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Transmission Planning Assumptions

Probabilistic Methodology Implementation for Base Case Creation

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BACKGROUND AND PURPOSE

Background

- ISO has been reviewing the key assumptions used in transmission planning studies and how they should be applied to Needs Assessment studies
- At the December 2015 and January 2016 PAC meetings, the ISO presented a conceptual methodology for base case assumption quantification
- At the February 2016 PAC meeting, the ISO shared with the PAC a summary of current industry efforts related to probabilistic transmission assessments
- At the May 2016, August 2016, and December 2016 PAC meetings, the ISO presented the PAC with detailed updates on the ISO's developing conceptual methodology for base case assumption quantification
- At the March 2017 PAC meeting, the ISO summarized the elements of the base case assumption quantification and described the plan to implement the new assumptions in late spring

Purpose of Presentation

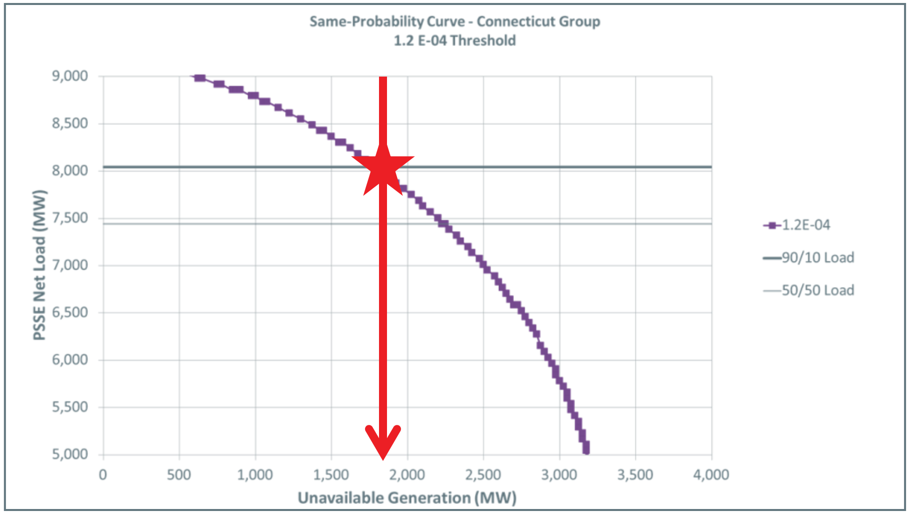
- Discuss implementation of probabilistic methods used to create same probability curves for use in creating dispatches for base cases of transmission Needs Assessments and Solutions Studies
  - Note update to transmission security probabilistic threshold calculation
- Review one simple example to demonstrate impact of the updated threshold calculation and overall method implementation
- Describe next steps for transmission planning assumptions

BASE CASE PROBABILISTIC METHODS

Implementation

Overall Concept

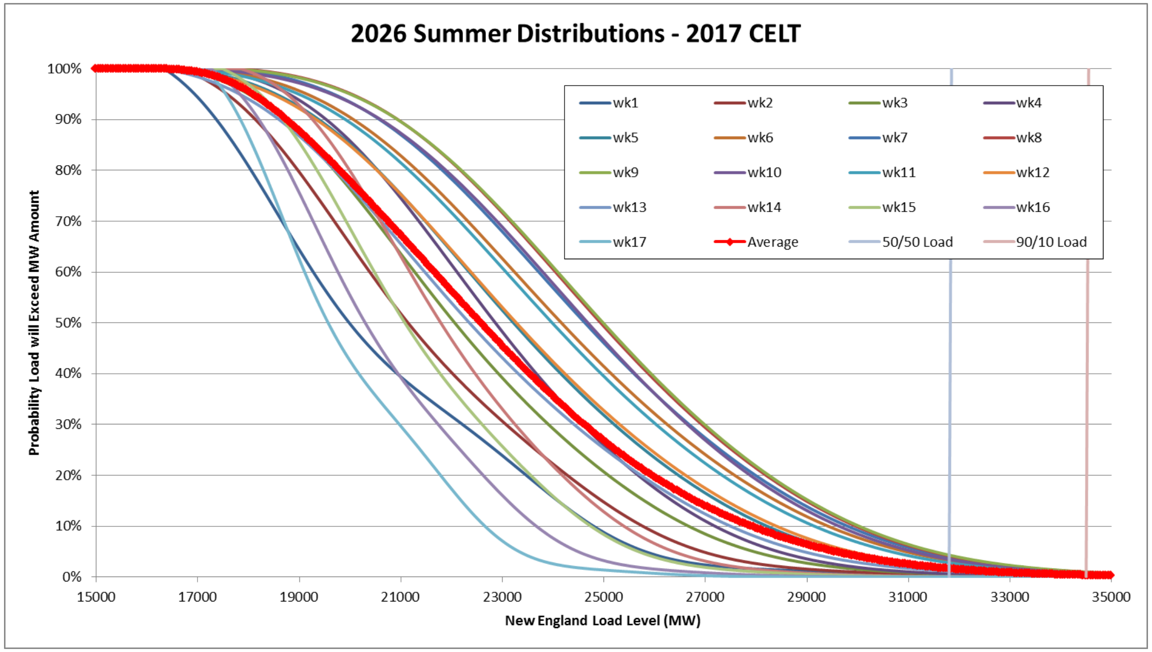
- Develop a "same-probability" curve to describe the combined likelihood of certain levels of load and generation unavailability in a given study area
- Use the curve to determine the representative amount (MW) of generation to be modeled out of service (unavailable) in the transmission Needs Assessment for the study area
  - Concept change from modeling a particular number of generators out of service in the study base cases to modeling a representative quantity (MW amount) of generation out of service[1]



