PJM Load Deliverability Test

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Deliverability Background

- Two types of risk must be considered when measuring the reliability of the power system
  - Generation risk
  - Transmission risk
- PJM's Reserve Requirement Study ensures that generation risk across PJM involves no more than one event in ten years where the generation supply is less than the demand on the system
- The concept of deliverability was introduced in order to ensure the transmission risk does not appreciably increase the overall generation risk
  - Load deliverability
  - Generation deliverability

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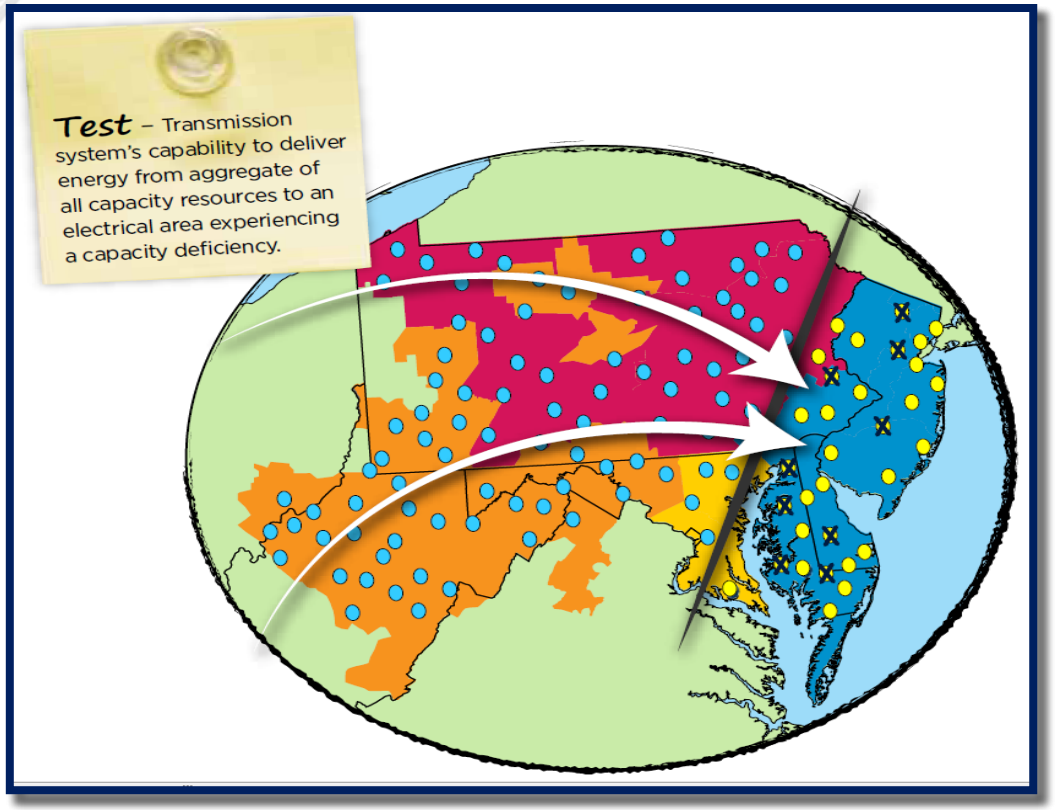
Load Deliverability Test

- The concept of load deliverability was first introduced at PJM about 50 years ago to ensure there was minimal transmission risk serving each Locational (load) Deliverability Area (LDA) in PJM
- The load deliverability test ensures sufficient transmission capability exists on the PJM system to supply emergency power from the aggregate of PJM generation to LDAs experiencing capacity emergency and high load conditions



