Integrating Energy Storage and Export Limitation into Interconnection Rules

PR IX Workshop

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IREC builds the foundation for rapid adoption of clean energy and energy efficiency to benefit people, the economy, and our planet.

Regulatory Team

Mission:

Help U.S. states and territories regulate their electric utilities to ensure distributed energy resources can rapidly and equitably decarbonize the grid

Smart DER Siting

Hosting Capacity Analyses, Queue Reporting, Pre-Application Reporting

Innovative DER Integration

Smart Inverters, Energy Storage, Flexible Interconnection

Rapid Utility Approval

Model Procedures, Freeing the Grid, State Engagement

Utility Accountability

Utility Best Practices, Regulatory Compliance

Clean & Equitable Grid

Distribution Planning, Interconnection Equity, Grid Disparity

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BATRIES Project Overview

Photo by Werner Slocum/NREL 66342

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We would like to thank the Department of Energy Solar Energy Technologies Office for supporting this project.

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BATRIES Project Snapshot

OBJECTIVE

Improve the interconnection process for storage and solar-plus-storage systems by reducing soft costs and increasing efficiency

OUTCOME

A nationally-applicable Toolkit of solutions for regulators, utilities, and storage developers

To download the Toolkit, go to:

energystorageinterconnection.org

BATRIES Project Team

Limited-Export

The exporting capability of a DER whose Export Capacity is limited by the use of any configuration or operating mode [in the list of acceptable export control measures approved by the PUC]

Toolkit Definitions, p. 43

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Inadvertent Export

The unscheduled export of active power from a DER, exceeding a specified magnitude and for a limited duration, generally due to fluctuations in load-following behavior

Toolkit Definition, p. 43

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How Commissions Can Enable Export-Controlled Storage Systems

Identify Acceptable Export Control Methods

Update Screening/Study Processes to Account for Controls

Allow for System Design Changes During Review

Updating Interconnection Rules: Acceptable Export Controls

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Solution: Identify Acceptable Export Control Methods

- Rules should identify the six acceptable means
- Identify technical requirements for each type (try not to duplicate or contradict certifications)
- Be explicit that if an applicant uses one of the acceptable means there does not need to be additional customized review and that the export capacity specified should be used in the review process
- Provides interconnection customers with necessary information to design their projects before submitting an application

Types of Controls

- Relays
  - Reverse power protection (device 32R)
  - Minimum power protection (device 32F)
  - Directional power protection (device 32)

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Types of Controls

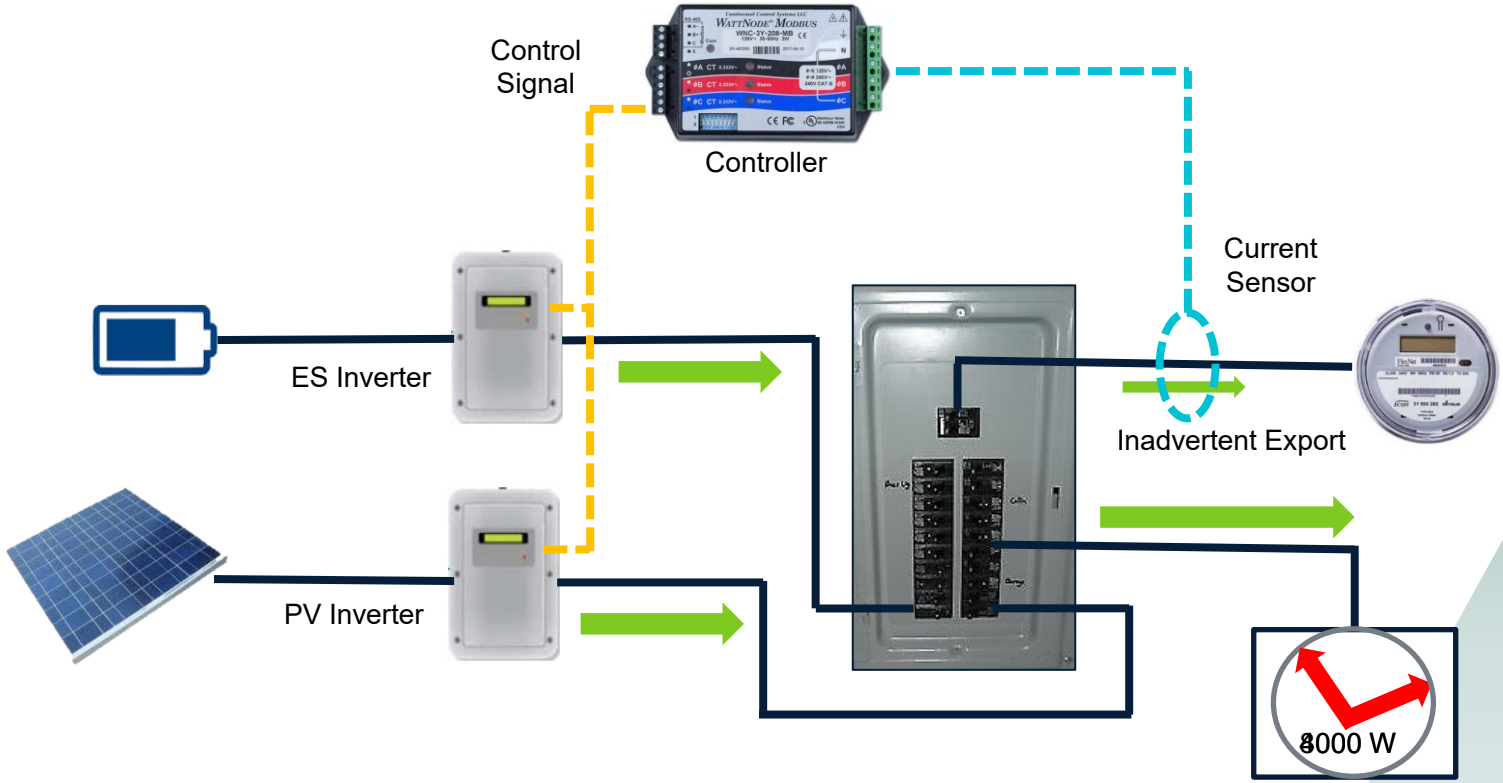
- Configured Power Rating (aka Nameplate Derating)

