Interconnection Study Criteria

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Introduction and Agenda

Part 1	Defining Interconnection and Reliability
Part 2	SPP, MISO and PJM Study Methods
Part 3	ERCOT's Approach
Part 4	Conclusions

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Who/what defines interconnection?

- FERC (Federal Energy Regulatory Commission)
  - Purpose: to foster competition in wholesale power markets
    - Energy Policy Acts of 1992 and 2005
    - Order No. 888
  - Major interconnection orders
    - Order 2003/2006 – Standardized generator interconnection procedures & agreement (GIP/GIA)
    - Order 661 – Connection requirements for wind generation
    - Order 827 – Power factor requirements
    - Order 842 – Primary frequency response requirement
    - Order 845 – Option to Build election, storage, contingent facilities, study process documentation, reporting, service below nameplate, surplus service, tech changes

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Who/what defines interconnection?

- NERC (North American Electric Reliability Corporation)
  - Purpose: to preserve the reliability of the North American bulk power system
  - Creates and enforces reliability standards
    - Interconnection requirements are very high level, details are left to the TSP/TO
  - Standards guiding interconnection studies
    - TPL-001-4 – Transmission System Planning Performance Requirements
      - Often referenced to set interconnection study methodologies
    - FAC-001-3 – Facility Interconnection Requirements
      - Transmission Owner must have interconnection requirements, coordinate with affected systems

Who/what defines interconnection?

- NERC (continued)
  - Standards guiding interconnection studies
    - FAC-002-3 – Facility Interconnection Studies
      - Study reliability impact of new interconnections
      - Adhere to NERC standards, regional/TO planning criteria, and facility interconnection requirements
      - Steady state, short circuit, and dynamics
      - Study assumptions, system performance, alternatives considered, coordinated recommendations
    - Many more standards related to model verification, plant operation, etc.

Who/what defines interconnection?

- Transmission Service Provider (TSP)
  - Transmission Owner by default
  - RTO/ISO by delegation/membership
  - Manages interconnection process
    - Defines interconnection study standards and procedures
    - Creates models
    - Performs impact studies to identify constraints and mitigations
  - Key documents: tariffs, interconnection procedures, business practices, joint operating agreements, working group documents, internal practices, computer programs/code

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Who/what defines interconnection?

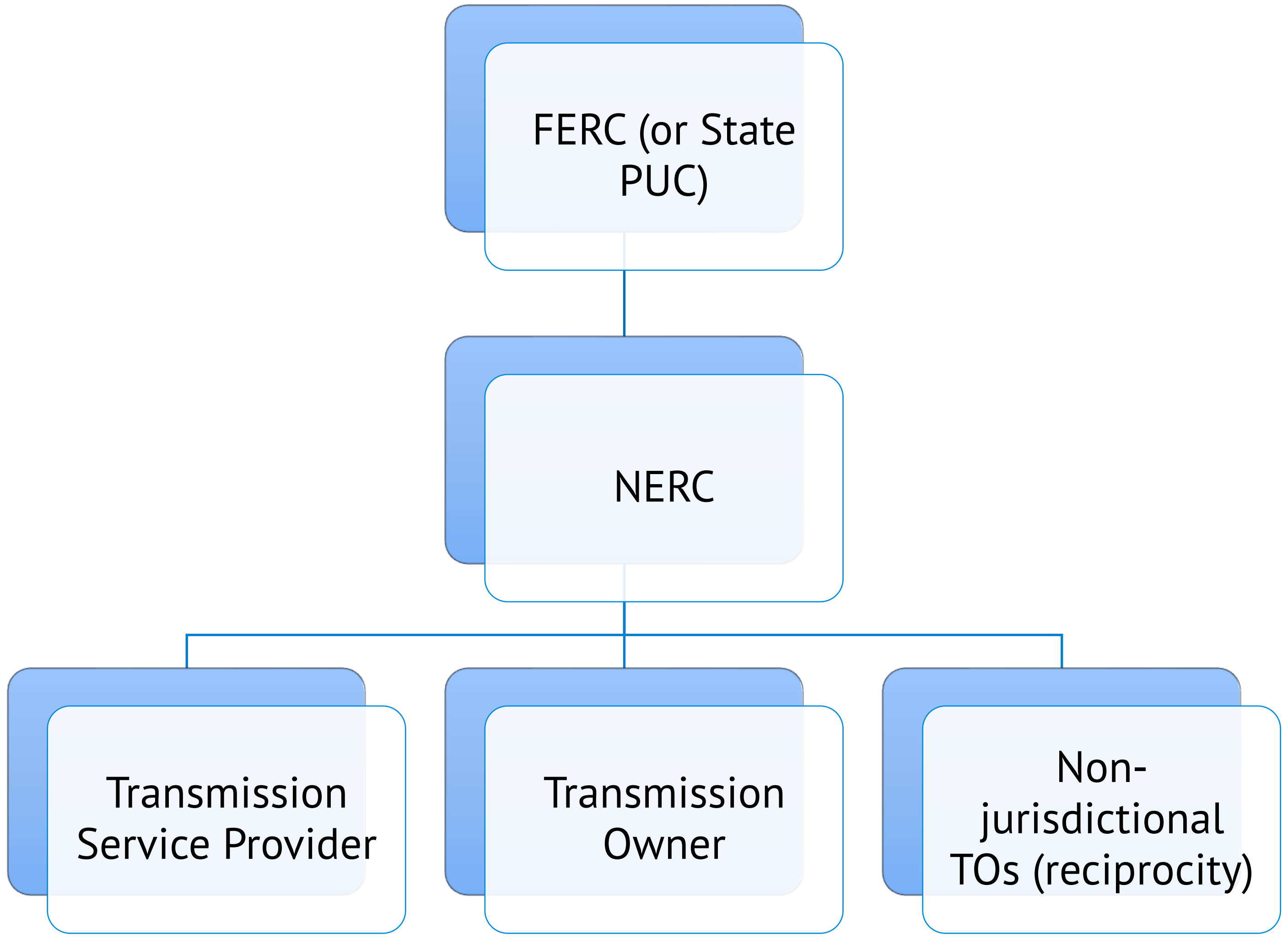
- Transmission Owner (TO)
  - Defines interconnection requirements
    - Transmission system ratings and limits
    - Physical connection requirements
    - Design standards
  - Identifies mitigation (collaborative with RTO/ISO)
  - Designs upgrades in facility study and provides cost/schedule estimates
  - Designs, procures and constructs upgrades (or oversees under Option to Build)
  - Key documents: interconnection requirements, planning criteria, rating methodologies, various EPC, land rights, environmental and permitting standards

Who/what defines interconnection?

- State Public Utility Commissions
  - Regulate sub-transmission/distribution interconnections
- Non-jurisdictional Transmission Onwers
  - Voluntary compliance with open access tariffs and interconnection procedures to maintain reciprocity
  - May become jurisdictional if part of an RTO/ISO

Summary of Interconnection

- Interconnection procedures
  - Highly regulated (FERC)
- Study methodology and criteria
  - Generally well-reviewed and documented, not always easy to find or fully documented
- Technical standards for generator design/performance
  - Highly regulated (NERC standards & GIA)
- Alternative mitigations selection
  - Mostly unregulated and generally undocumented. Area for growth
- EPC standards for transmission upgrades
  - Good Utility Practice standard, minimal regulation



What is Generation Reliability?

