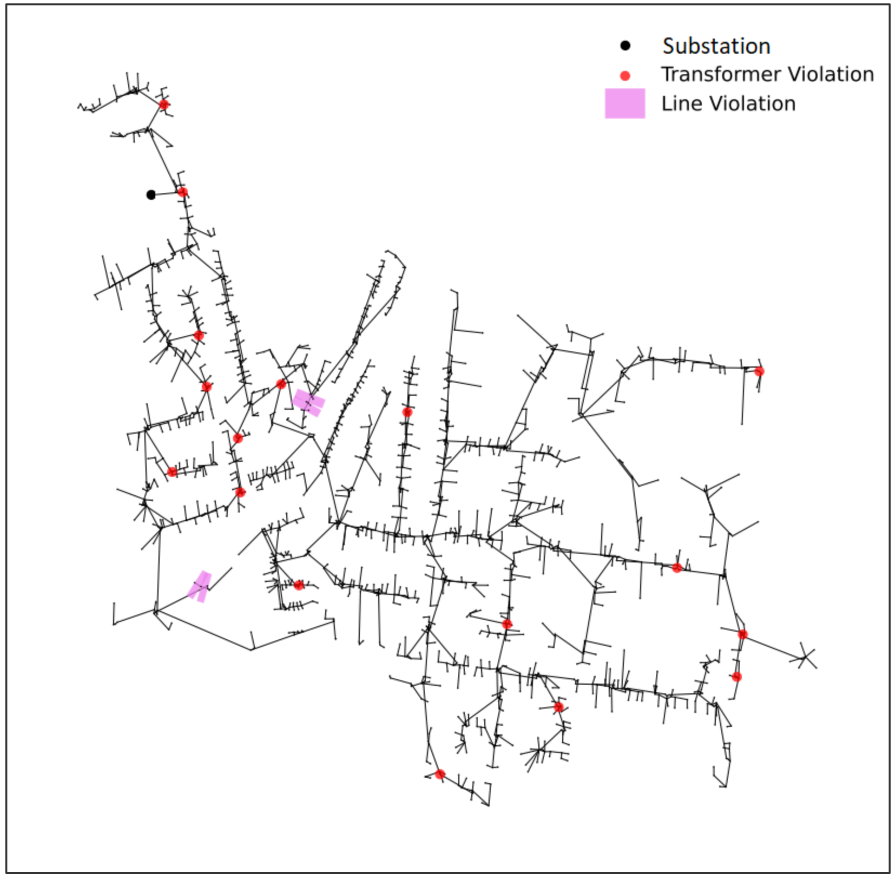
Federal Aviation Administration
- Vertiport Electrical Infrastructure Study

Cold Climate City in Northeastern U.S.
- Synthetic model for city blocks
- Building electrification and network upgrade costs analysis

Virginia (Dominion Energy), EVs@scale
- 100 feeders in different clusters
- Vehicle electrification grid impacts and hosting capacity (ongoing)