1. As discussed in the August 2016 PAC, at a minimum, at least one generator will be modeled out of service even if it is above the threshold amount.

Load Level Probability

- Based on most recent CELT forecast
- Took average of 17 summer weeks' cumulative distribution curves
- Details will be provided in Section 2.2.2 of the Transmission Planning Technical Guide (TPTG) when updated



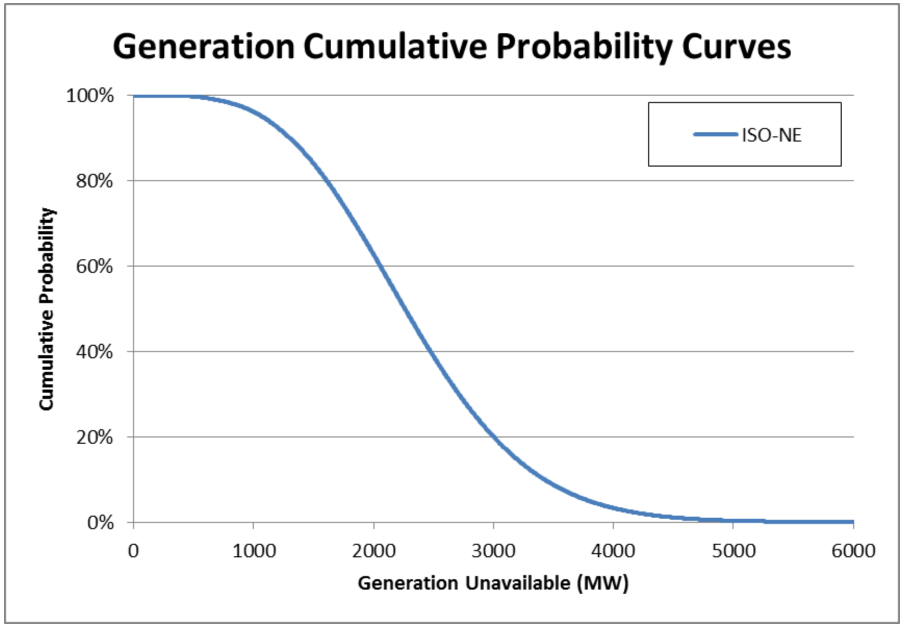
Unavailable Generation Probability

- Generation within a subarea was assigned the most recent historical 5-year EFORd (Equivalent Forced Outage Rate demand) if available or NERC GADS Class Averages
  - In some instances, a resource's five-year average EFORd reflects the past occurrence of a long-term atypical outage that has a low probability of reoccurrence. In these cases, the EFORd values for these units may be replaced by their average EFORd without the atypical event.
- Units with maximum power ratings derated according to the Technical Guide were not included in the unavailability calculation so they would not double count MW unavailability
  - See Section 2.3.5 of the updated TPTG for details

Resource Type	Existing	Future
Conventional Generation	5yr Avg (if known) NERC Class Avg (if unknown)	NERC Class Avg
Wind	De-rated Output	De-rated Output
Hydro Generation	De-rated Output	De-rated Output
Solar Photovoltaic	De-rated Output	De-rated Output
Waste (Municipal Solid and Wood)	5yr Avg	NERC Class Avg