IEEE Std 1547-2018 Nameplate Rating Parameter Name	IEEE Std 1547-2018 Nameplate Rating Parameter Label	Configuration Setting Parameter Name	Configuration Setting Parameter Label
Active power rating at unity power factor	NP_P_MAX	Active power rating at unity power factor applied setting	NP_P_MAX-AS
Active power rating at specified over-excited power factor	NP_P_MAX_OVER_PF	Active power rating at specified over-excited power factor applied setting	NP_P_MAX_OVER_PF-AS
Specified over-excited power factor	NP_OVER_PF	Specified over-excited power factor applied setting	NP_OVER_PF-AS
Active power rating at specified under-excited power factor	NP_P_MAX_UNDER_PF	Active power rating at specified under-excited power factor applied setting	NP_P_MAX_UNDER_PF-AS
Specified under-excited power factor	NP_UNDER_PF	Specified under-excited power factor applied setting	NP_UNDER_PF-AS
Apparent power maximum rating	NP_VA_MAX	Apparent power maximum rating applied setting	NP_VA_MAX-AS

Types of Controls

- Probabilistic Methods
  - Relies on nameplate power rating of DER to be small in comparison to load at the site
  - Example: “This option, when used, requires the nameplate rating of the DER to be so small in comparison to the Local EPS minimum load, that the use of additional protective functions is not required to ensure that power will not be exported to the Area EPS. This option requires the DER nameplate rating to be no greater than 50% of the Local EPS verifiable minimum over the past 12 months”

Certified Power Control System



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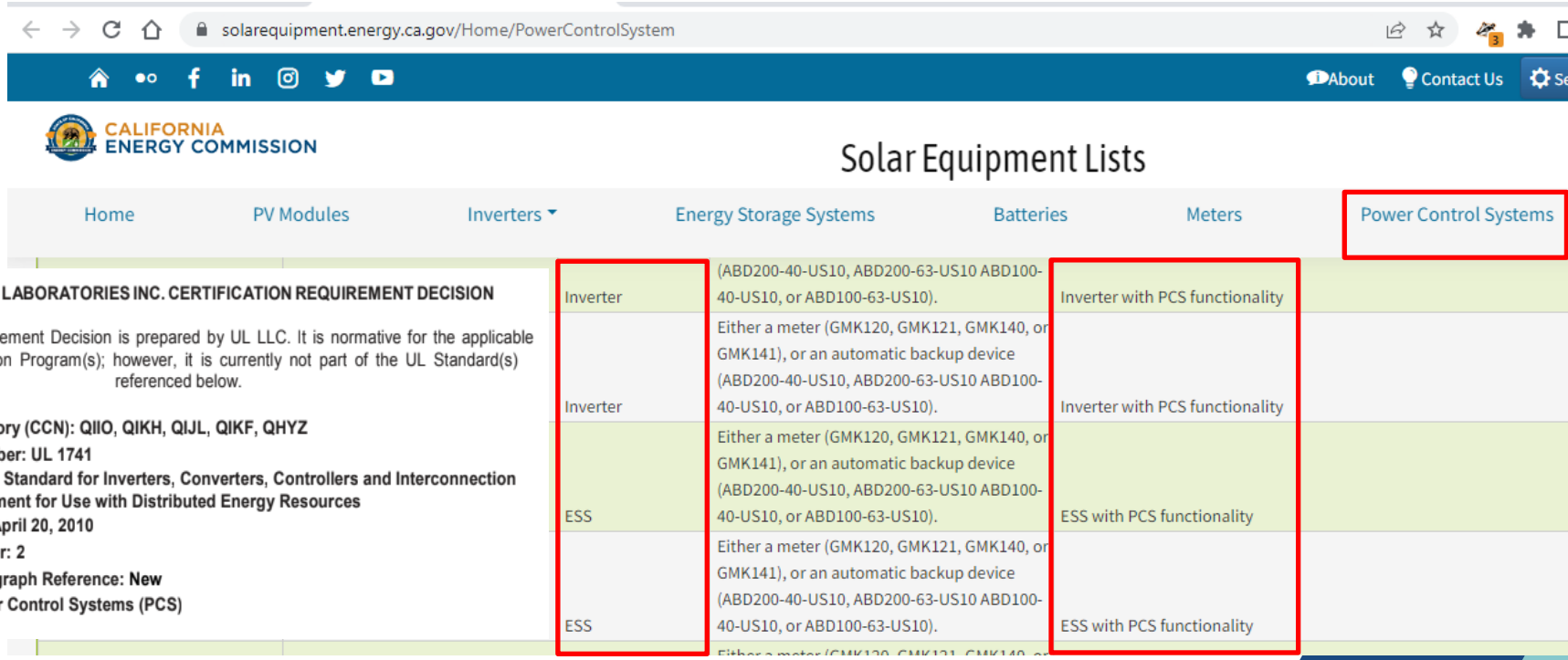
Certified Power Control Systems per UL 3141



