INTERCONNECTION INNOVATION e-XCHANGE
U.S. DEPARTMENT OF ENERGY

# *DER Flexible Interconnection Strategies and Approaches*

*An initiative spearheaded by the Solar Energy Technologies Office and the Wind Energy Technologies Office*

3:00 pm– 4:30 pm | March 15th, 2024
Webinar

i2x@ee.doe.gov | energy.gov/i2x

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# AGENDA

1. Introduction (Dexter Hendricks)
2. Challenges Implementing Flexible Interconnection (Jessica Lau)
3. i2X Technical Assistance Projects (i2X Partner Labs)
4. Questions & Open Discussion

# i2X Key Elements

**Mission:** To enable a **simpler**, **faster**, and **fairer** interconnection of clean energy resources all while enhancing the **reliability**, **resiliency**, and **security** of our electric grid.

## Stakeholder Engagement

Nation-wide engagement platform and collaborative working groups

## Data & Analytics

Collect and analyze interconnection data to inform solutions development

## Strategic Roadmap

Create roadmap to inform interconnection process improvements

## Technical Assistance

Leverage DOE laboratory expertise to support stakeholder roadmap implementation

# i2X Activity Highlights

## Stakeholder Engagement

- 800+ people at 530+ organizations partnered with i2X
- 20+ public events and engagements (e.g., RE+ 2022, 2023)
- 22 Solution e-Xchange meetings covering six topics
- EEJ Technical Advisory Committee
- 90+ Office-Hour Calls with stakeholders

## Data & Analytics

- BPS interconnection cost reports for MISO, PJM, NYISO, SPP, and ISO-NE, plus a summary published (LBNL)
- Queued Up report on BPS interconnection timelines (LBNL)
- Review of data availability for DER IX timelines by state

## Strategic Roadmap

- Transmission Interconnection Roadmap released in an RFI in October 2023. Final Roadmap is coming soon.
- Distribution Interconnection Roadmap will be released as a draft in an RFI soon.

## Technical Assistance

- 12 TA projects: flexible interconnection, utility data management, streamlining interconnection modeling, and alternatives to costly grid network upgrades
- Workforce Training: i2X/NERC bootcamp for BPS grid engineers on using Electromagnetic Transient (EMT) modeling methods and techniques

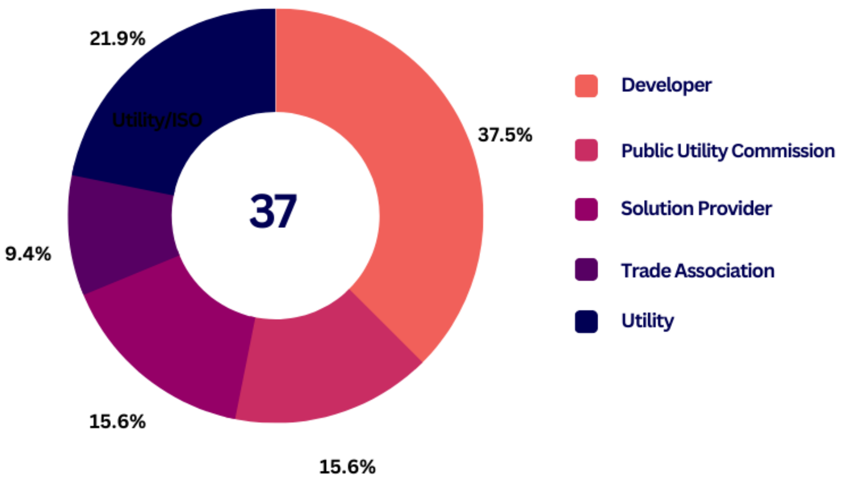
# i2X Technical Assistance Opportunity

- **Purpose:** To work on practical technical interconnection challenges that U.S.-based organizations are facing in the distribution grids or bulk power grid
- **Scope:** Solar, wind, energy storage or hybrid integration of these technologies
- **Lab Partners:** Sandia National Labs (SNL), Pacific Northwest National Labs (PNNL) and the National Renewable Energy Lab (NREL)
- **Partners:** 12 lead organizations to collaborate with i2X lab partners.
- **Project Timeline:** Projects began in Fall 2023 and run until Spring 2024.

# Technical Assistance Themes

- **Flexible Interconnection**
  - Financial Impacts of Curtailment
  - PCS Impacts on XFRMs
  - Flex IX modeling
- **Direct Transfer Trip (DTT)**
  - Alternatives to DTT
  - Guidance on anti-islanding mechanisms
- **Hosting Capacity Analysis (HCA)**
  - HCA Screening methods
  - Technology Inclusive HCA
- **Interconnection Process Standardization**
  - Pre-screening methods
  - Interconnection study automation
  - Procedures for detailed technical screens

Summary of TA Proposed Projects



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# CHALLENGES TO IMPLEMENTING FLEXIBLE INTERCONNECTION

**Jessica Lau | Manager, Grid Storage & Emerging Technology**

March 15, 2024

i2X DER Flexible Interconnection Strategies and Approaches Introductory Webinar

# Xcel Energy’s Stakeholder Survey told us:
## How would you define flexible interconnection?

### Overall, on Flexible Interconnection

- providing different options and approaches for interconnection
- less costly interconnection requirements by increasing controllability of distributed energy resources

### The benefit to the DER

- without major infrastructure upgrade cost
- reduce infrastructure construction timelines for interconnection

### What the DER does

- adjust the project’s output to respond to changing conditions
- Controlling and/or limiting the output of distributed generation

### The benefit to the Grid

- greater interconnection of distributed generation
- more renewable generation

# Near-Term Challenges to Implementing Flexible Interconnection

## Process

- Flexible Interconnection is an evolving strategy and continues to mature
- Complexity to develop new and repeatable process for how to study, implement, and operate it
- Timeline vs. Risk: Making timely progress while balancing technical risks

## Technical

- Identify the constraints that can be addressed by FI and which FI solution/technology
- Understand the extent that FI can address multiple DERs and multiple system constraints
- Identify conditions where FI could contribute to reaching another hosting capacity limit

## Experience

- Understand how to create positive customer and utility experience to participate in FI
- Define the long-term requirements and financial impacts to all customers
- Maintaining fairness for all customers and DER owners

# Long Term Considerations to Implementing Flexible Interconnection

- Developing a sustainable, scalable, and robust FI solution that works for customers and the utilities
- Integrating with other grid systems, like Distribution Management Systems, Advanced Metering Infrastructure, and Distributed Energy Resources Management System
- Avoid isolated deployments and stranded costs
- Ensure reliability and safety is maintained at all times

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# PNNL i2X TA related to Flexible Interconnection

March 15, 2024

**TA LEADS:**

**Todd Wall**

**Karyn Boenker**

**Jason Eisdorpher**

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# Oregon Public Utility Commission

## Hosting Capacity Analysis

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# Oregon PUC & Hosting Capacity Analysis

- Problem Statement: Provide technical assistance to Oregon Public Utility Commission in developing a Hosting Capacity Analysis program to identify potential headroom for DER interconnection.
- PNNL has engaged OR PUC and three of Oregon electric utilities during four meetings to ascertain utility general opinions and needs surrounding HCA.
- Conversations with the utilities have revealed three very different perspectives of utilities relating to:
  - The value assigned to HCAs by the utilities.
  - Plans for enhancing the current HCA analyses and uses.
- Recent meeting between OPUC and PNNL staffs identified clear next steps.
  - Interview DER owners to discover experiences and expectations of utility HCAs.
  - Work on vision of next generation HCAs to determine what enhancements are needed to utility HCAs to provide transparency for generators.

# EnPhase

## Service Transformer Thermal Impacts

PNNL is operated by Battelle for the U.S. Department of Energy

# EnPhase - Since Last Update

- Problem Statement: Mitigate thermal impacts on service transformers attributed to additional power flow from interconnected DER. Utilities have imposed service transformer upgrades as a result.
- PNNL is building a software tool whereby users may run simulations using real or theoretical data that will determine the long-term thermal impacts and any loss of lifetime because of DER.
- Finished debugging Python simulation tool (Jupyter notebook deliverable) and verified thermal impact results are valid.
- Began search and review of empirical study results to verify theoretical approach.
- EnPhase has identified and begun providing data for seven solar PV and storage field systems that will provide the input data to the software tool.


SIEMENS

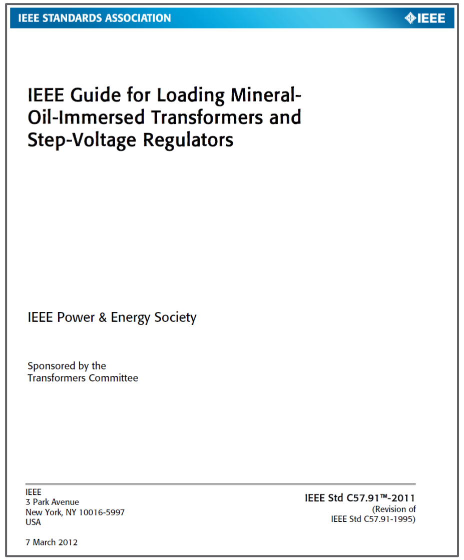
SIPROTEC 5

Overcurrent Protection

7SJ82/7SJ85

**V8.60 and higher**

Manual


IEEE STANDARDS ASSOCIATION

IEEE

IEEE Guide for Loading Mineral-Oil-Immersed Transformers and Step-Voltage Regulators