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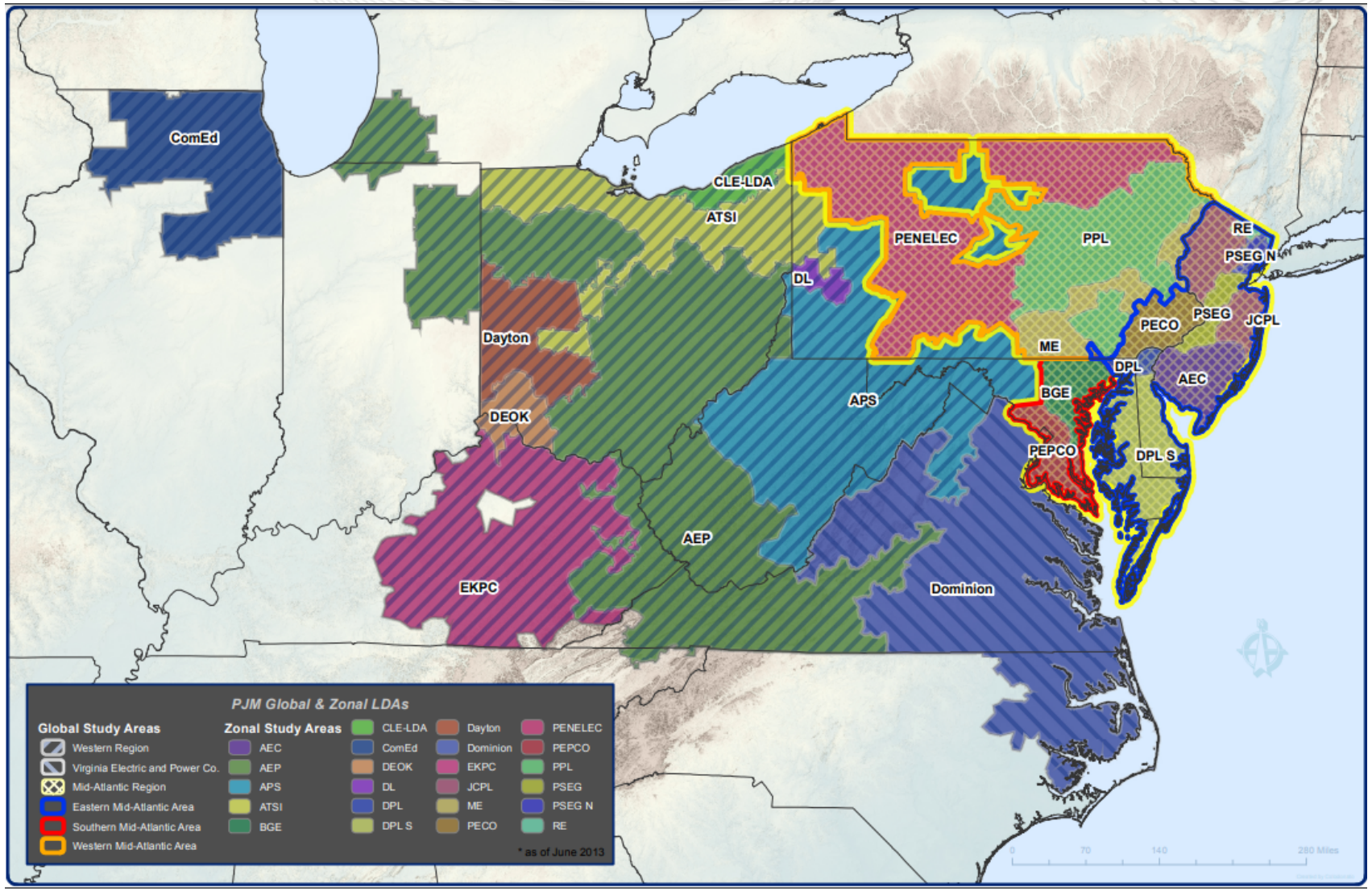
Locational Deliverability Areas



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Locational Deliverability Areas

- PJM currently has 27 LDAs comprised of 19 zonal LDAs, 3 sub-zonal LDAs and 5 global LDAs
  - Zonal LDAs correspond to traditional Transmission Owner electrical boundaries
  - Sub-zonal LDAs correspond to portions of zonal LDAs that have been carved out because of historical transmission import concerns
  - Global LDAs are comprised of combinations of zonal LDAs and may contain common EHV facilities that serve the zonal LDAs

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Applications of Load Deliverability Test