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UNDERWRITERS LABORATORIES INC. CERTIFICATION REQUIREMENT DECISION

This Certification Requirement Decision is prepared by UL LLC. It is normative for the applicable UL Product Certification Program(s); however, it is currently not part of the UL Standard(s) referenced below.

Product Category (CCN): QIIO, QIKH, QIJL, QIKF, QHYZ
Standard Number: UL 1741
Standard Title: Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use with Distributed Energy Resources
Edition Date: April 20, 2010
Edition Number: 2
Section / Paragraph Reference: New
Subject: Power Control Systems (PCS)

Inverter	(ABD200-40-US10, ABD200-63-US10 ABD100-40-US10, or ABD100-63-US10).	Inverter with PCS functionality
Inverter	Either a meter (GMK120, GMK121, GMK140, or GMK141), or an automatic backup device (ABD200-40-US10, ABD200-63-US10 ABD100-40-US10, or ABD100-63-US10).	Inverter with PCS functionality
ESS	Either a meter (GMK120, GMK121, GMK140, or GMK141), or an automatic backup device (ABD200-40-US10, ABD200-63-US10 ABD100-40-US10, or ABD100-63-US10).	ESS with PCS functionality
ESS	Either a meter (GMK120, GMK121, GMK140, or GMK141), or an automatic backup device (ABD200-40-US10, ABD200-63-US10 ABD100-40-US10, or ABD100-63-US10).	ESS with PCS functionality

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Updating Interconnection Rules: Evaluating Export-Controlled Systems

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What is the Project Size? Two New Definitions

- **Export Capacity** means the amount of power that can be transferred from the DER to the Distribution System. Export Capacity is either the Nameplate Rating, or a lower amount if limited using an acceptable means identified in [New Export Controls Section]
- **Nameplate Rating** means the sum-total of maximum rated power output of all of a DER's constituent generating units and/or ESS as identified on the manufacturer nameplate, regardless of whether it is limited by any approved means
  - If no export controls are used, Nameplate Rating = Export Capacity

Toolkit Definitions, p. 44

Chapter IV: Evaluation of Non-Export and Limited-Export Systems During the Screening / Study Process

Challenge

Evaluating non- and limited-export systems based on unrealistic operating assumptions can lead to overestimated grid impacts

Solution

- Identifies screens in which Export Capacity is appropriate for impact assessment (instead of Nameplate Ratings)
- Use a new Inadvertent Export Screen

Chapter IV: Evaluation of Non-Export and Limited-Export Systems During the Screening / Study Process

Screens in which Export Capacity is appropriate to evaluate impacts

- Fast Track Eligibility Size
- Penetration Screens
- Shared Secondary Transformer Screen
- Inadvertent Export Screen (new)

Screens in which Nameplate Ratings can still be used

- Spot Network Screen
- Protection Screens (Max. Fault Current & Short Circuit Interrupting Capability)
- Single-phase Imbalance Screen
- Transient Stability Screen

Penetration Screens

What are the Penetration Screens

- Refers to the 15% of peak load and 100% of min load screens
- Used in the Fast Track process (initial review and supplemental review)
- The 15% of peak load was set over 20 years ago
  - Designed as a conservative estimate or proxy for min load
  - At that time most utilities only recorded peak load
- As utilities started collecting min load data
  - Regulators added the 100% of min load in supplemental review
  - Today some states use 100% of minimum load in both initial and supplemental review

Penetration Screens

What are they designed to achieve?

- Evaluate generation that could cause reverse power flow
- When generation < min load, reverse power will not occur

But what happens when load is reduced?

- Non-Export projects can affect load (reduce min load)
- This is addressed in the review process through the min/peak component of the screen

Why is Export Capacity appropriate to use here?

- Using export controls, the export capacity is what contributes to the reverse power flow, not the nameplate rating

Penetration Screens

Redline of SGIP Screen 2.2.1.2:

For interconnection of a proposed DER ~~Small Generating Facility~~ to a radial distribution circuit, the aggregated Export Capacity ~~generation~~, including the proposed DER ~~Small Generating Facility~~, on the circuit shall not exceed 15 % of the line section annual peak load as most recently measured at the substation. A line section is that portion of a ~~Transmission~~ Distribution Provider's electric system connected to a customer bounded by automatic sectionalizing devices or the end of the distribution line.

Redline of SGIP Screen 2.4.4.1:

…Where 12 months of line section minimum load data (including onsite load but not station service load served by the proposed DER ~~Small Generating Facility)~~ are available, can be calculated, can be estimated from existing data, or determined from a power flow model, the aggregate Export Capacity ~~Generating Facility capacity~~ on the line section is less than 100% of the minimum load for all line sections bounded by automatic sectionalizing devices upstream of the proposed DER~~Small Generating Facility~~…….