IEEE Power & Energy Society

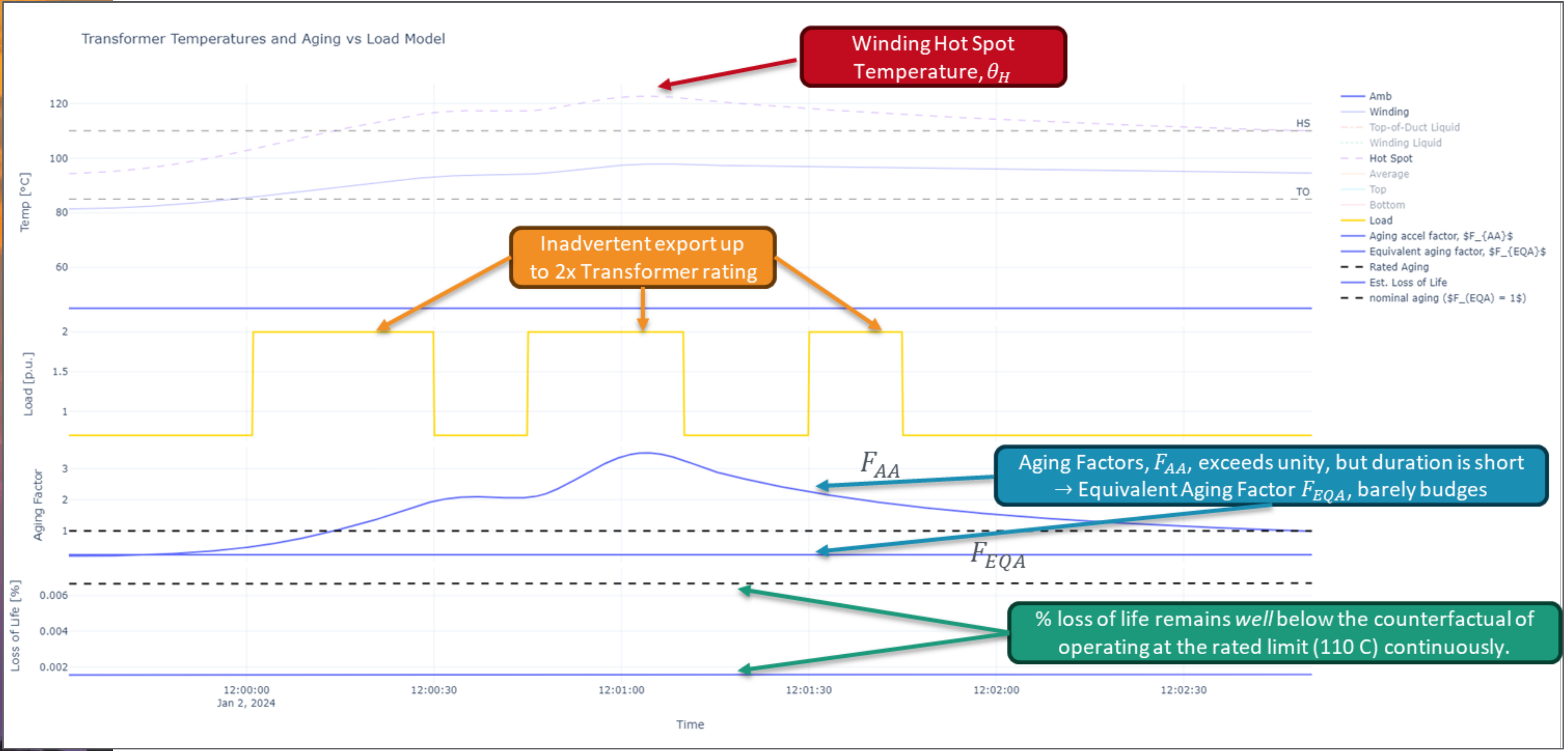
Sponsored by the
Transformers Committee

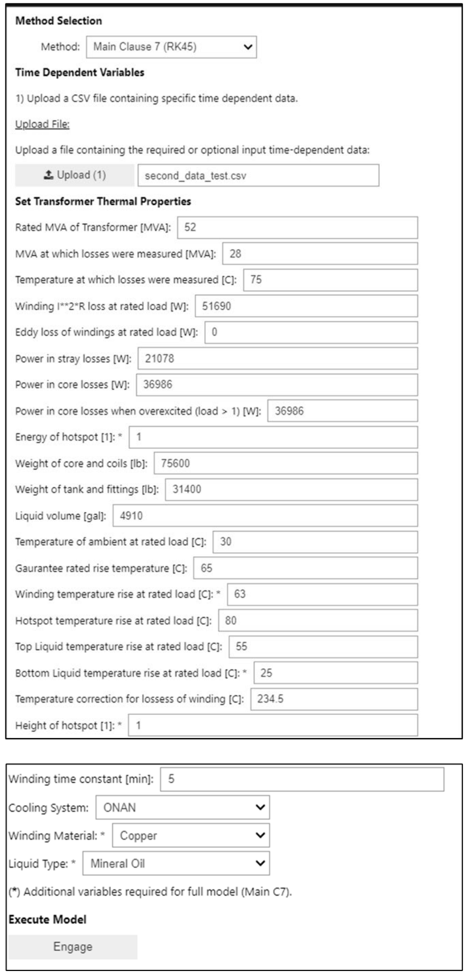
IEEE
3 Park Avenue
New York, NY 10016-5997
USA

7 March 2012

IEEE Std C57.91™-2011
(Revision of
IEEE Std C57.91-1995)

# Example of Transformer Thermal Impacts



# Solar and Storage Institute (SSII)

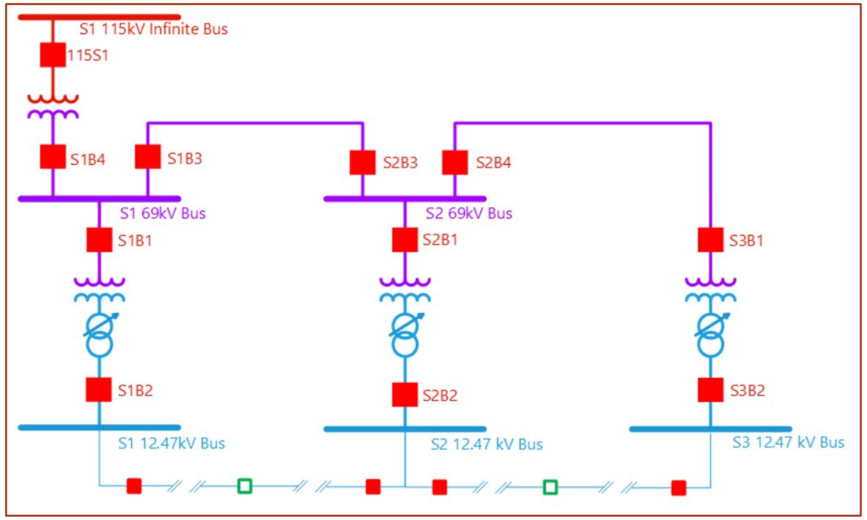
## Flexible Interconnection Modeling

PNNL is operated by Battelle for the U.S. Department of Energy

# Solar and Storage Industries Institute (SSII)


- Problem Statement: Solar and Storage Industries Institute (SSII) and affiliates have requested assistance developing a modeling and analysis method whereby the economic viability of conventional interconnection method – fixed export - will be compared to that of Flexible Interconnection.
- PNNL has received design packages for four community solar and/or storage projects, of which will be used to build power system models.
  - Packages contain all relevant PV module designs, inverter type and capabilities, one-line diagrams, and site plans; therefore, modeling them should be straightforward.
  - Assessing regional distribution infrastructure to translate to 9500 Node Feeder.
- PNNL will use system impact studies for the four community solar projects as a crux to identify basic framework and constraints for conducting the system modeling and identifying what grid violations that may be mitigated through flexible interconnection.
- Other TA participants are Coalition for Community Solar Access (CCSA), Nexamp, and Smarter Grid Solutions

# 9500 Test Feeder


| Type | Number of Buses | Number of Nodes |
|---|---|---|
| Three Phase | 847 | 2541 |
| Two Phase | 3 | 6 |
| Single Phase | 1902 | 1902 |
| Secondary Customer Buses | 2550 | 5100 |
| **Total** | **5302** | **9549** |

## Loads, Voltage Control, and DER

| Feeder | No. of Customers | Load kW | Load kVAR | No. of Regulator | No. of Capacitor | No. of DERs |
|---|---|---|---|---|---|---|
| $S_1$ | 268 | 3432.6 | 855.9 | 2 | 2 | 7 |
| $S_2$ | 475 | 4803.1 | 1554.0 | 2 | 1 | 6 |
| $S_3$ | 532 | 5432.8 | 1355.3 | 2 | 1 | 2 |
| **Total** | **1275** | **13668.5** | **3765.2** | **6** | **4** | **15** |

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# Xcel Energy and Commonwealth Edison Company (ComEd)

## Flexible Interconnection Program Considerations

U.S. DEPARTMENT OF ENERGY BATTELLE

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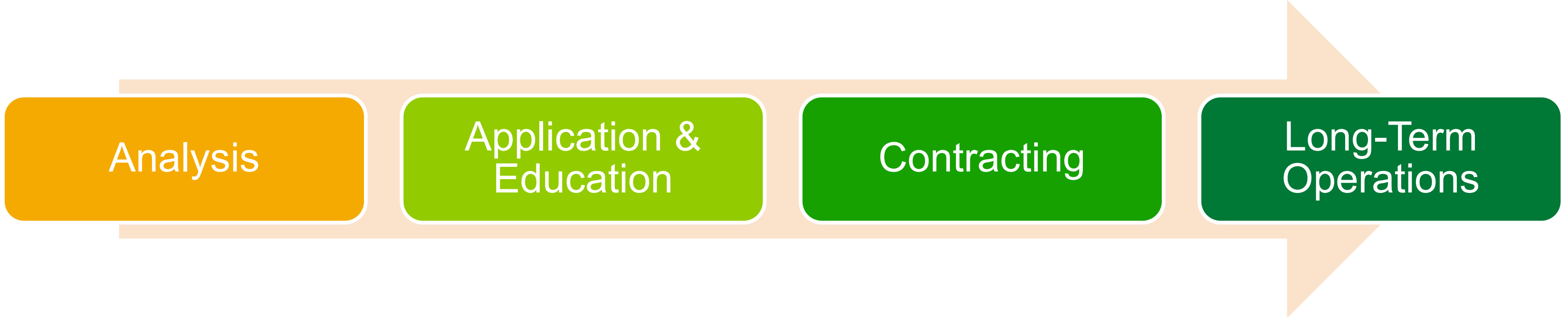
# Flexible Interconnection Program Considerations

- **GOAL →** Deliver considerations and best practices for an end-to-end FIX process framed by stages, such as; analysis, application, contracting, and long-term operations.
  - Project is set to complete by early summer.
  - Technical studies and long-term planning elements are secondary, stretch topics, but are being discussed.
- **CONTEXT →** Xcel and ComEd are in different stages of piloting a flexible interconnection program that aims to open up capacity for renewables within constrained locations on the grid.
  - ComEd pilot is not public but is showing promising results for future publication.
  - Xcel has requested a focus on community solar projects waiting for upgrades to be completed, but our results will also be useful for long-term endeavors that may help avoid upgrades.
- **TOOLS EMPLOYED →** PNNL is using flow charts and decision trees to map process steps and dependencies, while also moderating technical side discussions.