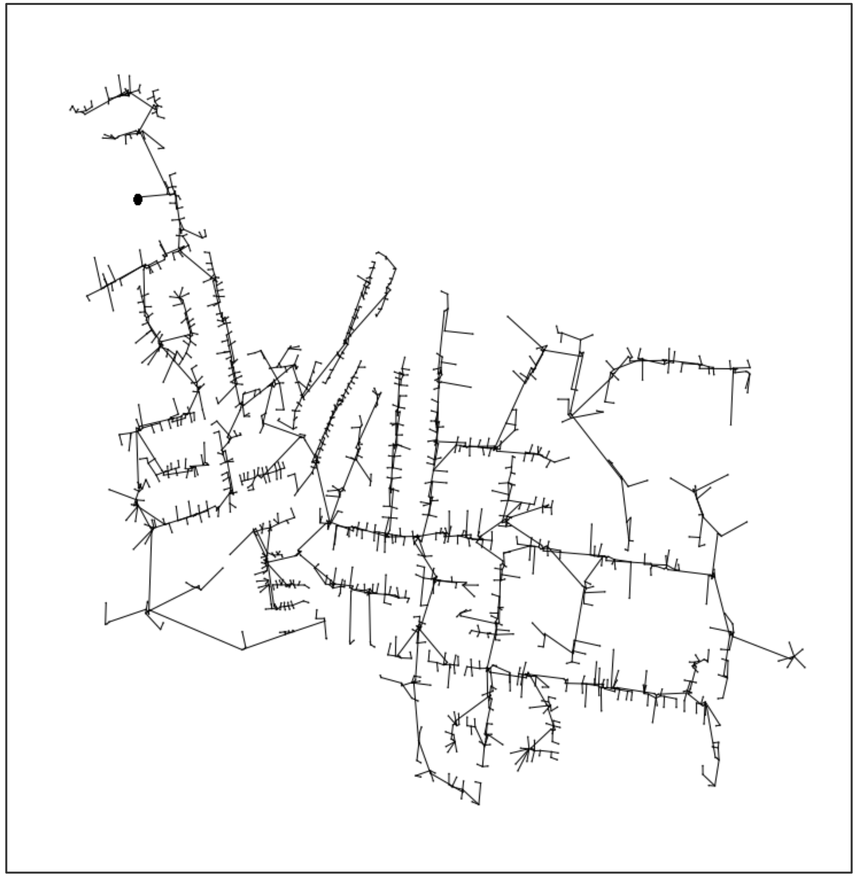
Network Upgrades

Before Thermal Upgrades



Number of thermal violations = 21

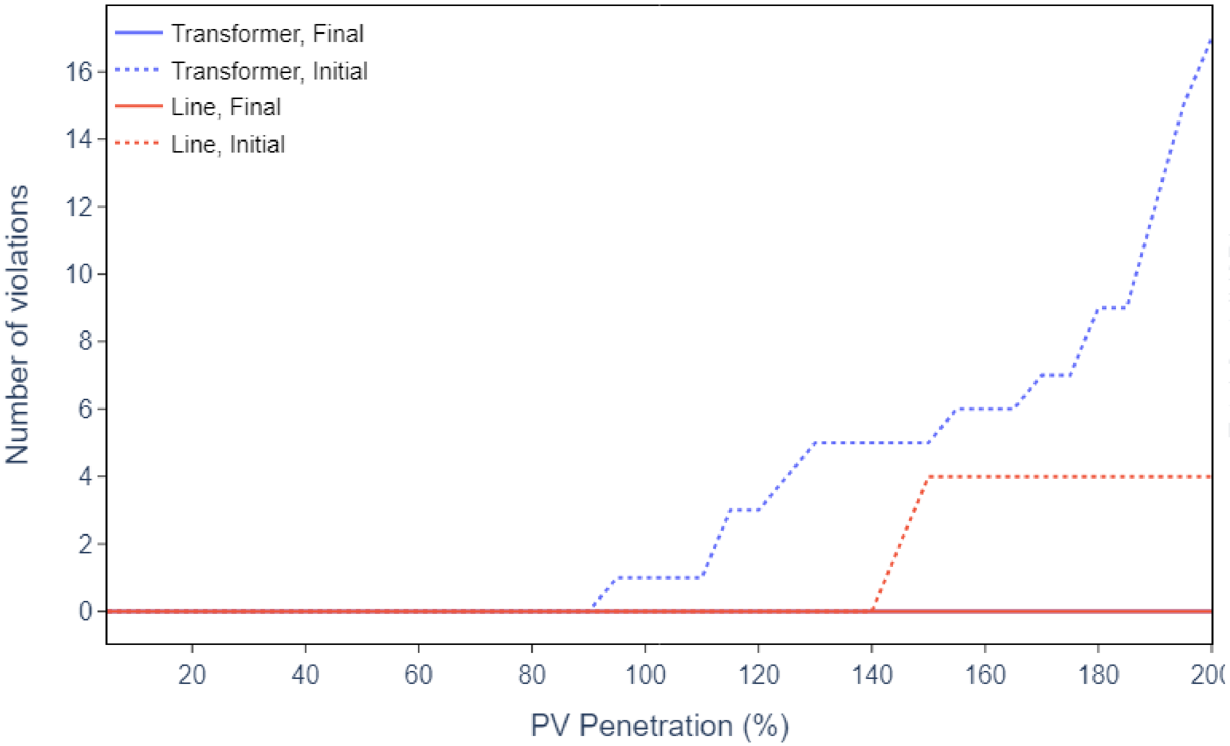
After Thermal Upgrades