- How do generators contribute to reliability?
  - Creation of electrical energy for load (diversity in time of production)
  - Resource adequacy (individually measured as accredited capacity)
  - Dispatchable
  - Voltage support
  - Frequency control
  - System inertia
  - Short circuit contribution (protection and control)
- Does reliability mean the same thing for generation as it does for load?
  - Always able to deliver power?
  - Never causes an overload?
  - Never causes a stability risk?

What is Generation Reliability?

- FERC
  - Interconnection Service Types
    - Energy Resource (ERIS)
      - Identify facilities necessary to operate the generator at full output
      - Grants energy injection on an "as available" basis
      - Subject to congestion/curtailment
    - Network Resource (NRIS, aka capacity)
      - Study generator comparably to existing Network Resources
      - Confirm aggregate generation can serve aggregate load under peak load conditions
      - May allow receipt of Network Integration Transmission Service (NITS) without further study
      - Confirms deliverability for ancillary services/capacity
      - Does NOT eliminate congestion

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What is Generation Reliability?

- FERC
  - Transmission Service (TSR)
    - Path (firm or non-firm) from source to point of energy withdrawal from system
    - More common in non-RTO/ISO systems
    - Ensures generator's capacity can be delivered for capacity accreditation
    - May be granted hedging rights against congestion
  - Types
    - Network Integration (NITS)
      - Path to load
    - Point to Point (PTP)
      - Path to different transmission system

What is Generation Reliability?

- FERC
  - Service Types: ERIS vs NRIS vs TSR
    - Generator reliability represents the connectedness of generator to load, not whether load is served
    - Varying services types warrant different study methodologies, or degrees of connectedness
    - ERIS studies should not identify upgrades as "deep" into the system as NRIS or TSR studies
    - All service types still subject to congestion and curtailment
    - Exact methodology and criteria are left to TSPs and TOs

What is Generation Reliability?

- FERC
  - Upgrade assignment and design guidance
    - Upgrades are assigned to generators only if not required "but for" the interconnection
      - Order 2003
      - Docket ER09-1581 Brookings Order regarding MISO generator interconnections
    - Although some "headroom" is inevitable, FERC guidance is to target least cost solutions
    - Alternative solutions (e.g. grid-enhancing technologies) can enable low-cost access to services from generators.
      - Improved policies and flexibility are needed.

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What is Generation Reliability?

- NERC
  - Facility interconnection standards have minimal detail
  - TSPs often lean on TPL-001-4 for guidance in interconnection & TSR studies
    - Defines model seasons and years to study
    - Defines contingency events to study
    - Defines acceptable system adjustments and outcomes including re-dispatch, interruption of firm service and loss of non-consequential load
    - Defines types of reliability violations (facility ratings, transient response, cascading, islanding)
    - Requires mitigation of any criteria violation
    - Corrective action plans are required and often involve transmission upgrades

What is Generation Reliability?

- NERC
  - How does TPL-001-4 apply to generation interconnection?
    - R2.1/2.4: Studies should include sensitivities, including variations of generation additions, retirements, dispatch scenarios, and power transfers
    - R2.7: Corrective action plans are NOT required for criteria violations only found in a single sensitivity
    - R4.1: Limitations to generators pulling out of synchronism, damping improperly, and not causing other transmission facilities to trip

What is Generation Reliability?

- NERC
  - How does TPL-001-4 apply to generation interconnection? (continued)
    - Table 1 defines acceptable performance for various contingencies
    - TSPs apply Table 1 to interconnection in different ways, including
      - No mitigation required
      - Mitigation required if interruption of firm transmission service not allowed
      - Mitigation of all P0-P7 contingencies required
    - However, Steady State and Stability item (e) applies to all event types, including system intact:
      - "Planned System adjustments such as...re-dispatch of generation are allowed if such adjustments are executable within the time duration applicable to the Facility Ratings."

What is Generation Reliability?

- Summary of FERC and NERC guidance
  - Generator "reliability" is a mix of three concepts:
    - The generator remaining stable and connected under defined conditions
    - Not causing other transmission system elements (generation, transmission, or load) to disconnect unnecessarily
    - The generator being sufficiently deliverable to provide its beneficial reliability characteristics
  - Individual generator "reliability" is <u>not</u> an absence of congestion or curtailment, even with NRIS or TSR service
  - Curtailing/re-dispatching a generator (including one under study) is not the same as disconnecting load and can be a permitted mitigation
  - Not all observed criteria violations warrant mitigation, even in stability studies. Service type is important.

Summary of Generator Reliability

- Our understanding of generator reliability and service types should influence:
  - How studies are performed
  - Whether observed criteria violations are mitigated
  - How observed criteria violations are mitigated
- Upgrade assignment (especially ERIS) should primarily be an economic proposition
  - If generator benefits from increased deliverability => interconnection upgrade
  - If load benefits from increased access to generator => regional planning upgrade