- Annually as part of the RTEP (summer and winter)
- Annually prior the RPM Base Residual Auction
- As needed for Interconnection Requests
- As needed for Incremental Capacity Transfer Rights (ICTRs)

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Core Load Deliverability Concepts

- Capacity Emergency Transfer Objective (CETO): The amount of power an LDA needs to import to ensure that there is no more than one loss of load event in 25 years
- Capacity Emergency Transfer Limit (CETL): The amount of power that an LDA can import
  - CETL < CETO conditions require transmission reinforcements
- Each LDA within PJM is assumed to be experiencing a generation deficiency independently
- No imports beyond firm from outside PJM

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CETL Case Development

- Start with the applicable RTEP base case and set PJM load to coincident peak levels
- Each LDA studied independently at higher of 90/10 load level minus demand response or 50/50 load
  - 90/10 load adder modeled at 80% Power Factor
- Two separate power flow cases created for each LDA at CETO level. Rest of PJM is assumed to be operating normally and generation is scaled up uniformly to supply the LDA's CETO
  - Mean Dispatch Case: models the average value of each generator's output for the LDA under study from over 10,000 unique dispatches at the CETO
  - Discrete Outage Case: models the most likely discrete generator outage pattern within the LDA at the CETO

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Mean Dispatch Case Creation Steps

1. All generators in the study area are sampled until 10,000 generation outage scenarios are found where the amount of generation selected is within +/- 2% of the amount needed to meet the target generator outage value required to model the import objective.
2. The 10,000 generation outage scenarios are determined by using a Monte Carlo simulation and assigning a random value between 1 and 0 to each generator in the study area. If the random value is greater than the generator forced outage rate, then that generator is turned on at its full capability. If the value is less than the generator forced outage rate, then that generator is turned off. There is no limit to the number of units that can be simultaneously outaged at a station.
3. Determine the average MW output of each generator in the study area by using its dispatched values in the 10,000 generator outage scenarios.
4. The reactive capability of each unit is reduced by the ratio of each unit's average MW output from the preceding step to the unit's maximum MW output.
5. Create a base case modeling the average MW output and reactive capability of each generator determined using the above steps.

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Discrete Outage Dispatch Case Creation Steps

1. Derate all generators in the zone by their EFORd.
2. Rank generators by EFORd^(1/PMAX).
3. To model discrete generator outages, select generators in rank order until the next selected generator would exceed 105% of the target generator outage value at the CETO.
   a) LDA target generator outage value = LDA UCAP – LDA target generation
   b) LDA UCAP = Sum (1-EFORd)*PMAX for each LDA generator
   c) LDA target generation = LDA load – LDA CETO
4. Multiple generators at the same substation may be taken off line unless the outaged MW to installed MW ratio is greater than 60%. (For example, if a station had 3-100 MW units, 1 unit would be outaged since 100 MW/300 MW = 33% but two units would not be outaged since 200 MW/300 MW = 66%)
5. Any remaining MW outages required to meet the target generator outage value will be obtained through a uniform scale of all on-line generation's MWs and MVARs in the study area.
6. The Transmission Owner(s) may request analysis of a different outage pattern. If this outage pattern results in more severe reliability problems it will be used in place of the original outage pattern only if both the Transmission Owner and PJM accept the new outage pattern.

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CETL Thermal Analysis

- CETL is the maximum amount of imports into the LDA where no relevant single contingency thermal, voltage magnitude or voltage drop issues exist
- The first step to determine the CETL is to find the thermal import limit into the LDA. This is done for separately for both the mean and discrete outage dispatch cases, i.e. start with the CETO and see how much additional power can be imported into the LDA
- PJM uses the TARA program transfer power into the LDA while simultaneously performing a security constrained redispatch of PJM generation outside the LDA
- Generation inside the LDA is decreased uniformly (MW and MVAR capability) until the import limit(s) is identified

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Load Deliverability Facilities

