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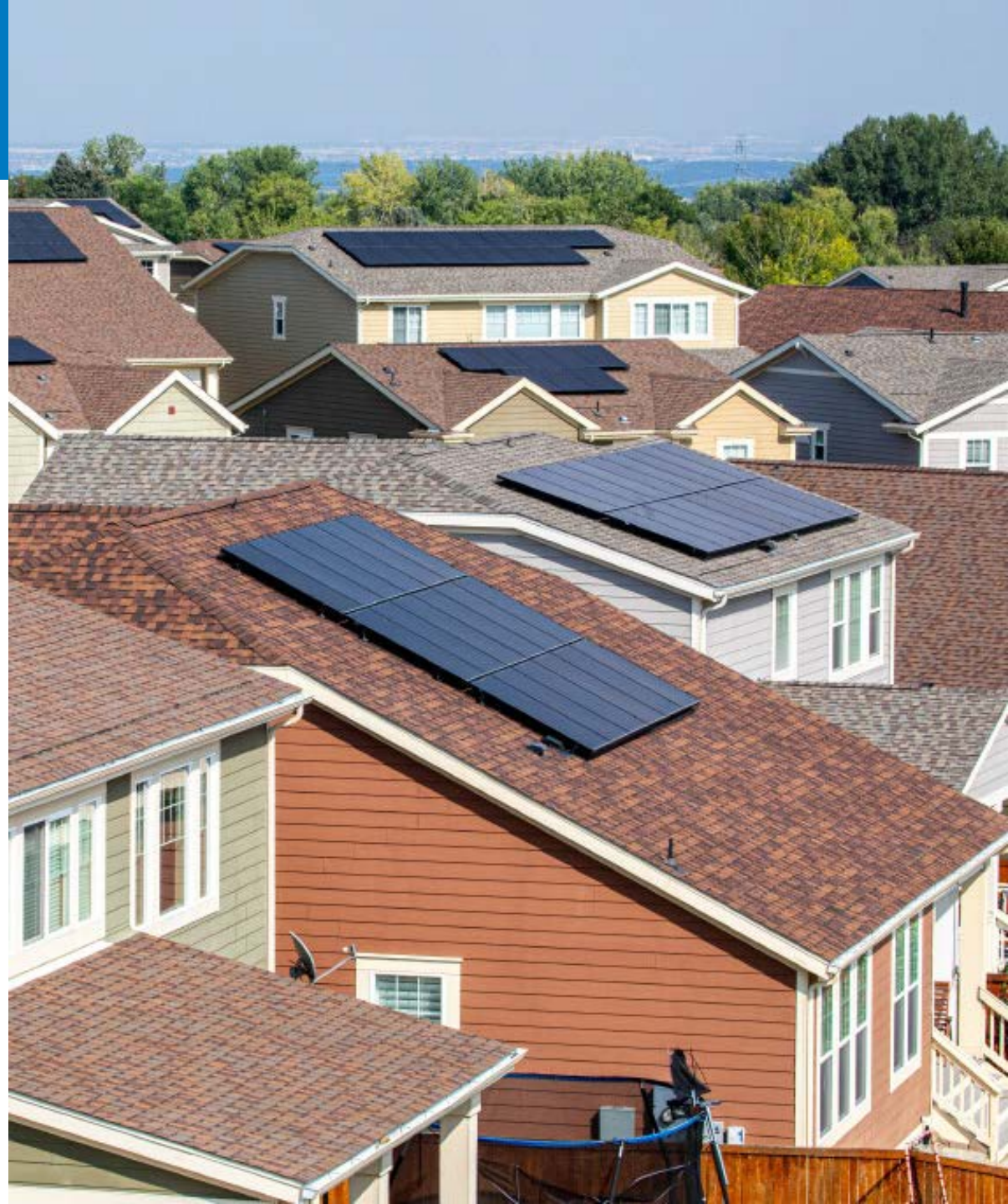
Want To Connect Rooftop Solar?

Customer experience…

- Unpredictable outcomes
- Interconnection logjams and wait times

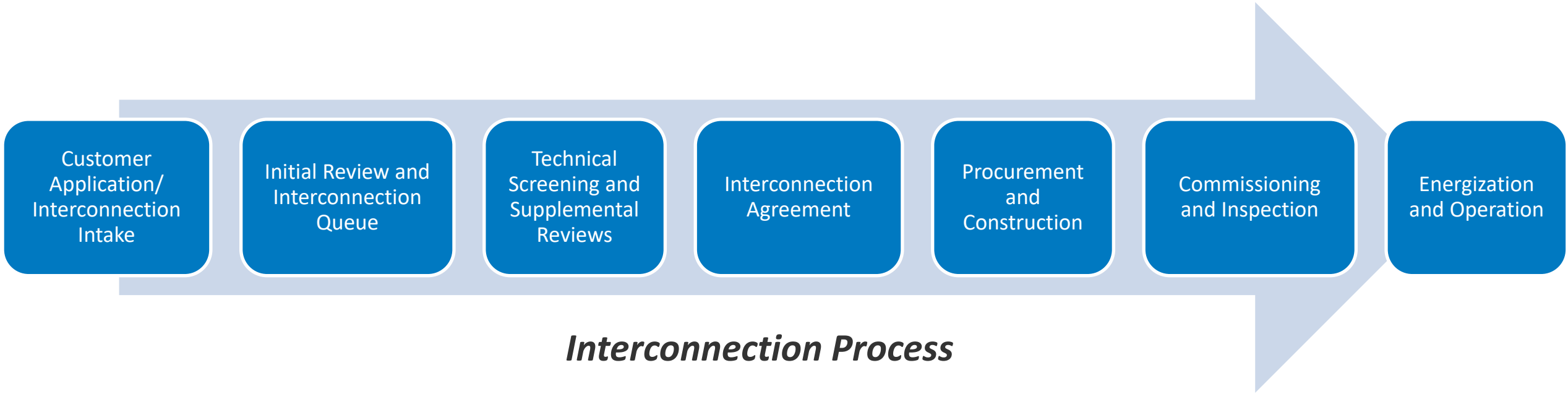
Utility planning engineers…

- Inundated with new requests
- Lack of visibility on system impacts



An Inefficient Interconnection Process

- Fast growing queue of distributed solar application requests being made to utilities
- Lack of ability to safely and quickly analyze the impact of these systems has led to a logjam of applications.

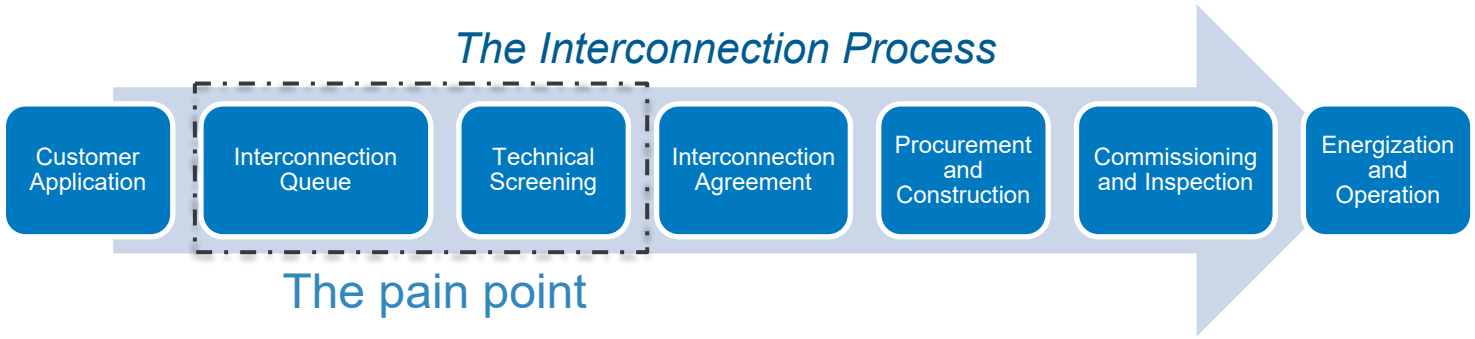


Interconnection Process

Challenges Need an Innovative Solution

Problem:

