Generator Deliverability Test Modifications: Light Load, Summer & Winter

Purpose

- Consider the evolving resource mix in PJM's planning process
  - In the RTEP Baseline Studies
  - In the Interconnection Studies

- Support operational flexibility

- Incorporate other miscellaneous improvements to the existing light load and winter generator deliverability tests

- PJM will be proposing modifications to each of the generator deliverability tests.
  - Procedures have been relatively unchanged for many years.
  - Multiple reasons for an update including a need better account for expected higher variability in dispatches under increased renewable penetration.
- Efforts to improve voltage testing to better account for operational concerns will be pursued separately.

Light Load – Review of Existing Procedure

- Load level
  - 50% of annual peak
  - Representative of November through April 12AM-5AM
- Base case dispatch: Historic capacity factors by resource type
- Interchange:
  - Historical values from/to each external zone connected to PJM
  - Historical values inside PJM
- MISO wind: 100% output
- Generator ramping procedure: Wind units inside PJM ramp from 40 to 80% output based on electrical proximity to flowgate under study and all remaining online units are scaled down uniformly to compensate.

Light Load – Review of Existing Procedure

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

Exhibit 5: Table 1 – Light Load Base Case Initial Target Dispatch

Table 2 – Light Load Study Generation Ramping Limits

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

Summer – Review of Existing Procedure

- Load level
  - Each PJM area at its annual 50/50 summer peak
  - Representative of June, July & August
- Base case dispatch: Capacity Resources online and scaled uniformly to serve load, losses and firm interchange
- Interchange:
  - Firm from/to each external zone connected to PJM
- MISO wind: From MMWG case
- Generator ramping procedure: Up to full output based on proximity to flowgate, and all remaining online units are scaled down uniformly to compensate

Winter – Review of Existing Procedure

- Load level
  - Representative of December through February 5AM-9AM & 4PM-8PM
- Base case dispatch: Historic capacity factors by resource type
- Interchange:
  - Firm from/to each external zone connected to PJM
  - Historical values inside PJM
- MISO wind: From MMWG case
- Generator ramping procedure: Based on proximity to flowgate, and all remaining online units are scaled down uniformly to compensate
  - Wind units ramp from 33 to 80%
  - Solar ramp from 5 up to 10%
  - All other units ramp up to 100%

Winter – Review of Existing Procedure

Network Model	Current year + 5 base case
Capacity Factor for Base Generation Dispatch for PJM Resources (Online in Base Case)	Solar – 5% Wind – 33% Water – 38% Nuclear – 98% Coal < 500 MW – 51% Coal >= 500 MW – 73% Landfill Gas – 46% Natural Gas – 25% Other Biomass Gas – 111% Oil (Distillate Fuel)– 1% Oil (Black Liquor)– 74% Oil (Kerosene)– 0% Oil (Residual Fuel)– 2% Municipal Solid Waste – 79% Wood Waste – 66% Waste Coal – 75% Petroleum Coke – 75% Other Solid – 19%
Interchange Values	Yearly long term firm (LTF) transmission service (except MAAC which will use historical averages)
Contingencies	NERC Category P0, P1, P2, P3, P4, P5, P6, and P7
Monitored Facilities	All PJM market monitored facilities