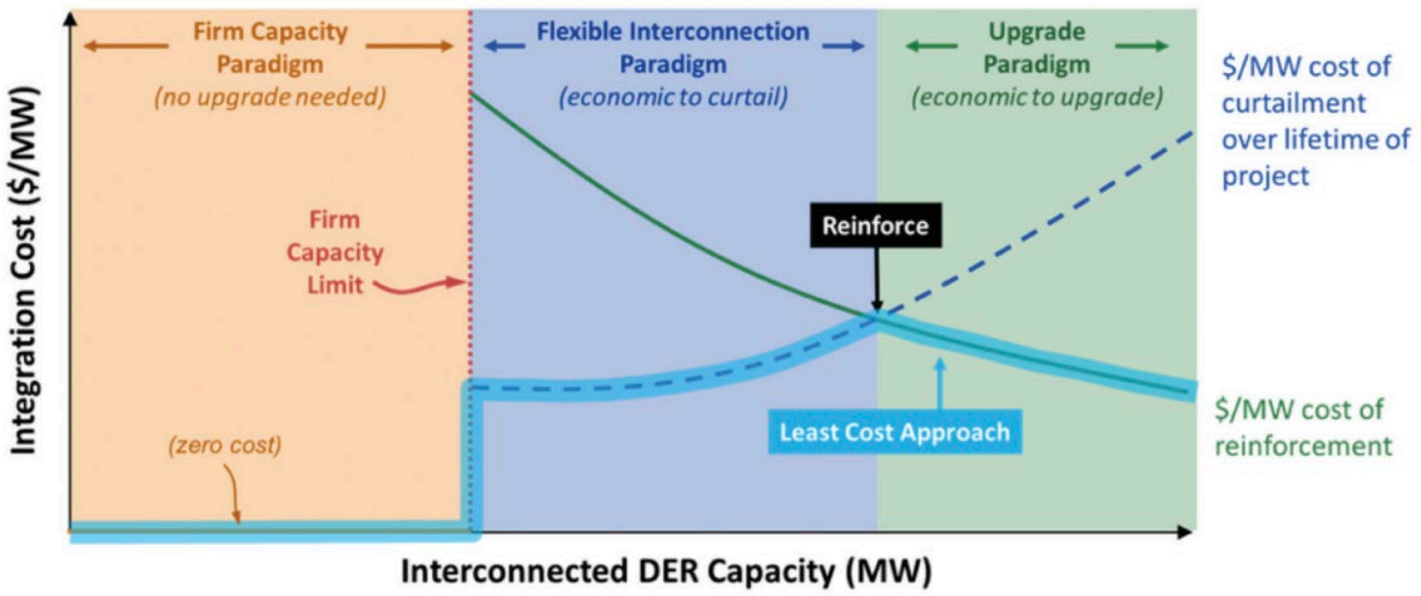


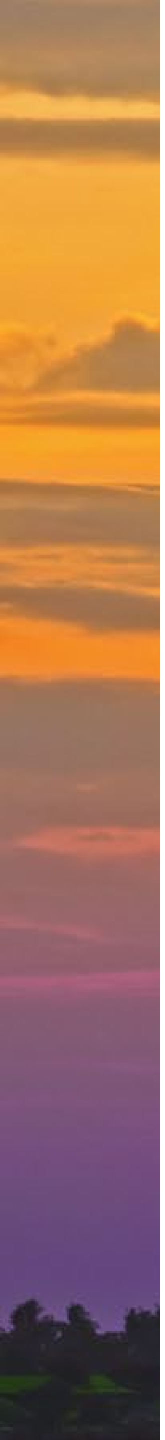
# Flexible Interconnection Program Considerations

- **MITIGATING FACTORS**
  - We are focused on upfront details and analysis shared between utilities and applicants that could help a FIX program operate efficiency.
  - We are also thinking about how to communicate FIX programs in order to achieve trust and participation.

- **LESSONS LEARNED→** With only a few pilots in the U.S. most of our understanding is coming from the U.K.
  - Flexible interconnection program limits have been set around 5-10% in the UK but actual curtailment has been much less. Communicating this is the hard part.
  - Determining the exact parameters and rules to guide such a program requires direction from a regulator.

Illustration of the economic opportunity for flexible interconnection from EPRI, 2020





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# Thank you

# NREL Overview of TA Requests relative to I2X

Jeffrey J. Cook PhD

TA Leads
1. Killian McKenna
2. Kwami Sedzro
3. Sanjana Vijayshankar

# TA Request 1: Hosting Capacity Modeling

**DER Exponential Growth:**

- The current trajectory of DER growth poses a challenge to traditional grid management practices.
  - This rapid increase in DER deployment is triggering the need for fixed and/or flexible interconnection solutions to ensure grid stability.

**Challenges in DER Projects:**

- DER projects are encountering escalating difficulties in connecting to the distribution grid.
- The volume, location, and design of projects seeking to interconnect, combined with other challenges like supply chain issues lead to delays and increased costs.
  - Interconnection delays hinder the progress of decarbonization goals in the state.

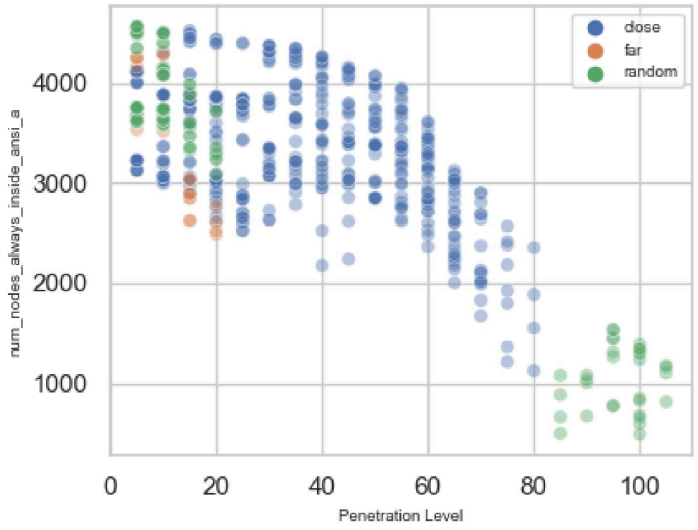
**TA Partner Initiatives:**

- Initiatives focus on a fundamental transformation of power grid planning strategies to accommodate the evolving energy landscape.
- The partner is exploring revisions to the cost-sharing model for grid upgrades, aiming to distribute costs in a manner that better advances the state's clean energy goals.

# Hosting Capacity Analysis

- We use authentic PV profiles and load data to conduct thorough power flow simulations at a hypothetical/representative feeder.
  - Baseline scenario: thermal and voltage violation metrics in the absence of any PV.
  - Modeled scenarios: Close, Far, and Random Placement
- These scenarios offer valuable insights into optimizing both the feeder and PV placement strategies.
  - Escalating PV penetration increases probability for voltage violations.
  - This is more likely when PV is closely positioned, as opposed to distanced or random.
- This analysis supports optimal positioning and capacity for PV deployment.

| Feeder | Placement | Sample | Penetration Level |
|---|---|---|---|
| IEEE 8500 | close | 1 | 5 % |
| | far | 2 | 10 % |
| | random | 3 | 15 % |
| | | ⋮ | ⋮ |
| | | 10 | 120 % |

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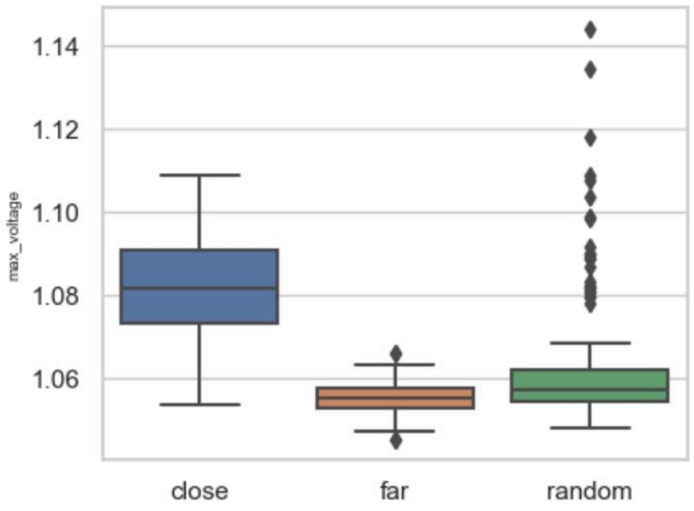
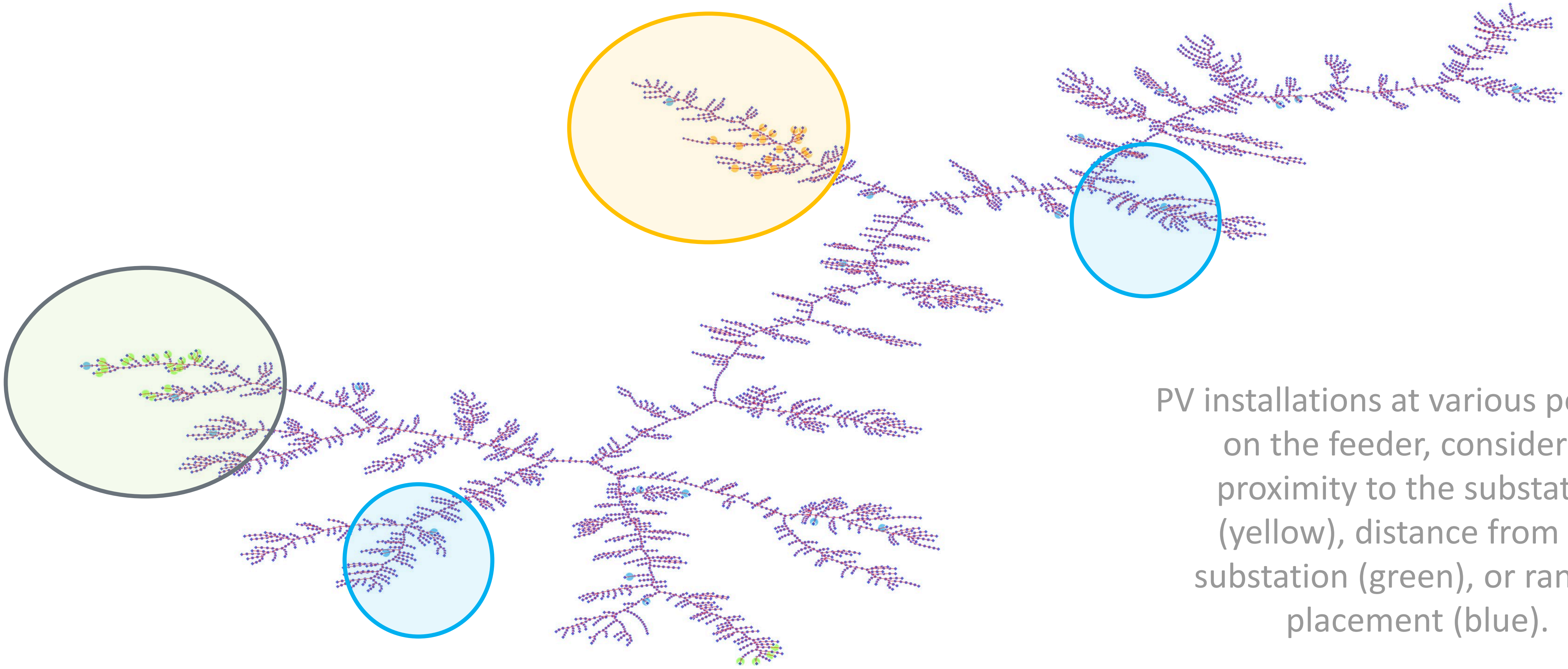