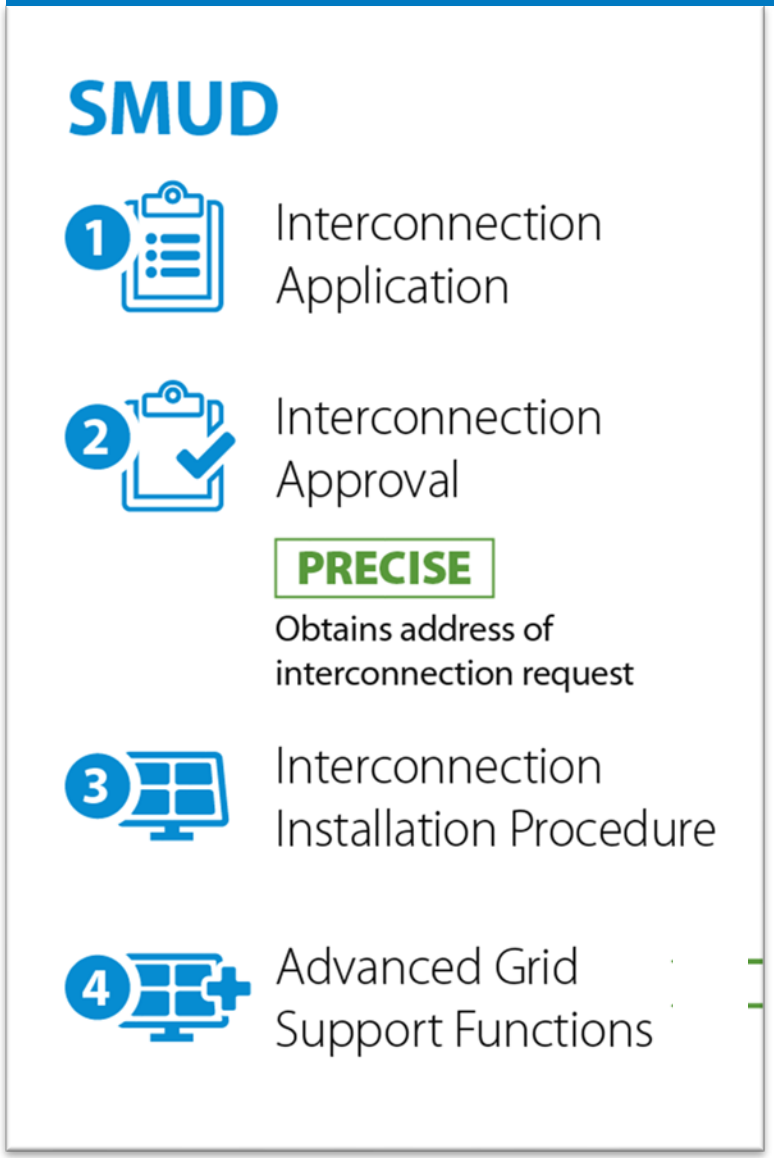
- Planning engineers are overrun by interconnection applications
- Need for a tool to provide fast and high visibility on network impacts
- Need for evaluation on how smart inverters can help grid integration.



Objective:

- Automate and streamline the interconnection process and leverage AIF where appropriate.

Streamlining Interconnections Through PRECISE™



An **automated interconnection evaluation tool** that quickly assesses the impact of solar on the grid and leverages smart inverter functionality

Developed in partnership with Sacramento Municipal Utility District (SMUD)

R&D 100 Award Winner 2019

Fully integrated and deployed at SMUD Spring 2022

PRECISE™ Offers Impactful Capabilities

- Automates interconnection evaluation to streamline solar grid integration
- Evaluates grid impacts, avoids costly and lengthy analysis by distribution planning engineers and the use of conservative heuristics
- Leverages advanced inverter functions *as needed*
- Provides a standardized, repeatable, automated way to evaluate solar interconnection requests
- Benefits utility/installer as well as customers/solar developers.

Efficient Workflows

Workflow

Utility Receives an Interconnection Request

Interconnection request comes through an application manager.

Interconnection Request Gets Processed by PRECISE

- Uses photovoltaic (PV) technical data and distribution system power-flow models
- Outputs network impacts and smart inverter benefits.

PRECISE Updates Utility Data Streams

PRECISE provides utility recommendations and network impact analysis.

Subworkflow

PRECISE Models PV Output

Based on technical parameters (tilt, azimuth, capacity, inverter ratio).

PRECISE Runs Power-Flow Cases

- Need for smart inverter functionality
- Checks voltage, loading, and curtailment
- Evaluates the need for capacity reduction.

PRECISE Recommendations

- Accept as is
- Use smart inverter settings
- Accept with reduced capacity.

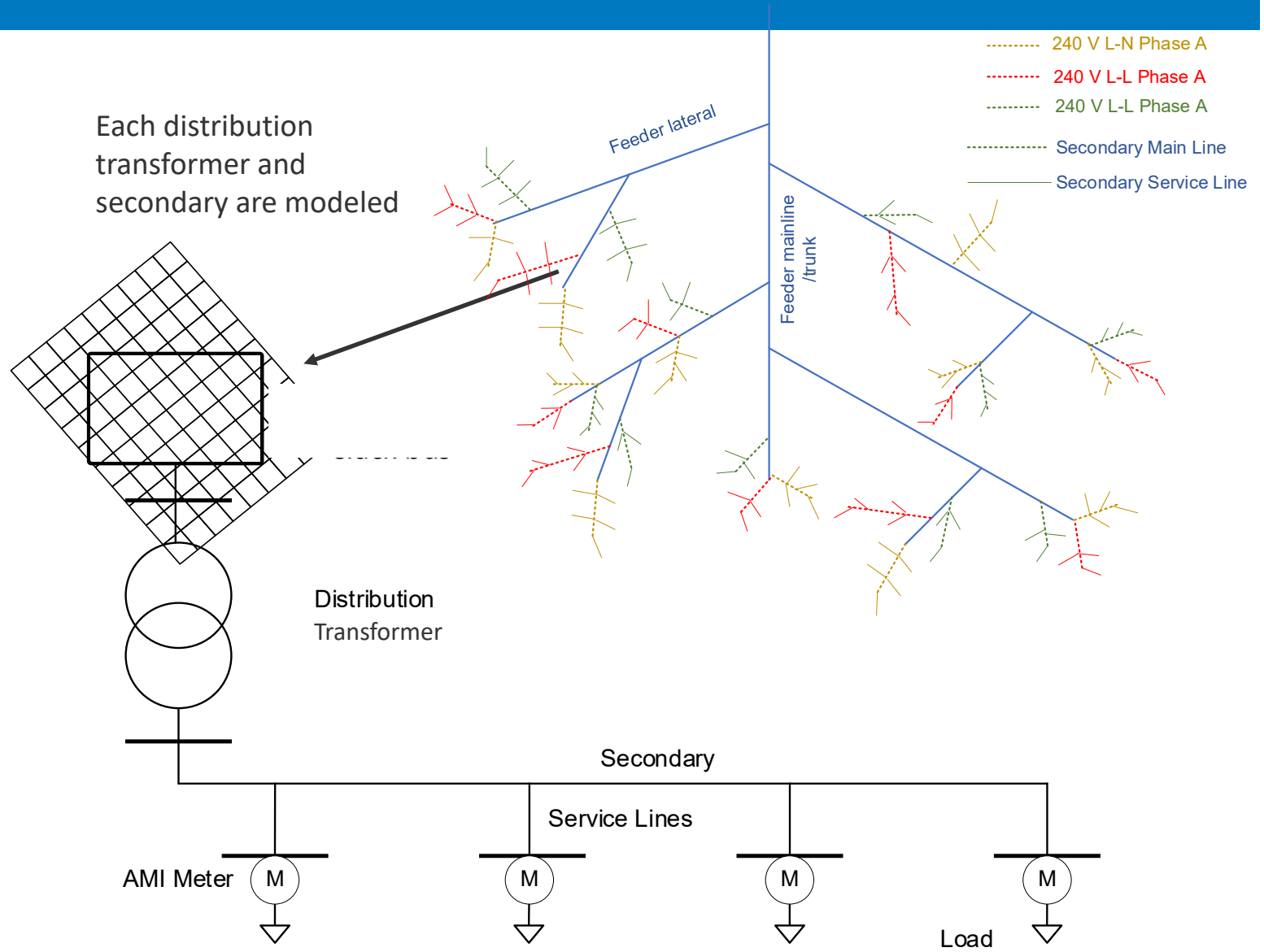
Integration of Siloed Data Systems and Comprehensive QA/QC

Advanced Metering Infrastructure	Geographical Information Systems (GIS)	Customer Information Systems	Interconnection Technical Data	Power-Flow Models	Supervisory Control and Data Acquisition
Net load profiles *Voltage profiles*	*Secondary information for model generation* *Meter mapping*	*Parcel to meter relationships* *Distributed energy resource (DER) ownership and programs*	*DER technical parameters* *Status of interconnection*	*Primary network information* *Connectivity and power-flow models*	*Voltage profiles for substations* *Time-series net load for feeders and the substation*

PRECISE uses diverse siloed distribution data to build a complete picture of the network and impact of incoming DERs.