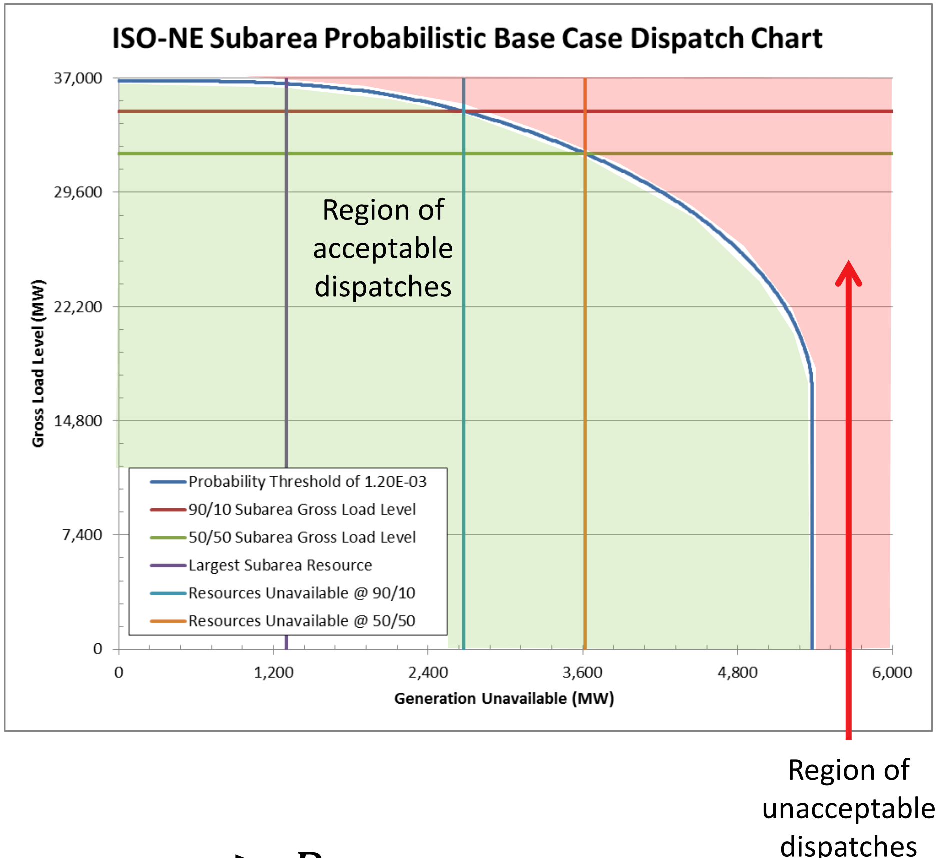
Unavailable Generation Probability, cont.

- Once all the units for a study area were identified, their probabilities were combined using the convolution method to create a single cumulative distribution curve
  - See Appendix for description of convolution method
- This curve identifies the probability that X MW or greater of generation will be unavailable



Same-Probability Curves

- The load and generation cumulative curves are then combined to find a new curve that provides for a given load level, the amount of unavailable generation where their two combined probabilities is equal to an established threshold



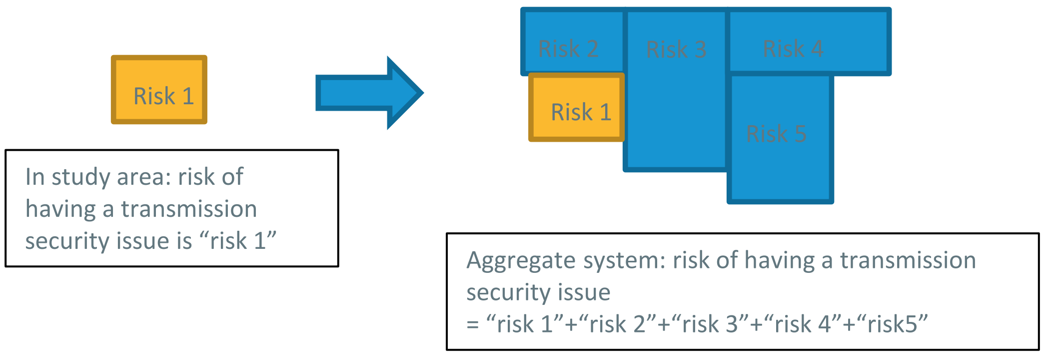
$$P_{Load\ Level} \times P_{Gen\ Unavail} \geq P_{Threshold}$$

Probabilistic Threshold

- The transmission security probabilistic threshold for the New England Control Area is derived from an amount of risk equivalent to planning our system's resource adequacy need to a Loss of Load Expectation (LOLE) of '1 day in 10 years'
- The New England LOLE is currently driven by summer week days
  – 85 days (17 weeks, 5 days/week) from June through September
- The load distribution used in the conceptual methodology is also based on summer week days
  – Combination of daily peak distributions for 85 days (17 weeks) from June through September
- Assuming a small, constant risk every summer week day, at criterion, the New England probability is equivalent to an probability of 0.1 days / 85 days = 0.001176 ≈ 1.2 E-03
  – See Section 3.1.3 of updated TPTG for details

Probabilistic Threshold, cont.

