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Conceptual Methodology for Base Case Assumption Quantification

PAC Meeting

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Outline

- Background
- External Efforts
- Transmission Planning Assumptions
  - Current Practices
  - New Concepts for Determining Assumptions
- Proposed Approach
- Next Steps
- Development Details
- Appendices

BACKGROUND

Purpose/Objective

- ISO has been reviewing the key assumptions used in transmission planning studies and how they should be applied.
  - NESCOE to ISO/PAC, 4/19/13

    'Problem statement: The use of subjective terms in our current planning procedure allows a wide range of subjectivity in base case development that can effectively defeat the purpose of standards. In New England, development of transmission planning base cases with widely varying degrees of likelihood calls into question what context can be given to terms such as "reasonable stress." '
- Review has included the consideration of modeling different forms of resource unavailability
- A major focus has been on the use of historical and projected statistics of key study parameters, such as resource unavailability and load levels to provide guidance in the development of reasonable (likely/probable) and consistent transmission planning assumptions to be used for deterministic transmission planning
- Industry efforts/tools regarding probabilistic transmission assessment, recognizing current criteria requirements and other potential applications (e.g.; FERC Order 1000 alternative comparison), are being explored

History of Past Discussions

- "Review of Transmission Planning Assumptions and Methods", PAC, September 17, 2014 (http://www.iso-ne.com/static-assets/documents/2014/09/a9_transmission_planning_assumptions.pdf)
  - Transmission Planning Considerations
  - Resource Unavailability
  - Probability of Critical System Conditions
- "Review of Transmission Planning Assumptions and Methods", PAC, April 28, 2015 (http://www.iso-ne.com/static-assets/documents/2015/04/a5_transmission_planning_assumptions_and_methods.pdf)
  - Review of Transmission Planning Assumptions and Methods – Approach
  - Resource Unavailability/Uncertainty
  - Assessment Methods and Considerations
  - Data Requirements and Review
  - Proposed Workplan
- Stakeholder preference subsequently expressed for focus on transmission planning assumptions

EXTERNAL EFFORTS

- Update

Involvement With Industry Probabilistic Transmission Assessment Efforts

- Electric Grid Resiliency Modeling Industry Summit, 9/22/15
- Electric Power Research Institute (EPRI) risk-based planning industry workshop, 11/19-20/15
- ISO has been reviewing available probabilistic-based transmission assessment efforts
  - Expect to discuss with PAC 1st quarter 2016

TRANSMISSION PLANNING ASSUMPTIONS

- Current Practices

Planning Technical Guide
– Load, Generator Unavailability, Transfers

Planning Technical Guide (http://www.iso-ne.com/static-assets/documents/2014/12/planning_technical_guide_2014-12-2_clean.pdf)

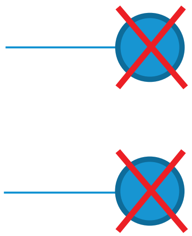
- Section 5 – Assumptions Concerning Load
- Section 10/Section 11 – Generators Out of Service in Base Case/Determination of Generation Dispatch in Base Case
- Section 13 – Interfaces/Transfer Levels to Be Modeled

Current Assumptions Concerning Load

- Disturbances are typically studied at peak load levels in steady-state analysis because peak load levels usually promote more pronounced thermal and voltage responses …
- When assessing peak load conditions, 100% of the projected 90/10 summer peak load for the New England Control Area is used.

Current Assumptions Concerning Generators Out of Service in Base Cases

- …generally two generation resources are considered out of service in the study area. .... Additional (more than two) generators may be considered to be out of service if the area under study has a large population of generators …



Two (or more) generators out in the base case represent:

- Higher generator forced outage rates than other transmission system Elements
- Higher generator outages and limitations during stressed operating conditions such as a heat wave or a cold snap
- Past experience with simultaneous unplanned outages of multiple generators
- High cost of Reliability Must Run Generation
- Generator maintenance requirements
- Unanticipated generator retirements
- Fuel shortages

Current Assumptions Concerning Generator Dispatch in Base Cases

- Wind - on-shore wind generation is modeled at 5% of nameplate and off-shore wind is modeled at 20% of nameplate
- Hydro generation is set at its historic capability that can be relied on for reliability purposes or at 10% of nameplate, which is an estimate of that historic capability…Post contingency, conventional hydro that has the capability to control water flow and has sufficient water storage capability is dispatched up to 100% of its nameplate to relieve criteria violations …facilities that have no control over water flow or limited water storage capability are dispatched at the same output pre and post contingency.
- Solar generation which has a nameplate capacity of 5 MW or greater will be modeled explicitly as generators…The amount of solar generation connected to the system that is represented in the models is derived by multiplying the nameplate capability by an adjustment factor of 26%...
- Solar generation (less than 5 MW) is distributed among distribution buses using information on the location of solar generation provided by distribution companies and based on the location of solar generators over 1 MW that submit information as required…