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Inadvertent Export Basics

- Non- or limited-export DERs may, in certain conditions, inadvertently output small amounts of power to the grid for short durations of time
- Inadvertent export is distinct from normal export and should be reviewed differently to avoid overstating impacts

PCS and Inadvertent Export Safety

- Supported by history of use
  - HI since 2015
  - CA since 2016
  - Multiple other states adopted export control since: IL, MA, ME, MD, MI, MN, NJ, NM, NV, OR (and expanded to scheduling in CA)
- Supported by UL Standard 3141
  - Includes failure evaluation (fail-safety)
  - Restricted access to settings

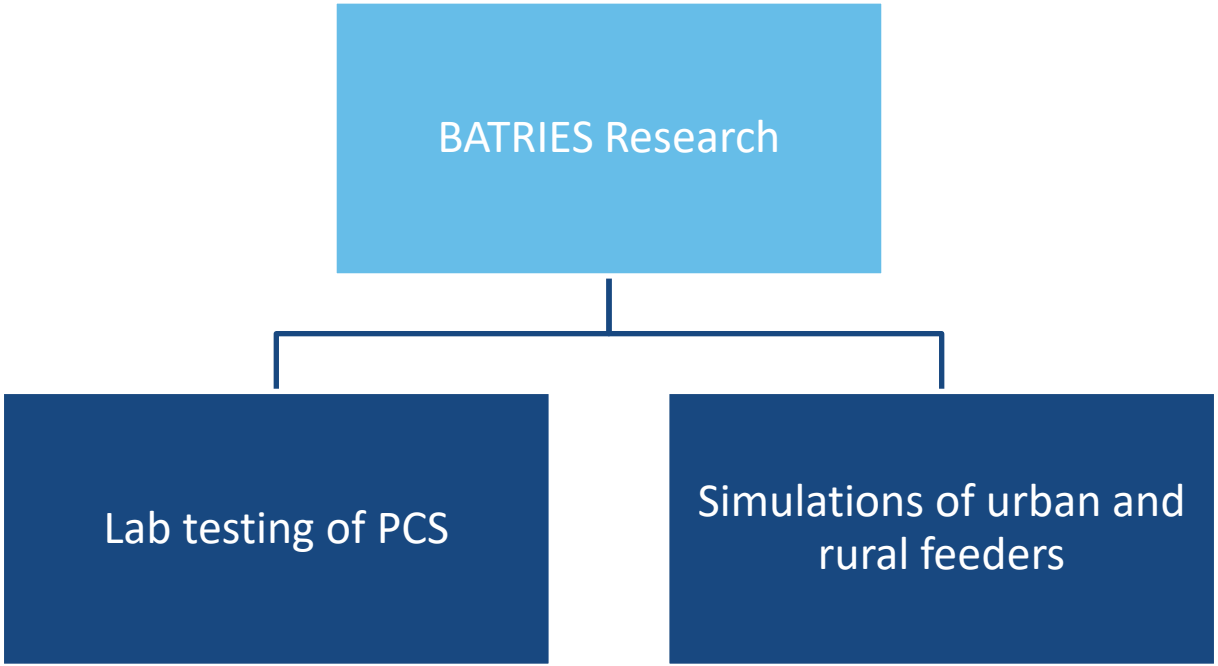
PCS and Inadvertent Export Safety

- Supported by NEC for conductor/bus overload protection
  - Allows 30s IE for fire safety
- Amount of IE at ~2600% Export Capacity to minimum load ratio is not dangerous for conductors
  - Emergency/overload rating is at least 600% of the current rating for 30 seconds and at least 800% for 15 seconds.
  - Overload ratings for most conductors, including smaller insulated cables, are over 300% for 100 seconds and over 1000% for 10 seconds.