Exhibit 6: Table 1 – Winter Peak Base Case Initial Target Dispatch

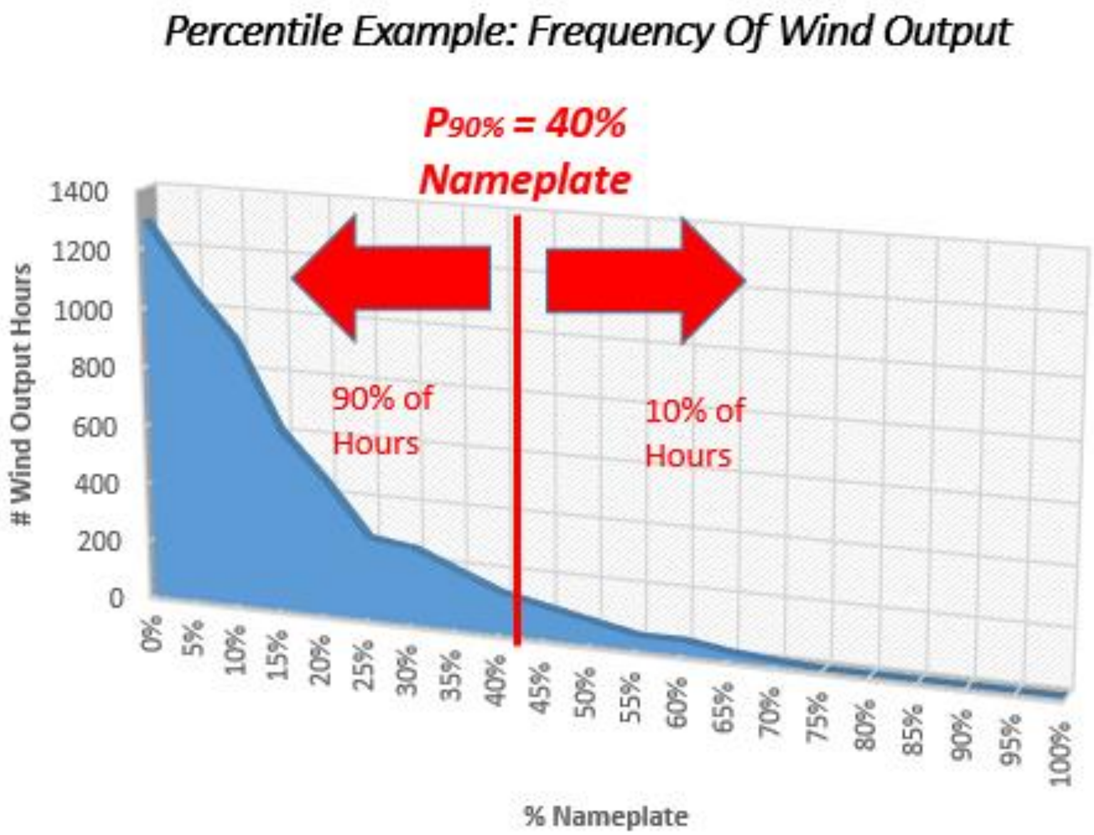
Table 2 – Winter Peak Study Generation Ramping Limits

Fuel Type	Ramping Limits (% of Pmax)
Solar	10%
Wind	80%
All other resources	100%

New Concepts

- The proposed changes to the generator deliverability test will use a few terms and concepts that warrant a brief overview.
- Deliverability Requirement: The ability of the transmission system to support the delivery to load of a specified MW injection at a location.
  - A prerequisite to the award of CIRs
  - Applicable to individual Capacity Resources, e.g. the deliverability requirements of a new queue unit
  - Also applicable to combinations of Capacity Resources, e.g. the deliverability requirements of all reasonably expected combinations of CIRs
  - Applicable to summer, winter and light load generator deliverability testing

- <u>Percentiles:</u> Represent the percentage of output hours with output levels below a particular output level.
- Example: if the P90% (90th percentile) of onshore wind outputs is 40% of nameplate, this means that 90% of the time onshore wind is producing less than 40% of nameplate.



- Block Dispatch: Groups resource types into three distinct categories based on economic considerations with block 1 containing the units expected to have the lowest offer prices and block 3 to have the highest. Each block will be dispatched as whole and block 1 will be dispatched first, then block 2 and 3 as need
  - Block 1: Nuclear, wind, solar, hydro, pumped storage, other renewables
  - Block 2: Coal, combined cycle gas
  - Block 3: IC/CT/ST oil and gas