Current Assumptions Concerning Interfaces/Transfer Levels

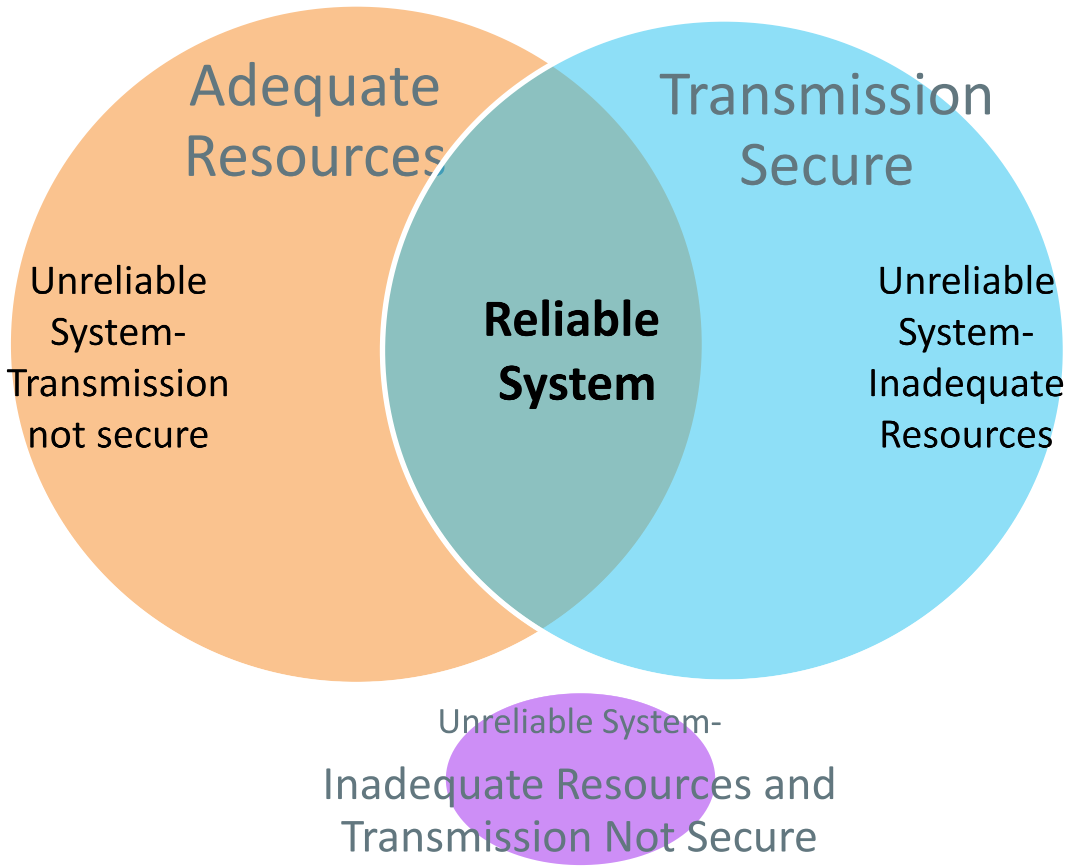
- The system is designed to preserve existing range of transfer capabilities....
- There may be a need to increase transfer capabilities as generation patterns shift across the system …
- Transfer levels for defined interfaces are tested based on the defined capability for the specific system conditions and system configurations to be studied. Transfer levels are also adjusted as appropriate for the load levels that are to be studied…
- Interface transfer levels are tested up to their capability in order to sustain the economic efficiency of the electric system and reliable operation and transmission service obligations of the New England transmission system…
- … November, 2013… reliability based needs and their related backstop transmission solutions will not be identified and developed to support power exports out of New England. The only exception to this policy change would be long term power exports realized through the Forward Capacity Market, such as certain power exports across the Cross Sound Cable…
- Proposed plan evaluation, pursuant to Section I.3.9 of the Tariff, must demonstrate that the project has not reduced transfer capability from pre-project levels.
- Transfer level modeling for those cases in which more than one coincident interface (i.e. surrounding interfaces rather than an interface internal to the study area) can impact a study area is based on a set of transfer level combinations that includes the maximum and minimum values for each interface.

TRANSMISSION PLANNING ASSUMPTIONS

- New Concepts for Determining Assumptions

Characteristics of a Reliable System

- In a reliable system, resource adequacy requirements are met while maintaining transmission system security

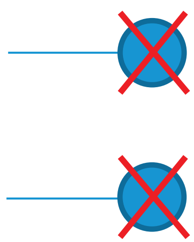


Potential Opportunities for Improvement

- 2 generators out in base cases
  - Comingles different types of uncertainties
  - May be too pessimistic in some cases, too optimistic in others
  - Potentially inconsistent depictions of the likelihoods of generator unavailability in different situations
- Load Level
  - Treatment of 90/10 load consistent with its likelihood
  - Coincident likelihood of 90/10 load and other critical conditions (e.g.; generation unavailability)
  - Consideration of the significant number of hours of relatively high load, but less than 90/10 or 50/50
- Transfers *(item for future discussion)*
  - Definition/description of transfer levels that should be maintained and why
  - Relationship between transmission service obligations (e.g.; CNRC, NRC) and transfer modeling
- Intermittent resources *(item for future discussion)*
  - Better integration/recognition of the stochastic nature of intermittent resources

General Representation of Resource Unavailability in Studies*

Generically model two generators out in the base case



Change generic representation to account for…

Sudden events:
- Modeled as contingencies (normal or extreme)

Longer duration, cumulative or concurrent events:
- Modeled as base case conditions (reasonably anticipated events or extreme system conditions)

Broad trends:
- Modeled as scenarios (each scenario is a fundamental assumed base condition)

Maintenance conditions:
- Model to be determined

* See Appendix I & http://www.iso-ne.com/static-assets/documents/2015/04/a5_transmission_planning_assumptions_and_methods.pdf

Base Cases - Reasonably Anticipated Conditions

- A base case captures the impacts of possible combinations of generation and load that reasonably stress the transmission system
- Multiple base cases are used to represent the different stresses that can result from different patterns of generation unavailability and load
- How can base case generation and load conditions that are reasonable, representative, and comprehensive be determined consistently?
- How can the probabilities of these conditions be used to establish what is reasonable?