(2)

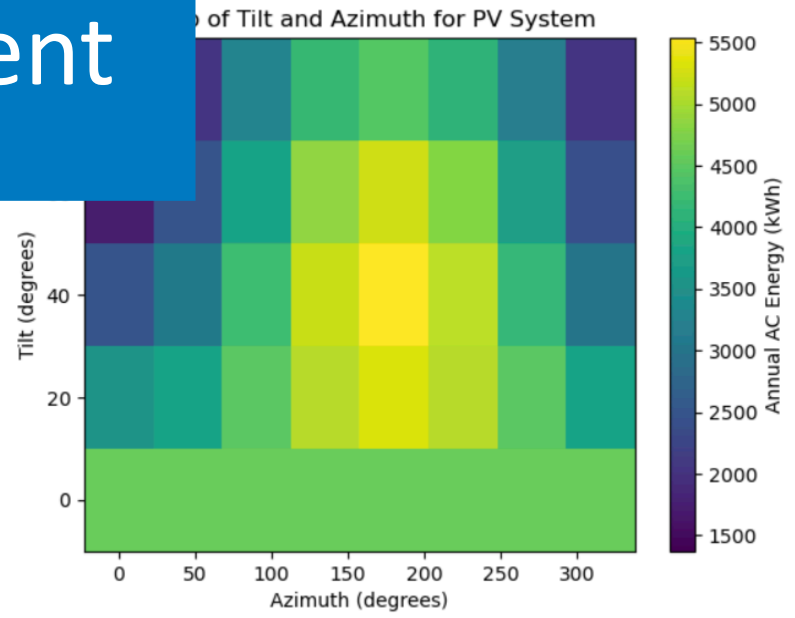
# PV placement strategies

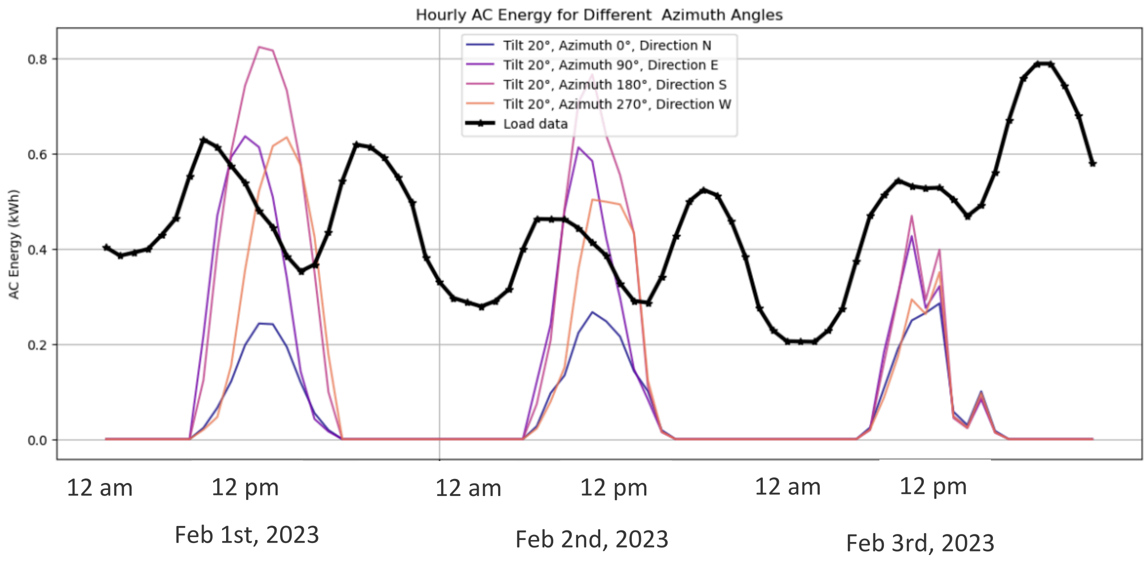


PV installations at various positions on the feeder, considering proximity to the substation (yellow), distance from the substation (green), or random placement (blue).

# Effects of Azimuthal Placement

- The placement of PV panels on rooftops significantly influences power production, particularly in relation to azimuth positioning.
- To identify the most effective azimuth placement, we conduct multiple sweeps using PVWatts, exploring various azimuth and tilt configurations.
- Azimuth impacts
    - South-facing: optimal power production.
    - West-facing: Temporal delay, resulting in later peak energy production throughout the day.
- South- and west-facing orientation can provide different benefits to the PV system owner and grid operator.



# TA Request 2: Integrating and Automating Advanced Interconnection Evaluation

NREL Lead: Killian McKenna: Killian.McKenna@nrel.gov.

# Technical Assistance Overview

- Assessing current utility interconnection practices, experiences, data availability and fidelity, and current level of data integration.
- Defining requirements of advanced interconnection technical assessments, with user-oriented design for what technical screens should entail, what network impacts should be examined, level of automation, and when should supplemental screens be used.
- Roadmap for data integration and automation to perform automated detailed interconnection technical screens.

# Ideal Interconnection Roadmap

## Evolution of Interconnection Process

Low Complexity
Low visibility of impacts
Reliance on heuristics

High Complexity
High visibility on impacts
Relying on network data/models

- Data (GIS, AMI, SCADA, DER application)
- DER and Feeder Modeling
- Automation
- Computational Resources