PCS and Inadvertent Export Safety

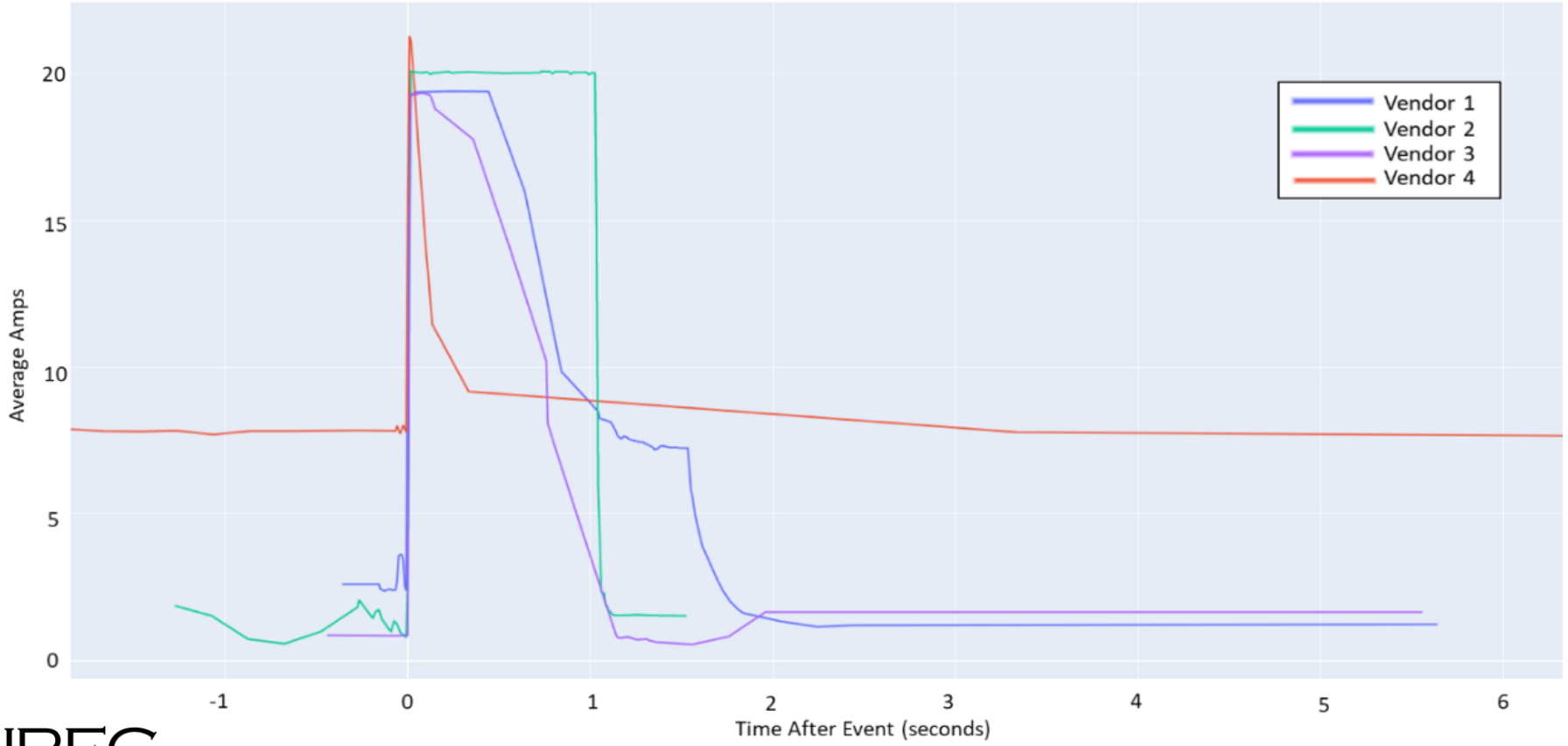
- Supported by research
  - ERPI modeling showed significant nameplate rating additions of non-export DER before IE voltage issues can arise under worst-case scenarios (BATRIES report)
  - PNNL *Evaluating the Thermal Impacts of Inadvertent Export on Service Transformers* (Oct 2024) found little concern for transformer lifetime impact: “the thermal impacts of inadvertent exports are largely negligeable “

Defining how to Address Inadvertent Export



Chapter V of the Toolkit includes a detailed discussion this Research

Inadvertent Export Power Control System Testing



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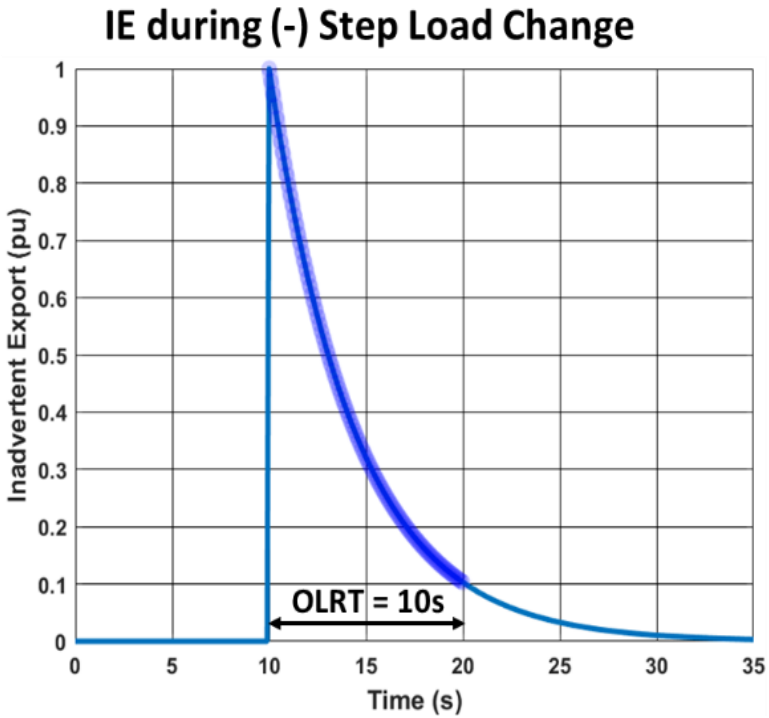
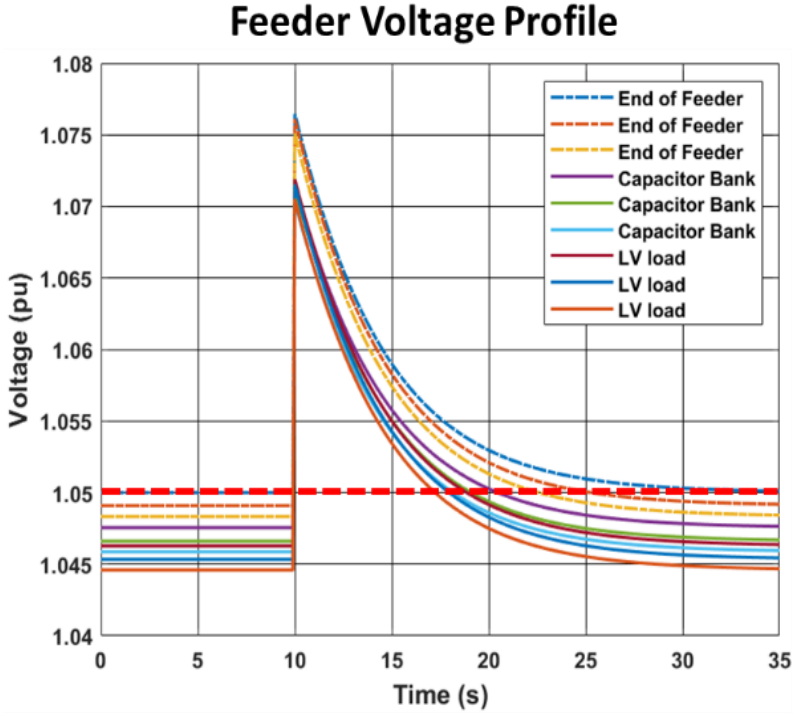
Maximum IE with 100% coincident