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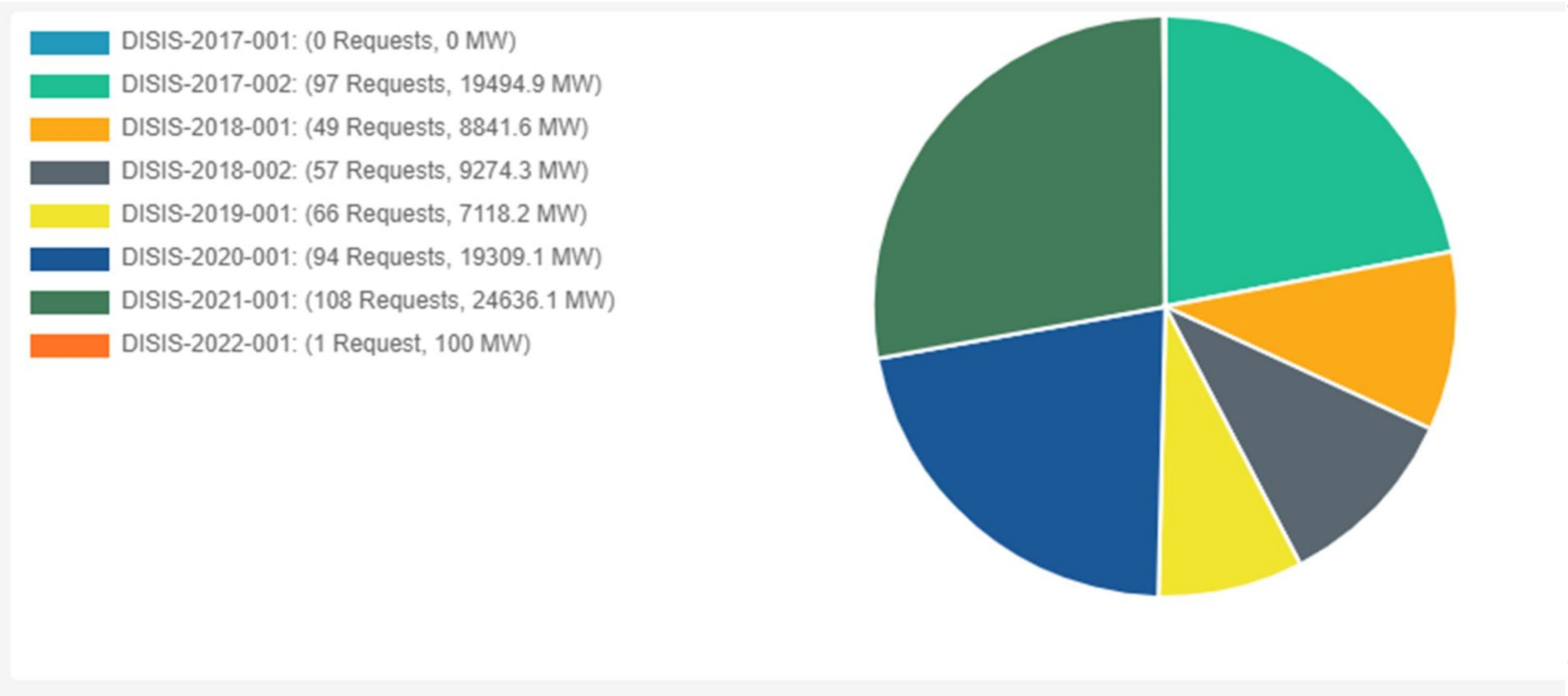
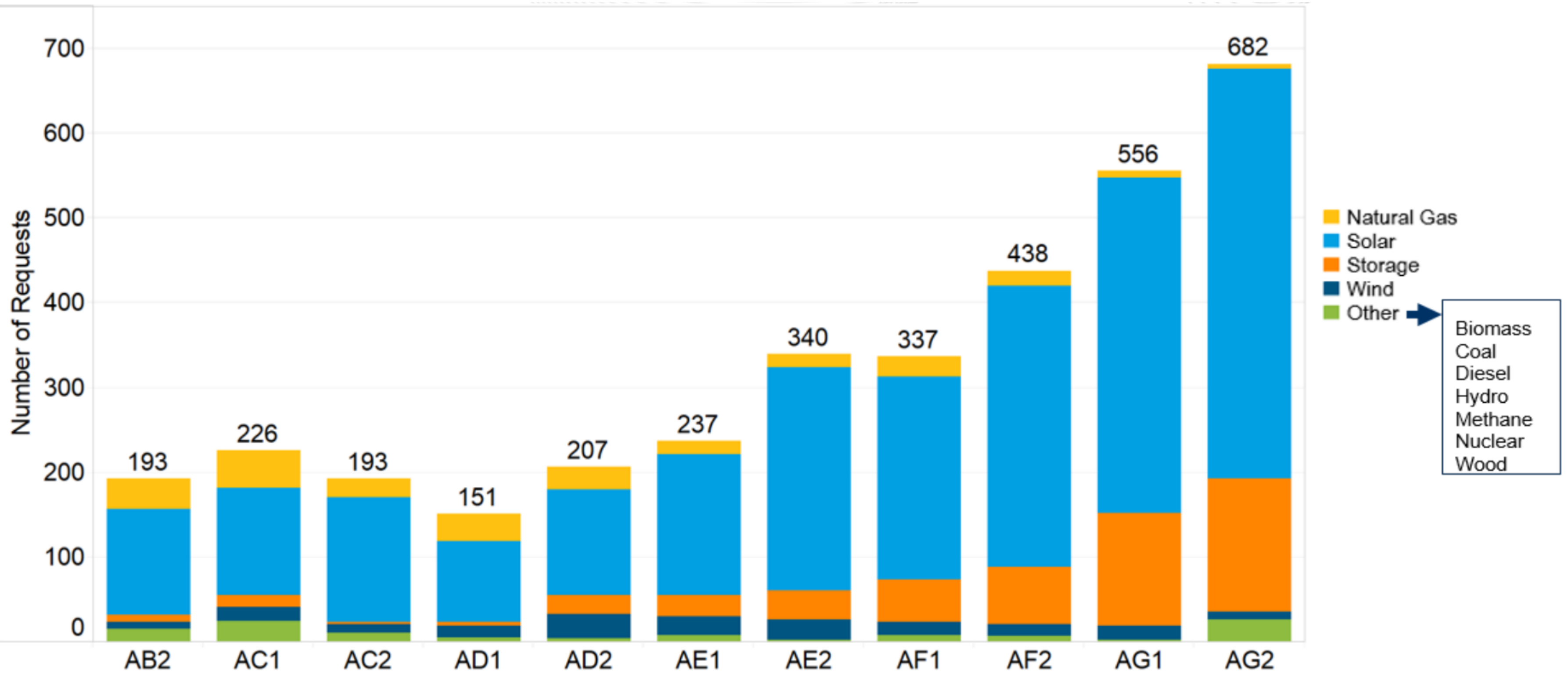
Interconnection Study Criteria: Invest and Connect