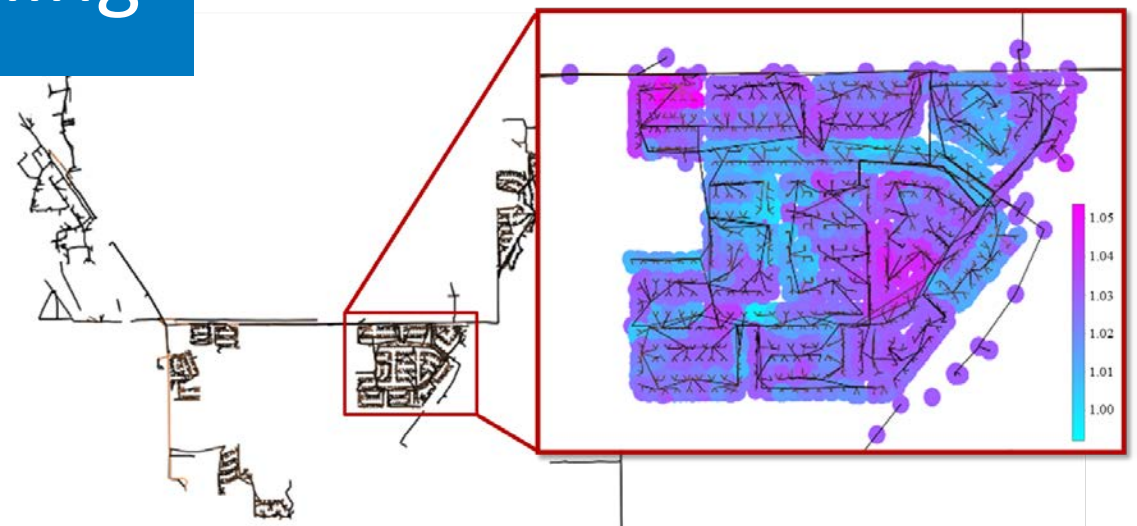
Network Modeling: Capturing to the Grid Edge

- Models each distribution feeder, using GIS and Synergi and modeling power flow in OpenDSS
- For a single utility, the National Renewable Energy Laboratory (NREL) has modeled ***over 800 feeders*** and ***thousands of network secondaries.***



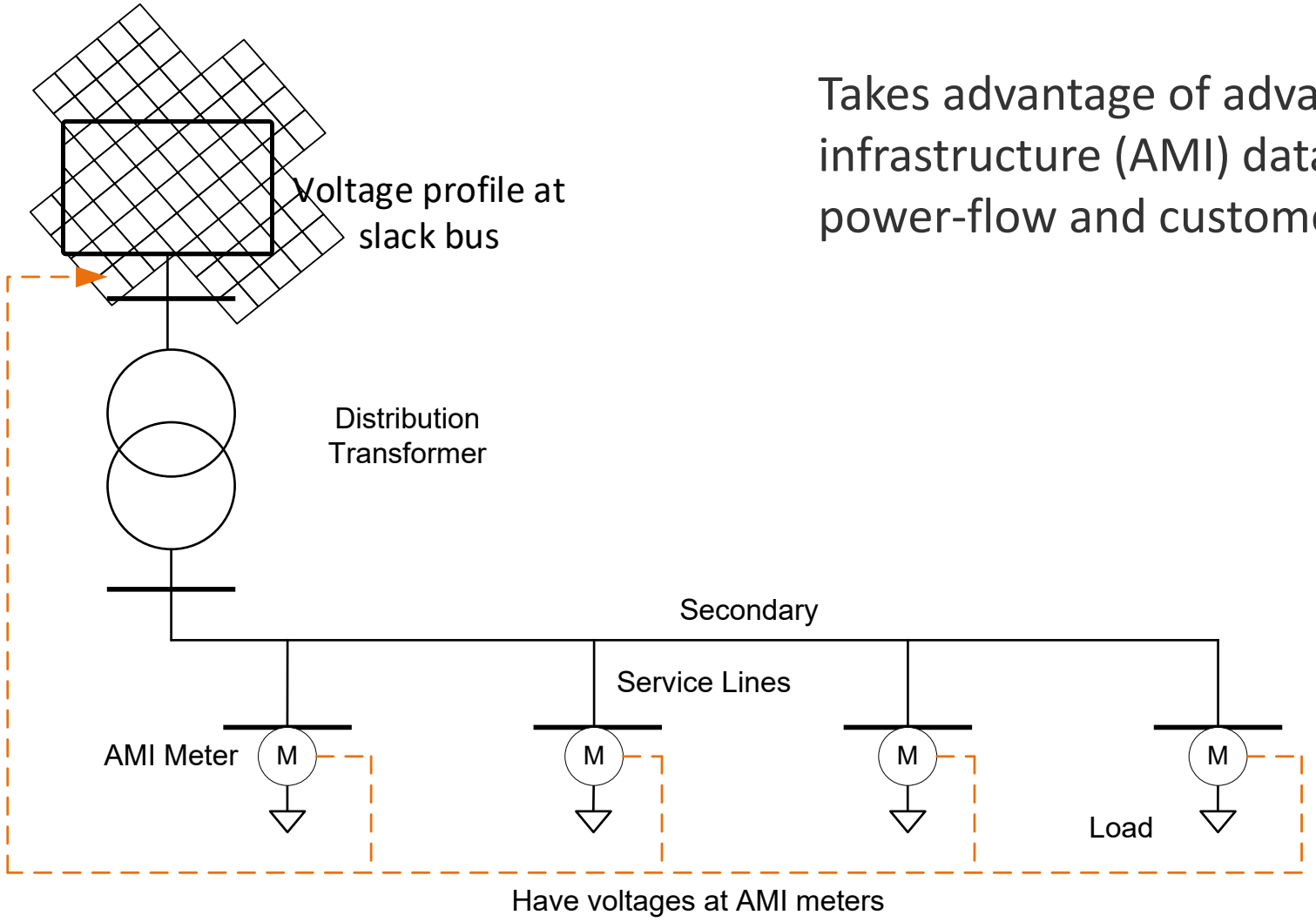
High-Fidelity Network Modeling

Builds out models of network secondary and service lines, capturing grid-edge power flow where utilities typically have low visibility.

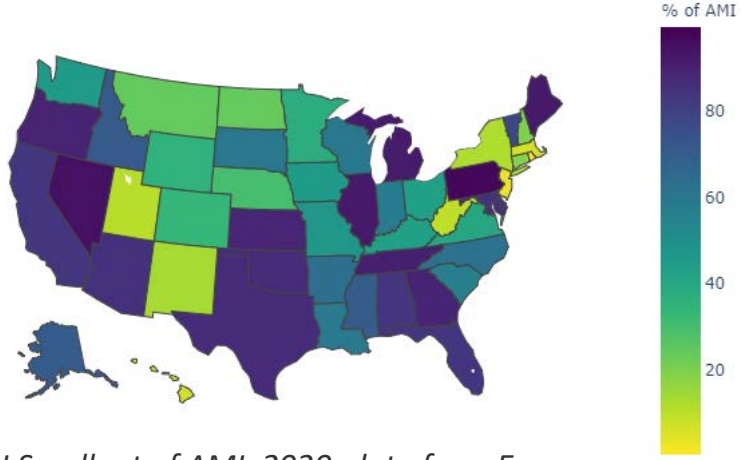


Leveraging AMI Voltage Data

Use AMI voltages to estimate the correct voltage profile on the high-voltage side of the distribution transformer



Takes advantage of advanced metering infrastructure (AMI) data to capture grid-edge power-flow and customer load profiles.

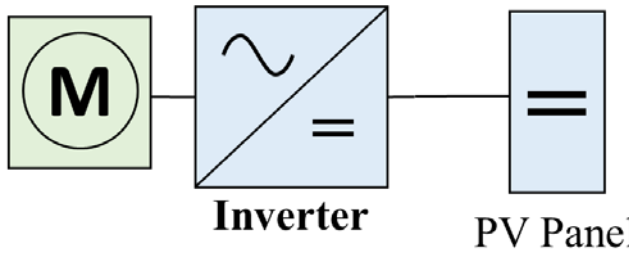


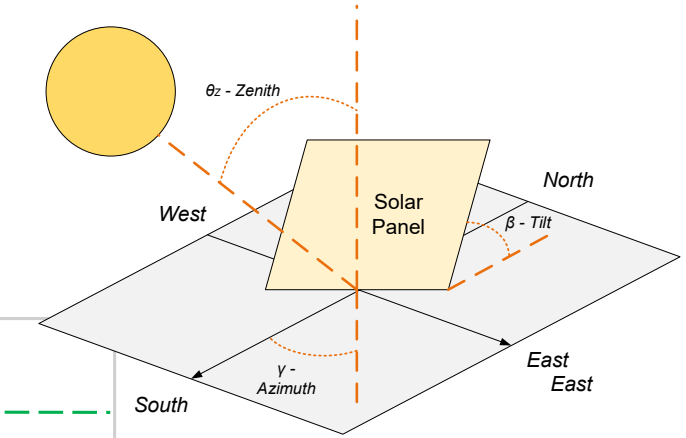
U.S. rollout of AMI, 2020, data from Energy Information Administration (EIA).