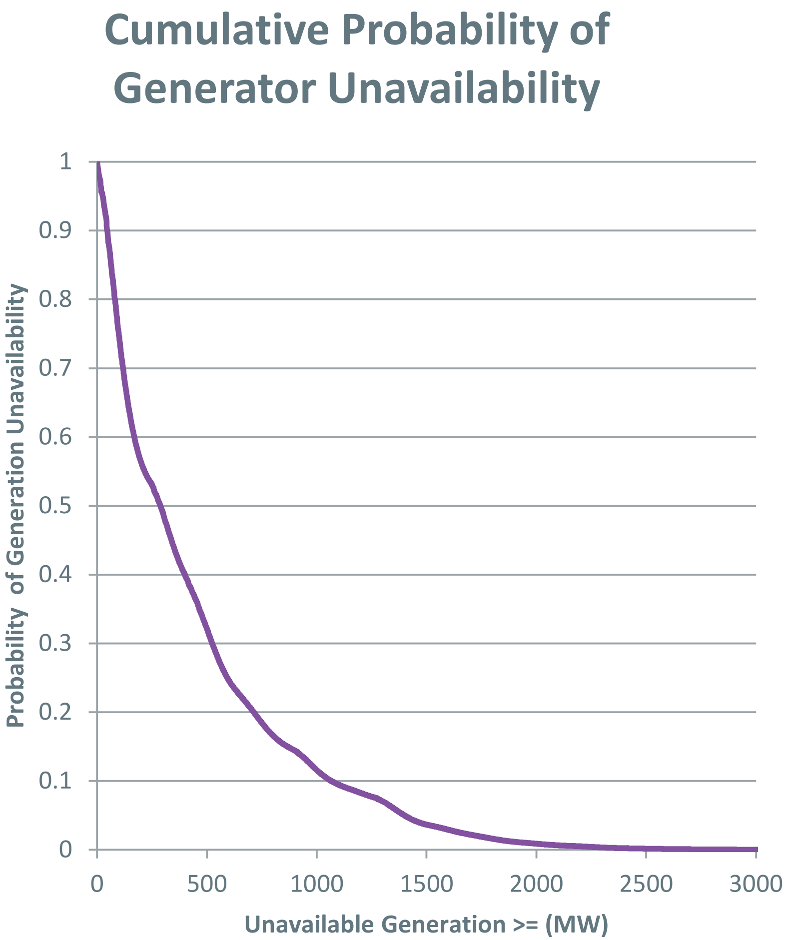
Probabilistic Considerations

- The probability of the specific conditions in a particular singular base case may not be the most comprehensive way to describe the likelihood of the stressed system conditions that need to be considered in a transmission planning analysis
- The probabilities of the different possible system conditions represented by a single base case need to be aggregated to determine the likelihood of the stresses represented by that base case
- The cumulative probability of the variables (typically load levels and generation unavailability) that impact the particular area under study needs to be considered in order to reflect the likelihood of the range of possible stressed system conditions
  - Probability density describes the probability of a specific condition*
  - Cumulative probability is the aggregation of the probabilities of the specific conditions; expressing the probability of a range of conditions*
- Challenges:
  - How can the cumulative probability of the key variables in a study area be determined?
  - How can it be used to guide the development of reasonable and representative study conditions?

* See Appendix II & http://www.iso-ne.com/static-assets/documents/2014/09/a9_transmission_planning_assumptions.pdf

Describing a Comprehensive Range of Conditions Using Cumulative Probability

- Example: Likelihood of 400 MW Being Unavailable in Connecticut (Assumes unavailability rate of 5% for all units)



- A case with a 400 MW generator (e.g., Bridgeport 3) out of service would appear to have a probability of .05 (5%)
  - Unavailability rate = .05 (5%)
- The actual probability of only a single 400 MW generator unavailable (and all other units available) is 0.00118 (.118%)
  - Unavailability of a single generator x Availability of all 73 other units in CT = 0.05 x 0.95^{73} = 0.00118
- However, there are 2^{73} (9,444,732,965,739,290,427,392) conditions with this single generator unavailable.
  - The sum of the probabilities of all of these conditions = .05 (5%)
- There are many other ways to have 400 MW or more unavailable in CT
- There is actually a 40% chance that generator outages in CT will be equal to or greater than 400 MW

Similar to Slide 39-"Review of Transmission Planning Assumptions and Methods", PAC Meeting, September 17, 2014

PROPOSED APPROACH

Conceptual Approach for Transmission Planning Assessments

Proposed Approach To Transmission Planning Assessments

- Develop a scope of study that separately recognizes the different types of resource unavailability to be studied
- Model/capture sudden events/outages as contingencies
- Develop study base cases based on the approximate cumulative probability of base conditions to capture the reasonable range of stressed system conditions
- Model the following concerns/conditions as scenarios
  - Potential unit/plant retirements/delisting
  - Other potential longer duration, cumulative or concurrent events resulting in extended unit/plant outages
- Future Efforts:
  - Develop decision criteria/guidelines regarding the results of scenario-driven concerns
  - Develop methodologies to assess the ability of the system to reasonably support maintenance

Proposed Approach To Develop Study Base Cases

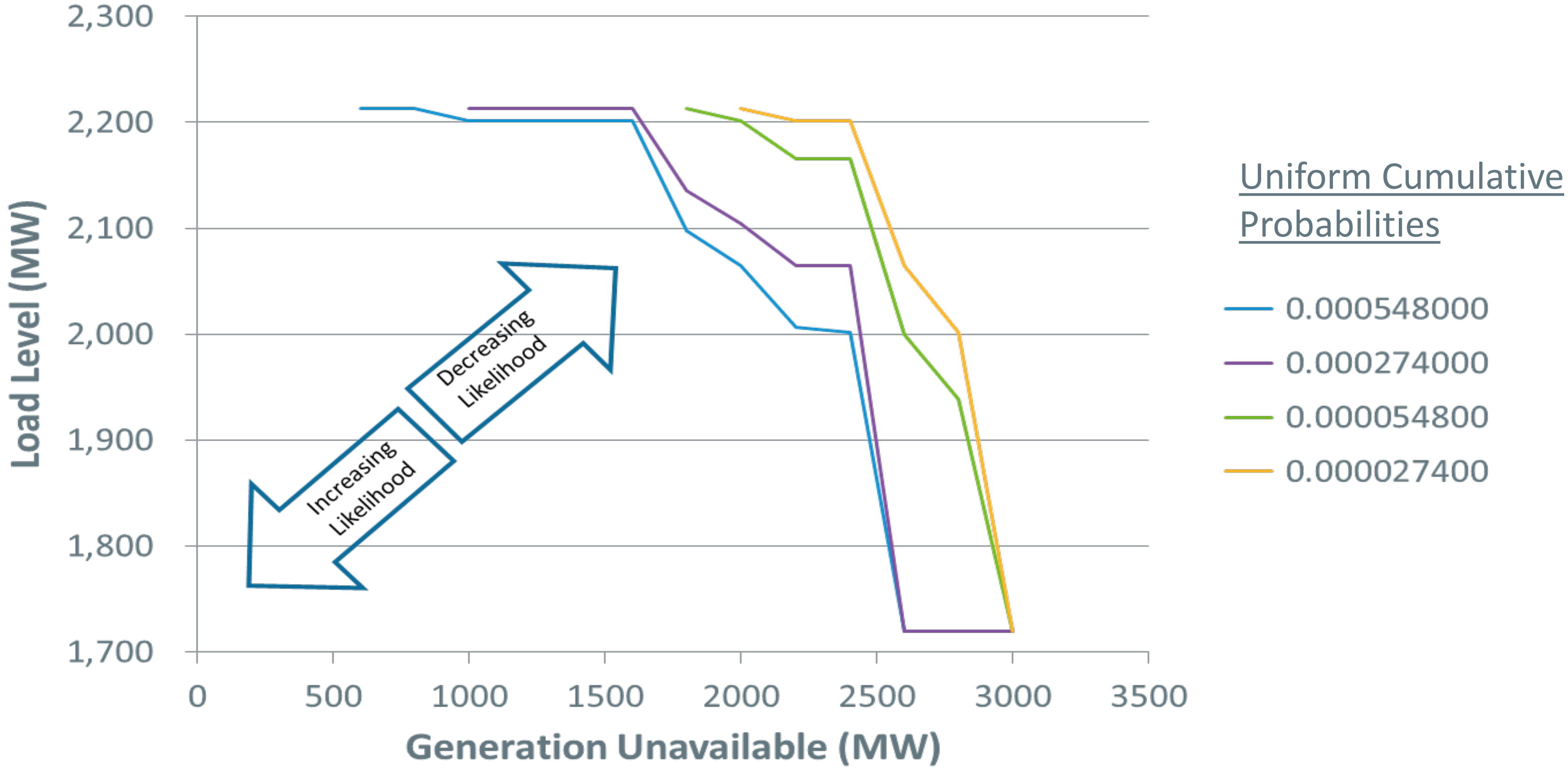
Approximating the Cumulative Probability of Key Conditions in a Study Area