New Concepts

- Energy-only MW: The MW capability of a generator or of a Merchant Transmission Facility (MTF) that is not examined as part of the generator deliverability test. A facility's energy-only MW may be different for each season.
  - Example 1: A 100 MW gas unit requests 80 MW CIRs. The unit therefore has 20 MW of energy-only MW.
  - Example 2: A 100 MW MTF has 80 MW of firm transmission. The MTF therefore has 20 MW of energy-only MW.
  - Example 3: A 100 MW wind farm has a summer deliverability requirement of 40 MW. The unit therefore has 60 MW of summer energy-only MW.
  - Example 4: A 100 MW solar farm has a winter deliverability requirement of 5 MW. The unit therefore has 95 MW of winter energy-only MW.
- While energy-only MW will not be considered in the generator deliverability testing, they will be examined as part of a new Individual Plant Deliverability test to ensure the maximum output capability of each generating plant and MTF is deliverable by itself in each season.

Summary of Changes

- Merged summer, winter and light load generator deliverability testing methods
- Harmonized dispatch procedures for all three RTEP base cases
  - Added new block dispatch approach to dispatch cases. No LDA allowed to import more than CETO in base case to ensure a realistic dispatch.
  - Only firm interchange modeled in base cases with separate procedures for performing sensitivities on historical interchange using simplified approach
- Redefined light load period to include any nighttime <u>and</u> daytime hours between 40-60% annual peak load
  - Established 59 deg F as default light load temperature rating set
  - Ramping procedures more consistent with summer and winter, i.e., ramp nuclear, coal, combined cycle and all renewables

Summary of Changes

- Established new deliverability requirements
  - Better account for volatility of wind and solar by using $P_{80\%}$-$P_{90\%}$ for Harmers and $P_{20\%}$ for Helpers
  - Removed all ramping caps except PGEN*EEFORd, which will be an overall ramping cap and even apply to the 50/50 generators
  - Single contingency and common mode outage testing is now identical – no more 80/20, only 50/50
  - Energy-only portion of units not studied in generator deliverability but as part of new Individual Plant Deliverability test
  - MISO wind considered in both light load and winter tests and option to consider other RTO renewables in the future
- Facility Loading Adders modelled at base case setting for resource type instead of 85%
- Remove EEFORd for plants < 50 MW

Summary of Changes

- Manual 14a Changes
  - Update references to account for Manual 14b changes
- Manual 14b Changes
  - Sections 2.3.6, 2.3.7, 2.3.10, 2.3.11, and 2.3.13
  - Attachments C.3, D-2 and D-3