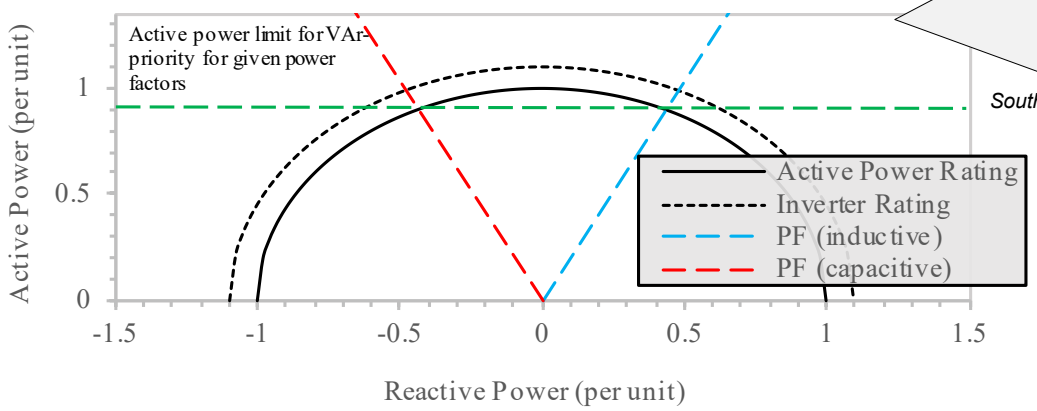
Holistic Solar Modeling

- Uses NREL advanced solar modeling to capture individual panels, tilt, and azimuth
- Leverages local irradiance data
- Inverter models capture AC to DC ratios and model advanced inverter functions including volt-VAR and volt-watt.

Photo by Dirk Jordan, NREL

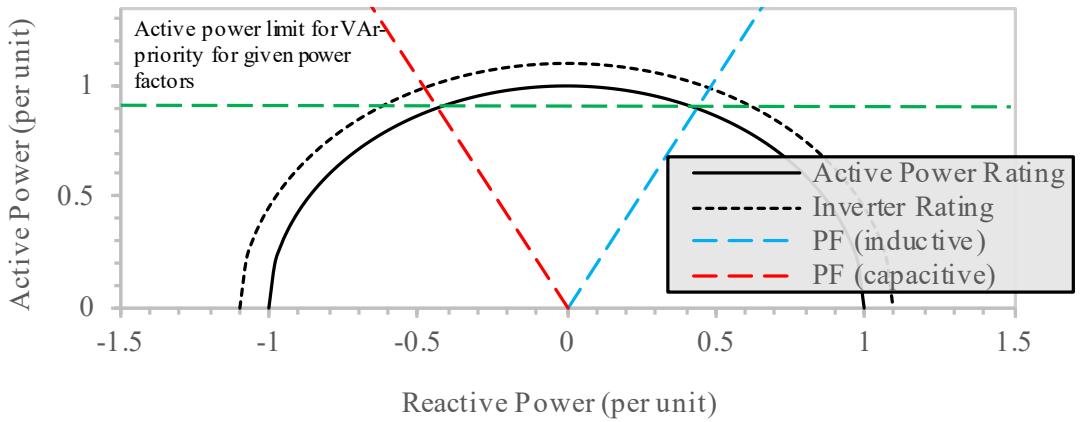




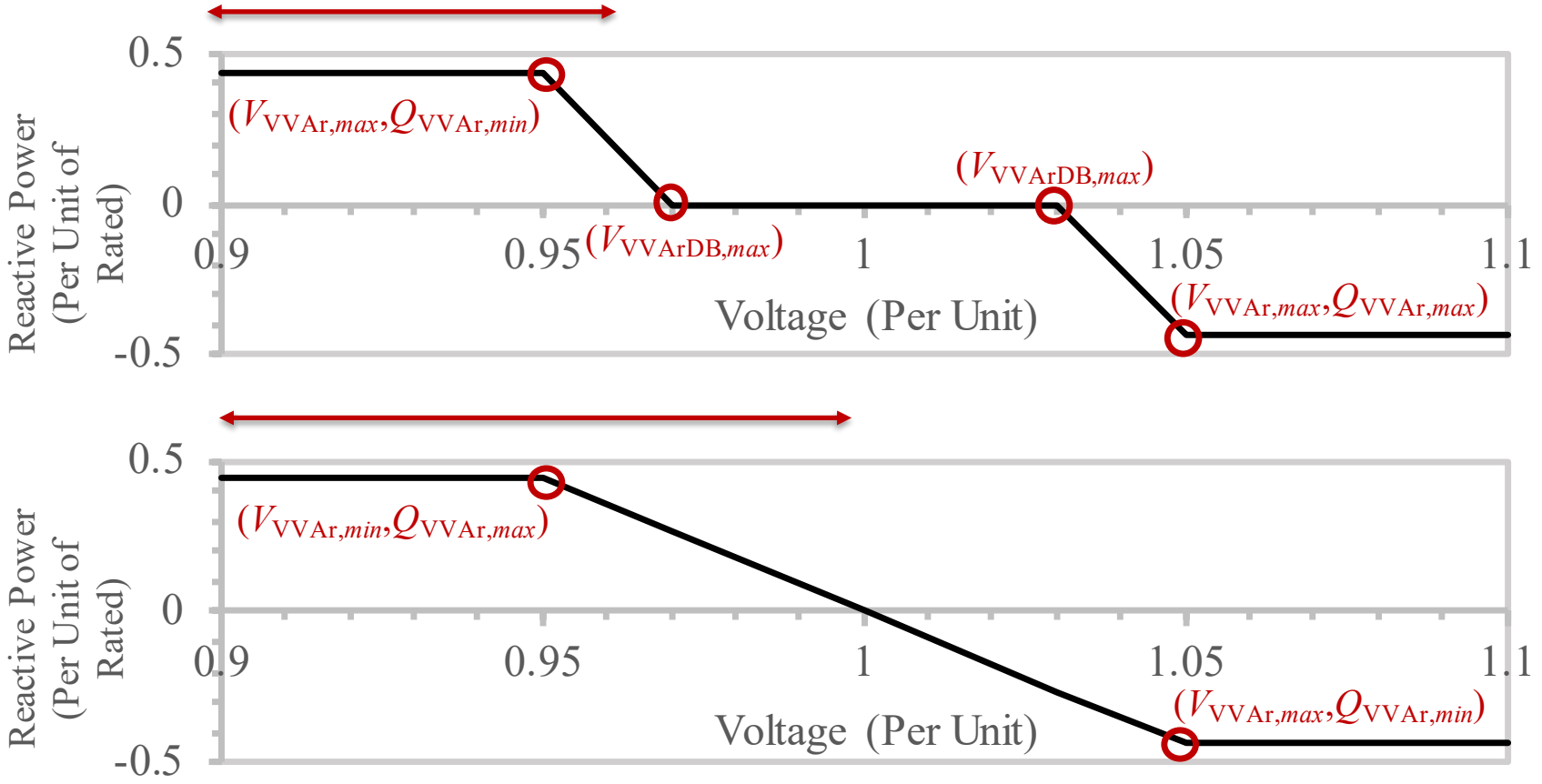


Inverter Modeling and Volt-VAR Curves

Inverter limits will cause active power curtailment when hitting capacity limits



Can explore multiple design choices associated with solar smart inverter voltage control.



PRECISE at SMUD

An adaptable workflow

Successful Deployment

- Deployed in February 2022
- Automatically evaluates all incoming rooftop solar PV applications.