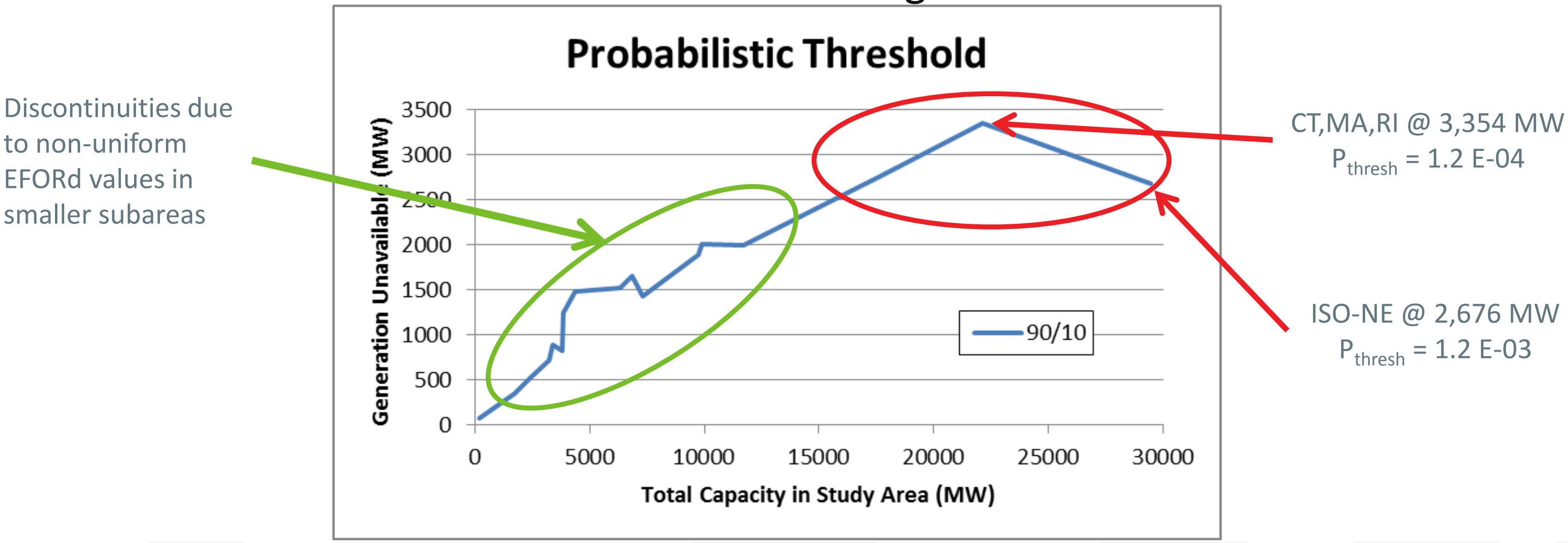
- Transmission planning study areas are sub-sections of the aggregate system



- Each sub-section carries its own risk and the aggregate system additively carries the risk of all its sub-sections
  - Assumes that the transmission security risk of a study area is not improved by it being part of the aggregate system
  - Assumes that the transmission security risk of each study area is independent
- At the December 2016 PAC, the ISO introduced the sub-division of the New-England-wide value (e.g. 1.2 E-03) by 10 to be used as a probabilistic threshold (e.g. 1.2 E-04) for any size study area

Probabilistic Threshold, cont.

- During the Summer of 2017, initial methodology implementation demonstrated that the 1.2 threshold of 1.2 E-04 intended to be representative for multiple smaller study areas appeared to be misrepresentative and overly conservative for larger study areas
- Compared to New England as a whole, where a threshold of 1.2 E-03 would be used, application of a threshold of 1.2 E-04 to a study area as large as Southern NE (CT, MA, and RI), the methodology would indicate that more generation should be modeled unavailable in the study area than would be calculated to be unavailable in all of New England



Probabilistic Threshold, cont.

- To address this issue, a new formula was developed to calculate the probabilistic threshold based on the amount of capacity in a study area compared to total NE capacity

$$P_{Study\ \ Area} = P_{Thresh\ Max} - \left\{ (P_{Thresh\ Max} - P_{Thresh\ Min}) \times \left(1 - \left[\frac{Resources_{Study\ \ Area}}{Resources_{New\ England}} \right] \right) \right\}$$

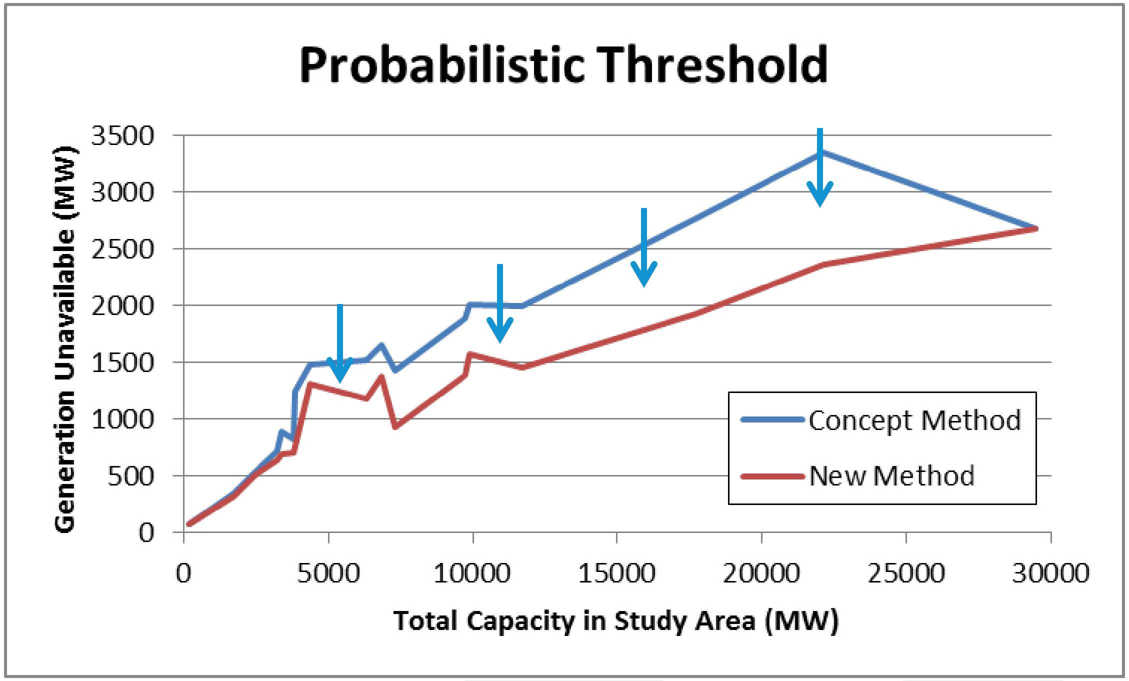
  - Maximum Threshold: 1.2 E-03
  - Minimum Threshold: 1.2 E-04

