Strategies for Improving Technical Screens

GMLC Interconnection Cohort Workshop #3

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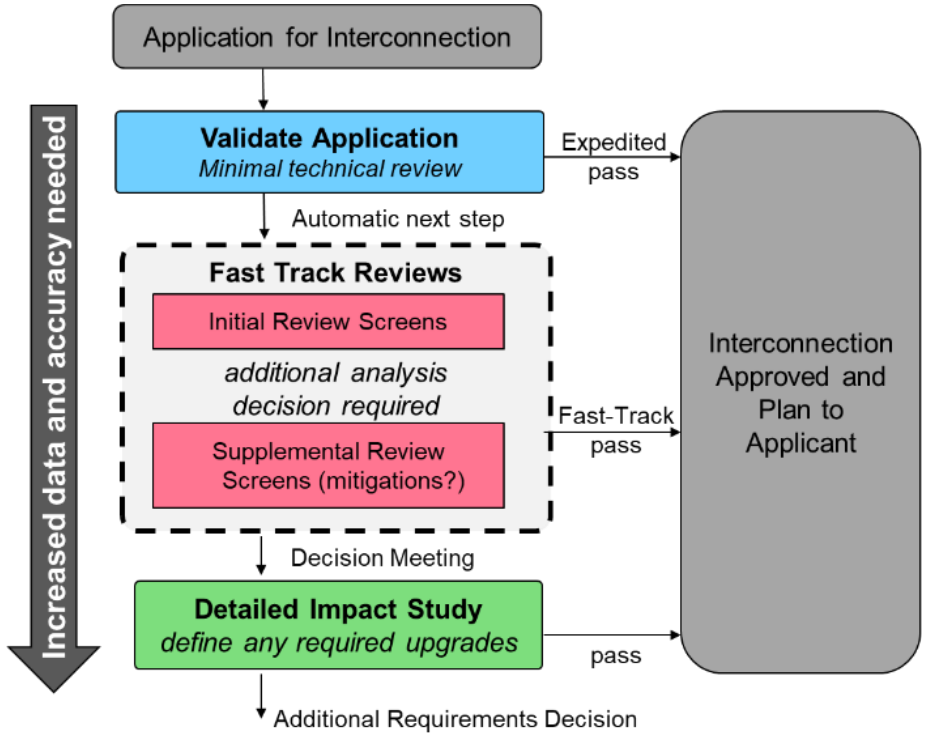
Agenda

- History & Background: Screens
- Motivations to Evolve Procedures
- Suggested Improvements to Screens (and beyond)
- Conclusions and Future Directions

Existential Questions

- Increasing levels of DER interconnections resulting in more applications going to detailed study review
- New technologies require modification to existing methods to properly assess potential impact

- How can initial/supplemental reviews be improved?
- What data and modeling approaches can be incorporated?
- Can automation be integrated into the review process?



History & Background: Screens

Developments in Interconnection Processes & Technical Review

Timeframes	DER Development Period	Status of Technical Review
1978 to 1999	Beginning of commercial renewables era	Mostly manual reviews, several early IEEE DER Guides, review screens added to CA Rule 21 in 1999*.
2000 to 2012	Incentives and market growth (increasing renewables system sizes and deployments)	Distribution grid support limited by IEEE 1547-2003; FERC-SGIP** 2005 creates "fast track" review and more visibility on screening criteria and process review times.
2013 to 2021	Cost competitiveness (Renewables – mostly PV and wind – becoming economically viable)	Growing pressure from PUCs to streamline processes, track review times, and add application portals; IEEE 1547a-2014 allows, then IEEE 1547-2018 requires, grid support.
2022 forward	Proliferating solar and battery storage with smart inverters	Automation expected, DER grid support capacities and penetration levels will need to be considered.

*Notes: *Electric Rule 21 formalized technical concerns into a predefined set of screens, offering a path to simplified connection. **FERC's SGIP, defined processes of technical screening, the "fast track" concept, and types of studies including decision points in reviews. Its requirements are very similar to CA Rule 21.*