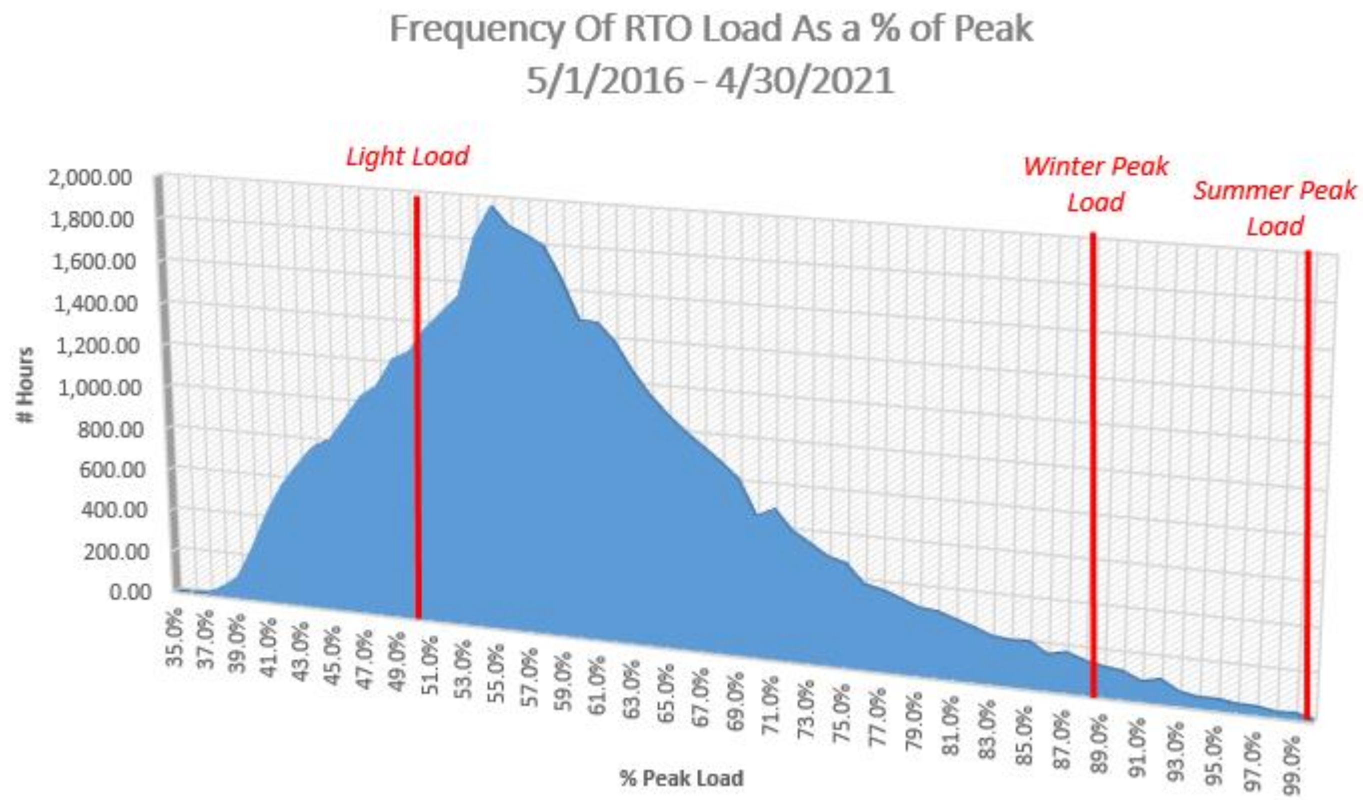
Proposed Modifications: Load Level

- **Load Level**
  - Proposal
    - Summer: No change
    - Winter: No change. Slight shift in evening hours from 4PM-8PM to 6PM-10PM based on recent loss of load studies.
    - Light load
      - Keep 50% of annual peak
      - Use load hours between 40% and 60% of the annual peak for historical generation data necessary to represent the 50% load level
  - Justification for change
    - Want to consider both daytime and nighttime hours
    - Also considered using minimum load level but that is extremely rare condition compared to 50% of peak which is a load level much closer to the range of load levels that occurs most frequently in PJM

Light Load

- Graph illustrates number of hours at each PJM load level as a percentage of the annual peak load, and where on the histogram each of the three PJM generator deliverability periods is focused.

- Light load
  - ✓ 50% of peak load
  - ✓ 80% of load hours are above and 20% below
  - ✓ Captures higher concentration of load hours than summer and winter



- Proposal
  - Summer & Winter: No change
  - Light load: Use temperature adjusted ratings for light load period, e.g. over the past year 59 deg F was the average temperature across PJM during the proposed light load hours
- Justification for change
  - Currently use summer ratings, e.g. 95 deg F, for light load which is too conservative

Proposed Modification: Base Case Dispatch

- Block Dispatch
  - Block 1: Nuclear, wind, solar, hydro, pumped storage, other renewables
    - Nuclear at PMAX * (1 – PJM EEFORd)
    - Pumped storage at historic capacity factor for resource type in light load and PMAX * (1 – PJM EEFORd) in summer & winter
    - Wind and solar at historic capacity factors for resource type, region and period
    - Hydro and other renewables at PMAX * (1 – PJM EEFORd)
  - Block 2: Coal, combined cycle gas
    - Turn on all units and scale up uniformly to meet system needs up to PMAX * (1 – EEFORd)
  - Block 3: IC/CT/ST oil and gas
    - Turn on all units and scale up uniformly to meet system needs up to PMAX * (1 – EEFORd)
- Notes
  - For summer period use CIRs in place of PMAX and historic capacity factor
  - Batteries offline