Interlinked Databases

Greater use of AMI/SCADA

More sophisticated DER modeling

Batch DER Screening/Studies

Critical Time-point / Time-series Powe-flow Assessment

Evaluate Transmission Export Impacts

Automated Interconnection Process

Battery Energy Storage Operations

Multi-DER interconnection

Flexible Interconnection

Better Screening and Models for Planning Engineers

# Utility Interconnection Process

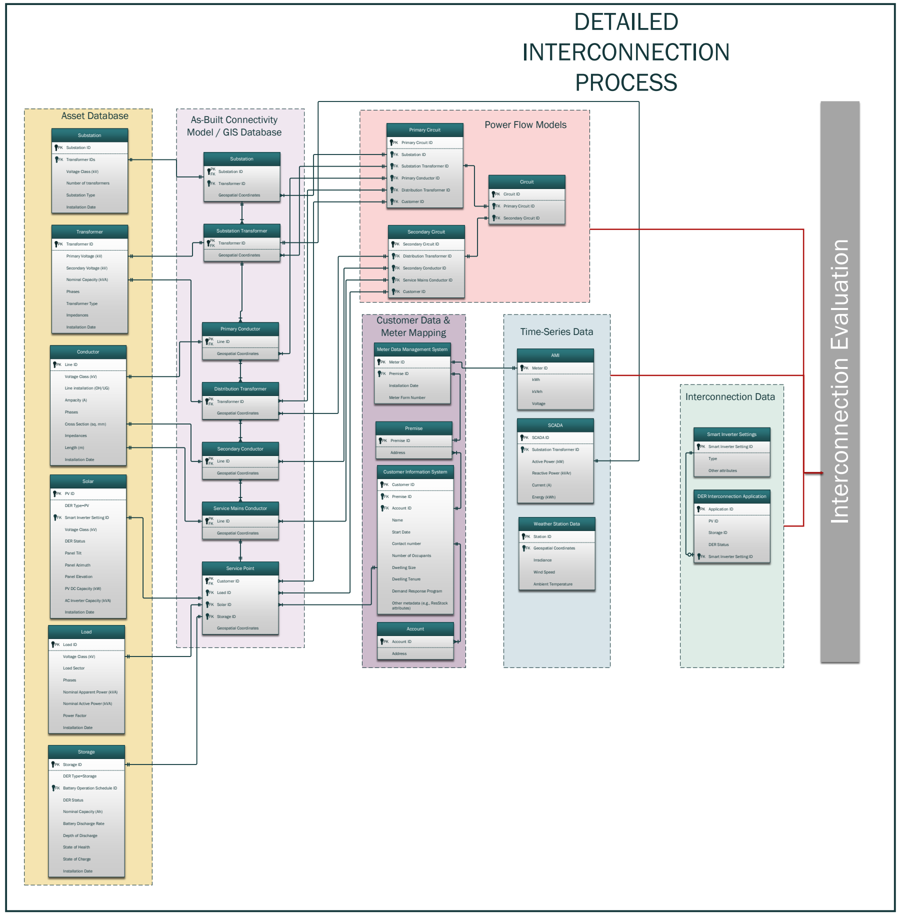
Detailed data architecture and flows

Interconnection metrics and required datasets

## ***Over 70 metrics for interconnection***, required datasets, orders for metric screening processes

| Metric | Planning Engineer Notification Criteria / Metric Fail Criteria | Purpose | Data / Models required | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | CIS | AMI | SCADA | Asset Database | GIS | DER Model | Powerflow model: Snapshot (single timepoint or multiple critical timepoints) | Powerflow model: QSTS (8760/ 576/ seasonal profile) |
| DER Size | >= 100 kW | | | | | | | | | |
| Voltage level on which DER is connected | - | | | | | | | | | |
| Power exported across PCC | > limit (if applicable) | | | | | | | | | |
| Certified Equipment? | Non-Certified | | | | | | | | | |
| System type to which DER is connected (networked/radial) | Networked | | | | | Y | | | | |
| Interconnection Configuration | Incompatible with line configuration | | | | | Y | | | | |
| Service Voltage imbalance if 1ph | > 20% of service transformer nameplate rating | | | | | Y | | | | |
| Distance from Substation, Line size, DER size | Is okay if (< 2.5 electrical circuit miles, distribution line from the substation to the Point of Interconnection is composed of large conductor/feeder section (i.e., 600A class cable)) | | | | | Y | Y | | | |
| % ( All DERs Nameplate Capacity / ***Substation Transformer Nameplate rating*** ) | > 100% | Substation Transformer Thermal Impact | | | | Y | Y | | | |
| % ( All DER Nameplate Capacity / ***Service Transformer Nameplate rating*** ): if applicable | > 100% | Service Transformer Thermal Impact | | | | Y | Y | | | |
| % ( All DERs Nameplate Capacity / ***Line Section rating*** ) | > 100% | | | | | Y | Y | | | |
| % ( DER Export Capacity, Aggregated with Other Generation Export / ***Substation Transformer Nameplate rating*** ) | > 100% | Substation Transformer Thermal Impact | | | | Y | Y | | | |
| % ( DER Export Capacity, Aggregated with Other Generation Export / ***Service Transformer Nameplate rating*** ): if applicable | > 100% | Service Transformer Thermal Impact | | | | Y | Y | | | |
| % ( DER Export Capacity, Aggregated with Other Generation Export / ***Line Section's Nameplate Rating*** ) | > 100% | | | | | Y | Y | | | |
| % ( DER Export Capacity, Aggregated with Other Generation Export / ***Line Section's Peak Load*** ) | > 30% | | Optional | | | Y | Y | | | |
| | | | | | Y | Y | Y | | | |
| | | | Y | Y | Y | Y | Y | | | |
| % ( DER Export Capacity, Aggregated with Other Generation Export / ***Line Section's Gross Daytime Minimum Load*** ) | > 100% | | Optional | | | Y | Y | | | |
| | | | | | Y | Y | Y | | | |
| | | | Y | Y | Y | Y | Y | | | |
| % (Reverse Power-flow / ***Substation Transformer Nameplate rating*** ) | > Limit or 100% | Substation Transformer Thermal Impact | | | Y | Y | Y | Y | | |
| | | Substation Transformer Thermal Impact | Y | Y | Y | Y | Y | Y | | |
| | | Substation Transformer Thermal Impact | Y | Y | Y | Y | Y | Y | Y | |
| | | Substation Transformer Thermal Impact | Y | Y | Y | Y | Y | Y | | Y |
| % (Reverse Power-flow / ***Service Transformer Nameplate rating*** ): if applicable | > Limit or 100% | Service Transformer Thermal Impact | | | Y | Y | Y | Y | | |
| | | Service Transformer Thermal Impact | Y | Y | Y | Y | Y | Y | | |
| | | Service Transformer Thermal Impact | Y | Y | Y | Y | Y | Y | Y | |
| | | Service Transformer Thermal Impact | Y | Y | Y | Y | Y | Y | | Y |
| % (Reverse Power-flow / ***Line Section's Nameplate rating*** ) | > Limit or 100% | Upstream Line Thermal Impact | | | Y | Y | Y | Y | | |
| | | Upstream Line Thermal Impact | Y | Y | Y | Y | Y | Y | | |
| | | Upstream Line Thermal Impact | Y | Y | Y | Y | Y | Y | Y | |
| | | Upstream Line Thermal Impact | Y | Y | Y | Y | Y | Y | | Y |
| % (Reverse Power-flow / ***Line Section's Peak Load*** ) | > 30% | Upstream Line Thermal Impact | | | Y | Y | Y | Y | | |
| | | Upstream Line Thermal Impact | Y | Y | Y | Y | Y | Y | | |
| | | Upstream Line Thermal Impact | Y | Y | Y | Y | Y | Y | Y | |
| | | Upstream Line Thermal Impact | Y | Y | Y | Y | Y | Y | | Y |
| % (Reverse Power-flow / ***Line Section's Gross Daytime Minimum Load*** ) | > 100% | | | | Y | Y | Y | Y | | |
| | | | Y | Y | Y | Y | Y | Y | | |
| | | | Y | Y | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | | Y |
| Fault Current Contribution of DER aggregated with other generation | > 10% of max. fault current at primary nearest to POI | | | | | Y | Y | | | |
| % (Short-Circuit Interrupting Capability of DER aggregated with other generation / Short-Circuit Interrupting Capability) | > 90% | | | | | Y | Y | | | |
| In an area with known transient stability limitations to generating units? | Yes | | | | | | Y | | | |
| Is PCC on transmission | If Interdependencies exist | | | | | | | | | |
| Min. loading, number of customers (safety & reliability screen) | significant minimum loading levels dominated by a small number of customers (i.e., several large commercial customers). | | Y | | Y | Y | Y | Y | | |
| | | | Y | Y | Y | Y | Y | Y | | |
| | | | Y | Y | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | | Y |
| Maximum Line Thermal Loading | | | | | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | | Y |
| Maximum Transformer Thermal Loading | | | | | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | | Y |
| Number of Lines outside loading bounds | > 0 | | | | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | | Y |
| Number of Transformers outside loading bounds | > 0 | | | | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | | Y |
| Maximum Duration (hours) of any line outside loading bounds | > 0 | | Y | Y | Y | Y | Y | Y | | Y |
| Maximum Duration (hours) of any transformer outside loading bounds | > 0 | | Y | Y | Y | Y | Y | Y | | Y |
| Maximum Voltage | | | | | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | | Y |
| Number of nodes violating ANSI C84.1 Upper Limit | > 0 | | | | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | | Y |
| Number of nodes violating ANSI C84.1 Upper Limit with buffer | > 0 | | | | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | Y | |
| | | | Y | Y | Y | Y | Y | Y | | Y |
| Maximum Duration (hours) of any node violating ANSI C84.1 Upper Limit | > 0 | | Y | Y | Y | Y | Y | Y | | Y |
| Maximum Duration (hours) of any node violating ANSI C84.1 Upper Limit with buffer | > 0 | | Y | Y | Y | Y | Y | Y | | Y |
| ANSI C84.1 Upper Limit Violation 1.05 p.u. + duration threshold (e.g., number of hours over limit and/or magnitude threshold [e.g., 1.051 p.u. is OK) | hours > 0, magnitude > 1.051 | | Y | Y | Y | Y | Y | Y | | Y |
| Short-Circuit Study | | | | | | | | | | |
| Circuit Protection & Coordination Study | | | | | | | | | | |
| Impact on System Operation | | | | | | | | | | |

## ***Data architecture*** for AMI, SCADA, GIS, CIS, and Application Data



# TA Request 3:

# Limited generation profiles and DER Power control systems for flexible interconnection

NREL Lead: Killian McKenna:
Killian.McKenna@nrel.gov.

# Activities

- **Flexible Interconnection Needs Assessment -** what a successful implementation of flexible interconnection/limited generation profiles/time-series export/import limits would look like. This will include what needs to be considered (uncertainty in net load conditions, future upgrades, load and DER growth) and what needs to be included in the analysis.
- **Analysis Scenarios:** Examine nameplate vs PCS screens, probability of network violations, time-series import/export limits and use-cases for flexible interconnection
- **Roadmap for Enabling Flexible Interconnection -** The roadmap will outline options for how a utility can perform the technical analysis required for leveraging DER PCS as part of interconnection studies. This will recommend ways such that utilities avoid import/export limit calculations becoming a burden to their planning engineers and exacerbating the DER logjam experienced by utilities.

# Spectrum of Flexible Interconnection Solutions

Increasing complexity and coordination / Reduced unnecessary import/export limitations

**Fixed import/export limits**

- Time-series (monthly/daily/hourly) profile issued to load/DERs
- E.g., CPUC Limited Generation Profile

**Flexible Customer Oriented Solutions**

- Load/DER import/export limiting device with local management scheme
- Customer monitors local network constraint

**Flexible – Local Distribution Management**

- Remote intertrip (remote unconditional tripping)
- Local measurement and dispatch of customer devices/DERs

**Flexible – Area Distribution Management**

- Area control, e.g., advanced distribution management system (ADMS) + distributed energy resource management system (DERMS)
- Advanced and coordinated constraint management

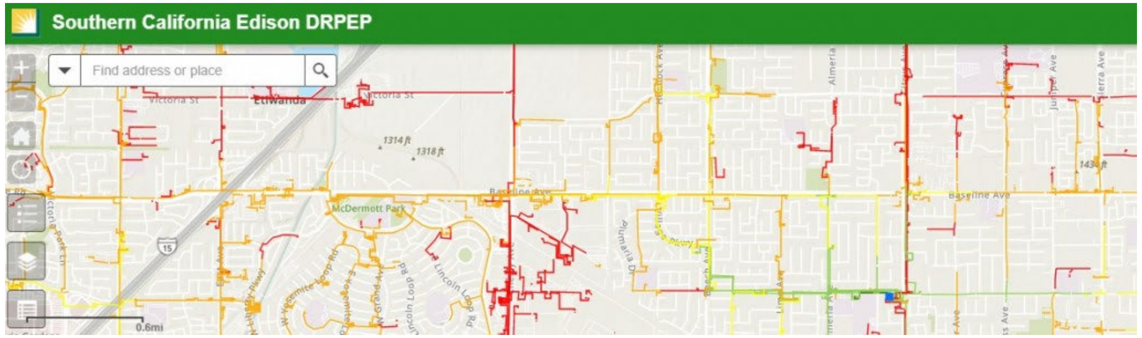
- NREL are focusing on fixed export limit profiles, examining limited generation profiles proposed by the California Public Utilities Commission
- The focus is on examining how NREL's PRECISE interconnection tool can be leveraged to generate flexible interconnection profiles

# TA Request 4: Hosting Capacity Analysis

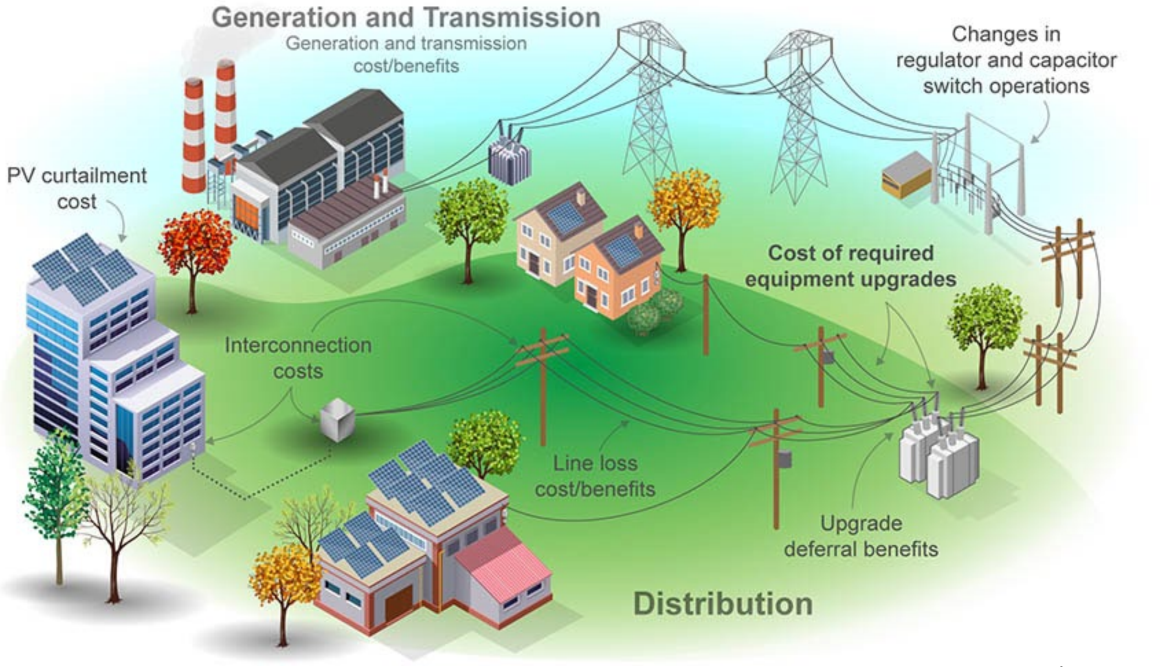
NREL Lead: Kwami Senam A. Sedzro, PhD: Kwami.Sedzro@nrel.gov.