History & Background: Screens

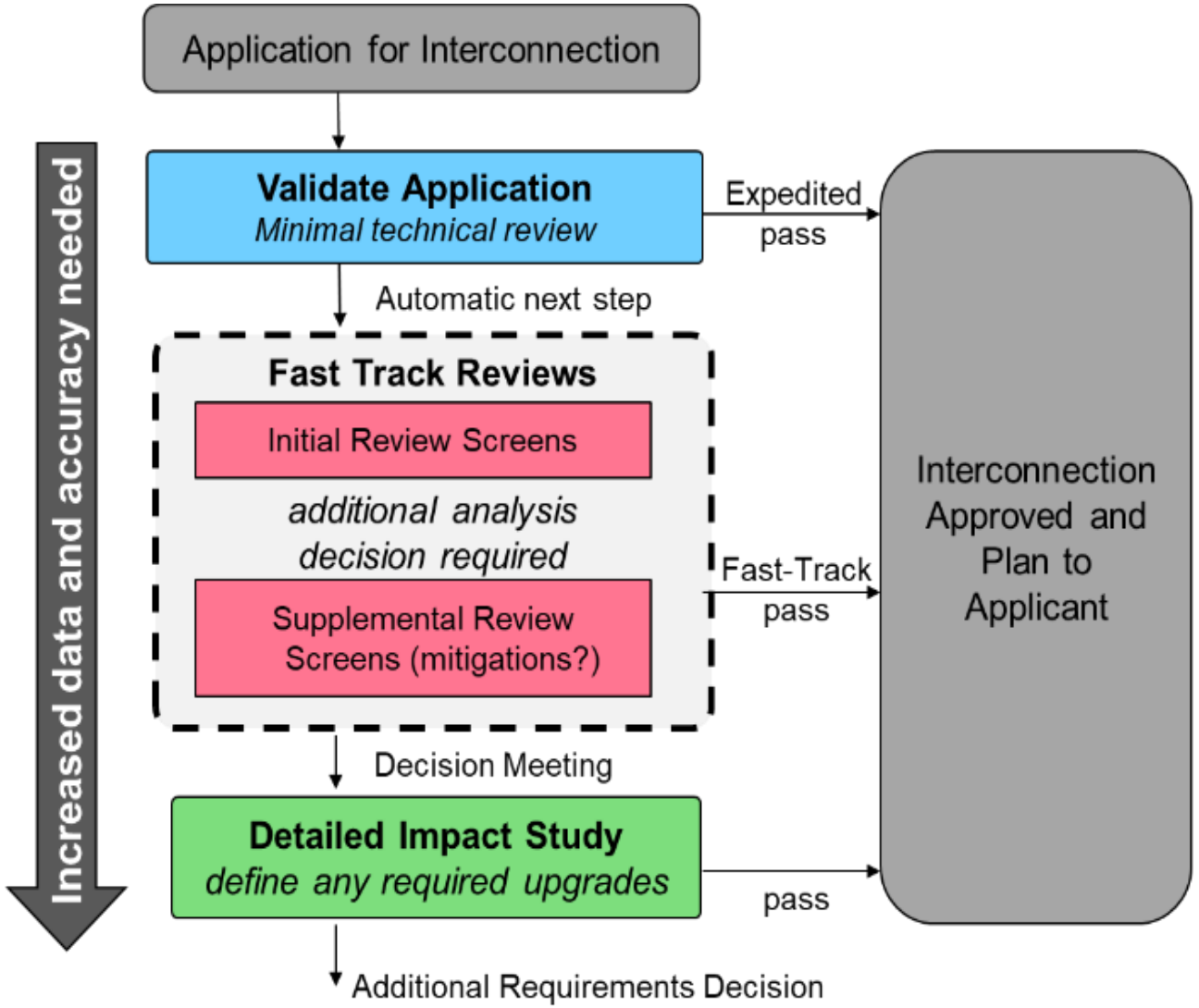
The Evolving Distribution Interconnection Process

- **CA Rule 21** (evolving since **1999**, regularly updated)
- **FERC SGIP** (established in **2005**, *the Small Generator Interconnection Procedure*, 13 screens, study type defined, "transmission" viewpoint)
- **MN, NY, NC/SC, MI, NM**, others following the SGIP Fast Track review model.
  - *Typical issues: 15% peak/100% min load capacity[1], screening criteria[2], hosting capacity[3], export limiting[4], power quality[5] and protection[6].*

[1] Alternatives to the 15% Rule: Modeling and Hosting Capacity Analysis of 16 Feeders, EPRI 2015
[2] Model Interconnection Procedures, IREC 2019
[3] Defining a Roadmap for Successful Implementation of a Hosting Capacity Method for New York State, EPRI 2016
[4] Considerations for Application of Export Limiting Power Control Systems, EPRI 2020
[5] DER Power Quality Issues, EPRI 2018
[6] On Good Behavior: Inverter-Grid Protections and Integrating Distributed Photovoltaics, IEEE PES Nov/Dec 2020

History & Background: Screens

Key Characteristics of Technical Review (modeled after SGIP)