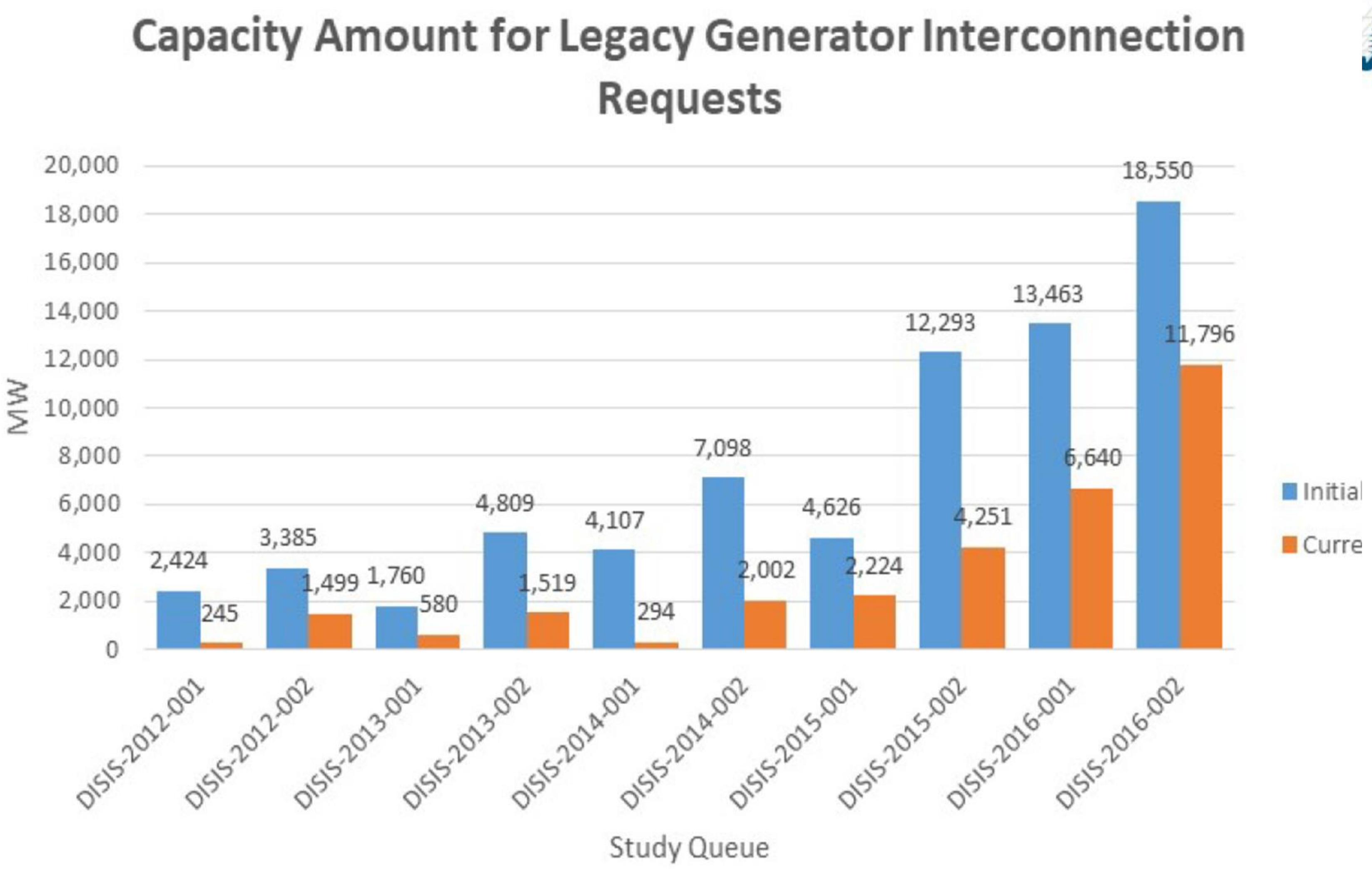
Challenges

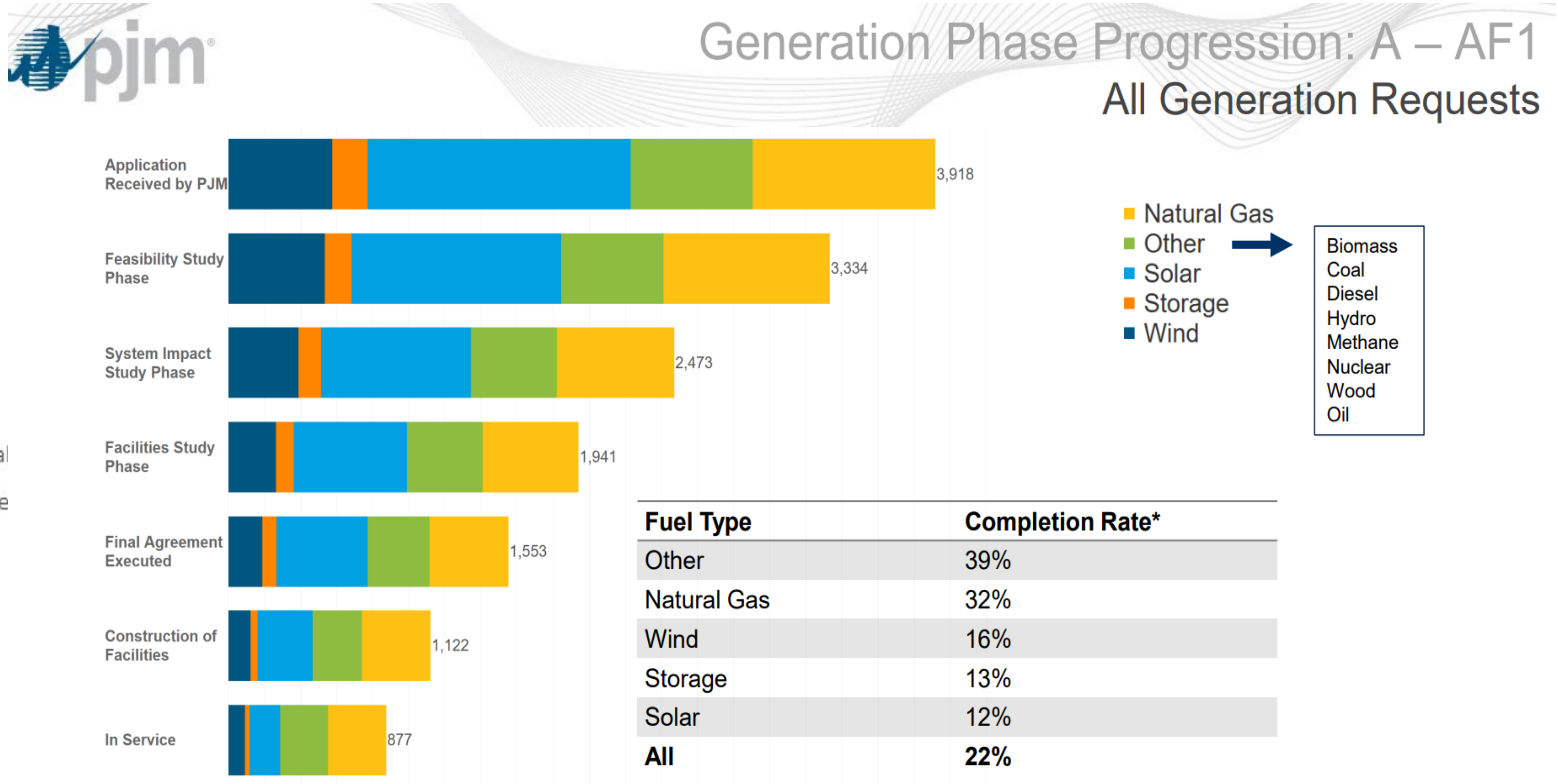
Active Requests





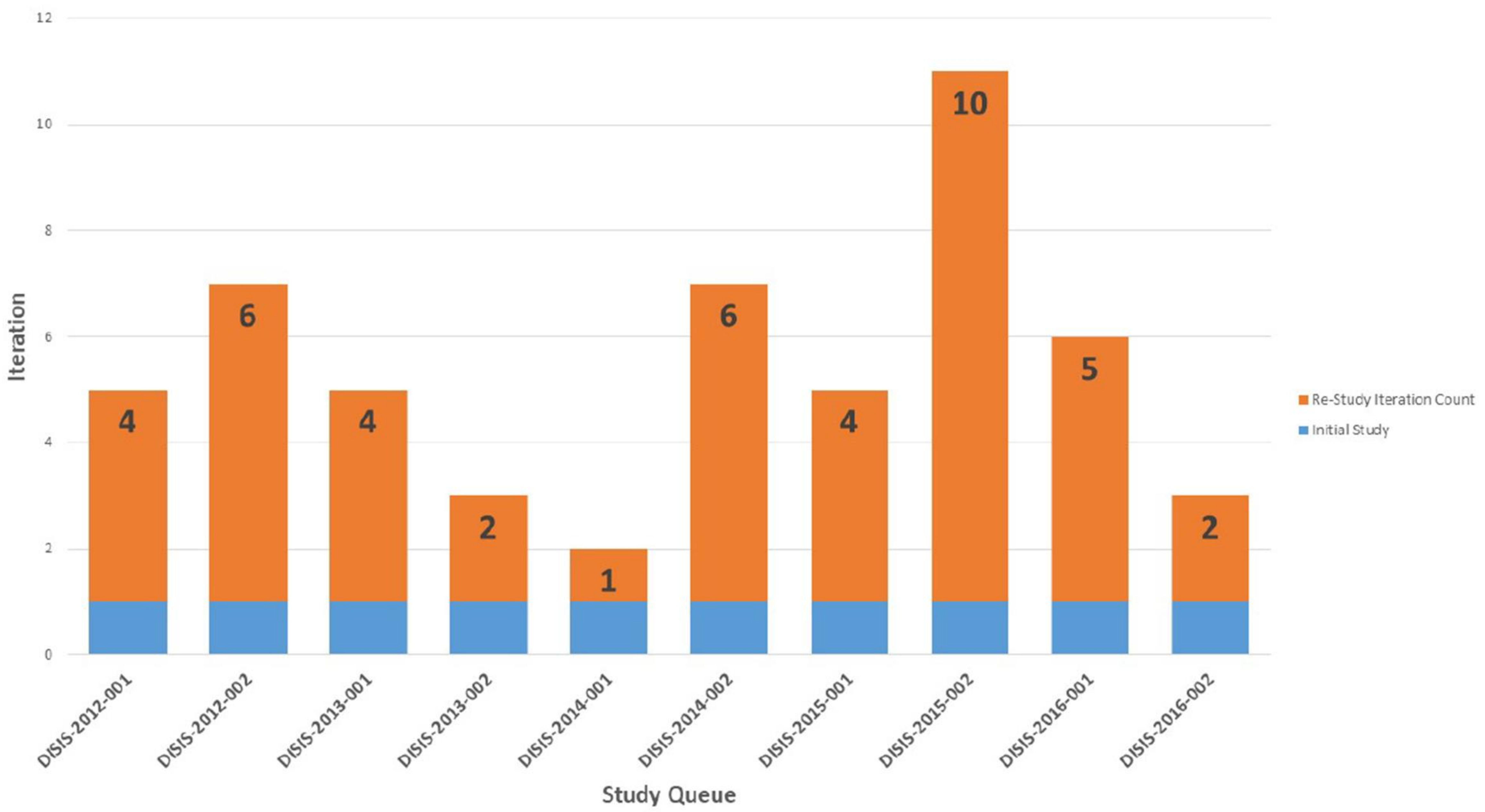
IC Withdrawals





Fuel Type	Completion Rate*
Other	39%
Natural Gas	32%
Wind	16%
Storage	13%
Solar	12%
All	**22%**