- PJM monitors all internal transmission facilities for its load deliverability test and screens criteria violations for upgrades that pass an outage transfer distribution factor (OTDF) cutoff test and are on PJM's monitored facility list (lists of PJM monitored lines and substations are available at http://www.pjm.com/markets-and-operations/ops-analysis/transmission-facilities.aspx.)
- The resulting list of facilities constitutes the PJM Load Deliverability Facility List and may vary from study to study because changes in system topology may change the OTDF
- See Appendix for more details on the criteria for defining a PJM Load Deliverability Facility

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Non-PJM Facilities

- For transmission facilities outside of but electrically close to PJM, PJM conducts joint coordinated interregional studies on a periodic basis that examine and address deliverability issues between PJM and adjacent external systems.
- Based on the results of these joint studies, PJM may choose to include specific non-PJM transmission facilities in the load deliverability test in order to account for significant loop flows that occur through non-PJM transmission systems when large transfers within PJM are present.
- In order for a non-PJM transmission facility to be included as an External Load Deliverability Facility in either the thermal or voltage load deliverability analysis, it must meet same OTDF cutoff rules that are required for Internal Load Deliverability Facilities.

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CETL Voltage Analysis

- After the CETL thermal import limit has been identified for both the mean and discrete outage dispatch cases, the TARA program is used to create the CETL power flow case
- Next, a single contingency screening is performed for each LDA at the thermal import limit to determine whether there are any relevant voltage magnitude or drop import limits
  - If there are no voltage issues at the thermal import limit, then the lower of the thermal import limits identified using the mean and discrete outage dispatch cases defines the CETL
  - If there are voltage issues at the thermal import limit, then PV analysis is used to determine the voltage import limit and it defines the CETL

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Consistency with PJM Emergency Operations Procedures

- In all cases, the study area CETL analysis should reflect actual PJM emergency operations procedures designed to make as much power available to the deficient study area as possible under the prevailing system conditions. This should include but is not limited to
  - The operation and redispatch of any available PJM generation external to the LDA regardless of system economics. Redispatch of Capacity Resources are allowed internal to the study area as well to relieve an overload provided that the CETO is increased by the amount of generation reduction required to eliminate the internal overload.
  - The activation of any PJM Load Management (LM) schemes within the LDA that may serve to unload limiting facilities to the extent that doing so does not reduce the load in the area under test below the expected 50/50 load.
  - The adjustment of any Phase Angle Regulators (PARs) which PJM or PJM member companies control within existing agreements for emergency operation. The PJM/NYISO PAR flows will be set according to Attachment B Section (B.3)(VII)(P).
  - The activation of any approved PJM or PJM member company operating procedure.
  - Operating procedures are described in PJM Manual M03 -Transmission Operations.

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Appendix

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Load Deliverability Facilities

- All non-radial facilities with a low side voltage 345 kV or greater will be included if their OTDF is greater than or equal to 5%.
- All non-radial facilities with a low side voltage 345 kV or greater will be included if their OTDF is greater than 2% and less than 5% unless both PJM and the TO agree that the facility should not be included.
- All non-radial facilities with a low side voltage 345 kV or greater will be not included if their OTDF is less than 2% unless both PJM and the TO agree that the facility should be included.
- All non-radial facilities with a low side below 345 kV with an OTDF greater than 10% will be included.
- All non-radial facilities with a low side below 345 kV with an OTDF between 5% and 10% will be included unless both PJM and the TO agree that the facility should not be included.
- All non-radial facilities with a low side below 345 kV with an OTDF less than 5% will not be included unless both PJM and TO agree that the facility should be included.
- All PJM monitored facilities will be included when determining any generation redispatch or PAR movements required for the base case development. However, only the facilities on the Load Deliverability Facility List will require a system upgrade if overloaded for this load deliverability test.
- The substations to be included for voltage analysis will be developed based on the Load Deliverability Facility List. In other words, the OTDF for a substation will be determined based on the highest OTDF of the transmission facilities directly connected to the substation under the contingency conditions that result in voltage issues. Additional substations will be included for voltage analysis if agreed to by PJM and the TO.

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RASTF education on locational/transmission aspects of the capacity market e.g. LDAs, CETO, and CETL.

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