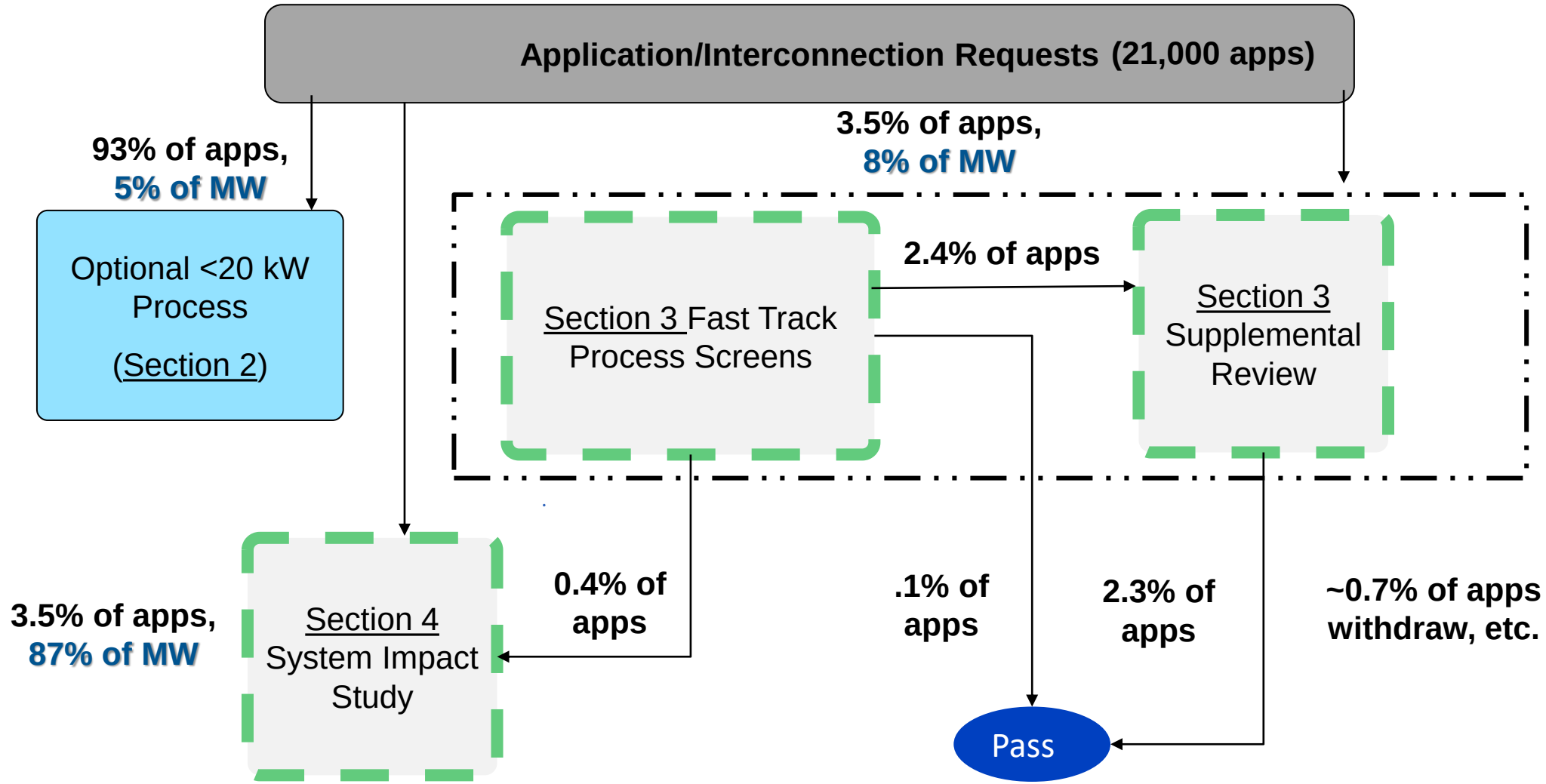


Three (3) Review Levels

1. 10-kW Inverter Process
   - DER type, location, size, service type
2. Fast Track Process (Screens /Supplemental Review)
   - Aggregate load/gen, system grounding, voltage, SC ratio
   - Min load, protection, PQ, safety/reliability
3. Study Process (Impact Studies)
   - Load flow, short circuit, thermal capacity, more PQ and protection

Interconnection Applications and Fast Track in NC/SC

Summary of DG applications NC/SC DEP/DEC May 2015- Aug. 2019



History & Background: Screens

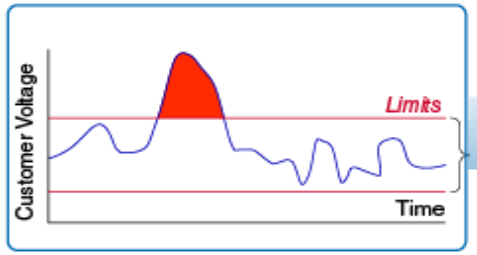
Current Practices for DER Interconnection

DER, Site and Connection Details

- DER size and type
- Grid location, feeder and service
- Transformer connection, grounding and back feed

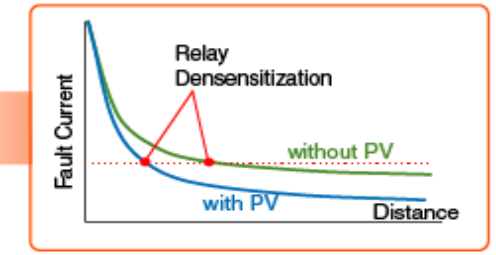
Technical Issues

Voltage



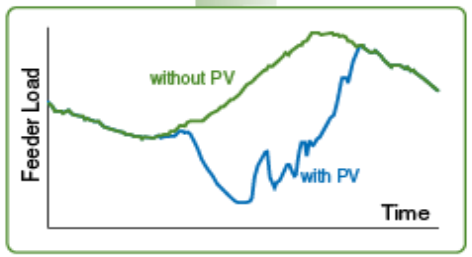
- Voltage regulation, limits balance, drop and rise
- Power Quality (flicker, harmonics, overvoltage)

Protection/Reliability



- Risk of islanding
- Short circuit contribution
- Ground fault OV (3Vo)
- Relay coordination

Capacity



- Thermal limits, overload, service capacity on primary and secondary
- Minimum stiffness ratio

Fast Track Technical Review Criteria I (ref. SGIP/IEEE)

Technical Considerations	Specific Technical Issue	FERC SGIP Section	Applies to	Typical Limits or Criteria	IEEE 1547-2018
basic	skip fast track option	new option	individual	varies	-
basic	qualifies for fast track	2.1	individual	<2MW	-
basic	expedited - no screening required	new option	individual	varies <50kW	-
basic	check service available	2.2.1.1	individual	yes	-
export limit	export control of power	add	individual	ΔV<3%	4.6.2
protection	15% of peak load (islanding)	2.2.1.2	aggregate	15-30%	8.1
export limit	if secondary/spot network	2.2.1.3	individual	5% or 50kW	9.2
protection	short circuit contribution	2.2.1.4	aggregate	90%/10%	11.4
protection	interrupting capability	2.2.1.5	aggregate	88%	6.2
protection	feeder GFO/ineffective grounding	Rev 2.2.1.6	individual	varies	4.12
thermal	shared secondary ratings exceeded	2.2.1.7	aggregate	20kW 65%	-
voltage	secondary imbalance	2.2.1.8	individual	20%	-
backfeed	transient stability limits	2.2.1.9	aggregate	>10MW	-
thermal	no construction required	2.2.1.10	aggregate	yes/no	-

Fast Track Technical Review Criteria II (ref. SGIP/IEEE)