SPP DISIS Restudies - Pre-Queue Reform



SPP

Request Types, Cases Used and Analysis

- Interconnection Requests can be studied for Energy Resource Interconnection Service (ERIS) and/or Network Resource Interconnection Service (NRIS)
  - All new projects must be studied for ERIS but do not need to request NRIS

- SPP runs thermal and voltage analysis for both ERIS and NRIS requests

- Prior Queued (PQ) and Current Queue (CQ) models are created to study these requests. These models are created for the following years and seasons:
  - **Year 2** – Summer Peak
  - **Year 5** – Light Load, Summer Peak & Winter Peak

Request Types, Cases Used and Analysis

- To simulate and analyze the variety of generation and service types included in a DISIS cluster, three dispatch scenarios are developed for both the prior-queued and current-queued model sets.

High-Variable Energy Resource (HVER)

Reflect scenarios in which Variable Energy Resources are generating at high levels and conventional resources are at relatively low levels. HVER scenarios are developed for summer and winter peak and light load seasons and evaluate both ERIS-only and NRIS requests

Low-Variable Energy Resource (LVER)

Reflect scenarios in which Variable Energy Resources are generating at low levels and conventional resources are at relatively high levels. LVER scenarios are developed for summer and winter peak seasons only and evaluate both ERIS-only and NRIS requests

Network Resource (NR)

Reflect scenarios in which NRIS generator output is maximized and ERIS-only generator output is minimized. NR scenarios are developed for summer and winter peak and light load seasons and evaluate only NRIS requests

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Case Development – Fuel Based Dispatch

HVER Dispatch

Fuel Type	In-Group						Out-Group					
	Summer Peak		Winter Peak		Light Load		Summer Peak		Winter Peak		Light Load	
	PQ	CQ	PQ	CQ	PQ	CQ	PQ	CQ	PQ	CQ	PQ	CQ
Combined Cycle	0%	0%	0%	0%	0%	0%	NC	0%	NC	0%	NC	0%
Combustion Turbine	0%	0%	0%	0%	0%	0%	NC	0%	NC	0%	NC	0%
Diesel Engine	0%	0%	0%	0%	0%	0%	NC	0%	NC	0%	NC	0%
Hydro	50%	50%	50%	50%	50%	100%	NC	0%	NC	0%	NC	0%
Nuclear	100%	100%	100%	100%	100%	100%	NC	0%	NC	0%	NC	0%
Storage	0%	100%	0%	100%	0%	0%	NC	0%	NC	0%	NC	0%
Coal	0%	0%	0%	0%	0%	0%	NC	0%	NC	0%	NC	0%
Oil	0%	0%	0%	0%	0%	0%	NC	0%	NC	0%	NC	0%
Waste Heat	0%	0%	0%	0%	0%	0%	NC	0%	NC	0%	NC	0%
Wind	40%	100%	45%	100%	75%	100%	NC	20%	NC	20%	NC	60%
Solar	40%	100%	10%	100%	0%	0%	NC	40%	NC	10%	NC	0%
Hybrid	See Hybrid Example											

LVER Dispatch

Fuel Type	In-Group						Out-Group					
	Summer Peak		Winter Peak		Light Load		Summer Peak		Winter Peak		Light Load	
	PQ	CQ	PQ	CQ	PQ	CQ	PQ	CQ	PQ	CQ	PQ	CQ
Combined Cycle	100%	100%	100%	100%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Combustion Turbine	100%	100%	100%	100%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Diesel Engine	100%	100%	100%	100%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hydro	50%	50%	50%	50%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nuclear	100%	100%	100%	100%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Storage	100%	100%	100%	100%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Coal	100%	100%	100%	100%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oil	100%	100%	100%	100%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Waste Heat	100%	100%	100%	100%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Wind	20%	20%	20%	20%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Solar	40%	40%	10%	10%	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Hybrid	See Hybrid Example											

Case Development – Fuel Based Dispatch

NRIS Dispatch

Fuel Type	In-Group						Out-Group					
	Summer Peak		Winter Peak		Light Load		Summer Peak		Winter Peak		Light Load	
	PQ	CQ	PQ	CQ	PQ	CQ	PQ	CQ	PQ	CQ	PQ	CQ
Combined Cycle	100%	100%	100%	100%	0%	0%	N/A	N/A	N/A	N/A	NC	0%
Combustion Turbine	100%	100%	100%	100%	0%	0%	N/A	N/A	N/A	N/A	NC	0%
Diesel Engine	100%	100%	100%	100%	0%	0%	N/A	N/A	N/A	N/A	NC	0%
Hydro	50%	50%	50%	50%	50%	100%	N/A	N/A	N/A	N/A	NC	0%
Nuclear	100%	100%	100%	100%	100%	100%	N/A	N/A	N/A	N/A	NC	0%
Storage	100%	100%	100%	100%	0%	0%	N/A	N/A	N/A	N/A	NC	0%
Coal	100%	100%	100%	100%	0%	0%	N/A	N/A	N/A	N/A	NC	0%
Oil	100%	100%	100%	100%	0%	0%	N/A	N/A	N/A	N/A	NC	0%
Waste Heat	100%	100%	100%	100%	0%	0%	N/A	N/A	N/A	N/A	NC	0%
Wind	20%	100%	20%	100%	60%	100%	N/A	N/A	N/A	N/A	NC	60%
Solar	40%	100%	10%	100%	0%	0%	N/A	N/A	N/A	N/A	NC	0%
Hybrid	See Hybrid Example											

Case Development – Hybrid Example

Prior-Queued Hybrid Example (HVER Model)

Hybrid Request	Hybrid Request Capacity	Type	Installed Capacity (MW)	Summer Peak (MW)	Winter Peak (MW)	Light Load (MW)
1	100 MW	Solar	50	40%*50 = 20	10%*50 = 5	0%*50 = 0
		Wind	100	40%*100 = 40	45%*100 = 45	75%*100 = 75
		Total	**150**	**60**	**50**	**75**
2	190 MW	Storage	100	0%*100 = 0	0%*100 = 0	0%*100 = 0
		Wind	200	40*200 = 80	45%*200 = 90	75*200 = 120
		Total	**300**	**80**	**90**	**150**

Study Hybrid Example (HVER Model)

Hybrid Request	Hybrid Request Capacity	Type	Installed Capacity (MW)	Summer Peak (MW)	Winter Peak (MW)	Light Load (MW)
1	100 MW	Solar	50	100%*50 = 50 → 33	100%*50 = 50 → 33	0%*50 = 0
		Wind	100	100%*100 = 100 → 67	100%*100 = 100 → 67	100%*100 = 100
		Total	**150**	**150 → 100**	**150 → 100**	**100**
2	190 MW	Storage	100	100%*100 = 100 → 63	100%*100 = 100 → 63	0%*100 = 0
		Wind	200	100%*200 = 200 → 127	100%*200 = 200 → 127	100*200 = 200 → 190
		Total	**300**	**300 → 190**	**300 → 190**	**200 → 190**