Winter & Light Load Capacity Factors For Solar & Wind

MAAC	Summer CF**	LL CF	Winter CF
Solar Fixed	47%	12%	5%*
Solar Tracking	64%	16%	5%*
Onshore Wind	16%	31%	40%
Offshore Wind	38%	49%	55%

PJM West	Summer CF**	LL CF	Winter CF
Solar Fixed	54%	13%	5%*
Solar Tracking	65%	14%	5%*
Onshore Wind	19%	35%	43%
Offshore Wind	N/A	N/A	N/A

DOM	Summer CF**	LL CF	Winter CF
Solar Fixed	55%	14%	5%*
Solar Tracking	66%	16%	5%*
Onshore Wind	20%	34%	41%
Offshore Wind	33%	52%	57%

*** No change from status quo assumptions**

**** Only used for Facility Load Adders and CIRs are used to set base dispatch**

Proposed Modification: Base Case Dispatch

- Justification for change
  - Adopt a simplified dispatch that seeks to simulate economic conditions
  - Appears to match well with historical regional dispatch patterns
  - Status quo relies only on historic capacity factors and therefore can’t keep up with rapidly evolving resource mix

Proposed Modifications: External Interchange

- Continue to maintain firm interchange in base cases and account for historical utilization
- Continue to preserve CBM in winter and summer testing
- Examine variations in interchange transactions based on historical transactions.
  - Light load: In addition to firm interchange, examine variations based average historical LL interchange directly in generator deliverability testing (similar to status quo)
  - Light Load, Winter & Summer: Test more extreme variations (P20% and P80%) of historical interchange outside of generator deliverability testing on base case for common mode outages only (new)
  - Condense historical interchange into 8 paths
    - Five external regions: North, West 1, West 2, South 1 and South 2 as defined in PJM CIL Study
    - All three Merchant Transmission Facility controllable tie lines

Proposed Modifications: External Interchange

- Justification for change
  - Status quo light load approach applies historical tie line flow to individual zones bordering PJM directly in the base case.
    - Does not properly account for the external source/sink of the transaction and loop flow.
    - By not including this tie flow directly in the base case, this proposed change will not allow historical non-firm transactions to relieve future planning problems.
  - No consideration is currently made for variations in PJM interchange under common mode outages in summer and winter studies.
  - Condensing multiple external border regions to five large external regions is sufficient to capture a broad range of historical transactions for sensitivity analysis in planning studies.

Proposed Modifications: Internal Interchange

- Do not hold internal interchange between PJM regions at historical levels and instead allow the block dispatch approach to dictate the PJM light load internal interchange.
- Ensure no area is exceeding its annual CETO plus a small margin in the base dispatch to account for generation ramping.
- Justification for change
  - Using historical internal interchange in a future planning model will not properly account for the rapidly evolving resource mix.
  - Using planning CETO levels has been a common practice in generator deliverability testing to ensure dispatch is not creating emergency conditions.

Proposed Modifications: Generator Ramping Proposal 1

- Specific Rules
  - Wind & Solar: ramp to the appropriate percentile historical output level for season/resource type/region.
  - Percentiles based on 10 years historic and backcast data
  - The output levels associated with the percentiles will be periodically updated.
  - Pumped Storage & Batteries (capability for “X” hours based on class duration)
    - Light load: +/-100% capability
    - Summer & Winter: +100% capability only

Proposed Default Deliverability Requirements For Wind & Solar As % Nameplate

MAAC	Summer P80%	Summer P90%	Winter P80%	Winter P90%	LL P80%	LL P90%
Solar Fixed	67%	N/A	5%*	N/A	23%	N/A
Solar Tracking	89%	N/A	5%*	N/A	33%	N/A
Onshore Wind	N/A	38%	N/A	73%	N/A	66%
Offshore Wind	73%	N/A	96%	N/A	92%	N/A