Technical Considerations	Specific Technical Issue	FERC SGIP Section	Applies to	Typical Limits or Criteria	IEEE 1547-2018
protection	100% of minimum load	2.4.4.1	aggregate	100%	8.1
voltage/PQ	within ansi limits	2.4.4.2	both	load flow	5.1
PQ	flicker	2.4.4.2	individual	Pst<.35	7.2.2
PQ	RVC	add 2.4.4.2	aggregate	MV-3%, LV-5%	7.2.3
voltage/PQ	short circuit ratio/PCC stiffness	new option	individual	20 times	-
PQ	harmonics	2.4.4.2	individual	I_{THD}<5%	7.3
PQ	LRO and GFO	add 2.4.4.2	individual	138% Vl-g or l-l	7.4.1
PQ	TOV	add 2.4.4.2	individual	p.u. 1.3 to 2.0	7.4.2
voltage	regulating equipment	add 2.4.4.2	both	.5-1.5%	-
safety-reliability	safety	2.4.4.3	aggregate	1547	4.6.2
protection	coordination	3.4	aggregate	hosting	-
protection	breaker reach	3.4	aggregate	min/max	-
protection	Substation GFO & 3V0	3.4	aggregate	sub upgrade	-
backfeed	backfeed limit/reverse power relay	3.5	individual	varies	-

Comparison of Voltage-related Screens

Requirements	CA Rule 21	FERC SGIP	MN[2]	NY SIR[1,2]	IEEE 1547[5]
Preliminary and Initial Screening Reviews					
% Peak Load limit_	15% (M)[4]	15%[4]	15% & 30%[4]	15% (E) [4]	N/A
1Φ/240V Service_ Unbalance limit_	Yes (E)	<20kW and <20%$_{Unbalance}$	<65%$_{Rated}$ <20%$_{Unbalance}$	None	N/A
Starting ΔV limit_	2.5/5% (C)	N/A	N/A	N/A	3%/5%
Stiffness Ratio limit_		N/A	N/A	$(V^2/R_s)/I_{DER}$>50 (F)[4]	N/A
Supplemental Screening Review					
% Min Load limit_	100% (N)[4]	100%[4]	100%[4]	100% (G)[4]	N/A
V_{REG} limit_	CA Rule 2 (O)[4]	no	1.5/3/5%[4]	MV-3%,LV-5% (H)[4]	N/A
RVC limit_	Yes (O)[3]	Yes[3]	MV-3%, LV-5%	IEEE1547 (H)[5]	MV-3%, LV-5%
Flicker limit_	Yes (O)[3]	Yes[3]	Yes[3]	IEEE1547 (I)[5]	P_{st}<.35
Distortion limit_	IEEE 519 (O)	IEEE 519	IEEE 519	IEEE1547[5]	I_{THD}<5%

1 Proposed by EPRI to NYSERDA and NYDPS to be considered, March 2018
2 Screening requirements currently under revision in these jurisdictions
3 Refers to IEEE 1453 for planning, assessment and measurement practices (with no individual DER limits)
4 Limits apply to both individual and aggregate DER
5 Refers to new limits in IEEE 1547, these address individual DER effect on voltage.

Motivations to Improve Review Procedures

Utility Perspectives

Compliance with IEEE Std 1547-2018 – Recognizing DER as grid supporting devices

Increasing number of applications – many under-prepared to handle high volumes

Low staffing – increasing number of applications w/higher penetrations requiring study

Improved hosting capacity allocation required – essential for informing utility decision-making

Protection issues and suggested mitigation options – frequently challenged due to cost

Complicating battery applications – new questions arising re: load/gen, scheduling, export control

Insufficient data and models – enhanced modelling capability is most common challenge

Motivations to Improve Review Procedures

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IEEE 1547 Raising Expectations for DER: Requiring Grid Support Functions

IEEE 1547-2003

- **Shall NOT** actively regulate voltage
- **Shall** trip on abnormal voltage/frequency

IEEE 1547a-2014
(Amendment 1)

- **May** actively regulate voltage
- **May** ride through abnormal voltage or frequency
- **May** provide frequency response

IEEE 1547-2018

- **Shall be capable of** actively regulating voltage
- **Shall** ride through abnormal voltage/frequency
- **Shall be capable of** frequency response

IEEE 1547a-2020

- **More flexibility** for configuration of the **degree to which** the Category III voltage ride-through **capability may be utilized**

Smart Inverters can support grid (set up challenge)

IEEE STANDARDS ASSOCIATION IEEE

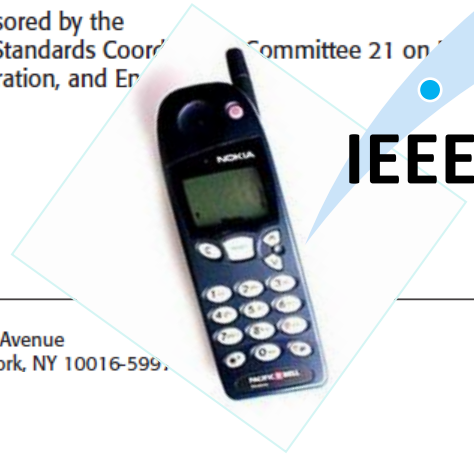
IEEE Standard for Interconnection and Interoperability of Distributed Energy Resources with Associated Electric Power Systems Interfaces

IEEE Standards Coordinating Committee 21

Sponsored by the
IEEE Standards Coor… Committee 21 on …s, Photovoltaics, Dispersed Generation, and En…

IEEE
3 Park Avenue
New York, NY 10016-599…

IEEE Std 1547™-2018
(Revision of IEEE Std 1547-2003)



IEEE 1547-2003

IEEE 1547a-2014

IEEE 1547-2018

Interconnection Standards are requiring grid support functions

Role of IEEE Std 1547-2018

IEEE Std 1547-2018

DERs

- Defines and Standardizes "smart DERs" across the industry
- All DER not just inverter based!