$$P_{Study\ \ Area} = 1.2\text{E-}03 - \left\{ (1.2\text{E-}03 - 1.2\text{E-}04) \times \left(1 - \left[\frac{Resources_{Study\ \ Area}}{Resources_{New\ England}} \right] \right) \right\}$$

- As the study area approaches the size of the New England Control Area, the threshold will converge to the system-wide value of 1.2 E-03

Probabilistic Threshold, cont.

- Amount of generation unavailable in a study area reduced in all instances due to a larger threshold based on the new formula
- Viewed as a more reasonable method to consider the relative size of the study area in the calculation of the transmission security probabilistic threshold and is now incorporated in the utility to create the probability curves



Create Base Cases for Needs Assessments Studies: Before and After Use of Probabilistic Methodology

Previous Methodology

- Model 90/10 peak load
- Determine series of representative (base cases) power-flow conditions by taking up to two generators out in different parts of the study area
  - ISO System Planning determines which generators should be modeled out of service in each base case

New Probabilistic Methodology

- Identify the groups of generators that respectively stress different parts of the study area
- Develop "same-probability" curves for each group of generators
- Model 90/10 peak load and/or other load levels as deemed relevant based on the shape of the "same-probability" curve
- Determine the total MW amounts of generation to simultaneously take out of service for each group of generators, based on the "same-probability" curve (no less than one generator)
  - ISO System Planning selects representative base cases by taking into account results from the prior steps and considering the largest generating unit in the study area

IMPLEMENTATION EXAMPLE

An Exercise to Demonstrate Implementation of Probabilistic Methods

Example Disclaimer

- The following example uses a hypothetical study area with NERC class average EFORd values. This example has no relation to a study area in New England, and is used for illustrative purposes only to demonstrate the utility to create the probability curves
- Unit specific EFORd values are confidential and not available to the public according to the ISO New England Information Policy.

Study Area Generation

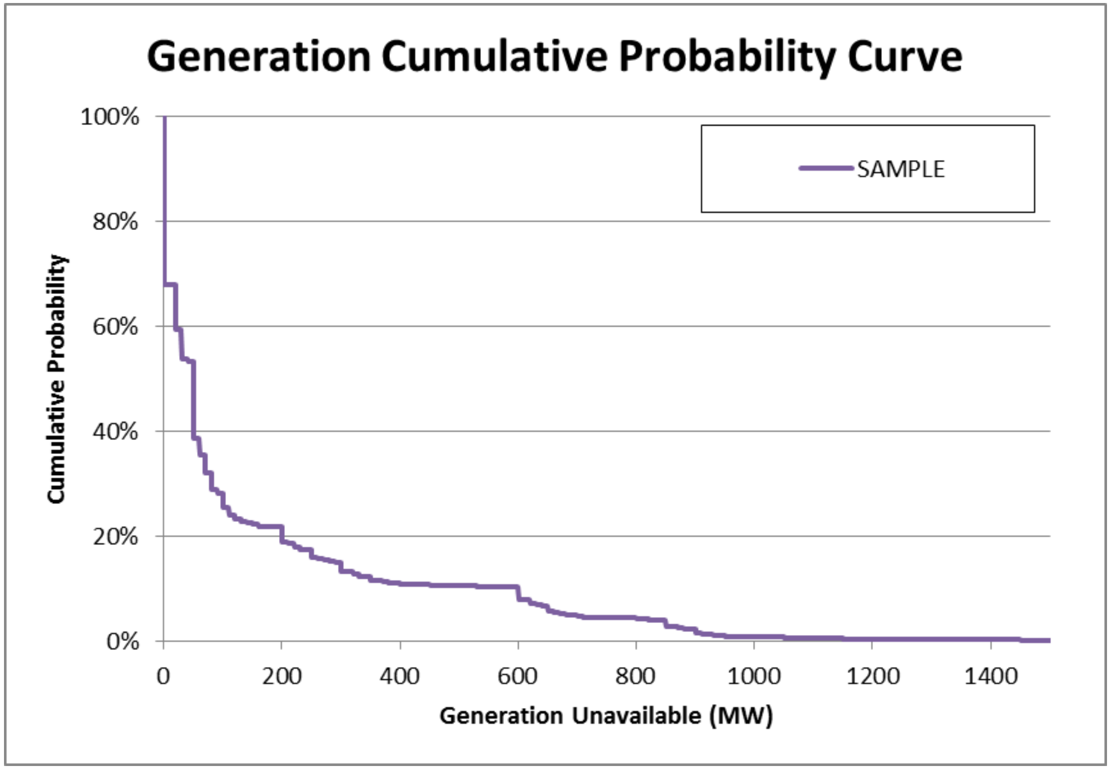
- The sample study area contains 13 resources totaling 2,480 MW to be included in the analysis. The wind, hydro, and PV resource totals for the area are excluded from the analysis since their maximum output is derated according to the transmission planning technical guide