- Determine a study area, based on potential transmission constraints and the coincidence of key system stressors (load and generation unavailability)
  - Implies that different areas of the system can be studied separately
- Identify the load and key resources which can stress the transmission constraints
- Determine the likelihood of exceeding various combinations of load and unavailable generation
  - Very similar to ICR calculation

Proposed Approach To Develop Study Base Cases

Cumulative Probability of Load and Unavailable Generation for a Defined Study Area (details on Slides 31-45)

Example: Load - 2200 MW 50/50; 2213 MW 95/5
Generation - 3000 MW Installed: 2@1000 MW, 2@500 MW; EFORd-5%



Proposed Approach To Develop Study Base Cases

Using the Cumulative Probability of Key Conditions in a Study Area to Develop Base Cases

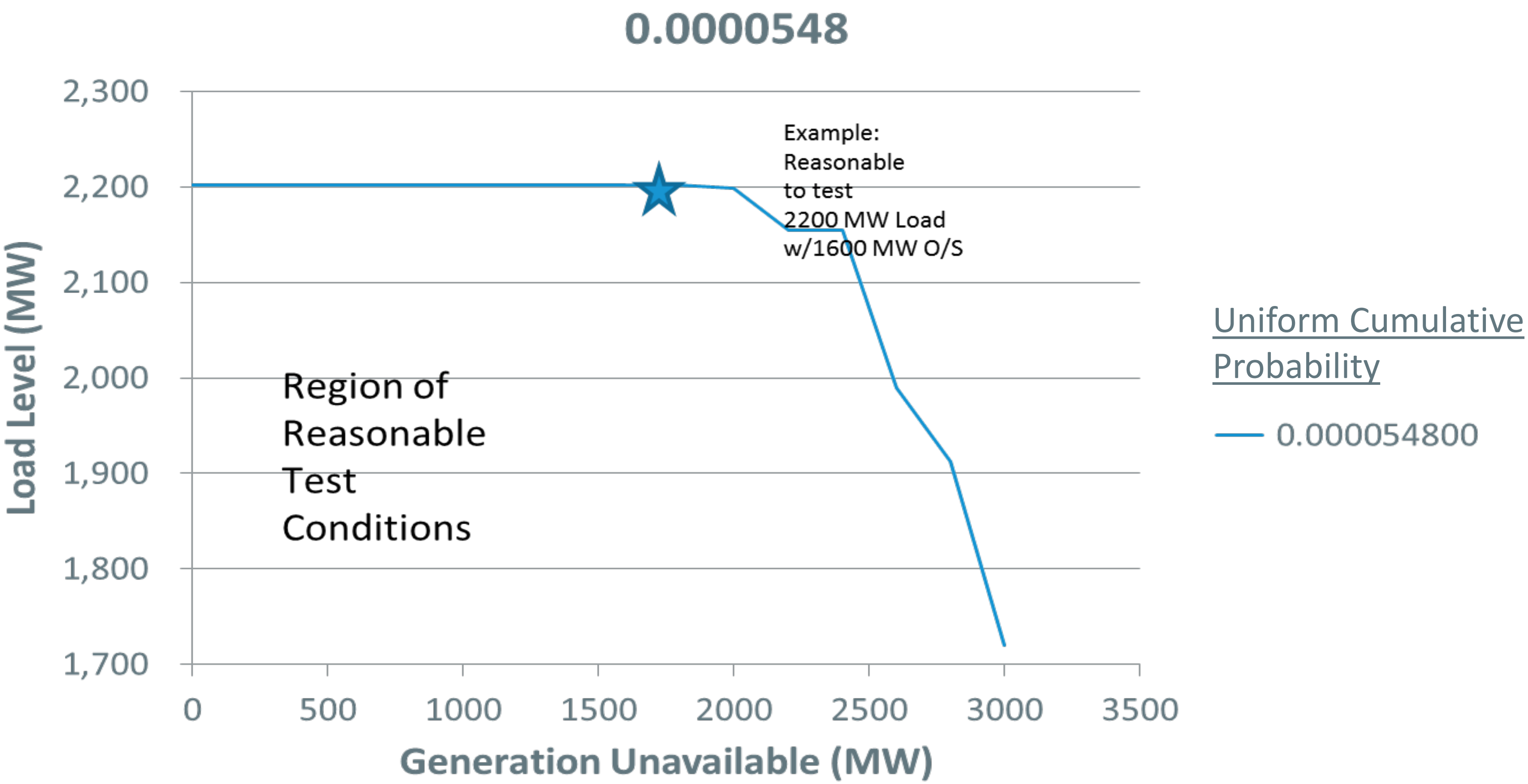
- Establish a threshold for an acceptable level of likelihood (minimum acceptable cumulative probability)
- Use that threshold to determine the boundary of reasonably anticipated system conditions (load and unavailable generation)
- Use the boundary to establish load and unavailable generation conditions to model in transmission planning studies