Study Methodology

- Run NERC TPL -001 (P0, P1, P2, P4, P5, P7) contingencies on all PQ and CQ cases and cross compare results. Any overloads that are exacerbated in the CQ models will have to be mitigated if they meet criteria, regardless if the equipment was overloaded in the PQ

- The following solution parameters will be used
  - Fixed Slope Decoupled Newton-Raphson
  - Tap Adjustment – Stepping
  - Switch Shunt Adjustments – Enable All
  - Adjust Phase Shift
  - Adjust DC Taps
  - VAR Limits – Apply Immediately

- For the study model build, area interchange control is enabled via tie lines and loads. During the contingency analysis area interchange is disabled

Thermal and Non-Converged Criteria

- Upgrades required to mitigate constraints identified in the HVER and LVER scenarios will be cost-allocated to every Current-Queue Request meeting any of the following criteria:
  - ➢At least 3% TDF on contingent elements that resulted in a non-converged solution
  - ➢At least 3% TDF impact where the constraint is identified under System-Intact conditions
  - ➢At least 20% TDF impact where the constraint is identified under contingency conditions
  - ➢At least 5% TDF impact where the constraint is identified under contingency conditions where the sum of all Current-Queue Requests having a TDF impact on the constrained element of at least 5% equals at least 20% of the constrained element's emergency rating

- Upgrades required to mitigate constraints identified in the NR scenarios will be cost-allocated to every NRIS Current-Queue Request meeting any of the following:
  - ➢At least 3% TDF impact, where the constraint is identified under System-Intact conditions
  - ➢At least 3% TDF impact, where the constraint is identified under contingency conditions

Voltage Criteria

- The constraints identified through the voltage scan are screened using the criteria below:
  - 3% TDF on the contingent element
  - 2% change in p.u. voltage.

Cost Allocation

- An analysis is performed to determine the System-Intact TDF, also known as a Power Transfer Distribution Factor (PTDF), that each Current-Study Request had on each new upgrade.

- The impact each Current-Study Request had on each upgrade project is weighted by the size of each request. Finally, the costs allocated to each Current-Study Request for a particular upgrade are then determined by allocating the portion of each request's impact over the impact of all affecting requests

- Study requests that are wind are cost allocated for Network Upgrades using the light load model

- All other study requests are cost allocated for Network Upgrades using the summer peak model

Cost Allocation

- Only projects that meet the thermal, non-converged and voltage constraint identification criteria are eligible for cost allocation
  - Project PTDF values do not impact constraint assignment

- SPP only considers projects with positive PTDF's eligible for cost allocation, unless the network upgrade is a new transmission line

MISO

Request Types, Cases Used and Analysis

- Developers can request ERIS, NRIS or partial NRIS. NRIS can never exceed the ERIS value for a plant

- MISO runs thermal and voltage analysis for ERIS requests and a deliverability analysis for NRIS requests.
  - Deliverability analysis based on “flowgate screening” which includes a dynamic dispatch for each flowgate (monitored element / contingency pair) to identify worst possible dispatch (criteria discussed in later slides)

- Bench and Study cases are created for the ERIS analysis based on two loading scenarios (Summer Peak and Shoulder). The NRIS model used is based on a Summer Peak loading scenario.

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Case Development

ERIS Cases

- Bench Case (pre-project) – existing generators and generators with signed IA dispatched based on MTEP 5 year out LBA dispatch
- DPP higher queued projects without a GIA dispatched based on their fuel type (table in next page) such that higher queued projects in MISO Classic are sunk into MISO Classic and higher queued projects in MISO South are sunk in MISO South
- Study Case (post-project) – based on bench case with study generators dispatched based on fuel type scaling down non-study generators in MISO South and MISO Classic by the MW amount added

NRIS Case

- Based on ERIS model with upgrades included
- ERIS only generators turned off
- NRIS generation set to at least pgen = 0 such that total generation in MISO Classic and South in the deliverability model is equal to the total generation in these regions for the study model
- ERIS generators with firm transmission treated as NRIS generators

Case Dispatch

Table 6-1 Dispatch per Fuel Type for Study and Higher Queued Generators (without a GIA)

Fuel Type under Study and Higher Queued	Summer Peak Dispatched as % of Interconnection Service	Shoulder Peak Dispatched as % of Interconnection Service
Combined Cycle	**100%**	**50%**
Combustion Turbine	**100%**	**0%**
Diesel Engines	**100%**	**0%**
Hydro	**100%**	**100%**
Nuclear	**100%**	**100%**
Storage[9]	**100%**[10]	**+/- 100%**
Steam – Coal	**100%**	**100%**
Oil	**100%**	**0%**
Waste Heat	**100%**	**100%**
Wind	**15.6%**[11]	**100%**
Solar	**100%**	**0%**[12]
Hybrid Facility[13] (Any combination of the above fuel types)	**Based on above dispatch assumptions of each fuel type with any adjustment based on requested interconnection Service**[14]	**Based on above dispatch assumptions of each fuel type with any adjustment based on requested interconnection Service**[15]

Example: Generic Dispatch Assumptions for Hybrid Facility

Scenario	Existing Generator 1 (Wind, Solar, CC etc.)	Study Generator 2 (Wind, Solar, CC etc.)	Study Generator 3 (Wind, Solar, CC etc.)	Study Generator 4 (Storage)	Interconnection Service Requested	Steady State (Shoulder Peak)[27]	Steady State (Summer Peak)[28]	NRIS or Deliverability (Summer Peak)
1	0	50	100	0	120	MIN (fuel type dispatch of both study generators, 120)		MIN (max. MW output of both study generators, 120)
2	0	100	0	+/-50	120	Discharging: MIN (fuel type dispatch of both study generators, 120) Charging: – fuel type dispatch of storage (non-storage offline)		Discharging: MIN (max. MW output of both study generators, 120)
3	100	0	0	+/-50	120	Discharging: MIN (fuel type dispatch of existing gen. + fuel type dispatch of storage, 120) Charging: – fuel type dispatch of storage (non-storage offline)		Discharging: MIN (max. existing gen. MW + max. storage MW, 120)
4	0	100	0	+/-50	150	Discharging: Fuel type dispatch of both study generators Charging: – fuel type dispatch of storage (non-storage offline)		Discharging: Max. MW output of both study generators
5	0	50	100	0	150	Fuel type dispatch of both study generators		Max. MW output of both study generators

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Study Methodology – ERIS

- Run NERC TPL -001 (P0, P1, P2, P4, P5, P7) contingencies on bench and study cases and cross compare results. Determine constraints based on the below criteria:

1. Study Project Distribution factor (Dfax)

Dfax ≥ 5% for system intact

Dfax ≥ 20% for contingency events

2. Study Project MW Impact

MW Impact of Study Project ≥ 20% of facility rating

3. Study Project Outlet

If outlet is overloaded or constraint is caused by contingency of outlet facility

4. Cumulative MW Impact

If 1, 2 or 3 are not met and total MW impact of entire study group ≥ 20% of facility rating and Study Project has MW impact > 5% of facility rating and Study Project has Dfax > 5%

Local TO Planning Criteria and Affected System Study Criteria

Steady State Voltage:
Bus voltage is outside of applicable normal or emergency limits, AND
Voltage degradation is greater than 1%

Study Methodology – NRIS

- Run P0 and P1 contingencies only on a Summer Peak NRIS case
- Based on flowgate screening with an 8000 MW cap and a 5% DFAX Cutoff. Only NRIS units considered, and these are ranked from highest DFAX to lowest.
- For each flowgate, a top 30 list is created and generators in that list are dispatched to their granted NRIS during the test. Generators in subsystem “MISO_IM” are uniformly scaled down. Any current DPP cycle projects with a DFAX > 5% will be included on top of the top 30 list.
- Adders added on top of top 30 list if they meet 5% DFAX Cutoff and 20% flowgate impact

Cost Allocation

Thermal – Based on MW impact on the constrained facility in the study case (see simple example below).