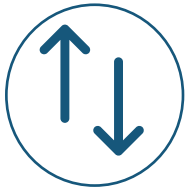
TECHNICAL

- Technical basis for regulatory proceedings
- Can be flexibly adjusted to regional differences
- Widely-accepted by industry

VALUE

- Avoid lengthy discussions with stakeholders
- Avoid specifying technical requirements
- Account for regional differences (flexibility)
- Accelerate regulatory proceedings
- Mitigate technical risks

Energy Storage: Recognizing Flexibility in Interconnection



Can serve as both generation and load

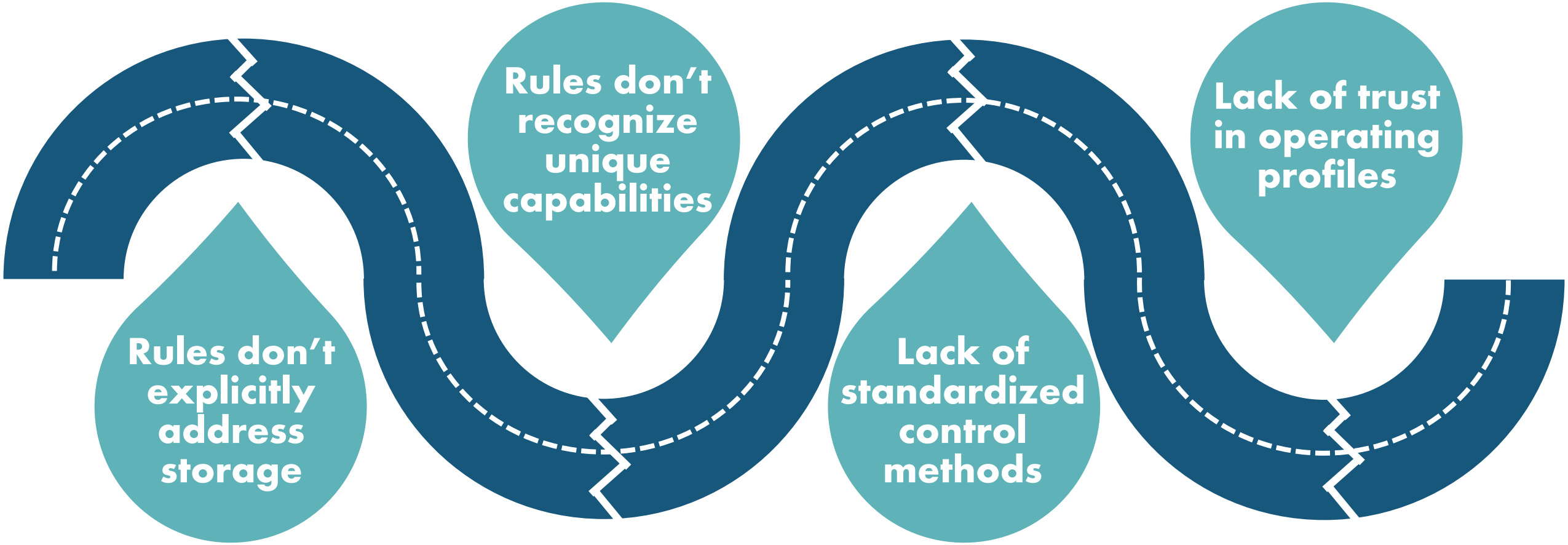
Can control active and reactive power

Offers multiple operating profiles

Can accommodate scheduled and limited exports & imports

Storage flexibility is the safe and reliable control of when, how much, for how long, and under what conditions storage imports and exports electricity

Barriers to Enabling Energy Storage Flexibility



BATRIES
BUILDING A TECHNICALLY RELIABLE INTERCONNECTION EVOLUTION FOR STORAGE

For more information: see BATRIES Energy Storage Toolkit (energystorageinterconnection.org)

Improvement Opportunities

Evolve Initial Reviews

- Increased automation where possible
- Streamline analysis to only include relevant study aspects

Hosting Capacity Analysis

- Incorporate hosting capacity analysis prior to screens
- Publicly available tools showing utility constraint points

Staff Learning

- Provide training aids
- Use of standardized checklists and Engineering Guides

Improvement Opportunities (2)

Enhance Feeder Modelling

- Increased updates to GIS data to capture feeder changes
- Maintain smart inverter settings in models for future studies

Mitigations and Upgrades

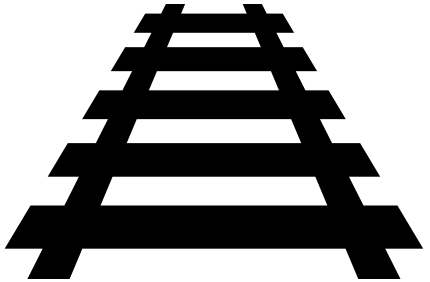
- Cluster studies for shared mitigation costs
- Consider changes to regulator and smart inverter settings

Support Stakeholder Initiatives

- Develop templates to streamline application process for developers
- Continuous review of study criteria and sharing lessons learned via working groups

Fast Track Reviews

Opportunities for Improvement



- Developing Better Screens
  - Most existing screening processes derived from FERC SGIP 2005
- **Recommendations**
  - Include screen for export limiting system
  - Modifying the grounding capability screen
  - Update power quality screen
  - Limit scope of review to relevant areas only
  - Allow additional time to complete supplemental reviews
  - Use engineering judgment to identify changes or mitigation options

Evaluate Non-Export and Limited-Export Systems During the Screening / Study Process

Opportunities for Improvement

Challenge

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

Solution

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

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

Opportunities for Improvement

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

Opportunities for Improvement

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.