Deployment Stats

1,700 applications processed in the first 6 months

Processed an average of 13 applications per day

Able to accept 70.77% applications with no modifications and 11.89% with standard smart inverter functions; 14% were recommended reduced capacity

Avoided thousands of work-hours of planning engineers' time

Enabled the interconnection of over 10 MW of rooftop solar to date

Runs thousands of power-flow scenarios for each incoming application

Modeled over 800 feeders and thousands of secondaries, capturing the entire service area

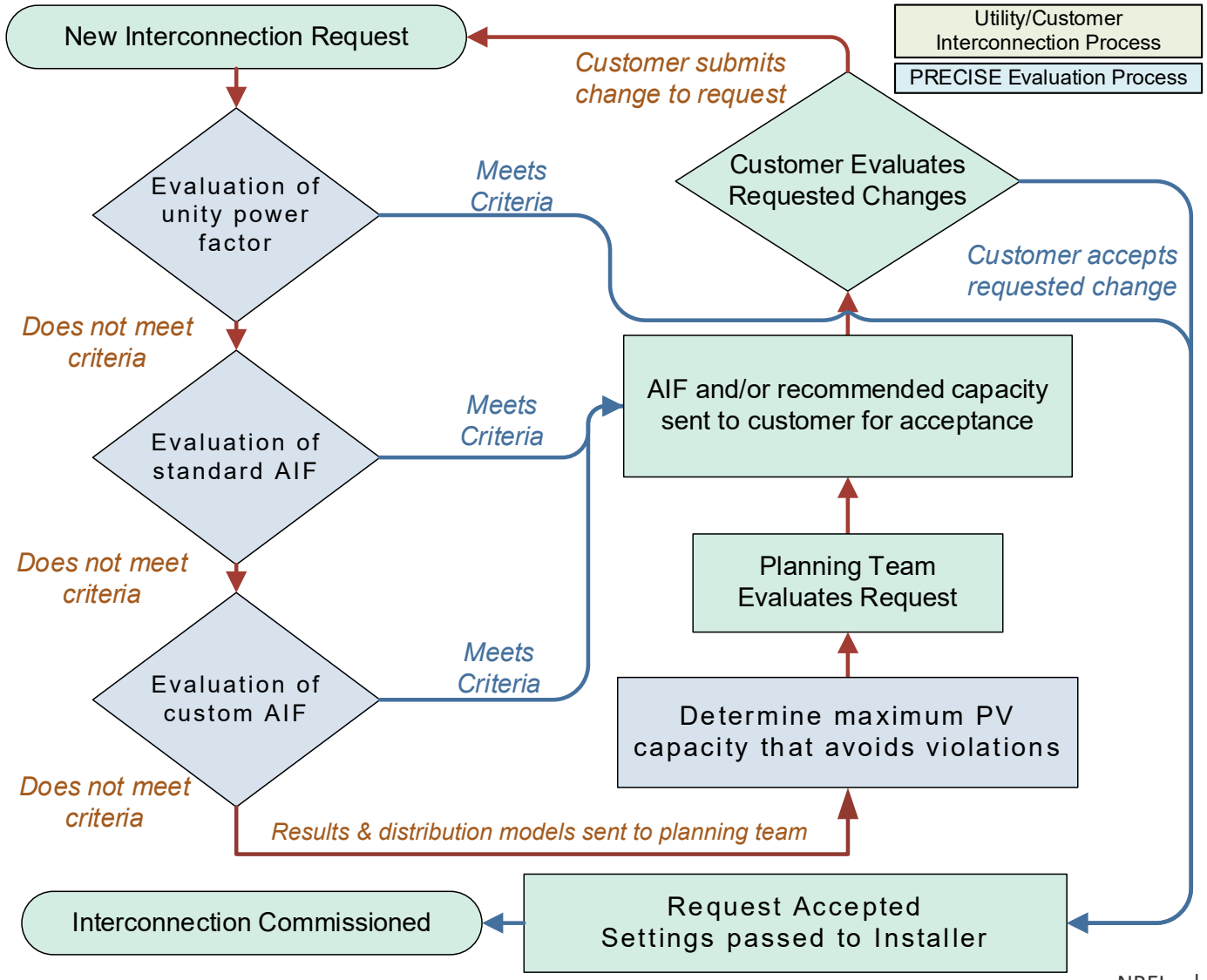
Applications processed within minutes

Realized SMUD Benefits

- **Avoided labor costs** of $300,000 in annual savings for every 5,000 applications processed
- **Enhanced customer experiences** and shortened application turnaround time; fewer rejected reapplications
- **Increased hosting capacity**
- **Avoided infrastructure expenditure** (secondary conductor and transformer) and associated soft costs.

Adaptable Workflow

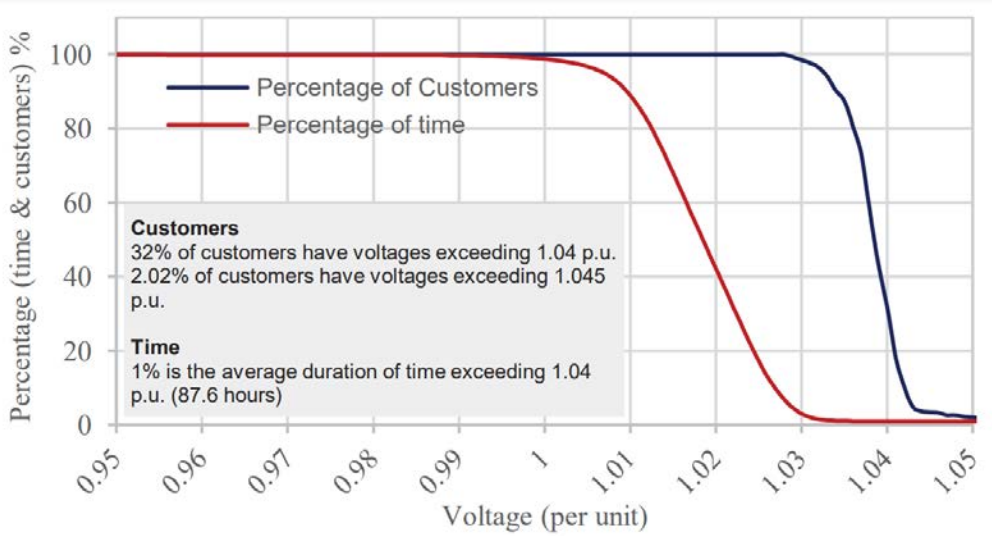
- Entirely modular and easy to adjust objective functions based on utility use cases
- Processes each interconnection and sets *as-needed* grid support functions.

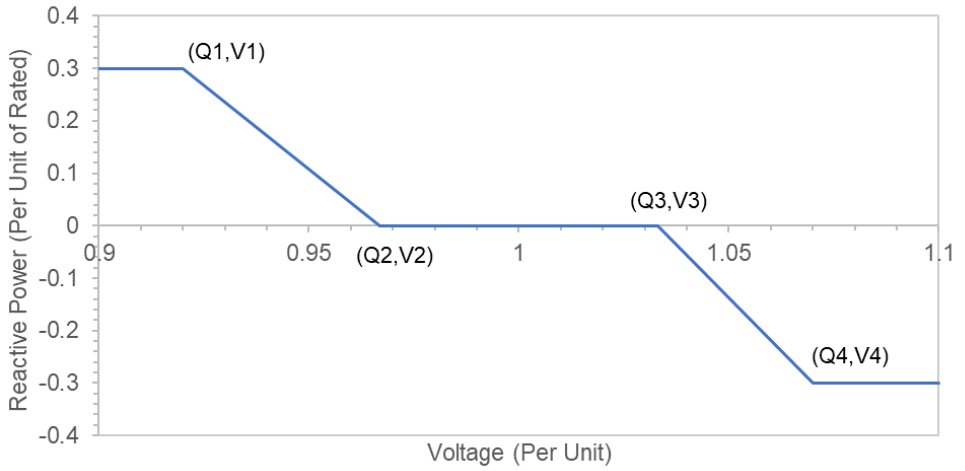


Current Constraints

Transformers and lines: Reverse power-flow constraints of 100% of nameplate loading for impacts of *net load*

Voltages: Evaluating against ANSI C84.1 ±5% and against against SMUD's normal bounds of voltage operation