Proposed Approach To Develop Study Base Cases

Boundary of Reasonably Stressed System Conditions, Assuming a Cumulative Probability Threshold of .0000548 (details on Slides 31-45)

Example: Load - 2200 MW 50/50; 2213 MW 95/5

Generation - 3000 MW Installed: 2@1000 MW, 2@500 MW; EFORd-5%



Using the Boundary of Reasonable System Conditions

- The boundary describes the region of reasonable test conditions; essentially the entire population of reasonable test conditions
- Still only need to test a limited number of representative conditions, NOT all of them
- The threshold probability establishes the boundary of what are reasonable concurrent load and generation unavailability conditions to model in transmission planning analyses
- May make sense to test more than one point
  - This is an approximation method meant to establish the ballpark of reasonable modeling conditions

Next Steps

- Reviewing the proposed approach
- Consider and establish the most appropriate study period
  - Which weeks of the year
  - Which hours of the day
- Consider and establish the appropriate/reasonable threshold of likelihood/probability
- Examine how best to consider transfers
  - Simultaneous transfers
  - Exports
- Examine how best to represent intermittent & distributed resources
  - Hydro
  - Wind
  - PV
  - Others

Next Steps (cont.d)

- Data Review
  - Examine the likelihood & implications of conditional dependencies (e.g.; do outage rates/capabilities change during high temperatures?)
  - EFORd for lower capacity factor units
  - Other?
- Criteria and guidelines for assessing scenario-related concerns
- Maintenance periods
  - Is the system capable of supporting generation and transmission maintenance?
  - How to assess this?
- Review of external efforts

Questions

DEVELOPMENT DETAILS
(TO BE DISCUSSED JANUARY, 2016)

Cumulative Probability of Load and Unavailable Generation for a Defined Study Area

Structuring the Study of the Transmission System - Determining a Study Area

- Transmission reliability analysis is typically structured to examine patterns of generation (un)availability and load level and location that may potentially be influencing parts of the transmission system
  - A single reliability study may examine multiple combinations of generation (un)availability for which the influence varies
  - Generation (un)availability may have nested, overlapping, or opposing impacts on different transmission constraints
- It can be very reasonable and more manageable to disaggregate the study of a larger system into smaller parts
  - Must be understood where this is appropriate
  - Different performance (e.g.; steady state vs. stability) may change the nature of appropriate study areas
  - Steady-state analysis can often be disaggregated
- Analytical methods/tools can be used to identify parts of the transmission system that are similarly influenced by generation unavailability and load level

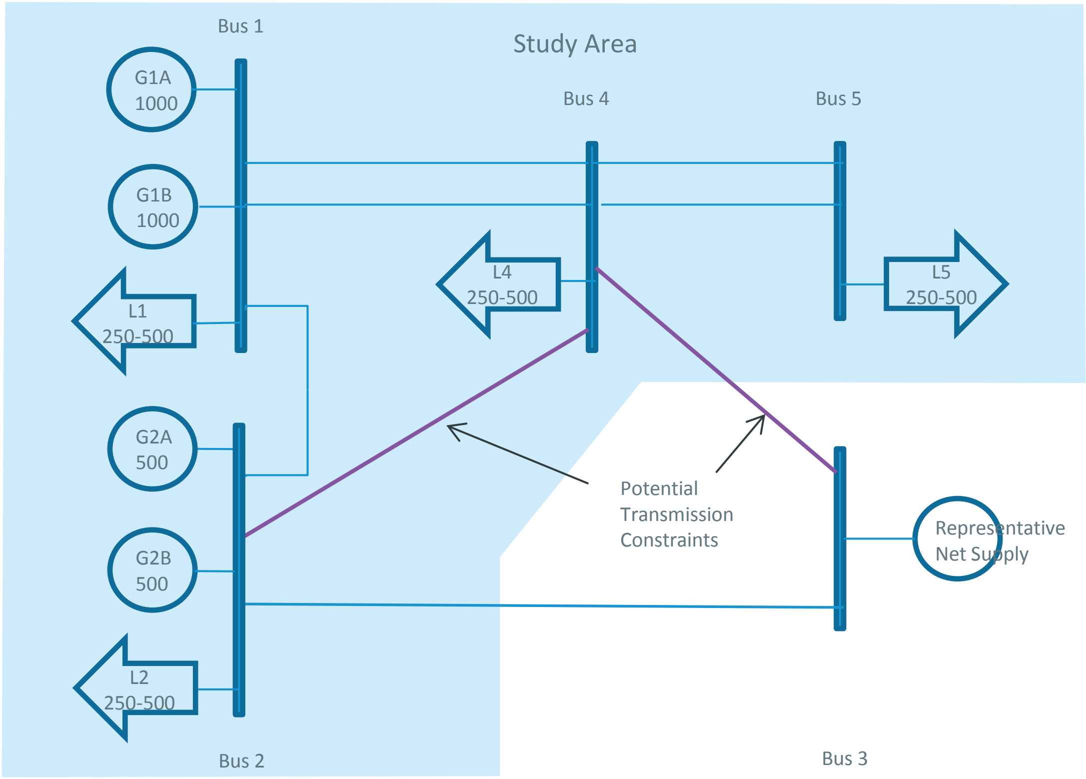
Determining the Likelihood of Stressed System Conditions

- Generation unavailability and load level are key variables in area transmission planning*
- Increasing load and decreasing critical generation (increased unavailability) tends toward increasing system stress
  - Load and generation impacts not exactly the same, but close enough
    - Load is distributed around the system
    - Generation mostly at specific and limited locations
  - Does not focus on problems specific to light load conditions
- The coincidence of the key stressors is what is significant to capture for transmission planning purposes
- The probability of occurrence of the combined values of load and unavailable generation describes the likelihood of stressed system conditions
  - Concept and calculation is somewhat similar to determination of LOLE/ICR
- Meant to provide broad and consistent guidance regarding which system conditions are reasonable to use in deterministic analyses. Not, in itself, meant to be a precise reliability quantification method

**Initial focus on load serving; exports and simultaneous transfers to be addressed subsequently*

Sample System

- 2000 MW Peak Load (50/50)/ 2213 MW (95/5)
- 3000 MW Installed Capacity (Unavailability increases transmission loading - "Helpers")