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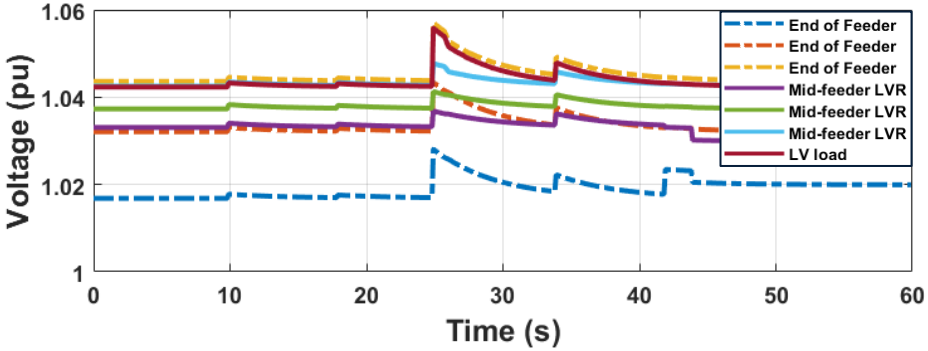
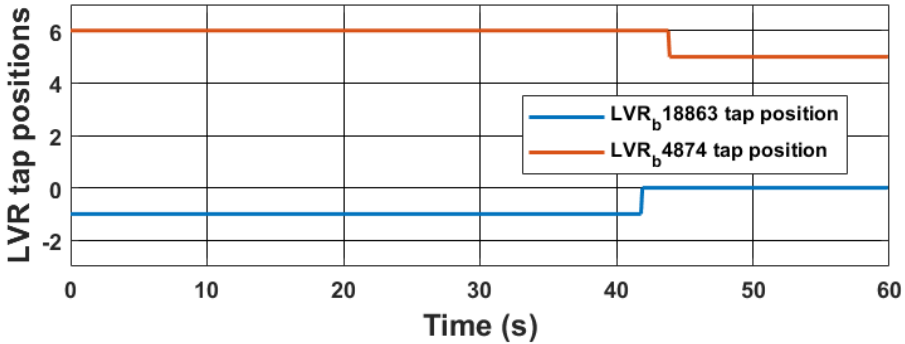
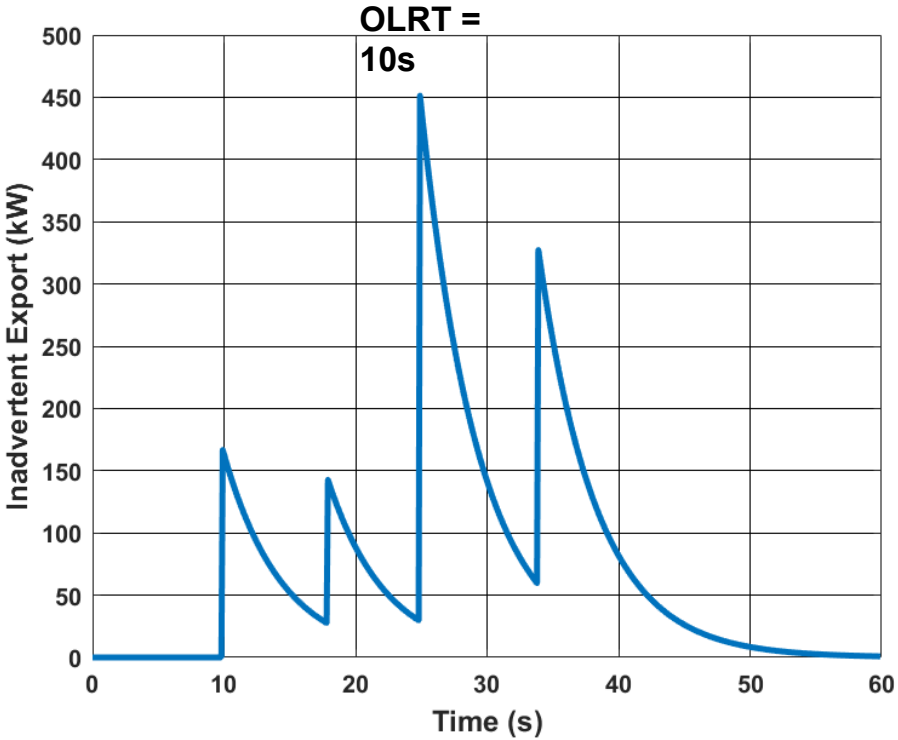
Case 3: LTC Tap Change