PJM West	Summer P80%	Summer P90%	Winter P80%	Winter P90%	LL P80%	LL P90%
Solar Fixed	76%	N/A	5%*	N/A	22%	N/A
Solar Tracking	84%	N/A	5%*	N/A	29%	N/A
Onshore Wind	N/A	52%	N/A	84%	N/A	77%
Offshore Wind	N/A	N/A	N/A	N/A	N/A	N/A

DOM	Summer P80%	Summer P90%	Winter P80%	Winter P90%	LL P80%	LL P90%
Solar Fixed	77%	N/A	5%*	N/A	29%	N/A
Solar Tracking	85%	N/A	5%*	N/A	38%	N/A
Onshore Wind	N/A	45%	N/A	78%	N/A	70%
Offshore Wind	68%	N/A	98%	N/A	95%	N/A

*** No generator ramping requirements**

New Proposed Default Deliverability Requirements For Wind & Solar As % Nameplate

- Percentile illustration: The $P_{90\%}$ for onshore wind during the summer in the MAAC region is 38%, which implies that during 10% of the peak summer hours onshore wind in wide areas across the MAAC region wind will likely be outputting more than 38% of their nameplate.
- Percentile weighting example: If region X is composed of two areas X1 and X2, where

Area	% of Nameplate	Nameplate (MW)
X1	40%	900
X2	60%	100

- Then the deliverability requirement level for region X is calculated as:

$$P = (40\% \times 900 + 60\% \times 100) / (900 + 100) = 42\%$$

Proposed Modifications: Generator Ramping Proposal 1

- General Rules
  - Light Load: Allow wind and solar resources to ramp to their default deliverability requirement. All other resources types in Blocks 1 & 2 can ramp to full output. Also allow pumped storage and batteries to ramp to +/- 100% of their “X” hour rating.
  - Summer: Allow resources in Blocks 1-3 including batteries to ramp to their CIR deliverability requirement as described in more detail on the next slide.
    - Energy-only portion of resources examined outside of generator deliverability testing using individual plant deliverability described later in this presentation.
  - Winter: Allow wind and solar resources to ramp to their default deliverability requirement. All other resources types in Blocks 1-3 can ramp to full output. Also allow batteries to ramp to +100% of their “X” hour rating.
- Justification for change
  - More closely matches operational reality
  - Improve operational flexibility to support evolving resource mix

Proposed Modifications: Generator Ramping Proposal 1

- During summer generator deliverability testing, ramping limits are based on a unit's CIRs.
- For Capacity Resources where the CIRs are equal to the summer maximum facility output of the unit, or in the case of batteries their "X" hour rating, the ramping limit is 100% of the CIRs.
- For Capacity Resources where the CIRs are less than the maximum output, the ramping limit will be equal to the CIRs, except for wind and solar resources for which the ramping limit will determined through the following relationship.
  - Actual ramping limit = Default ramping limit * Actual CIRs / Summer Capacity Factor for the resource type and region (MAAC, PJM West, Dominion) in which it is located
  - For example, a 100 MW onshore wind farm with 13 MW CIRs, a summer capacity factor of 15% and a default ramping limit based upon the $P_{90\%}$ for onshore wind farms in the same region is 45%. The actual ramping limit would be 39%.
  - IMPORTANT NOTE: Treatment of wind and solar units that are interconnected or have sought interconnection prior to the effective date of these rule changes is currently under discussion at the PJM PC Special Session – CIRs for ELCC Resources.