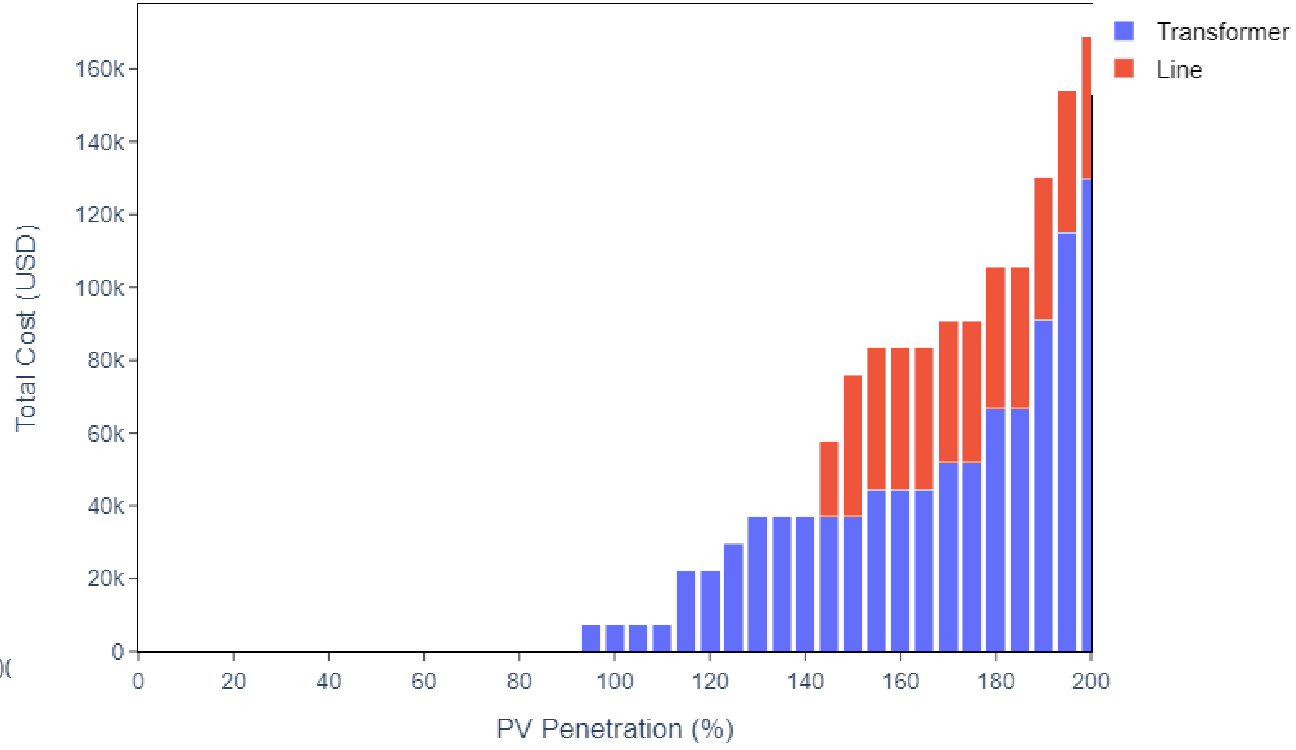
Number of thermal violations = 0

200% PV penetration; number of customers = 849, a SMART-DS feeder representing SF region