New Inadvertent Export Screen

Opportunities for Improvement

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

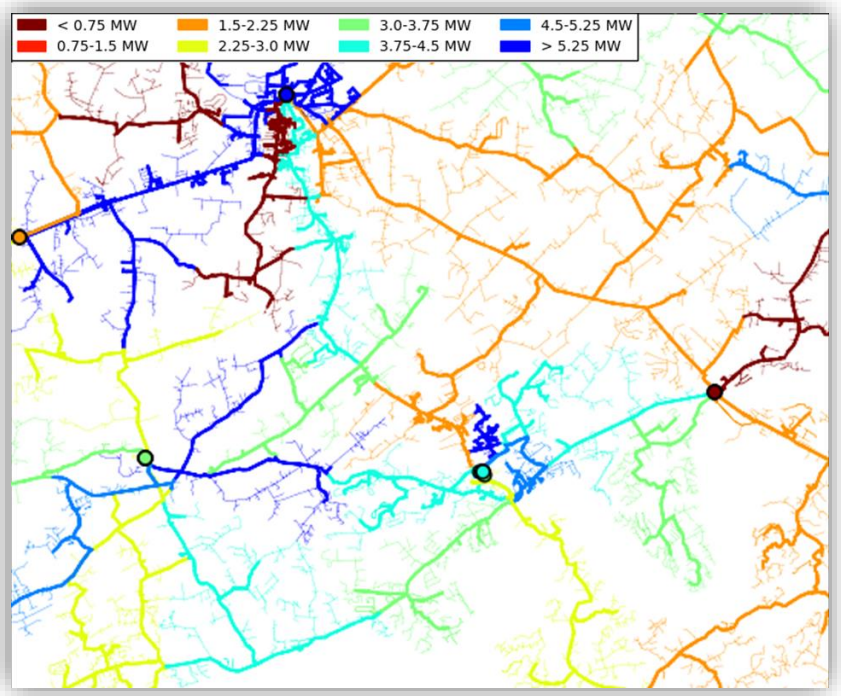
Incorporate Hosting Capacity Analysis into Review Process

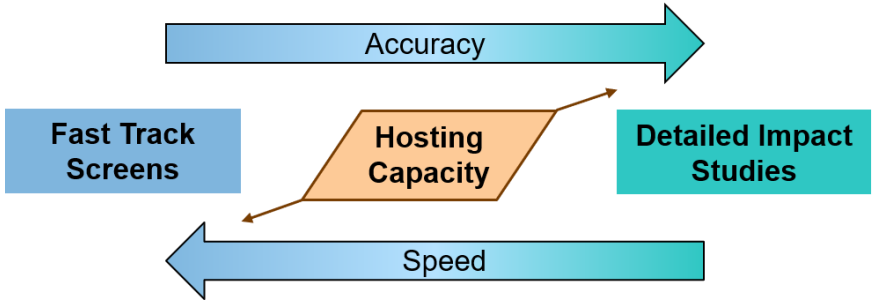
Opportunities for Improvement

Hosting Capacity: the amount of DER that can be accommodated without adversely impacting power quality or reliability under current configurations and without requiring infrastructure upgrades.

Key Motivations

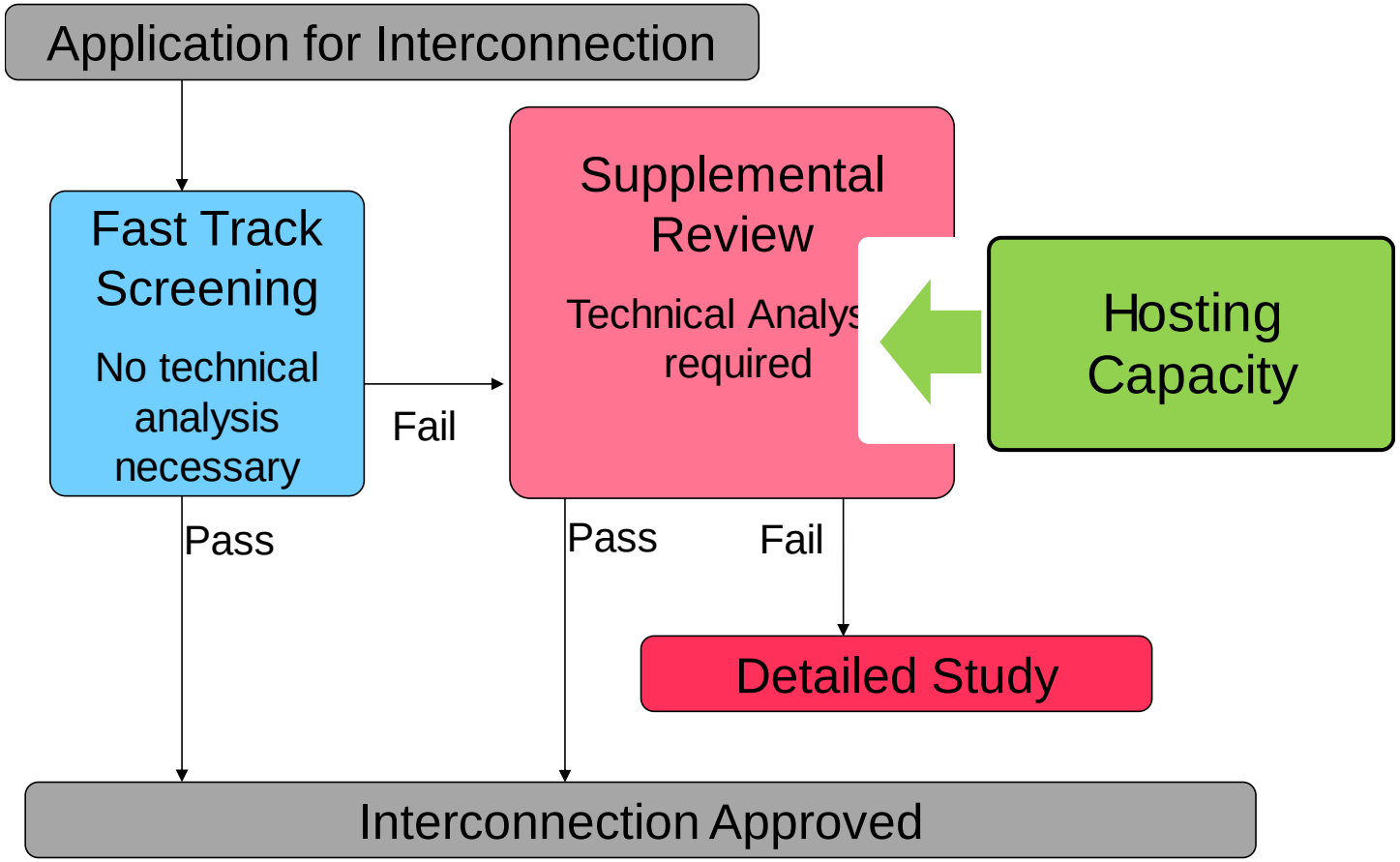
Motivation	Use Case Example
Regulatory	In California, changes to Electric Tariff Rule 21 directs utilities to use hosting capacity results (called Integration Capacity Analysis in California) in lieu of certain screens.
Accuracy	Hosting capacity can supplant screens that may not accurately capture safety or reliability impacts with results that explicitly identify when and where impacts will occur.
Transparency	Aligning screens and technical reviews with hosting capacity results can increase process transparency as well as the informative value of hosting capacity maps. Note: successful alignment requires significant data cleansing to ensure integrity of hosting capacity results.