Resource Name	Res MW	Res EFORd %
Combined Cycle 1	300.00	4.44%
Combined Cycle 2	200.00	4.44%
Combined Cycle 3	200.00	4.44%
Gas Turbine 1	50.00	9.19%
Gas Turbine 2	50.00	9.19%
Gas Turbine 3	50.00	9.19%
Gas Turbine 4	50.00	9.19%

Resource Name	Res MW	Res EFORd %
Nuclear Unit 1	850.00	3.46%
Oil Peaker 1	20.00	11.62%
Oil Peaker 2	20.00	11.62%
Coal Unit 1	600.00	7.04%
Biomass Unit 1	30.00	14.80%
Biomass Unit 2	60.00	9.19%

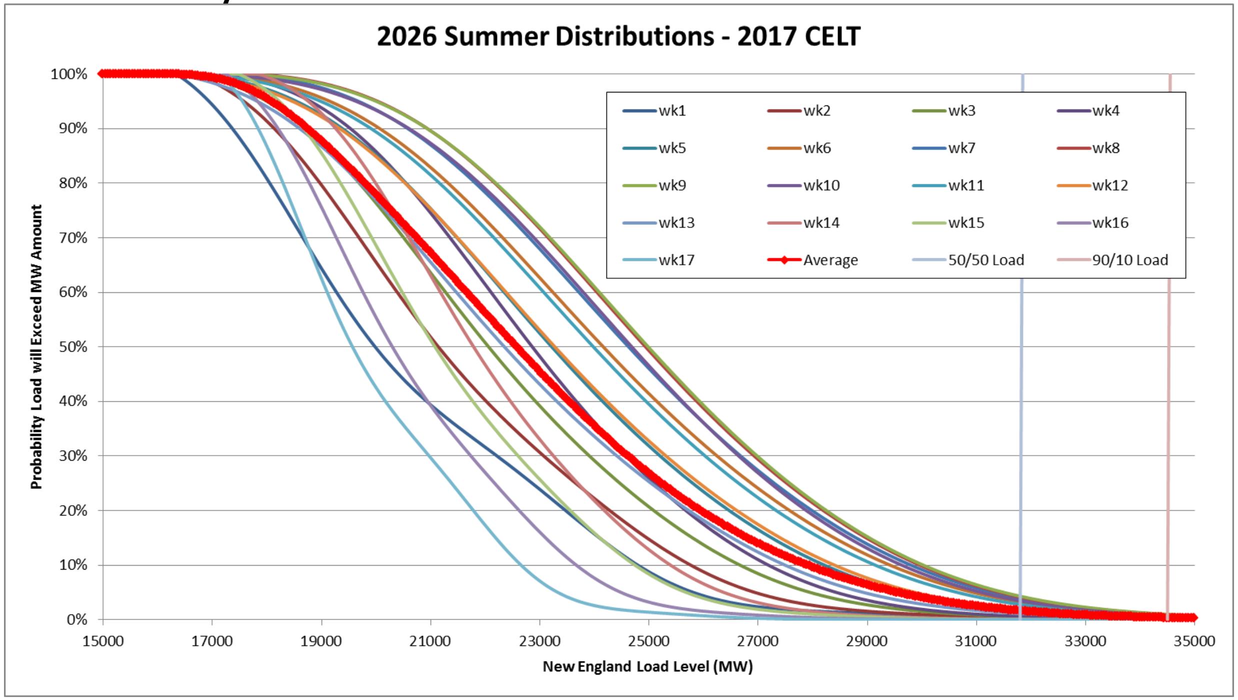
Study Area Generation, cont.