Customer AIF increases Q1 and Q4 setpoints

TechStack

Vue.js | Frontend JavaScript
framework

Microsoft SQL Server | SQL Database
For managing PRECISE data

python

OpenDSSDirect.py

OpenDSS
Distribution System Simulator

AIOHTTP
Asynchronous client/server framework

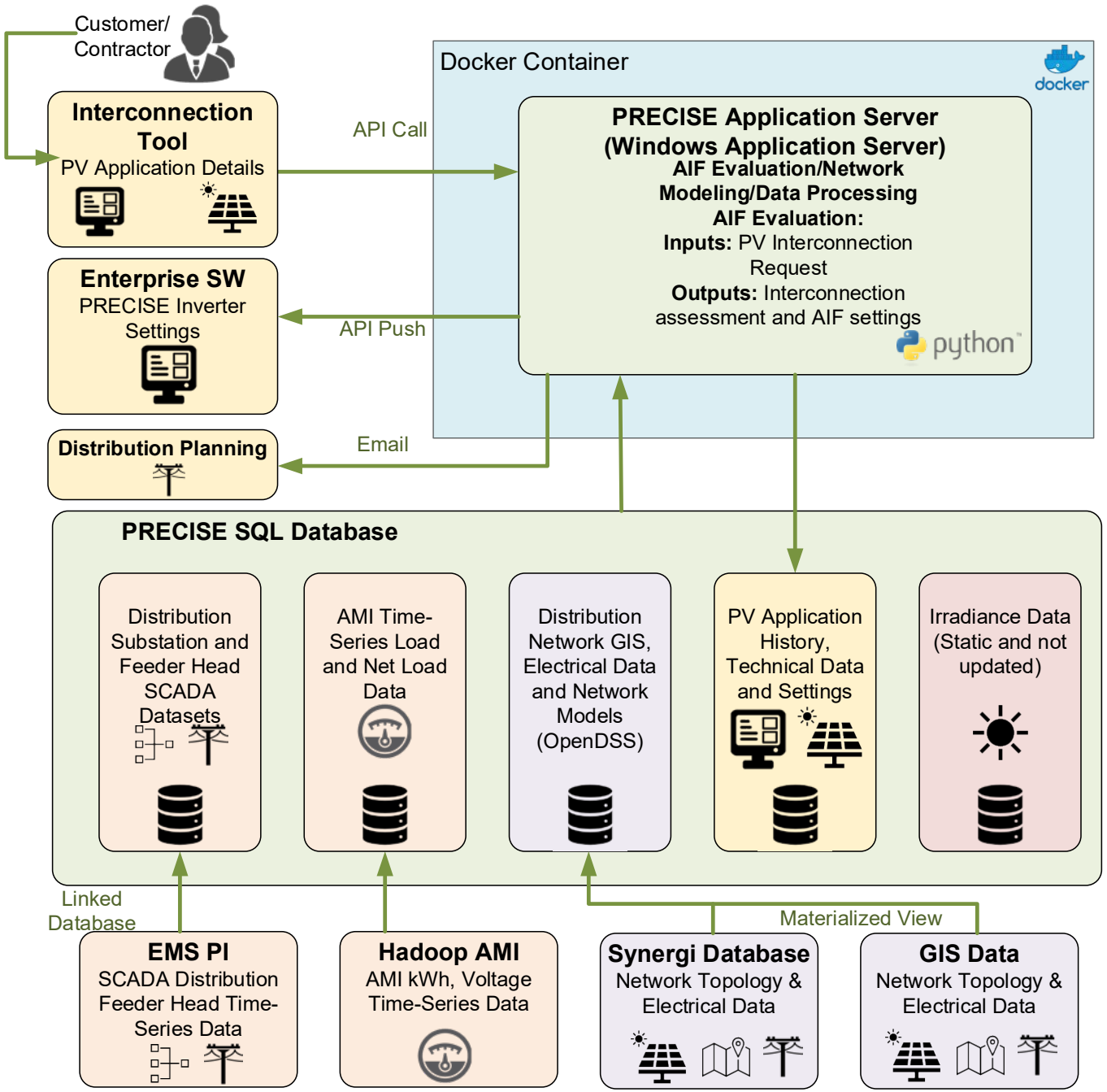
NREL/**ditto** | opensource distribution
model transformation tool

Third-party integration

- Oracle
- Control-M
- Elastic Stack
- PowerClerk
- Apache Hadoop
- Grafana
- Synergi Electric

Seamless Integration

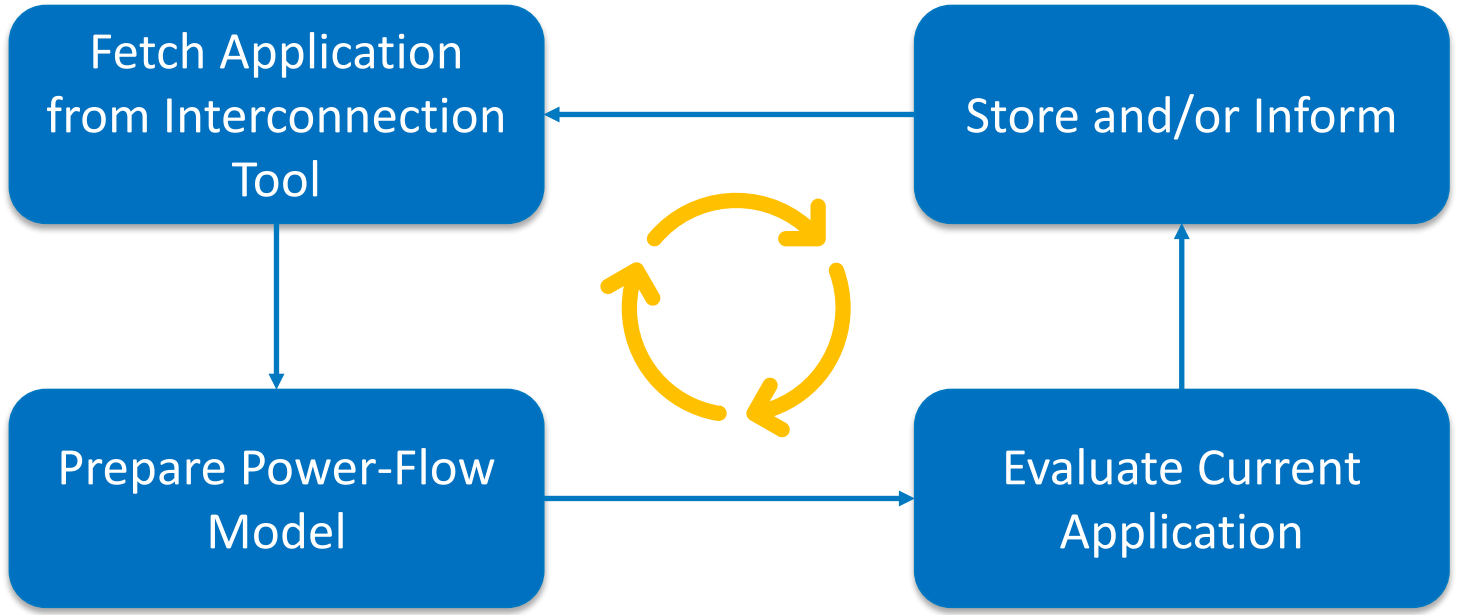
- On-premise solution that integrates directly to utility information systems
- Operates in an automated fashion, processing interconnection applications as they are received.



PV Application Processing

Queries every 10 minute to check if application is uploaded.

Stores results in database, sends email to planning engineers in case review is required.



Involves model query, AMI data query, updating model with time series, adding controllers, filtering unnecessary timesteps.

Adding PV model, generate POA, simulate inverter control scenarios, perform time-series simulation, generate inverter settings.

PRECISE Has a Tangible Impact on the Interconnection Process

"**PRECISE significantly reduces this evaluation time** by instantly determining optimal inverter settings for a given location." – Sheikh Hassan, Principal Engineer, SMUD

"This is a tremendous result for our team and has ensured staff gets the help they need while **speeding up the interconnection process and lowering costs for our customers**." – Sruthi Nadimpalli, IT Project Manager, SMUD

"The U.S. solar industry set a record for new installations in 2021, and in particular, **residential solar installations grew 30% year-over-year in the fourth quarter.**" – *Utility Dive*, article on PRECISE, November 2022