Assisting in Screening

Key Considerations: Accuracy, impact factors, need for engineering judgement

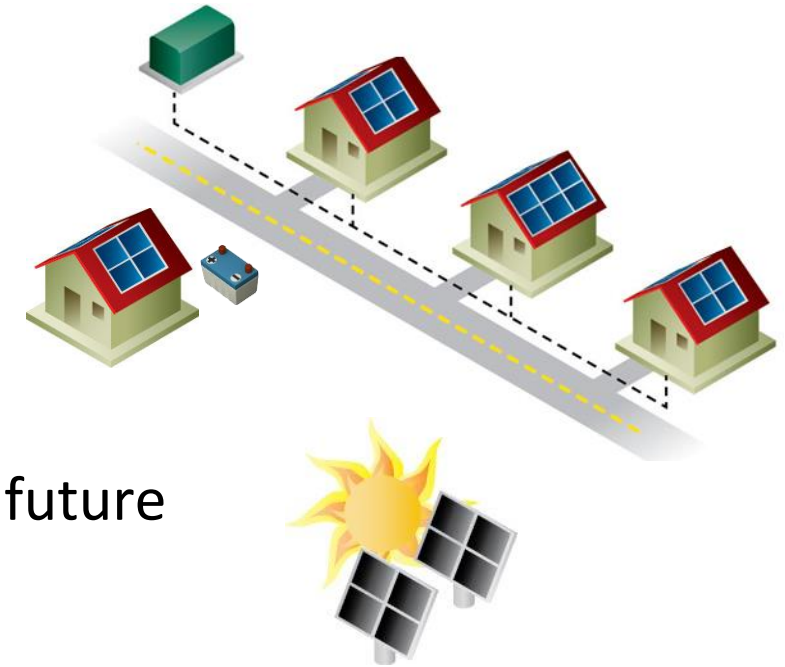


Some Summary Conclusions and Future Directions

- DER grid support capacities and penetration levels will need to be considered

- Increasing automation expected
  - First level initial technical screening may be automated (w/input of feeder data and locational considerations)

- Screens anticipated to evolve
  - New coverage: export limiting
  - Modified coverage: grounding capability, power quality
  - Scope of review to be more focused on relevant areas



- Hosting capacity analysis expected to play a larger role in the future
  - Input from hosting capacity analysis can streamline reviews