Voltage – Based on pro-rata share of voltage impact. Calculated by locking all voltage regulating equipment and backing off each project one at a time to identify their impact

Table 6-2 Example of Thermal Project Cost Allocation

Constraint	Mitigation	MW Impact Project 1	MW Impact Project 2
Overload of Line A	New Line X ($50M)	6	3
Overload of Line D	New Line X ($50M)	12	15
Overload of Line H	New Line X ($50M)	4	0
Total MW Impact	New Line X ($50M)	22	18
Cost Allocation		=(22/40*50) = $27.5M	=(18/40)*50 = $22.5M

Table 6-3 Example of Voltage Project Cost Allocation Methodology

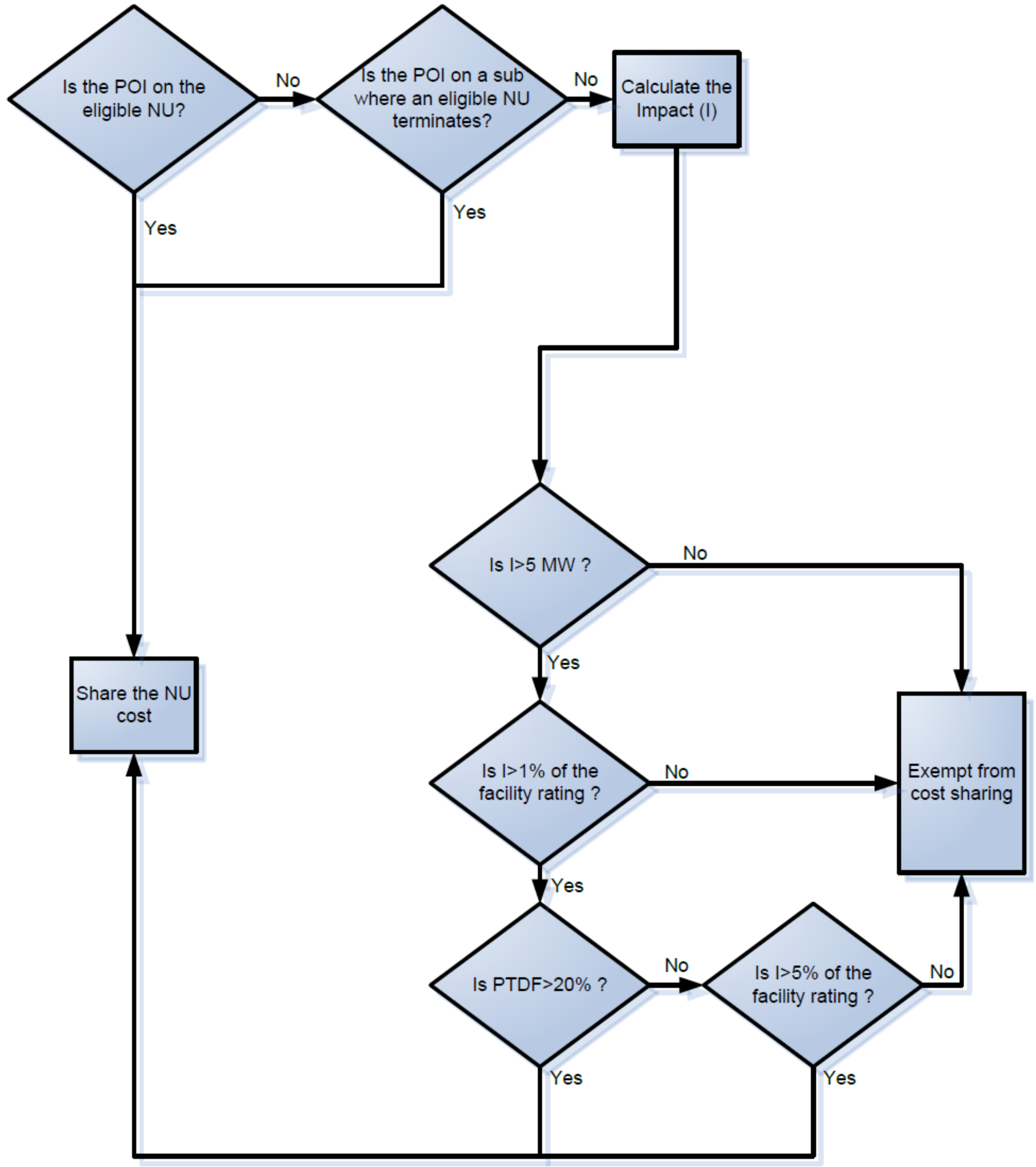
Project	Contingent Voltage with all DPP Projects	Δ Voltage with DPP Project removed	New Voltage	Type	Cost Allocation %
Gen A	0.75	0.01	0.76	Harmer	33.33%
Gen B		0.02	0.77	Harmer	66.67%
Gen C		-0.01	0.74	Helper	0.00%
Total		0.03			100.00%

Shared Network Upgrades Cost Allocation

- Intended as a test to check if new generators benefit from a network upgrade previously identified for a different generator and therefore share the cost with that generator for upgrades > $10 million USD

- If the new generator connects to that Network Upgrade or to a station where the upgrade terminates it will have a cost allocation

- Otherwise the following tests should be performed:
  - ➢Impact > 5 MW AND 1% of facility rating – if yes, check the following:
    - ❖Impact > 5% of facility rating AND PTDF > 20%



PJM

Request Types, Cases Used and Analysis

- Developers can request capacity or energy and typically both are requested
  - Generally, a mix of energy and capacity is requested. Typically, the energy value equals the MFO (maximum facility output) while the capacity requested is a percentage of the total request as is typically limited based on average capacity factors (see below). In the study however, the energy portion is modelled as MFO – capacity.

- PJM runs a generator deliverability study to assess potential thermal violations caused by interconnecting new generation

- The analysis is performed on a Summer Peak and Light Load Case

Study Methodology

- The analysis is based on a “flowgate screening” approach
  - ➢Dynamic dispatch for each flowgate (monitored element / contingency pair) to identify worst possible dispatch
  - ➢Harmer generators are ramped up while the rest of the generators in the PJM system are uniformly dispatched down
  - ➢Adders are turned on and dispatched if they meet DFAX criteria
  - ➢Impact of generators from nearby systems (e.g. MISO and NYISO considered)
  - ➢Impact of long-term firm contracts also considered
  - ➢Selection criteria is based on DFAX and availability of harmer generators (1- EEFORd)

- Single contingencies as well as common mode outages (stuck breaker, bus fault and tower contingencies) are considered.

- Ramping criteria during the generator deliverability tests is dependent on the contingency type.