# TA Request 4: Hosting Capacity Analysis

- Key Ask
  - Evaluate the design and recommend improvements to an approved hosting capacity analysis (HCA) pilot project
- Key Accomplishments
  - Biweekly meetings to scope and inform the study
    - NREL reviewed the methodology to ensure that metrics and assumptions were in line with industry's best practices
  - NREL made recommendations to address gaps
    - Rerun the HCA after model enhancement that accounts for advanced inverter functions for new solar PV plants
      - The current model was set to unity power factor
    - Quality-check hosting capacity numbers through an impact study of a deployment scenario at capacity equal to the maximum hosting capacity, because model does not use full power flow study in its incremental HCA




**Example of a hosting capacity map. *Source:* [Southern California Edison]**



# Solar Strategic Analysis & Institutional Support at NREL

With guidance from the U.S. Department of Energy Solar Energy Technologies Office (SETO), NREL researchers produce innovative and actionable solar analysis work within SETO's Strategic Analysis and Institutional Support Team (SAIS).

- Produce analysis designed to reduce solar installation costs
- Assess existing and new solar market opportunities
- Develop tools that inform decision making

Scan the code to visit the Solar Market Research and Analysis site on nrel.gov to access more solar analysis findings, data, and tools.

# Thank you

**Jeff Cook**
NREL Solar Analysis
Subprogram Manager
Jeff.Cook@nrel.gov

*Scan the code to sign up for the Solar Market Research and Analysis newsletter—the latest solar analysis from NREL sent to your inbox.*

# i2X Intro Webinar:
# Optimal Feeder Configurations to Support DER Interconnections

Matthew Reno, Joe Azzolini

3/15/2024

Sandia National Laboratories is a multimission laboratory managed and operated by National Technology & Engineering Solutions of Sandia, LLC, a wholly owned subsidiary of Honeywell International Inc., for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-NA0003525.

# Introduction

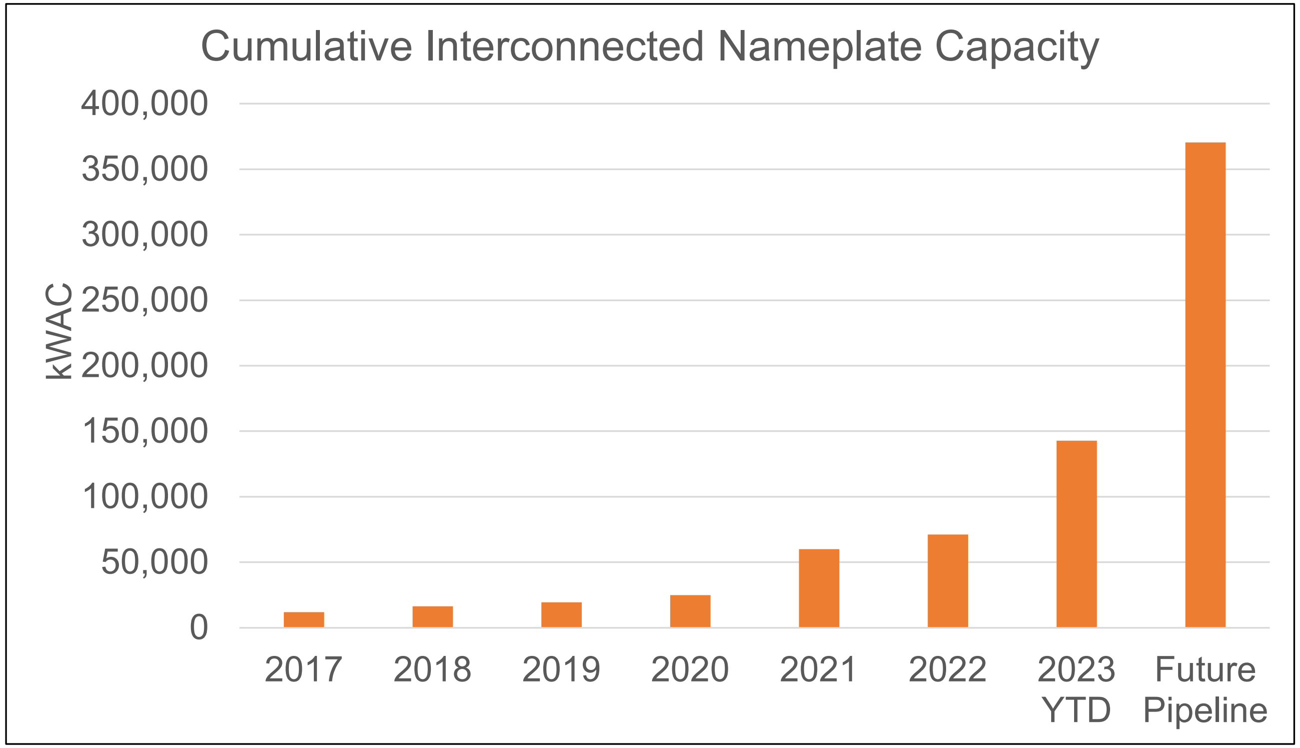
- For more than 100 years, Duquesne Light Company (DLC) has provided safe and reliable electric service to more than 600,000 customers across two counties in southwestern PA, including the city of Pittsburgh.

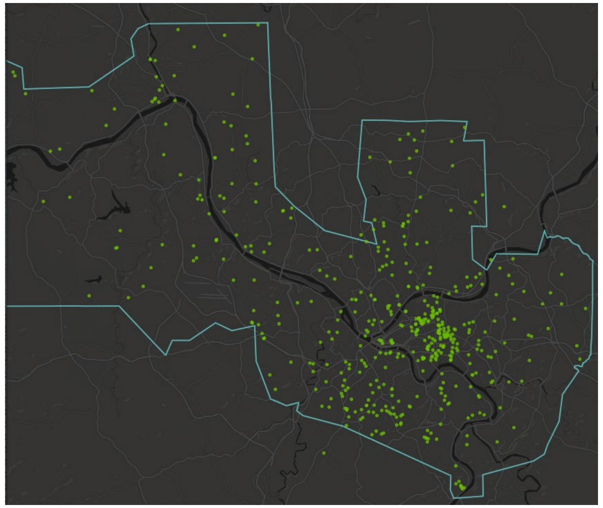

DUQUESNE LIGHT CO.

# Introduction

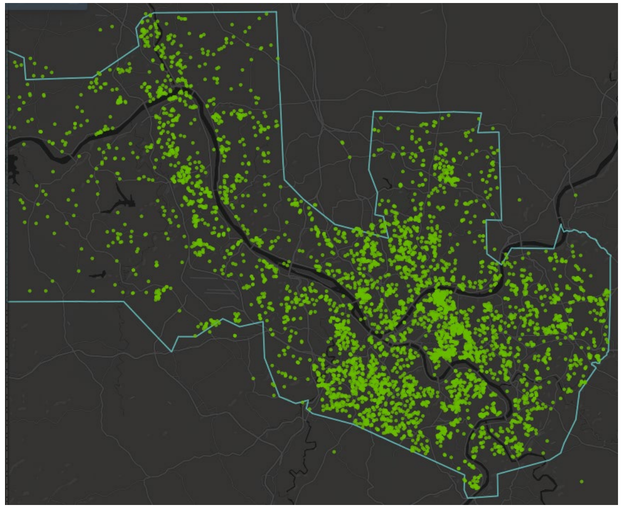
**Solar adoption trends:**

- Distributed Generation is growing exponentially
- Average of 175 new interconnection applications monthly over the last two years
- 62% annual increase from 2021 to 2022



DER Interconnections, 2016



DER Interconnections, 2022

DUQUESNE LIGHT CO.

# DLC Need

- Interconnection requests take a considerable amount of engineering resources to complete.
  - As requests become more frequent the System Planning group at DLC either needs to increase staffing or to **improve the study process through automation** and **expand study tools**
- Existing practices are extremely conservative, only considering worst-case scenarios
  - Not able to evaluate DERMS, volt-var or volt-watt settings, or flexible interconnections, that would enable greater utilization of our assets and reduce infrastructure investment to handle more DER

## Opportunities for Improvement

- DLC has many circuit ties and switching capabilities compared to similar utilities
  - Switching capabilities are often used in emergency situations, these connections are periodically studied to their potential to balance load across the network and improve system reliability
  - Considering switching operations rapidly increases the permutations of network configurations to be studied, necessitating an automated process
  - Being able to provide more flexibility in offering alternative solutions that may be less costly will encourage solar developers to work in DLC territory

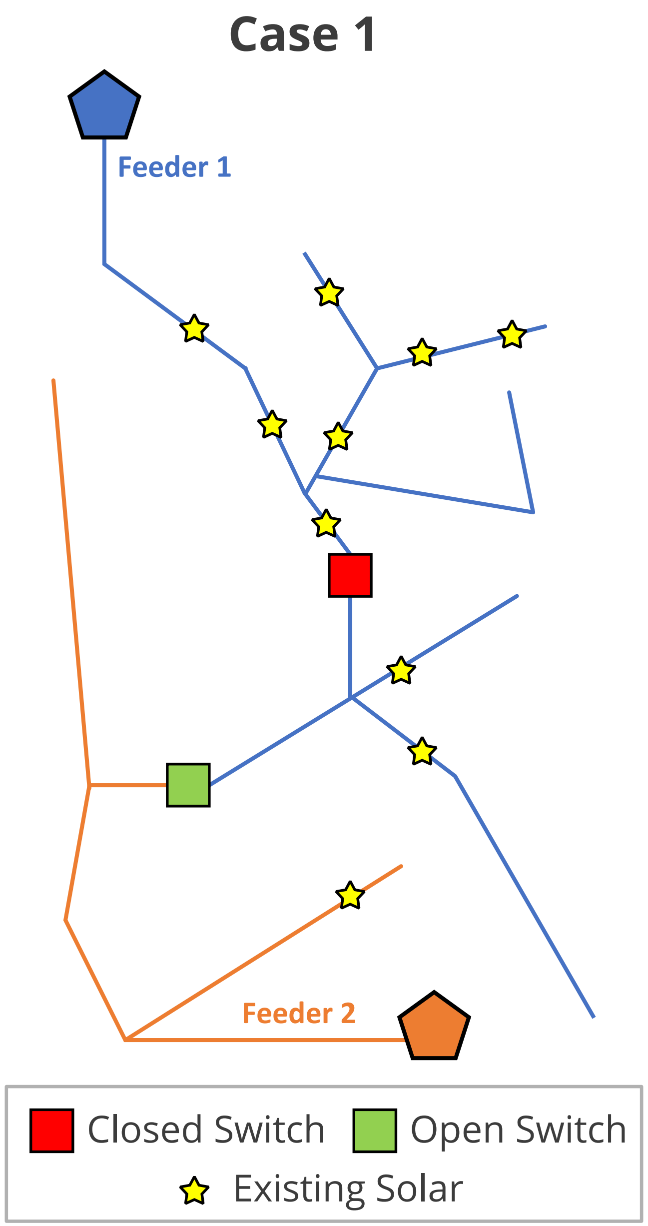
# DLC Need—Optimal Feeder Configurations