Q&A

Together...Shaping the Future of Energy®

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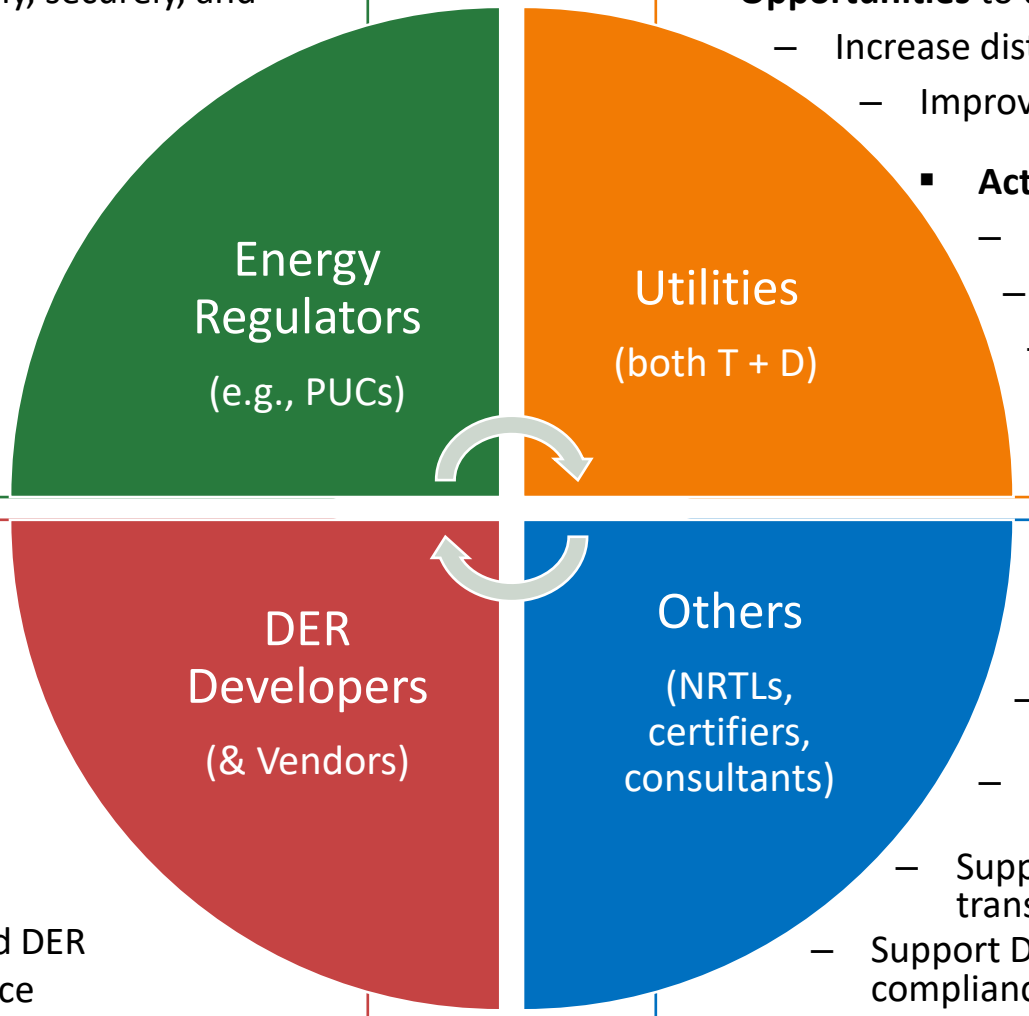
Appendix

Overview: Pathways in Today's Interconnection Review Process

Interconnection Review Pathway	Overview	Technical Scope / Criteria	Level of Review
Expedited Connection	Essentially an application completeness check, with review of one-line diagram.	Applicable only to small (0-50 kW), inverter-connected, certified DER that meet a size adequate to existing service criteria. Shared secondaries with neighbors, existing load demand may also be considered. Energy storage systems do not normally qualify.	Expedited connection typically offered without further screening.
Initial Screening	• First-level screens address concerns re: service type, relative individual DER size, aggregate capacity, grounding and protection compatibility. • All screens require "pass" to receive approval. Failure of a screen triggers decision to pursue supplemental screening or detailed studies.	Considerations include sufficient transformer capacity with compatible grounding configuration, network type (radial vs. network connections), individual/ aggregate DER relative to wires capacity, fault current contribution limits, generation relative to feeder peak load. Voltage regulation or stiffness factor screen sometimes included. Proof of DER certification required.	With sufficient DER/feeder information, review at technician level can result in interconnection approval with little/no engineering judgement.
Supplemental Review	• More detailed second level screens cover concerns from initial screens: maintaining feeder well-being, potential for substation or bulk system impacts requiring study. • The need to apply all supplemental screens for approval varies, as does supplemental review fee/amount.	Three criteria usually applied (none offer specific conditions for running a test): 1. Aggregate DER cannot exceed minimum feeder load 2. Power quality must be maintained within standards*, voltage regulation limits must also be checked** 3. Safety/reliability must not be compromised by individual or aggregate DER***.	Feeder and DER details with engineering judgement and load flow analysis studies required.
Detailed Studies	• Required for large DER and when feeder modifications anticipated; offered as option when screens are failed. • Involves detailed impact analysis specific to interconnection request, with accompanying fee.	• Addressed same issues as in screening. Analyses may be informed by failed initial/supplemental screening results, but will be re-conducted with up-to-date utility models, other data sources. • Typical criteria: thermal ratings, voltage regulation, power quality, and protection coordination; not all areas are required in every study.	Power system analysis tools for load flow/short circuit protection, supporting engineering analysis required. Studies generally involve snapshot power flow analysis. Electromagnetic Transient Analysis (EMT) may be required for situations where power flow is insufficient. System mitigations/cost estimates are study outcomes.

Summary: IEEE 1547-2018 — What Does It Mean for Me?



- **Opportunities** to integrate DER reliably, securely, and efficiently into the grid
- **Actions required** to
  - Assign performance categories per DER technology and use case
  - Specify "preferred" utility-required profiles for DER functional settings
  - Specify certification for DER equipment and possibly verification for DER facilities

- **Opportunities** to utilize advanced DER capabilities
  - Increase distribution hosting capacity
  - Improve bulk system reliability
- **Actions required** to specify
  - Functional settings ≠ "preferred"
  - Performance categories
  - Communication interface
- **Coordinate across T&D**

- **Opportunities** to interconnect larger amounts of DER
- **Clarity** regarding
  - Interconnection capabilities
  - Reference point of applicability
  - Functional settings
- **Potential need** for more sophisticated DER facility evaluations to verify compliance

- **Opportunities** for new business
  - Testing and certification of advanced DER units
  - Evaluation and verification of DER facilities
  - Support utilities in distribution planning with advanced DER functions
  - Support reliability coordinators in transmission planning with DER
  - Support DER developers in verification / compliance through DER evaluations