Total of 2 LVR operations

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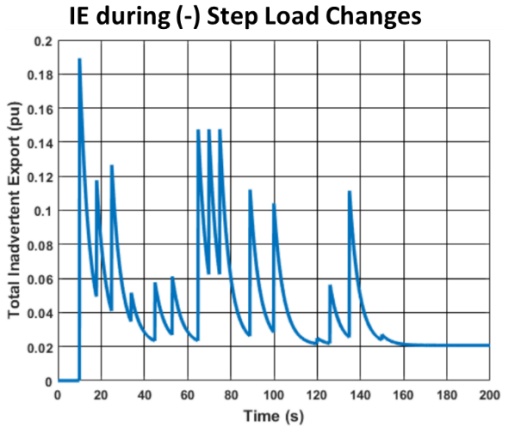
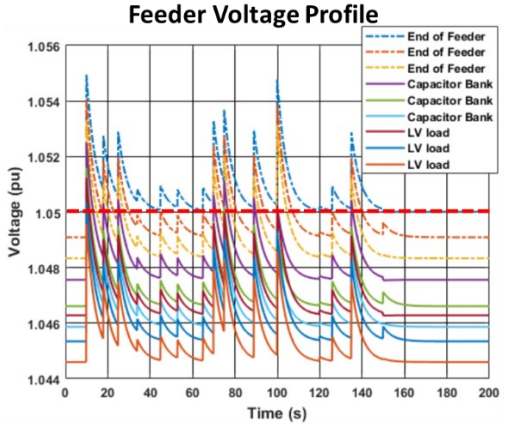
Evaluation of IE; Urban Feeder Results max in 200s

Cases	OLRT (s)	Load (MW)	Exporting Solar PV (MW)	Export-Controlled Storage (MW)	Steady-State Voltage Rise	Steady state plus short-term Voltage Peak	
						Max Coincident	Max During 200s Period
1	NA	0.65 min	0.65	0	103.0%	NA	NA
2	NA	0.65	2.9	0	105.0%	NA	NA
3	30	0.65	0.65	0.65	103.0%	103.7%	103.2%
4	10	0.65	0.65	1.85	103.0%	105.0%	103.3%
5	30	0.65	0.65	1.92	103.0%	105.0%	103.4%
6	10	0.65	2.46	2.46	104.7%	107.0%	105.0%
7	30	3.2 max	2.9	2.9	101.7%	105.2%	102.7%
8	30	0.65	2.9	2.9	105.0%	107.6%	105.5%





Cases	OLRT	Min Load (MW)	Exporting Solar PV (MW)	Export-Controlled Storage (MW)	Nameplate DER (MW)*	Steady-State Voltage Rise (pu, RMS)	Steady State plus Short-term Voltage in RMS**
							Max RMS Rise: 60s Period
1	30s	5.92	5.92	0.46	6.38	104.4%	106%
2	10s	5.92	5.92	0.486	6.41	104.4%	105%
3	30s	5.92	1.37	1.37	2.74	103.7%	106%
4	10s	5.92	1.46	1.46	2.92	103.8%	105%
5	30s	5.92	5.92	5.22	11.14	105.0%	111.1%
6	10s	5.92	5.92	5.22	11.14	105.0%	110.8%

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Summary of Research Findings from Chapter V of the Toolkit

1. Testing indicates that open loop response times in several PCS products are significantly faster than 30 seconds (typically 2-10 seconds)
2. Feeders can host more DER capacity if the DER is export-limited.
3. DER capacity on the urban feeder could be doubled with export limiting compared to steady export.
4. The rural feeder's capacity for inadvertent export is very location dependent.

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New Inadvertent Export Screen

2.2.1.3 For interconnections that can introduce Inadvertent Export (IE)* greater than 250 kW. The IE should not cause a change in medium voltage exceeding 3%. Voltage change will be estimated applying the following formula:

Formula	$\frac{(R_{SOURCE} \times \Delta \boldsymbol{P}) - (X_{SOURCE} \times \Delta \boldsymbol{Q})}{V^2}$

Where:

$\Delta \boldsymbol{P}$ = (DER apparent power Nameplate Rating – Export Capacity) × PF,

$\Delta \boldsymbol{Q}$ = (DER apparent power Nameplate Rating – Export Capacity) × $\sqrt{(\mathbf{1} - \boldsymbol{PF^2})}$,

R_{SOURCE} is the grid resistance, X_{SOURCE} is the grid reactance,

V is the grid voltage, PF is the power factor

* Calculated IE as the nameplate rating – export capacity

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Updating Interconnection Rules: Changing System Design to Add Storage