**Example Case 1:**

- In this example, Feeder 1 already has a high penetration of existing distributed solar
- In this scenario, Feeder 1 is approaching its PV hosting capacity limit
- However, there are sections of the feeder that have minimal solar installations

**Solution:**

- Re-configure the feeders to increase the total hosting capacity of the system



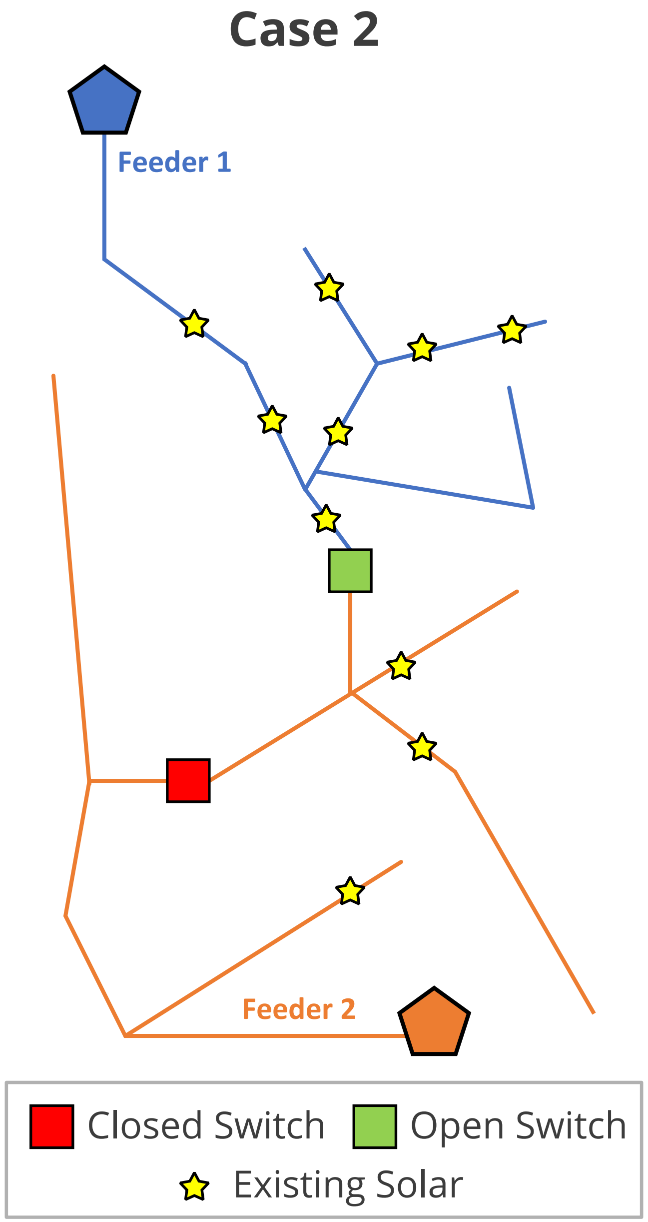
# DLC Need—Optimal Feeder Configurations

**Example Case 2:**

- In this example, the only changes were that the states of the two switches were reversed
- This allowed Feeder 2 to pick up several sections of Feeder 1

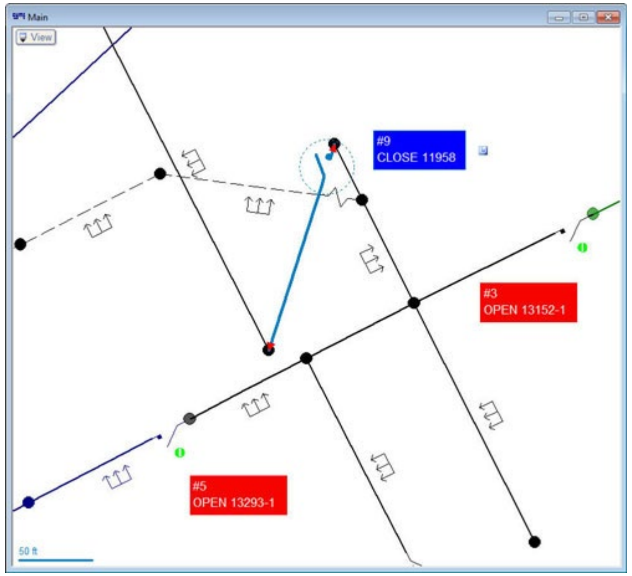
**Results:**

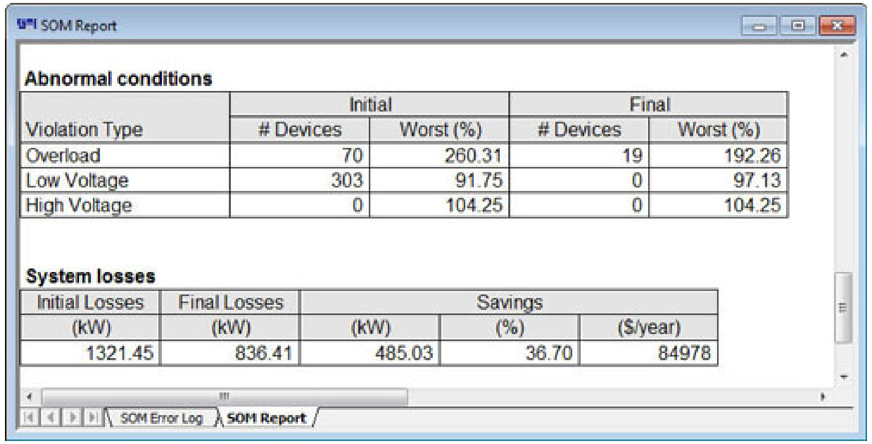
- Feeder 2 still has plenty of available hosting capacity
- Feeder 1 may also recoup some hosting capacity, as two of the PV systems at the end of the feeder were transferred to Feeder 1
- Overall, total system hosting capacity was increased



# Challenges with Existing Software

- Several software packages exist for studying optimal feeder reconfigurations
- Existing tools are mostly focused reducing losses and increasing loading capacity
  - Modules are not fully integrated with hosting capacity tools and their capabilities are limited in handling time-series data
- **CYME Network Configuration Optimization Module [1]**
  - Perform load transfer studies to minimize voltage violations, minimize overloads, improve system kW losses to reduce operating cost
- **EPRI Automated System Configuration Assessment Tool [2]**
  - This tool determines the possible set of alternate configurations that can be assembled from identified ties and existing switching devices. Recent updates enable integration with EPRI DRIVE but not available through CYME





SOM Report

**Abnormal conditions**

| | Initial | | Final | |
|---|---|---|---|---|
| Violation Type | # Devices | Worst (%) | # Devices | Worst (%) |
| Overload | 70 | 260.31 | 19 | 192.26 |
| Low Voltage | 303 | 91.75 | 0 | 97.13 |
| High Voltage | 0 | 104.25 | 0 | 104.25 |

**System losses**

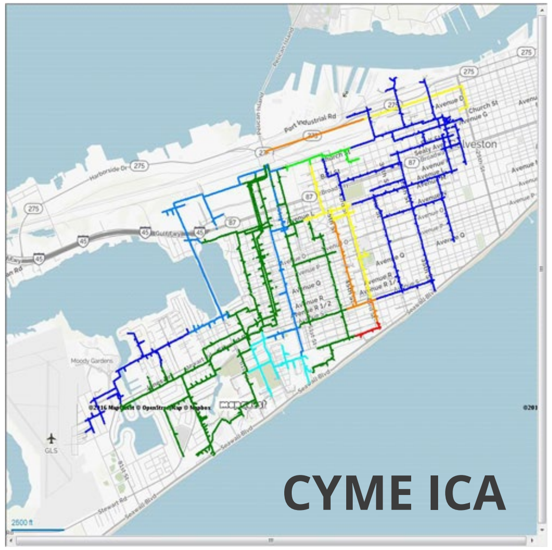
| Initial Losses | Final Losses | Savings | | |
|---|---|---|---|---|
| (kW) | (kW) | (kW) | (%) | ($/year) |
| 1321.45 | 836.41 | 485.03 | 36.70 | 84978 |

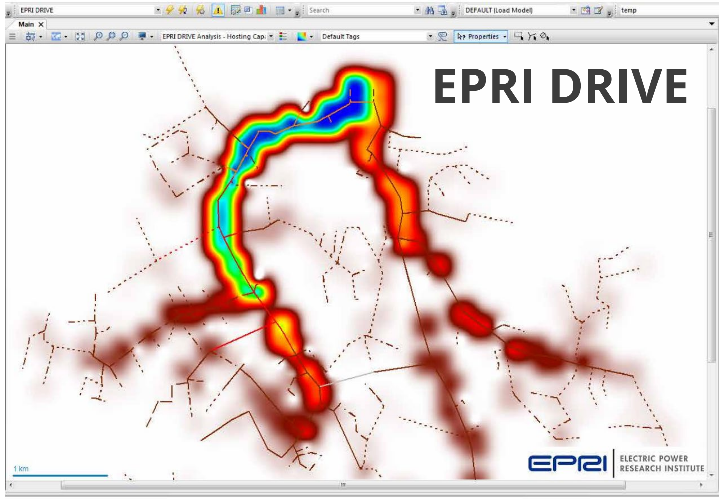
SOM Error Log | SOM Report

1 https://www.cyme.com/software/cymdistsom/#:~:text=The%20Network%20Configuration%20Optimization%20module%20is%20an%20additional%20module%20to,losses%20and%20voltage%20violations%20counts.
2 https://www.epri.com/research/products/000000003002023237

# Challenges with Existing Software

- Existing tools mostly consider specific configurations, and only under minimum and maximum loading conditions
- Several software packages exist for conducting hosting capacity analysis (HCA), including:
- **CYME Integration Capacity Analysis (ICA) [3]**
  - The maximum HC is determined based on a set of user-defined thresholds that includes thermal overloads, reverse power flow, abnormal steady-state voltages, transient voltage variations (flicker), reduction of protection reach and sympathetic tripping
- **EPRI Distribution Resource Integration and Value Estimation (DRIVE) Tool [4]**
  - The calculation method provides aggregate and granular HC results for each distribution feeder and considers numerous circuit-specific attributes, such as topology, equipment nameplate data, device settings as well as peak and minimum loading conditions
- **And other tools, etc.**