- Using the convolution method, a cumulative distribution curve is created for the 13 resources



Study Area Load

- Assume the sample study area has 8% of ISO load. Based on the 2017 CELT Forecast, that will equate to
  - 90/10 Load of 2,790 MW
  - 50/50 Load of 2,570 MW
- Then the cumulative distribution load curve for New England is scaled down to the study area load



Study Area Probabilistic Threshold

- Based on the revised equation presented earlier today, the transmission security probabilistic threshold for the sample study area is:

$$P_{Study\ \ Area} = P_{Thresh\ Max} - \left\{(P_{Thresh\ Max} - P_{Thresh\ Min}) \times \left(1 - \left[\frac{Resources_{Study\ \ Area}}{Resources_{New\ England}}\right]\right)\right\}$$

$$P_{Study\ \ Area} = 1.2\text{E-}03 - \left\{(1.2\text{E-}03 - 1.2\text{E-}04) \times \left(1 - \left[\frac{2{,}480\ MW_{Study\ \ Area}}{29{,}437\ MW_{New\ England}}\right]\right)\right\}$$

$$P_{Study\ \ Area} = 0.0012 - \{0.00108 \times (1 - 0.0842)\}$$

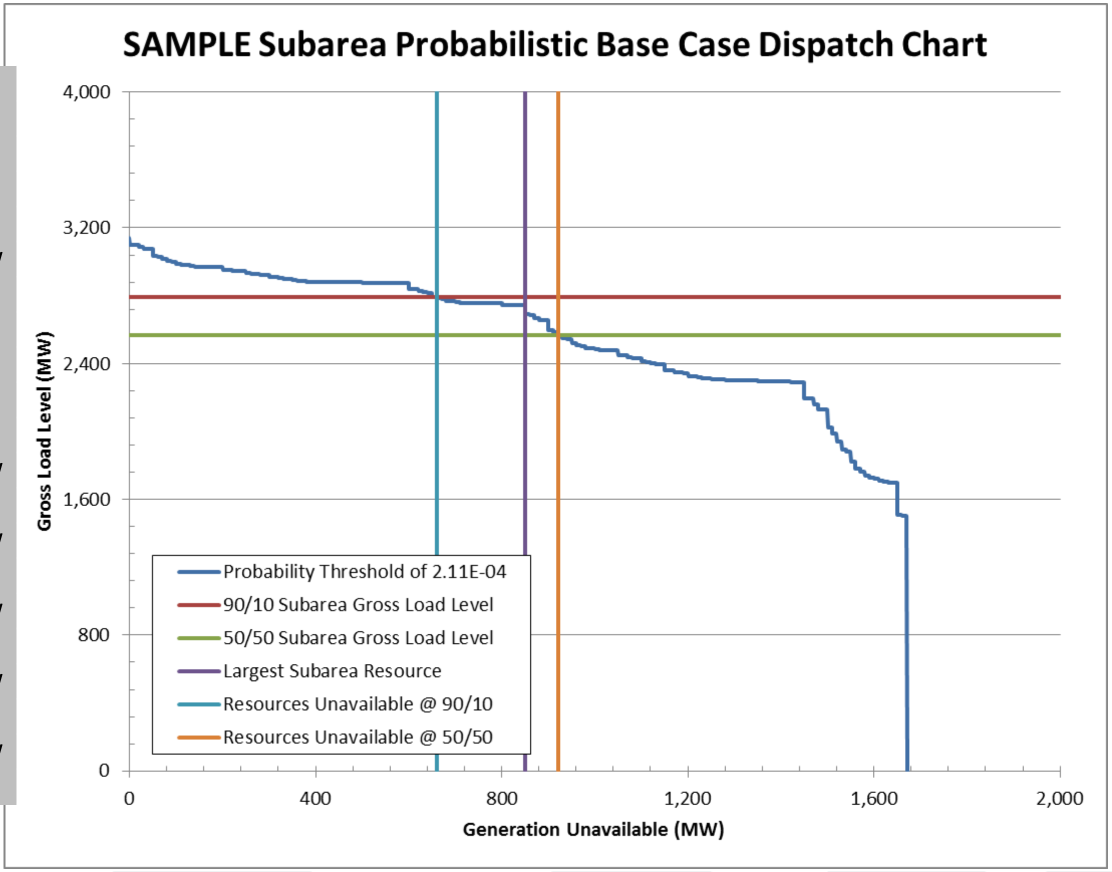
$$P_{Study\ \ Area} = 0.0012 - \{0.00108 \times 0.9157\}$$

$$P_{Study\ \ Area} = 0.0012 - 0.000989 = 0.000211 = 2.11\text{E-}04$$

Study Area Same-Probability Curve

- Combining the generation and load probability curves and setting a threshold of 2.11E-04, the following curve is created

Probability Threshold	2.11E-04	
Subarea Name	SAMPLE	
Subarea Total MW Resources*	2,480	MW
Subarea # of Resources*	13	
Subarea load % of ISO-NE	8.00%	
90/10 Subarea Gross Load Level	2,790	MW
50/50 Subarea Gross Load Level	2,570	MW
Largest Subarea Resource	850	MW
Resources Unavailable @ 90/10	661	MW
Resources Unavailable @ 50/50	921	MW



Study Area Same-Probability Curve, cont.