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Study Methodology

Single Contingencies	Common Mode Contingencies
• Only capacity portion is ramped up • DFAX cutoff is 5% or 10% for 500kV and above flowgates • Harmer generators ramped up based on an 80/20 criteria ➢ Harmers are ranked based on DFAX. ➢ The availability (1-EEFORd) of the unit with the highest DFAX is multiplied by the availability of the unit with the second highest DFAX and so on until the expected availability of the selected units is as close to but not less than 20% ➢ Adders turned on and ramped based on the DFAX cutoff above or based on an impact of greater than 5% to the facility rating. Only 85% of adder impact is considered	• **Both capacity and energy** portions are ramped up • DFAX cutoff is **10% for all voltage levels** • Harmer generators ramped up based on an **50/50 criteria** ➢ Harmers are ranked based on DFAX. ➢ The availability (1-EEFORd) of the unit with the highest DFAX is multiplied by the availability of the unit with the second highest DFAX and so on until the expected availability of the selected units is as close to but not less than 50% ➢ Adders turned on and ramped based on the DFAX cutoff above or based on an impact of greater than 5% to the facility rating. Only 85% of adder impact is considered

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Light Load Considerations

Target Initial Dispatch

Network Model	Current year + 5 base case
Load Model	Light Load (50% of 50/50 summer peak)
Capacity Factor for Base Generation Dispatch for PJM Resources (Online in Base Case)	Nuclear – 100% Coal >= 500 MW – 60% Coal < 500 MW – 45% Oil – 0% Natural Gas – 0% Wind – 40% All other resources – 0% Pumped Storage – full pump
Capacity Factor for Base Generation Dispatch for MISO Resources (Online in Base Case)	Wind – 100%
Interchange Values	Historical values
Contingencies	NERC P0, P1, P2, P4, P5 and P7
Monitored Facilities	All PJM market monitored facilities

Ramping Limits for generators

Fuel Type	Ramping Limits (% of Pmax)
Nuclear	100%
Wind	80%
Coal >=500 MW	60%
Coal < 500 MW	45%
All other resources	0% (not ramped)

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Cost Allocation

Allocation based on MW Impact considering below criteria:

Current process:

< 5 million USD – contingent on 5 MW AND 1% Rating Increase (RI) Or 5% DFAX and 3% RI

- 5% DFAX or 5% RI for facilities below 500 kV and 10% DFAX or 5% RI for facilities over 500 kV
- No inter-queue cost allocation

>= 5 million USD – contingent on 5 MW AND 1% RI

- 5% DFAX or 5% RI for facilities below 500 kV and 10% DFAX or 5% RI for facilities over 500 kV

Changes in the new process:

- No inter queue cost allocation regardless of upgrade value
- Mechanism for using forfeited readiness deposits for underfunded network upgrades

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Upcoming Proposed Changes

- Currently several proposed changes being discussed such as: redefining light load periods, single and common mode tests are now identical except for DFAX cutoff, MISO wind changes, block dispatch, no EEFORd value for units less than 50 MW and many others

		Base Case Dispatch	
Period	**Resource Type**	**Existing**	**Proposed***
Summer	Fixed Solar	38%	47-55%
Summer	Tracking Solar	~60%	64-66%
Summer	Onshore Wind	13%	16-20%
Summer	Offshore Wind	~30%	33-38%
Winter	Fixed Solar	5%	5%
Winter	Tracking Solar	5%	5%
Winter	Onshore Wind	33%	40-43%
Winter	Offshore Wind	60%	55-57%
Light Load	Fixed Solar	0%	52-59%
Light Load	Tracking Solar	0%	54-58%
Light Load	Onshore Wind	40%	29-34%
Light Load	Offshore Wind	60%	46-49%

		Generator Deliverability Harmer Ramping			
		Single Contingency		Common Mode Outage	
Period	**Resource Type**	**Existing**	**Proposed***	**Existing**	**Proposed***
Summer	Fixed Solar	38%	67-77%	100%	67-77%
Summer	Tracking Solar	~60%	84-89%	100%	84-89%
Summer	Onshore Wind	13%	38-52%	100%	38-52%
Summer	Offshore Wind	~30%	68-73%	100%	68-73%
Winter	Fixed Solar	10%	5%	100%	5%
Winter	Tracking Solar	10%	5%	100%	5%
Winter	Onshore Wind	80%	73-84%	100%	73-84%
Winter	Offshore Wind	80%	96-98%	100%	96-98%
Light Load	Fixed Solar	0%	78-87%	0%	78-87%
Light Load	Tracking Solar	0%	82-86%	0%	82-86%
Light Load	Onshore Wind	80%	66-80%	80%	66-80%
Light Load	Offshore Wind	80%	90-93%	80%	90-93%

Interconnection Study Criteria:
Connect and Manage

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ERCOT – Connect and Manage Philosophy

- ERCOT's unique characteristics
  - Single state interconnection, no FERC oversight
  - Generation primarily seen as bringing benefits due to capacity shortages
  - Interconnection upgrades are not built beyond what is necessary for physical grid connection
  - Even physical grid connection facilities are funded by load
- Interconnection studies largely don't matter, except to
  - Confirm accurate modeling
  - Confirm compliance with generator performance standards such as voltage ride through, reactive capability, power system stabilizer performance, primary frequency response, etc.
  - Identify potential significant constraints to power injection for generator sizing

ERCOT – Connect and Manage Philosophy

- Queue priority doesn't exist because there are no upgrades or rights to transmission
  - Approach eliminates interdependency between projects for interconnection processing.
  - No re-studies occur due to withdrawals.
  - No security is required for potential harm to other generators
  - Generators can achieve operations in under 3 years, including both studies and EPC
- Risk of congestion and curtailment is borne by generators

- Many of the benefits of the Connect and Manage philosophy can be realized through modifying study procedures and criteria to localize upgrades assigned in interconnection processes. See Enel's recent whitepaper for more details.

Final Thoughts

Summary

- New generation reduces cost to load and/or increases reliability
- FERC policy and NERC standards promote competition and permit generation curtailment/re-dispatch in many situations
- Service type and purpose is important in designing study procedures and criteria
- Interconnection processes, methodologies, criteria, solutions, and requirements vary significantly
- A TSP's procedures and criteria must be understood holistically and evaluated for consistency with FERC and NERC guidance
- Upgrade assignment in ERIS studies should primarily be an economic proposition
- The Connect and Manage approach reduces interdependence which plagues queues and accelerates access to new generation

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Why is this discussion important?

- The global push for decarbonization and cost of renewable energy is driving a fundamental change in our generation mix
- Electrification is driving increased energy use
- System capacity margins are inadequate in some areas already
- Current interconnection processes are severely backlogged and often assign hefty upgrade costs, preventing access to beneficial new generation
- Transmission is being designed inefficiently through interconnection processes. Centralized planning to maximize benefit to load is needed.
- Changes are needed to ensure sufficient generation is online and adequately connected to load

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Thank you

Contact for questions/information

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About EPE

Electric Power Engineers, LLC (EPE) is a leading consulting engineering firm focused on the energy transition, providing power systems engineering services to a diverse client base.

Mission

To build a platform to connect our teams and harness the synergies and expertise among all services, therefore, fueling innovation to enable our vision.

Vision

To be the leader and innovator in the application of a holistic approach to study, design, and implement an infrastructure that enables an integrated grid of the future.

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We supports utilities, independent system operators, project developers, owners, independent power producers, energy storage facilities, and other grid stakeholders. You can rely on our specialized industry expertise and wide skillsets across complex regulations and systems to address constantly changing requirements.

Power Delivery	Power Generation and Renewables	Energy Storage
Distributed Energy Resources (DER)	Industrial and Commercial	Governments and Universities

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- Energy Resource Integration and Interconnection
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