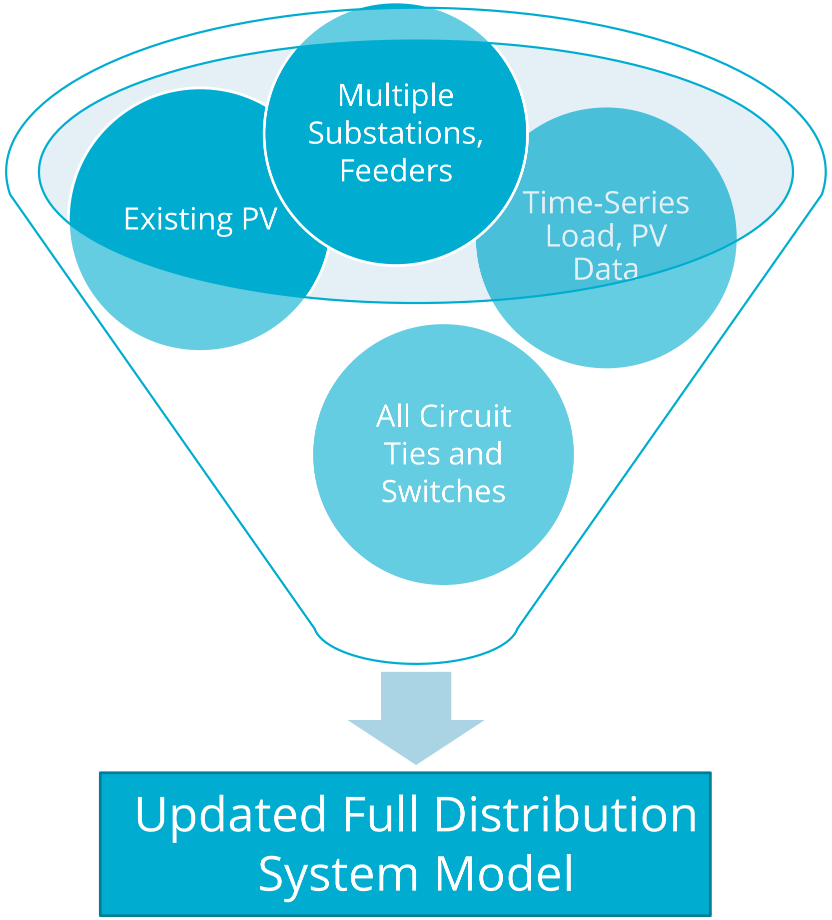



3 https://www.cyme.com/software/cymeica/
4 https://cyme.com/software/cymeepri/BR917075EN-epridrive.pdf

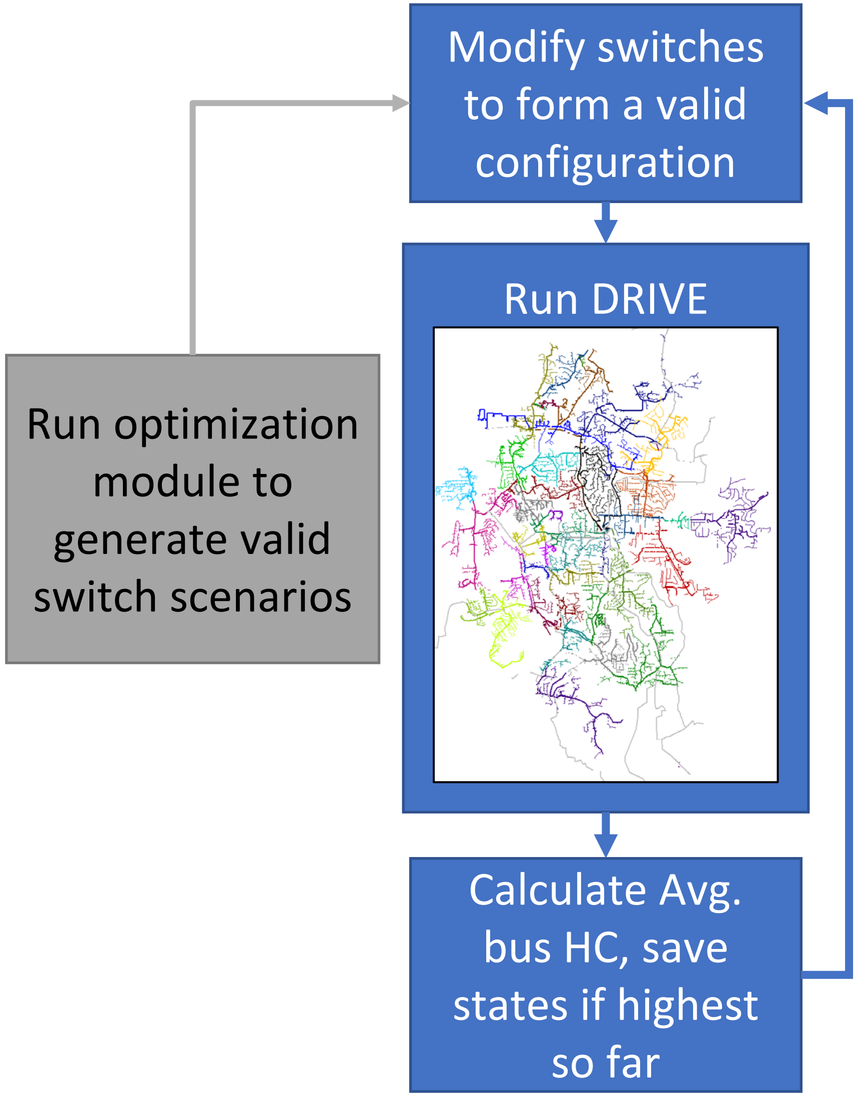
# Challenges with Modeling Practices

- Proper analysis requires detailed, up-to-date, and full distribution system models with multiple feeders/substations
- Specific challenges for this task include:
  - **Modeling of existing PV systems.** Utilities may have only included large utility-owned PV in their models. Info from approved PV requests often reside in a different database. However, inclusion of all PV is required, especially as penetrations rise.
  - **Inclusion of normally open switches.** Models may have been simplified to reduce complexity/computation time, but the inclusion of switch locations is required.
  - **Time-series modeling for loads and PV.** Time-series measurements, such as from smart meters, is required to analyze the time-dependent interactions between load and generation across the feeders, especially if seasonality is to be considered (e.g., "optimal" configurations may differ from summer to winter). Similar to the PV info, this data may reside in a different database as it is primarily used for billing.



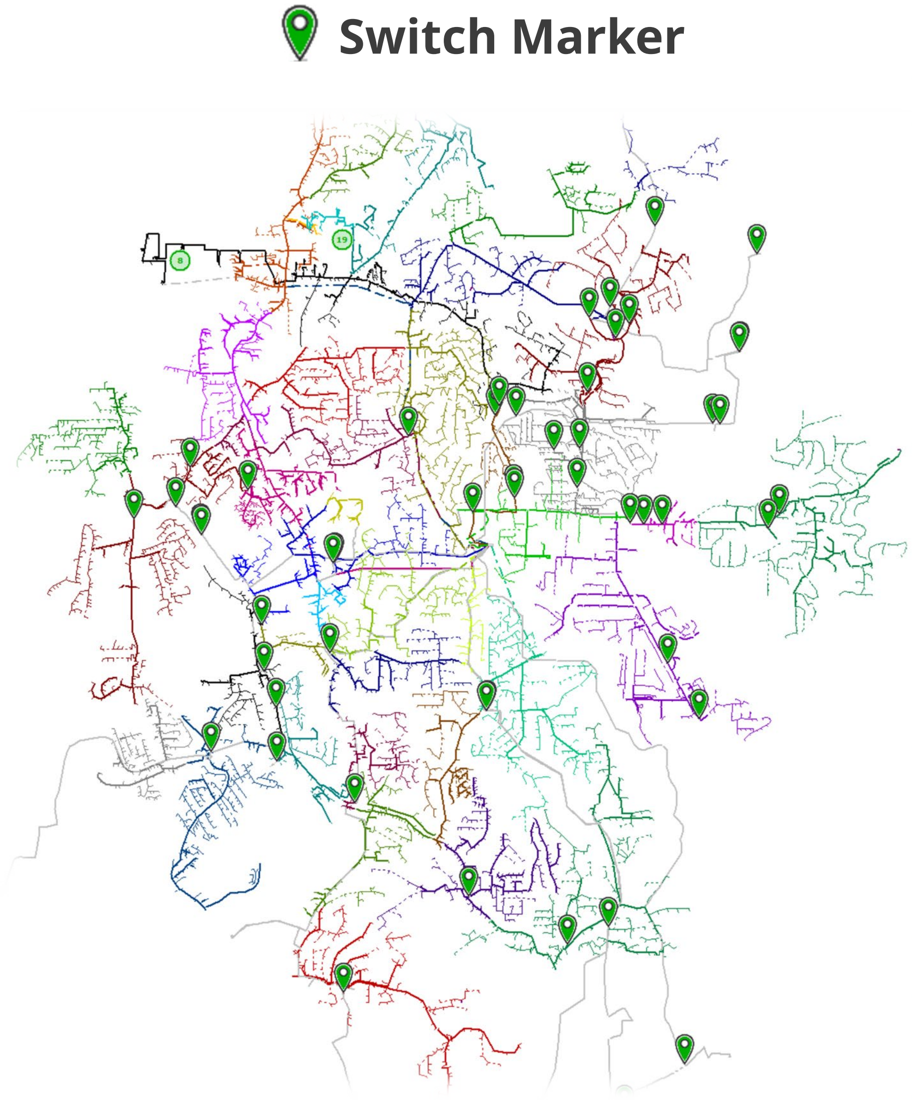
# Implementation Plans

- Leverage python scripting and several analysis modules in CYME to implement a custom solution for evaluating the DLC objectives
- For example, the network configuration module can be implemented to generate a subset of possible switching operations
  - Large systems may have near-infinite possible permutations of switch states, so optimization methods are required
- From there, we can iterate through the valid configurations and use the EPRI DRIVE module to evaluate the impacts to total hosting capacity
- With different load and generation models, we can analyze the impacts of seasonality on the results as well



# Conclusions and Expected Outcomes

- The proposed approach will enable tangible improvements in the automation and analysis practices for evaluating PV requests
- The approach maximizes the use of existing tools whenever possible to ensure that the results are robust and reliable
  - Distribution systems may have 10s or 100s of circuit switches, meaning there are near-infinite unique configurations to consider
- The outcome will be a script-based tool that integrates with CYME to evaluate feeder reconfigurations and propose sets of switching states to optimize the system for enhanced hosting capacity
- The tool can be utilized dynamically to ensure optimality is maintained across seasonal changes and as new PV installations come online over time
- This can also be used to inform operations teams on problematic switching configurations to avoid



# THANK YOU

## Questions?

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Joe Azzolini (jazzoli@sandia.gov)

# Questions?

INTERCONNECTION INNOVATION e-XCHANGE
U.S. DEPARTMENT OF ENERGY