- Based on the curve, the following base case dispatches for the study area are in the acceptable region of the curve:
  - 90/10 Load Level w/ Largest Single Gen OOS
    - 2,790 MW of load
    - Largest study area unit unavailable
      - Example Disp 1: Nuclear Unit 1 OOS (850 MW)
  - 90/10 Load Level w/ probabilistic resources unavailable
    - 2,790 MW of load
    - Combination of study area units not to exceed 661 MW unavailable
      - Example Disp 2: Coal Unit 1 and Gas Turbine 1 (650 MW Total)
      - Example Disp 3: CC 1, CC 2, and GTs 1-3 (650 MW Total)
  - 50/50 Load Level w/ probabilistic resources unavailable
    - 2,570 MW of load
    - Combination of study area units not to exceed 921 MW unavailable
      - Example Disp 4: Coal Unit 1 and Combined Cycle 1 (900 MW Total)
      - Example Disp 5: Nuclear Unit 1 and Biomass 1 (910 MW Total)

NEXT STEPS

Next Steps

- Continue with implementation of the base case probabilistic methodology
  - Planning technical guide changes presented today at the PAC
  - Sample Needs Assessment Scope of Work presented today at PAC incorporating probabilistic methods for base case creation
  - Identify refinements as experience is gained
- Development of guidelines for assessing scenario-related concerns
  - High Impact, Low Frequency events (e.g. gas pipelines, extreme weather events)
- Data analysis
  - Research most appropriate data for transmission planning studies
    - Review outage rate for lower capacity factor units
    - Examine how best to represent intermittent resources
    - Examine sensitivity of load distribution to distributed resources
- Analysis of high maintenance periods
  - Is the system capable of supporting generation and transmission maintenance simultaneously?
  - Do we need to assess this? If so, how?

Questions

APPENDIX

Convolution Method for Generation Cumulative Distribution Curve Creation

Theory – Convolution

- The formal process of calculating the total combined probability distribution for a specified amount of loads or generation is called convolution
- The calculation is done by reversing one of the distributions and stepping it across the second distribution, multiplying each set of values together and summing them to give the value in the desired distribution
- We will do an example[1] of two generators on the next few slides…

(1) Example from: Booth, R.R., "*The A-B-C of Probabilistic Simulation – A simple explanation of principal features and uses.*" Feb. 1971

Theory – Convolution, cont.

- We will take two generators (P_1 and P_2) that have the following probability distributions

Gen Level	P_1	P_2
0	0.2	0.1
100	0.6	0.7
200	0.2	0.2

- The procedure is as follows
  - Reverse P_2's probability
  - Step it across P_1 multiplying probabilities that have the desired total value
  - Sum all the probabilities that have the same desired total value

Theory – Convolution, cont.

- Step 1 – Probability of 0 MW

Gen Level	200	100	0	100	200	P_{0MW}
P_1			**0.20**	0.60	0.20	
P_2	0.20	0.70	**0.10**	→		
P_1 x P_2	0.00	0.00	**0.02**	0.00	0.00	0.02

- Step 2 – Probability of 100 MW

Gen Level		200	100	100	200	P_{100MW}
P_1			**0.20**	**0.60**	0.20	
P_2		0.20	**0.70**	**0.10**	→	
P_1 x P_2	0.00	0.00	**0.14**	**0.06**	0.00	0.20

Theory – Convolution, cont.

- Step 3 – Probability of 200 MW

Gen Level	0	0	200	200	200	P_{200MW}
P_1			**0.20**	**0.60**	**0.20**	
P_2		→	**0.20**	**0.70**	**0.10**	
P_1 x P_2	0.00	0.00	**0.04**	**0.42**	**0.02**	0.48

- Step 4 – Probability of 300 MW

Gen Level	0	0	0	300	300	0	P_{300MW}
P_1			0.20	**0.60**	**0.20**		
P_2			→	**0.20**	**0.70**	0.10	
P_1 x P_2	0.00	0.00	0.00	**0.12**	**0.14**	0.00	0.26

Theory – Convolution, cont.

- Step 5 – Probability of 400 MW

Gen Level	0	0	0	100	400	100	0	P_{400MW}
P_1			0.20	0.60	**0.20**			
P_2				→	**0.20**	0.70	0.10	
$P_1 \times P_2$	0.00	0.00	0.00	0.00	**0.04**	0.00	0.00	0.04

- Putting it all together, the probability distribution of a ‘total system’ generation level, given the independent probabilities of two generators is shown in the table below

Gen Level	0	100	200	300	400
Total System Probabilistic Distribution	0.02	0.20	0.48	0.26	0.04
Total System Cumulative Distribution	1.00	0.98	0.78	0.30	0.04

- This same theory can be applied to combining the probabilities of each generator being unavailable to create a single cumulative probability distribution for a given group of generators