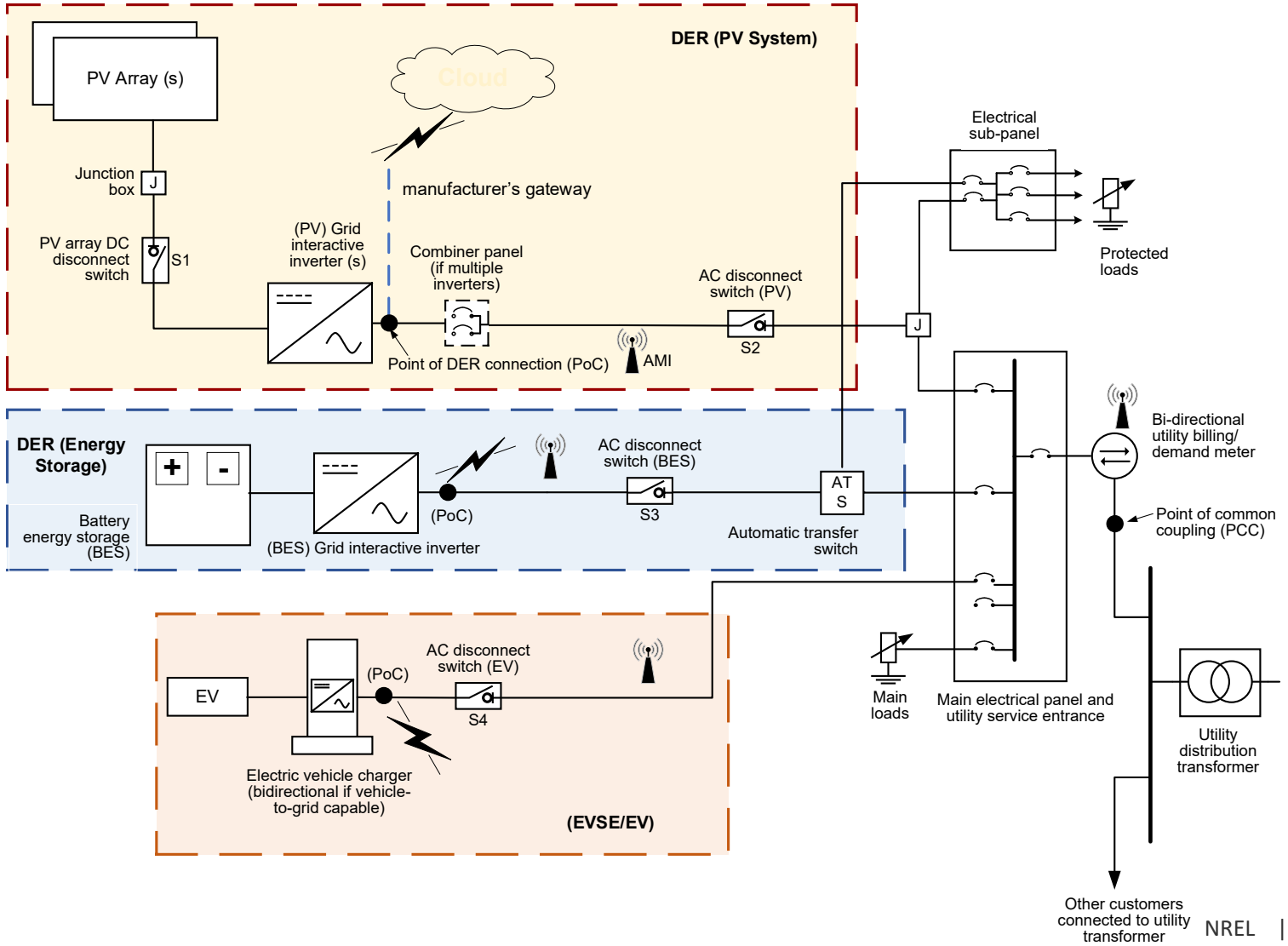
"**interconnection queues have grown to almost unmanageable levels**... In January, a PV Intel report found no less than 639 GWac of large-scale solar projects in the queues of the seven wholesale power markets … Comparing that to the queues that PV Intel tracked in 2019, it shows a more than 3x increase." – *PV Magazine USA*, article on PRECISE, November 2022

Future of PRECISE

Tackling Increased Complexity

Interconnecting Multiple DER Types

- Has developed the automation needed to perform the power flow for diverse incoming DERs
- Next phase is working on evaluating more complex interconnections, including DER storage, EVs, V2H, V2G, and DER gateways.

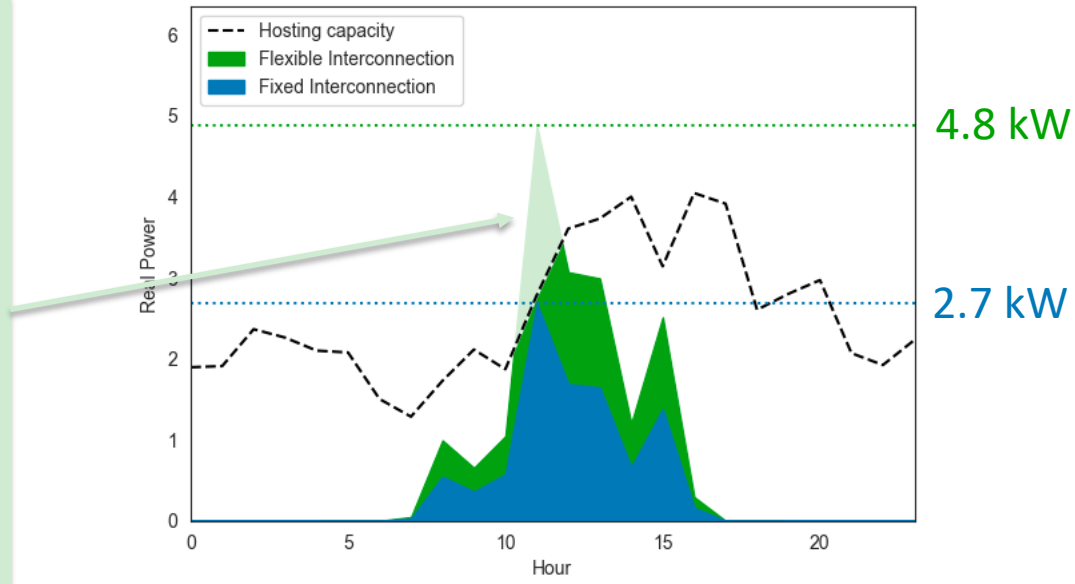


Flexible Interconnection

PRECISE is working to enable flexible interconnection:

- Using DER control schemes to manage export to stay within grid constraints
- DER export capacity is time-varying and location-dependent.

Single-site hosting capacity with oversized DER requires curtailing or shifting DER production.

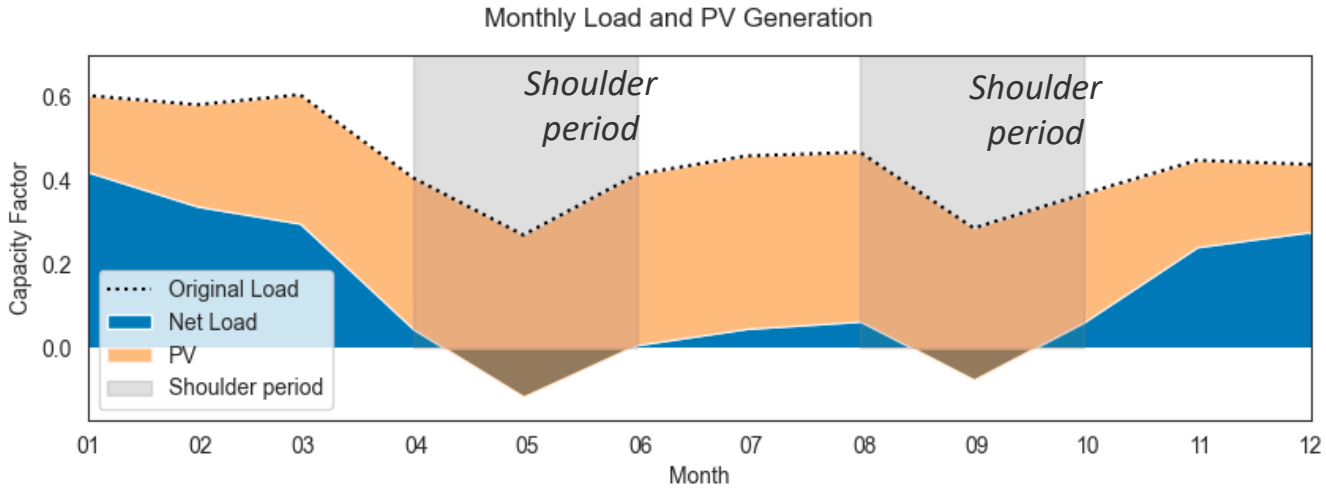


Flexible interconnection restricts DER production during limited periods.

Conventional interconnection reduces DER nameplate.