Proposed Modifications: Generator Ramping Proposal 2

- Wind and solar ramp down to 20th percentile historical output level for season/resource type/region.
- Percentiles based on 10 years historic and backcast data
- The output levels associated with the percentiles will be periodically updated.
- Justification for change
  - More closely matches a stressed dispatch that would be seen in operations rather than just maintaining average expected outputs on the receiving end of a constraint
  - Improve operational flexibility to support evolving resource mix

Proposed Availability Under Stressed Conditions For Wind & Solar As % Nameplate

MAAC	Summer $P_{20\%}$	Winter $P_{20\%}$	LL $P_{20\%}$
Solar Fixed	28%	0%	0%
Solar Tracking	38%	0%	0%
Onshore Wind	0%	15%	8%
Offshore Wind	0%	13%	9%

PJM West	Summer $P_{20\%}$	Winter $P_{20\%}$	LL $P_{20\%}$
Solar Fixed	33%	0%	0%
Solar Tracking	43%	0%	0%
Onshore Wind	0%	13%	9%
Offshore Wind	N/A	N/A	N/A

DOM	Summer $P_{20\%}$	Winter $P_{20\%}$	LL $P_{20\%}$
Solar Fixed	35%	0%	0%
Solar Tracking	48%	0%	0%
Onshore Wind	0%	17%	11%
Offshore Wind	0%	13%	9%

Proposed Modifications: Generator Ramping Proposal 3

- Instead of modeling Facility Loading Adders at 85% of peak output, model them at the same % output that the resource type is modelled in the base case block dispatch.
  - Facility Loading Adders are offline units electrically just outside of the 50/50 dispatch.
  - Use regional, seasonal capacity factors for wind and solar
- Justification for change
  - The use of the 85% level to model Facility Loading Adders was a legacy number carried over from the original summer peak generator deliverability test and is inappropriate for light load, winter and even summer where units are modelled at various output levels based on their resource type, load level and interchange.

Proposed Modifications: Generator Ramping Proposal 4

- Do not assign generators < 50 MW a EEFORd.
- Justification for change
  - With the proliferation of smaller units, larger units are often not being ramped to full output.

Proposed Modifications: Generator Ramping Proposal 5

- Instead of capping ramping to online PMAX * PJM Avg EEFORd (status quo approach), cap ramping of both adders and 50/50 generation to online PGEN * PJM Avg EEFORd. Similarly cap wind and solar reductions to the $P_{20\%}$ level to be no more than the online PGEN * PJM Avg EEFORd.
  - PMAX is the maximum MW output of a generator
  - PGEN is the actual MW output of a generator
- Justification for change
  - This metric attempts to restrict the ramping to an amount that may realistically be needed/occur during the period under study. Using PMAX does not make sense when many of the units are dispatched well below that level.

Proposed Modifications: Generator Ramping Proposal 6

- Establish same procedures for single and common mode analysis
  - Instead of using 80/20 for single contingency ramping and 50/50 for common mode ramping use 50/50 for both.
  - Ramp generators to same output levels for both tests.
  - Energy-only portion of unit will be studied using separate individual plant deliverability procedure described later in this presentation
- Justification for change
  - With declining EEFORds the number of generators in the 80/20 excluding wind and solar now averages around 28, whereas the number of generators in the 50/50 averages around 12. With removal of EEFORd for units less than 50 MW dispatches will be more concentrated with higher MW machines.
  - Change will allow the removal of operational contingencies and greatly simplify analysis by having a shared, common dispatch on which all contingency analysis is performed.

Proposed Modifications: Generator Ramping Proposal 7

- Establish individual facility deliverability for each generator and controllable MTF connected to PJM
  - Requires that each individual generating plant and controllable MTF be ramped to its maximum seasonal capability. Under these conditions the system must be secure for single and common mode contingencies.
- Justification for change
  - While large numbers of variable resources will not be simultaneously tested at 100% MFO because of the negligible likelihood of such an occurrence, individual variable resources are much more likely to achieve such levels and should therefore individually be capable of full output in the base case to ensure their MFO is deliverable.
  - Removed energy-only testing from generator deliverability test as PJM has less than 2,000 MW of energy-only MW.