Determining Incremental PV Integration Costs

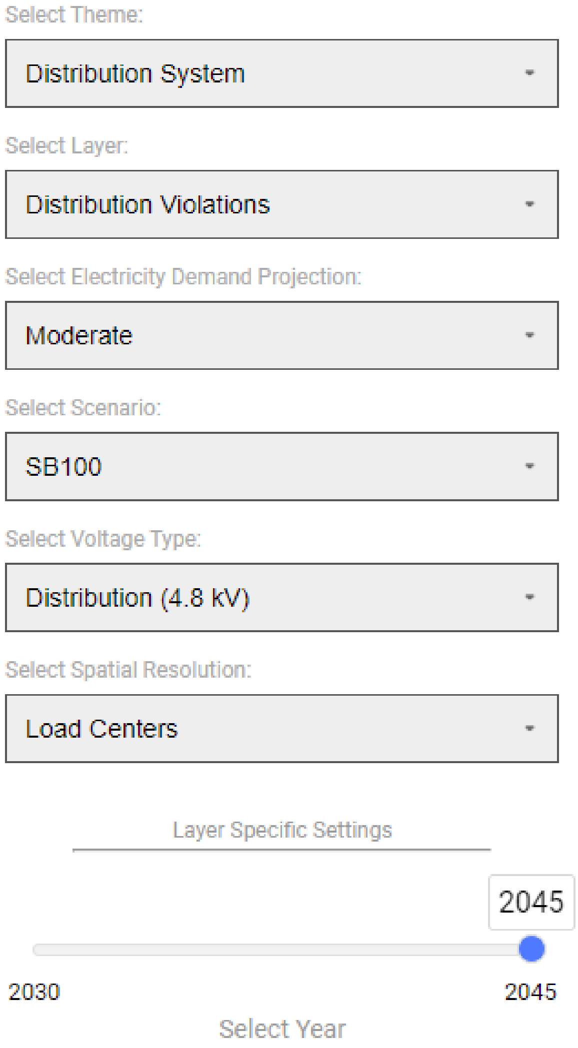


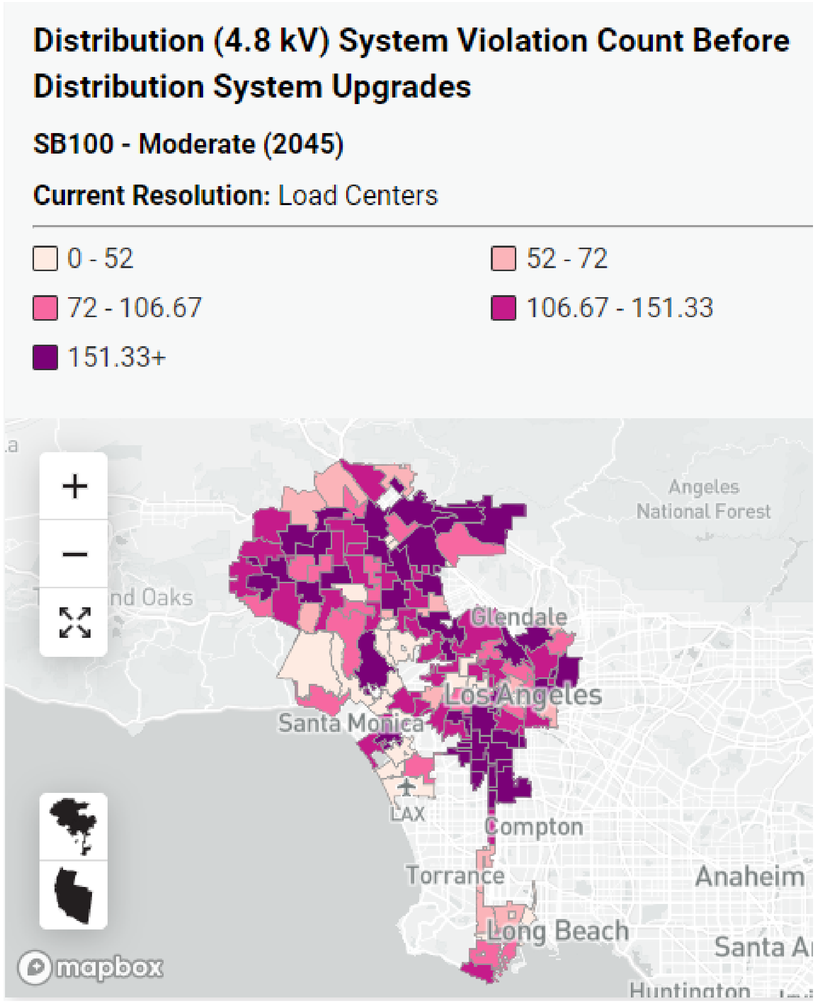
Cost (USD) to mitigate thermal violations at each PV adoption level (%)