Use Cases

- Shoulder periods with low net load limit DER interconnection capacity.
- Reducing DER exports only during constrained periods provides multiple benefits:



Utility

Enhanced hosting capacity

Use of existing infrastructure

Stopgap for upgrades

More DER interconnection

DER output when needed most

More renewables and electrification

DER Customer

Revenue from faster connection

Deferral or avoidance of upgrade costs

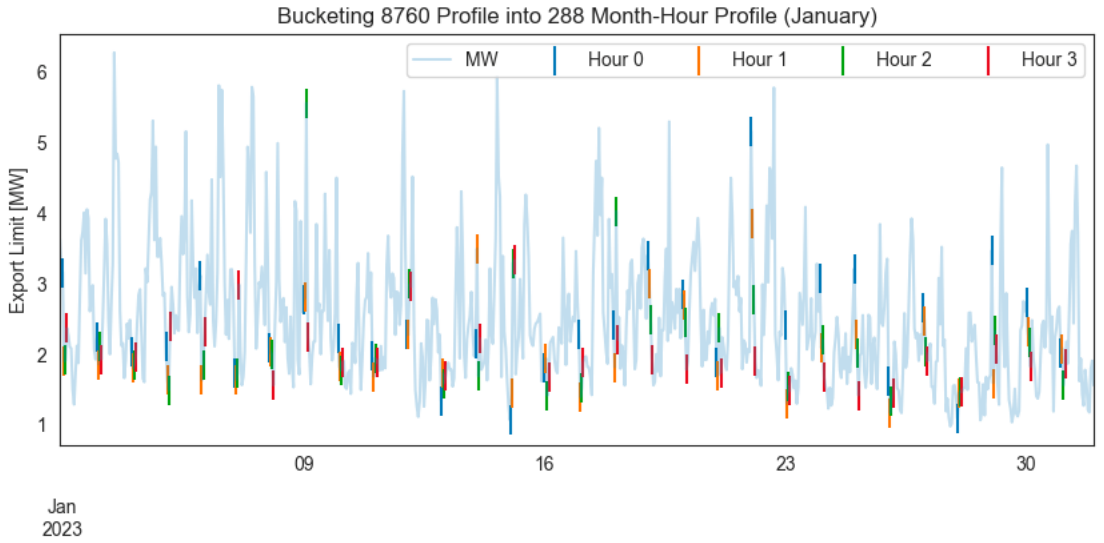
Types of Profiles

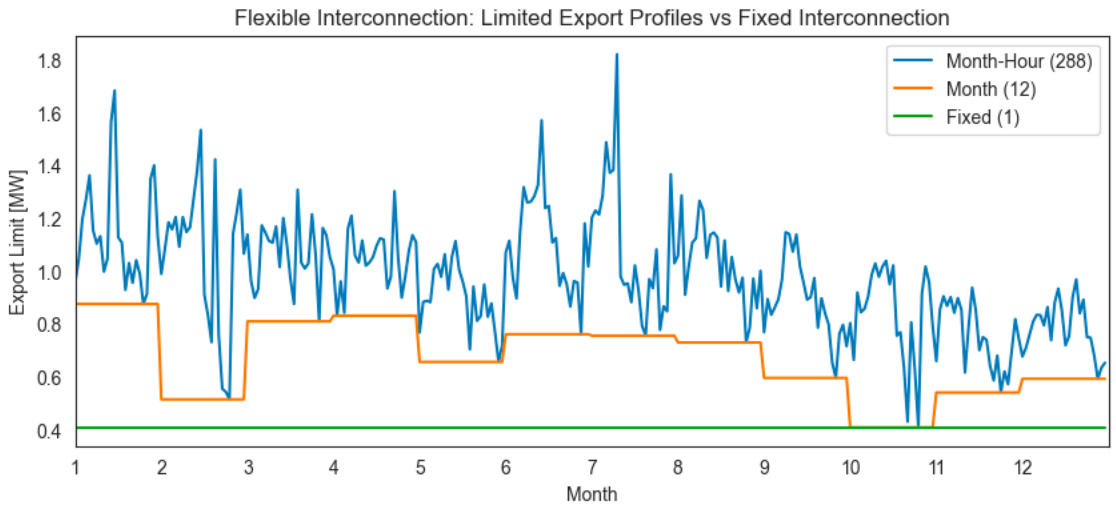
- Flexible interconnection can take the form of a schedule of DER export limits.
- Each hour of 8760 time series is bucketed into appropriate schedule hour.
  - 288-value profile: export limit per month-hour (12 x 24 = 288)
  - 12-value profile: export limit per month
- Compute export limit for each bucket with a safety buffer.

Higher-resolution profile allows for more DER export.

Lower-resolution profile has more margin of safety.

Fixed capacity results in least DER interconnected.

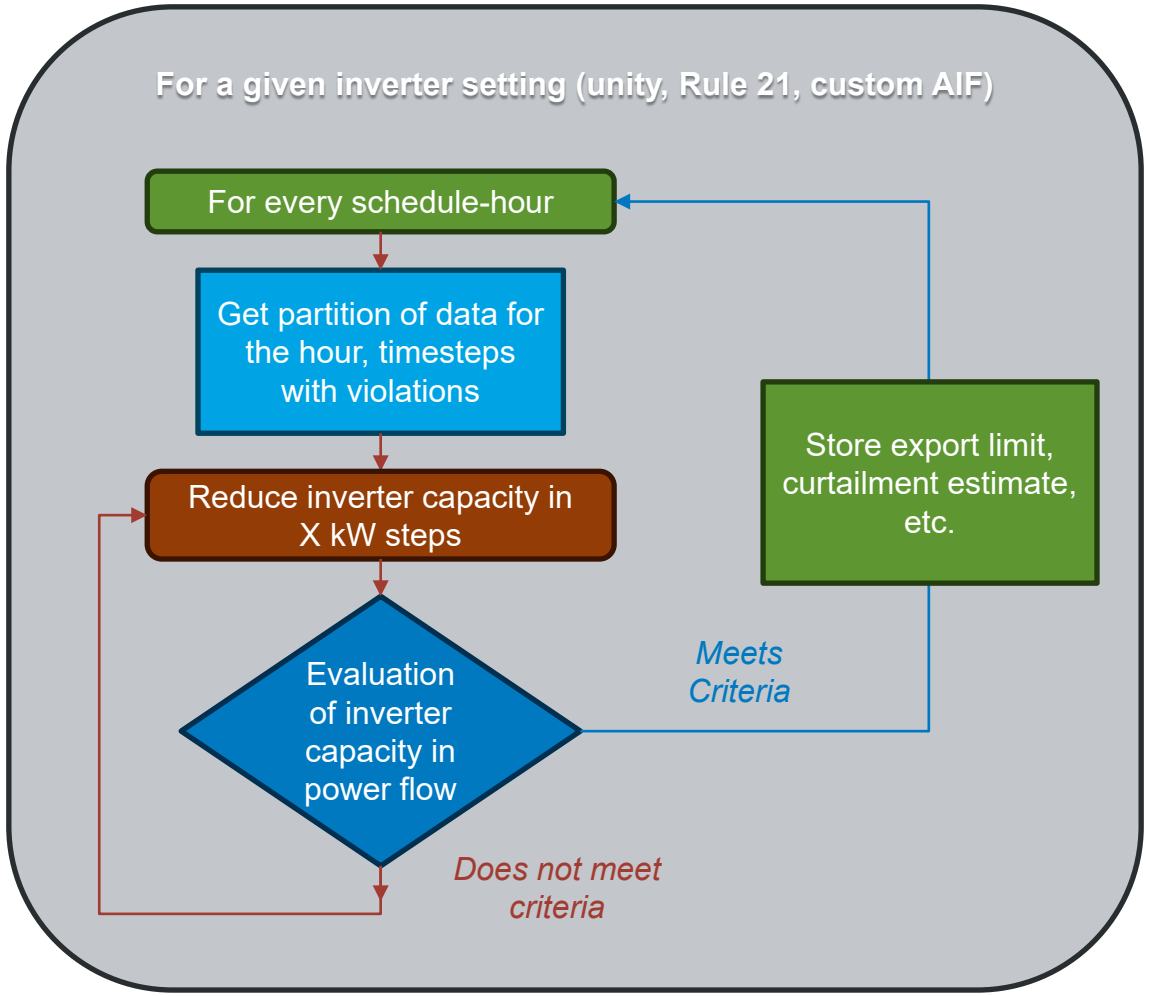




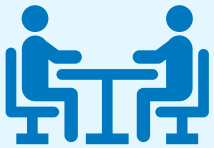
PRECISE Flexible Interconnection Workflow

- Process is started via an interconnection application and provides time-varying export bounds for their specific system
- Uses power-flow time-series simulations to determine maximum inverter capacity for each schedule hour.

Flexible interconnection evaluation process



Ready for Deployment



PRECISE is a partnership between NREL and Sacramento Municipal Utility District (SMUD).

We are looking for partners to advance the state of the art and deploy PRECISE.

PRECISE is available to license, and NREL and SMUD are interested in working with partners to expand its capabilities.

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- July 9—dsgrid: Demand-Side Grid Toolkit
- August 13—Cambium Data Sets

Thank you

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