Proposed Modifications: Generator Ramping Proposal 8

- Do not modify MISO wind dispatch in base case, but instead use generator deliverability tool to ramp MISO wind to same value as PJM wind is ramped
- Consider MISO wind ramping in light load and winter using same ramping values for PJM onshore wind
- Periodically review assumptions regarding external RTO wind and solar as increased penetration unfolds.
- Sink MISO wind to MISO North per MISO planning process
- Justification for change
  - Allows testing over a range of expected and extreme MISO wind levels

- Comparing potential reliability violations of status quo and proposed generator deliverability procedures
  - 2026 RTEP Light Load
  - 2026 RTEP Winter
  - 2026 RTEP Summer
- Expect to share test results prior to 11/2/2021 Regular PC Session
- Expect to share summer only test results at 10/13/2021 Special PC Session

Interconnection Queue Testing Results

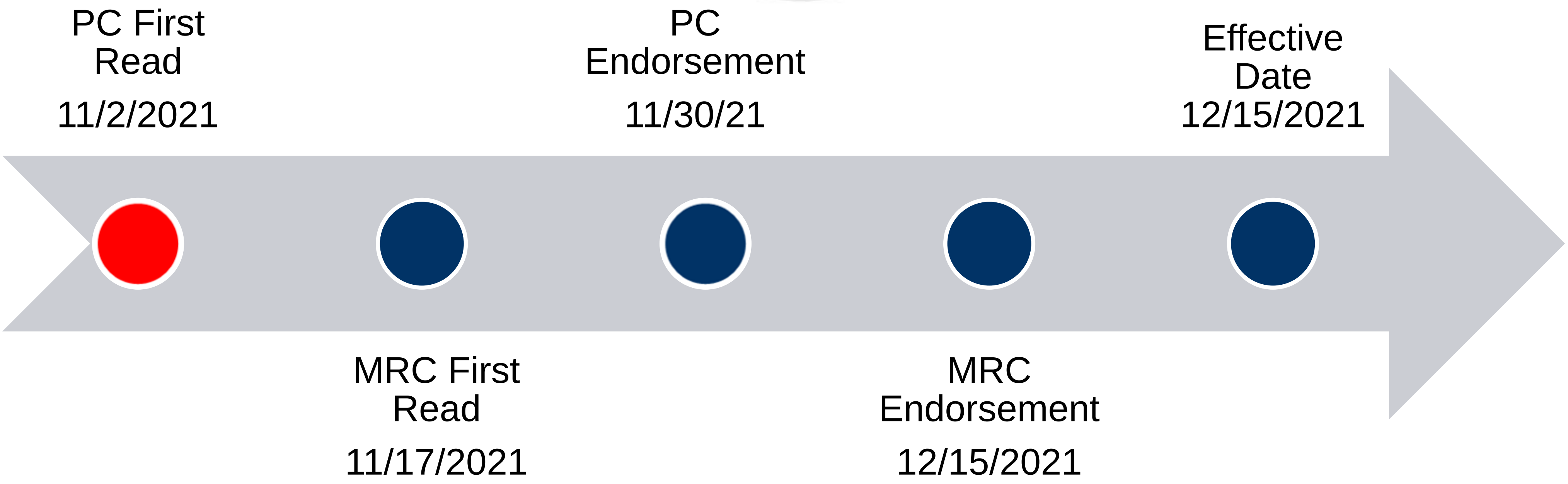
- Using Impact Study Base Case (2024 RTEP Light Load & Summer) for AG1 queue
- Applying unique commercial probability forecast for each queue project to reduce its maximum output.
  - Example: 100 MW unit has a 60% chance of reaching commercial operation so it is modelled as a 60 MW unit.
- 124,000 MW (47,000 MW capacity) non-commercial queue generation was examined

Unit Type	Com Prob
Wind	31%
Solar	50%
Natural-gas	76%
Hydro	20%
Coal	41%
Nuclear	62%
Oil	56%
Other	4%

Interconnection Queue Testing

- Comparing potential reliability violations of status quo and proposed generator deliverability procedures
- AG1 Queue 2024 RTEP Light Load & Summer
  - Status Quo
  - Proposed
- Expect to share test results prior to 11/2/2021 Regular PC Session
- Expect to share summer only test results at 10/13/2021 Special PC Session

Review and Approval Timeline



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