Sample System Element Characteristics

- L1, L2, L4 & L5 all influence the loading on the potential transmission constraints of the system
- The unavailability of G1A, G1B, G2A & G2B, individually and together, influence the loading on potential transmission constraints of the system ("Helpers")

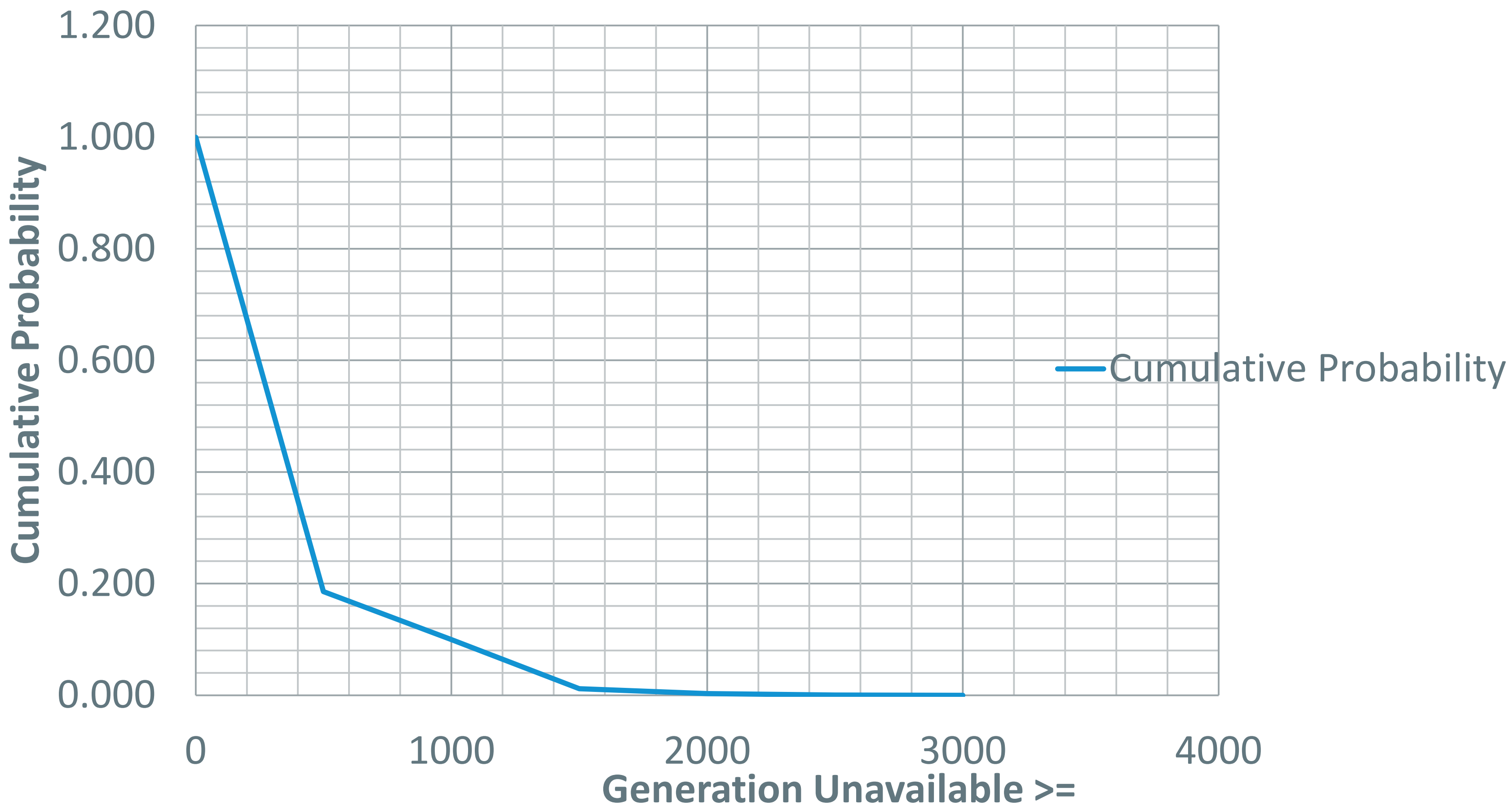
Cumulative Probability of Generation Unavailability

- Calculated in the same manner as in Installed Capability Requirement (ICR) calculation

- Sample System:
  - G1A, G1B, G2A, G2B all have .95 availability (.05 EFORd)
  - Generators are modeled with two states of operation: available, unavailable

- More complex considerations will be addressed in the future:
  - Intermittent resource time of day/seasonal operating characteristics
  - Other conditional dependencies, such as seasonal variation in EFORd

Generation Unavailability Cumulative Probability - Sample System G1A, G1B, G2A, G2B



Generation Unavailability and Load Level

- If generation unavailability was the only key variable, then Generation Unavailability Cumulative Probability would describe the risk of stressed conditions and could be used to define reasonable base cases,

But…

- Load level is also a key variable and should be considered in determining the cumulative probability of stressed system conditions