The Los Angeles 100% Renewable Energy Study

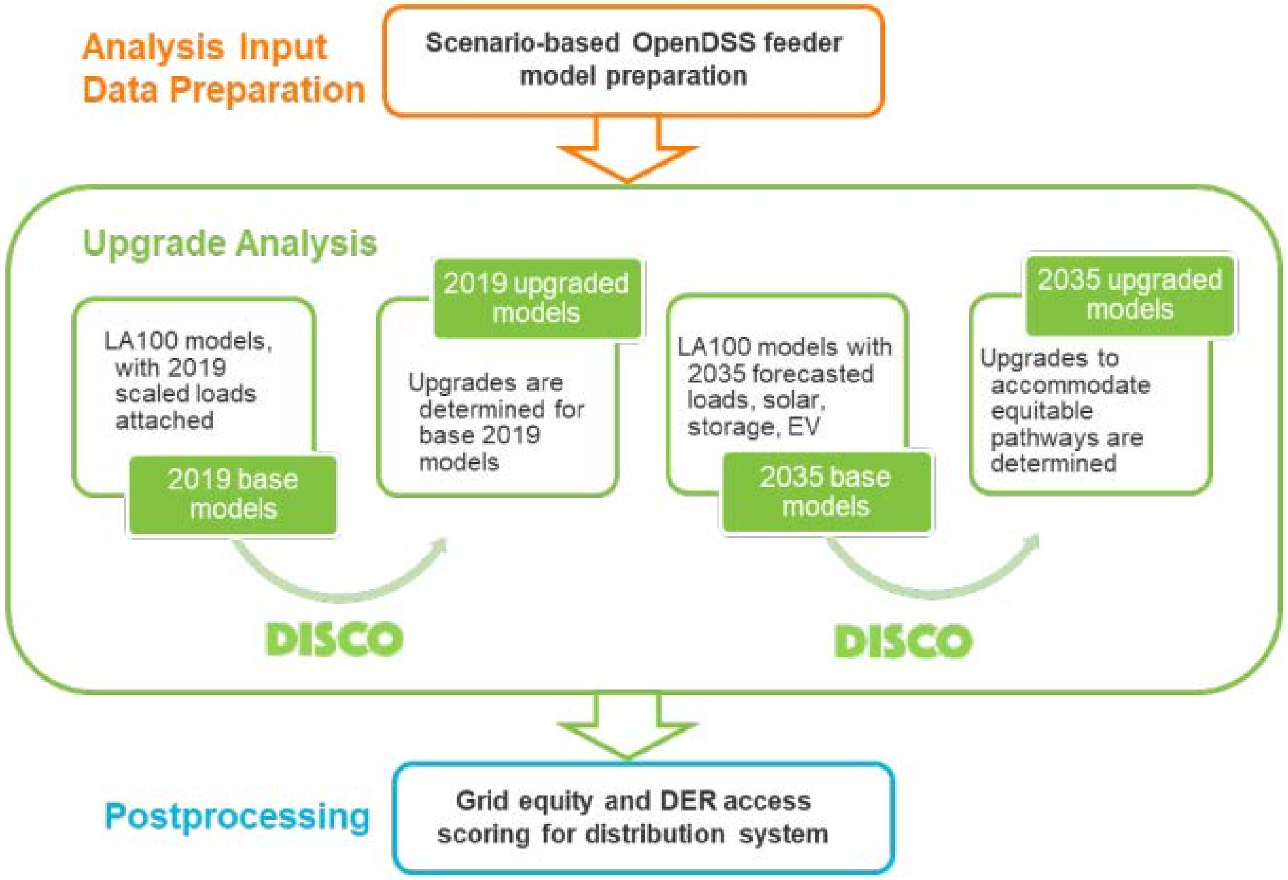
Data Viewer:
https://maps.nrel.gov/la100/data-viewer





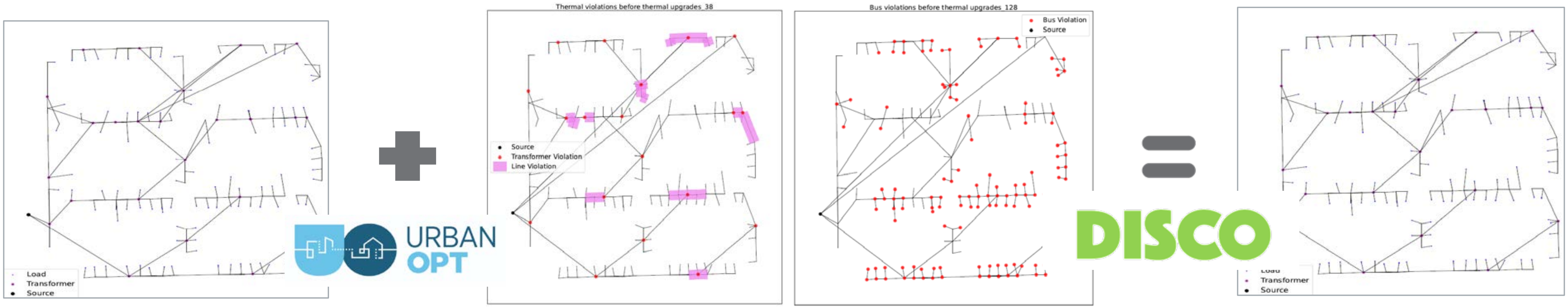
Source: LA100: The Los Angeles 100% Renewable Energy Study

Computing Grid Equity Score in LA100 Equity Strategies



Equitable distribution grid upgrade analysis workflow

LA100 EQUITY STRATEGIES



Baseline grid

Electrification loads
Introduce severe power quality issues in distribution grid

Upgraded distribution grid
with electrification loads

Assessing Upgrade Costs To Accommodate Electrification in a Cold-Climate Northeastern U.S. City

A combination of mitigation strategies to reshape the projected electrified load profile can reduce the net cost of electrification—for both consumers and grid operators.

Future Directions

Possible Future Directions

- Expand EV impact studies and include cluster-based EV hosting capacity analyses
- Update cost database and create a feedback loop to optimize DER placement to manage costs
- Streamline model intake and impact readability for improved usability

Use Case References

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Questions?

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