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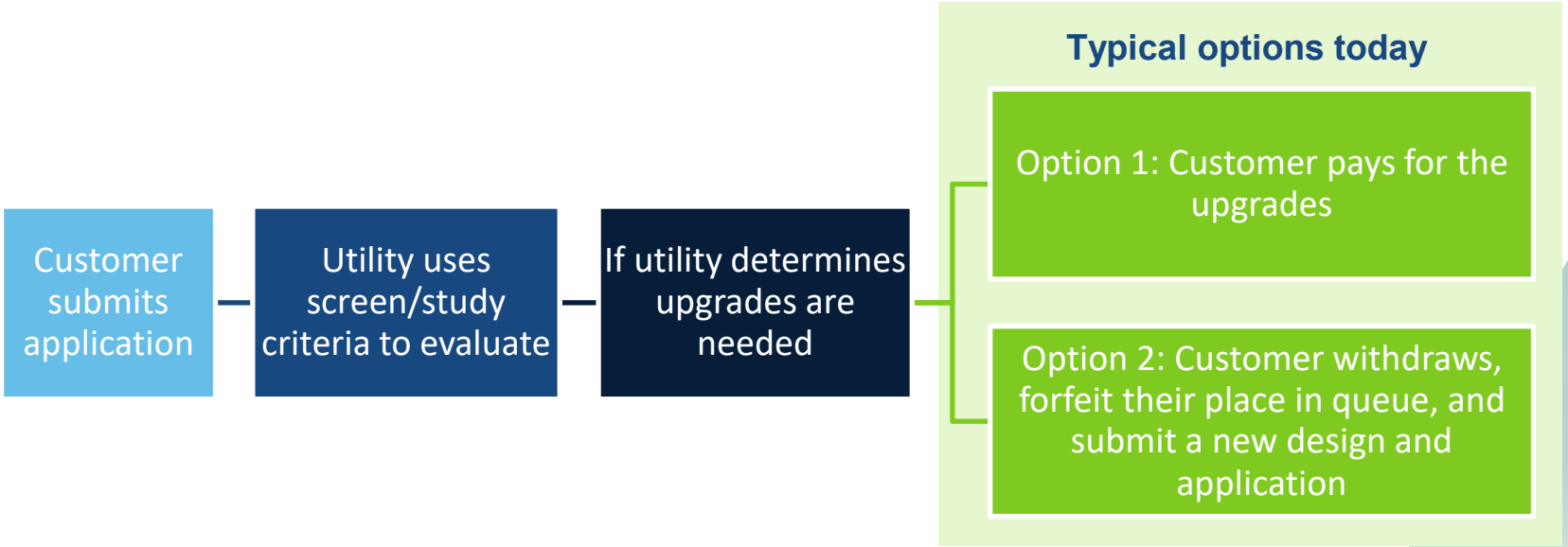
Current Process for Changing System Design During Interconnection Review



Most states rules don't include provisions for system design changes i.e., There is no place to allow for potential design changes to address screen results failure (We need **Option 3**)

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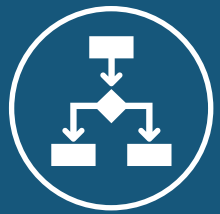
Solution: Allow for System Design Modifications During the Review Process

SCREENING RESULTS SHOULD INCLUDE RELEVANT & USEFUL DATA



IMPACT STUDY RESULTS SHOULD INCLUDE ANALYSIS OF ALTERNATE OPTIONS

ALLOW FOR SYSTEM MODIFICATIONS DURING THE REVIEW & STUDY PROCESSES

How to enable design changes during review – Sample results

Sample Penetration Screen Result:

Example: An Ideal 15% Screen Result

For interconnection of a proposed DER to a radial distribution circuit, the aggregated Export Capacity, including the proposed DER, on the circuit shall not exceed 15% of the line section annual peak load as most recently measured. A line section is that portion of a Distribution Provider's electric system connected to a customer bounded by automatic sectionalizing devices or the end of the distribution line.

Export Capacity of DER Application		kW
Export Capacity of Active DER on Feeder		kW
Export Capacity of DER ahead in Queue		kW
15% of Peak Load		kW
Aggregate Export Capacity, Including Proposed DER		kW
Export Capacity of DER, as % of Load		%
Passes Screen	No	

Sample Detailed Study Result:

Upgrade Required	Option 1 X MW	Option 2 X MW @ 99% PF	Option 3 0.8*X MW	Failures Addressed
3VO Installation	$ 600,000	$ 600,000	$ 0	Overvoltage Transmission System Fault
Load Tap Changer Bi-Directional Co-Generation Capability	$ 0	$ 0	$ 30,000	Substation Regulation for Reverse Power
Supervisory Control and Data Acquisition (SCADA) With Direct Transfer Trip	$ 120,000	$ 120,000	$ 120,000	Unintentional Islanding
Existing Utility Recloser Upgrade	$ 60,000	$ 60,000	$ 60,000	Unintentional Islanding
Upgrade Voltage Regulator Controls	$ 15,000	$ 0	$ 0	High Voltage
Total	$ 795,000	$ 780,000	$ 210,000	

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To download the Toolkit, go to:

energystorageinterconnection.org

If you have any questions, contact:

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