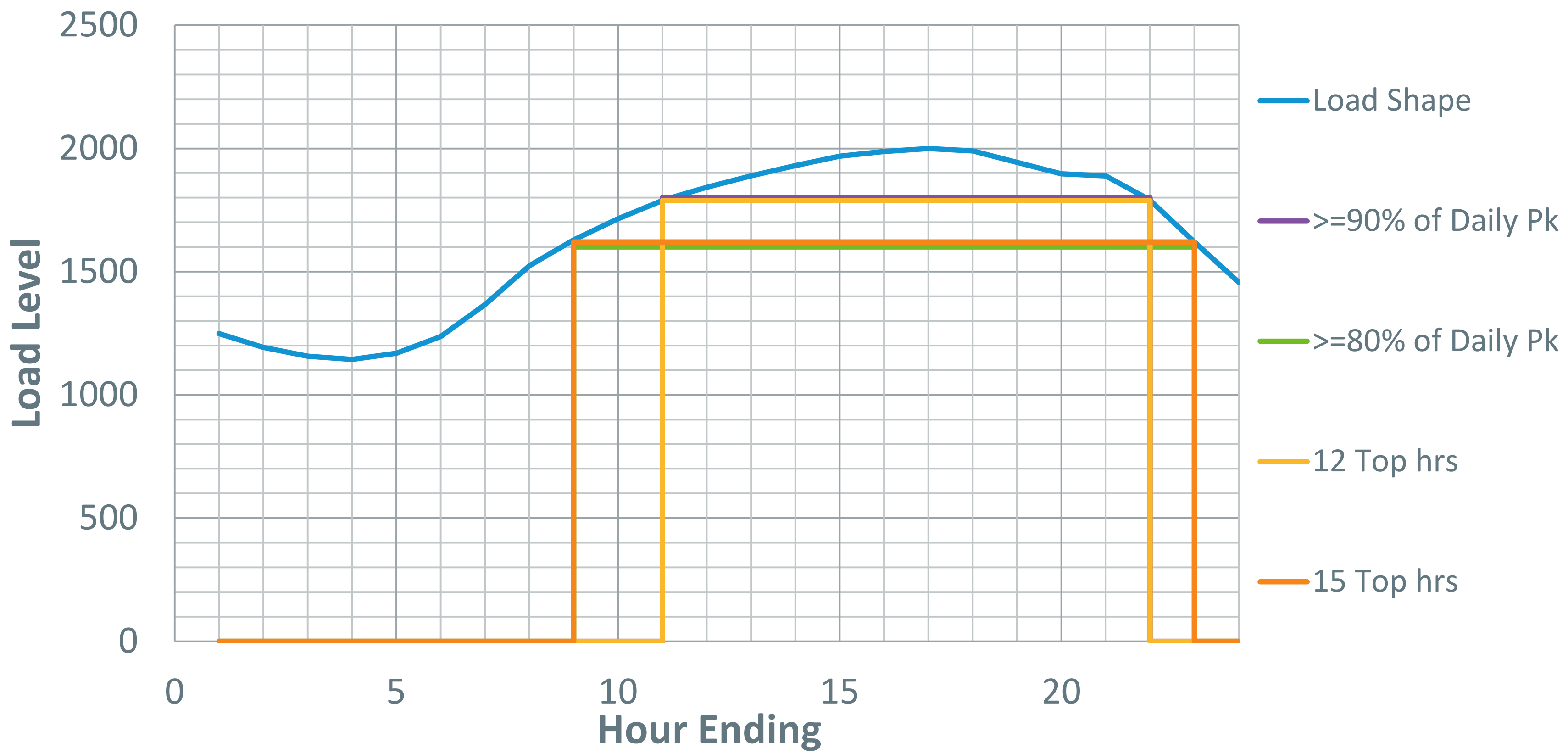
!! WARNING !!

Consideration of load can be a little more challenging than consideration of generation unavailability

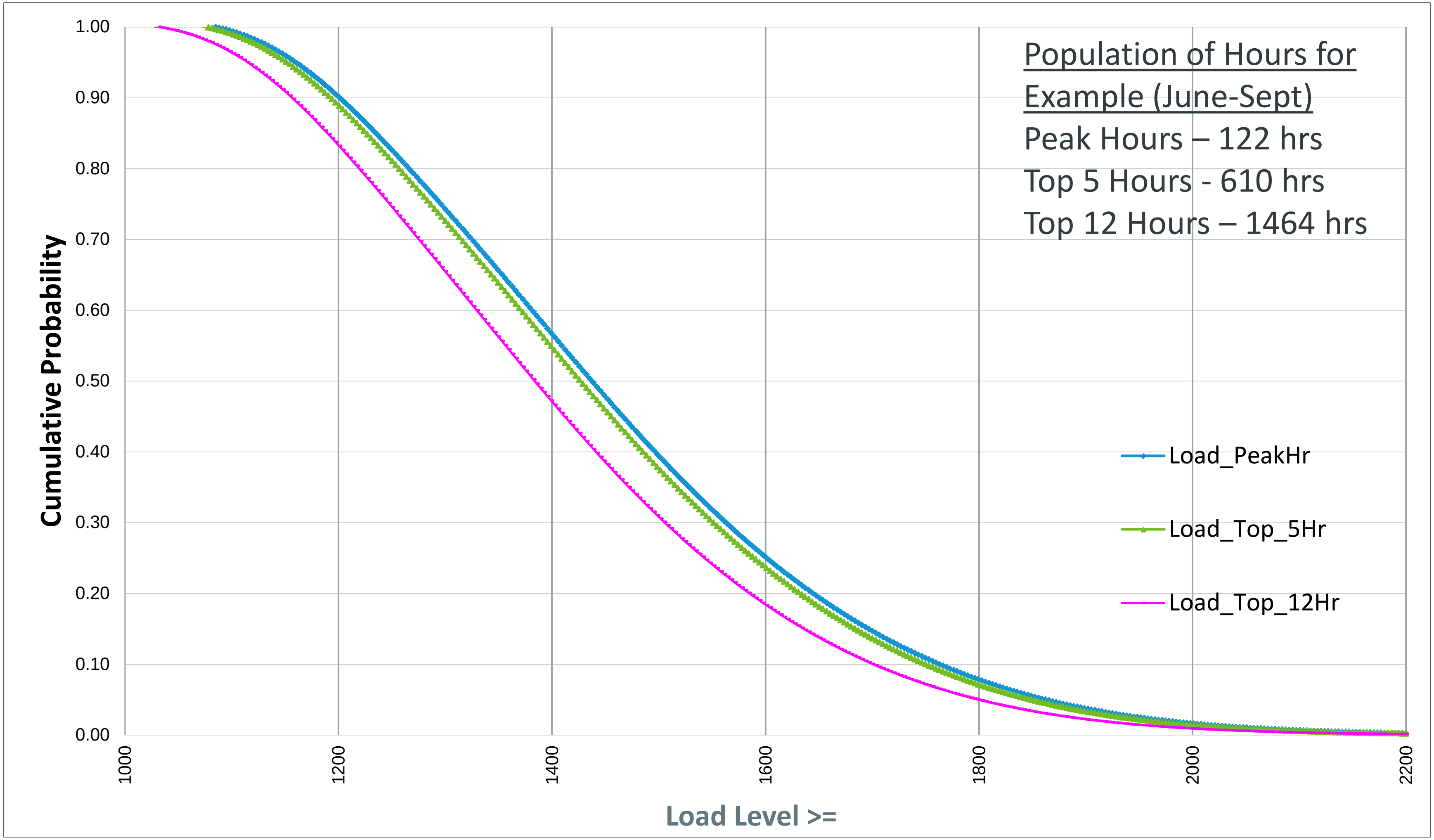
Cumulative Probability of Load
- Which Hours?

- Cumulative probability calculated in a manner similar to how load probability is determined for Installed Capability Requirement (ICR) calculation, but may need to consider a larger population of hours
  - Similarly to ICR calculation, need to consider load shape and weather-related risk
- To assess the range of conditions over which the system must operate securely, the period (load hours) over which the operating/planning risk is consequential must be captured
  - E.g.; business day vs. middle of the night
- The population of load hours used in determining the likelihood of load conditions should reflect this operating/planning period
  - Too few hours will overstate risk, likelihood and duration, or severity
  - Too many hours will understate risk, likelihood and duration, or severity
- The peak load, top 5, and top 12 hours of business days in June, July, August, September are illustrated
  - Captures critical conditions for operating the system (85-90% of the daily peak)
  - Puts the relative likelihood of 95/5, 90/10, 50/50, 10/90 conditions in perspective relative to total seasonal business day operating hours
    - How many hours of exposure to these peaks are there?
  - Does it get into weeks/hours where load is too light?

Load Shape (50/50) for Sample System
Σ L1, L2, L4, L5



Load Cumulative Probability for Various Hours of the Day (June, July, August, September)
- Sample System Σ L1, L2, L4, L5



Putting it All Together
- Cumulative Probability of Load and Unavailable Generation

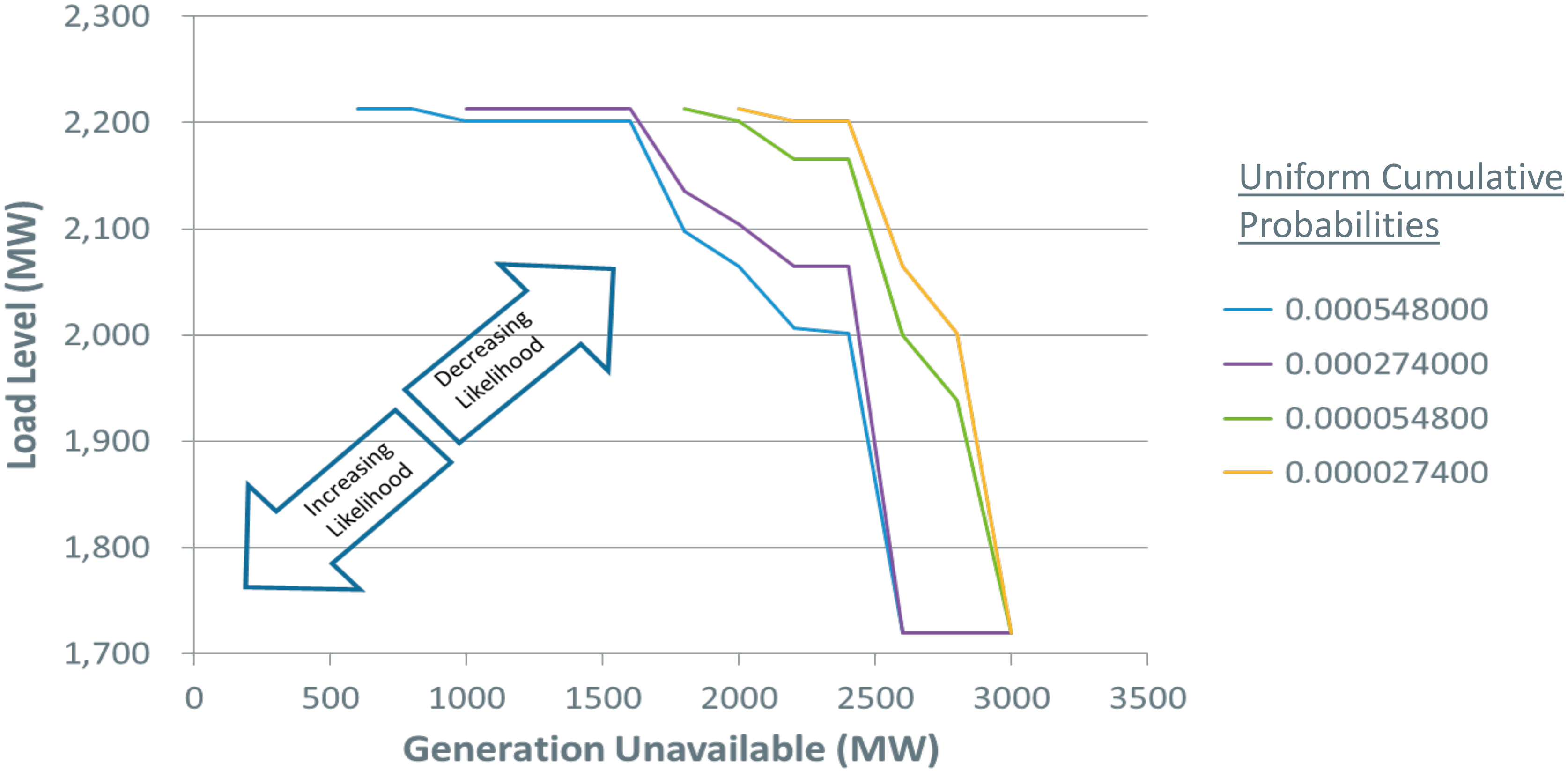
- The probabilities of generation unavailability and load are combined to develop combined cumulative probabilities
  - Example captures the top 12 hours of business days in June, July, August, & September
- The results are expressed in terms of a family of curves, describing combinations of load and unavailable generation with the same cumulative probability
- Similar calculation as used to determine Installed Capability Requirement (ICR), with greater number of hours
- Again, this is not meant to create a NE-wide reliability metric, but to guide the development of reasonable base case conditions for a given transmission study area

Proposed Approach To Develop Study Base Cases

Cumulative Probability of Load and Unavailable Generation for a Defined Study Area

Example: Load - 2200 MW 50/50; 2213 MW 95/5

Generation - 3000 MW Installed: 2@1000 MW, 2@500 MW; EFORd-5%



Using the Cumulative Probability of Load and Unavailable Generation to Establish a Boundary of Reasonable System Conditions, *or,*
"So now what do I do with these funky –looking curves ???"

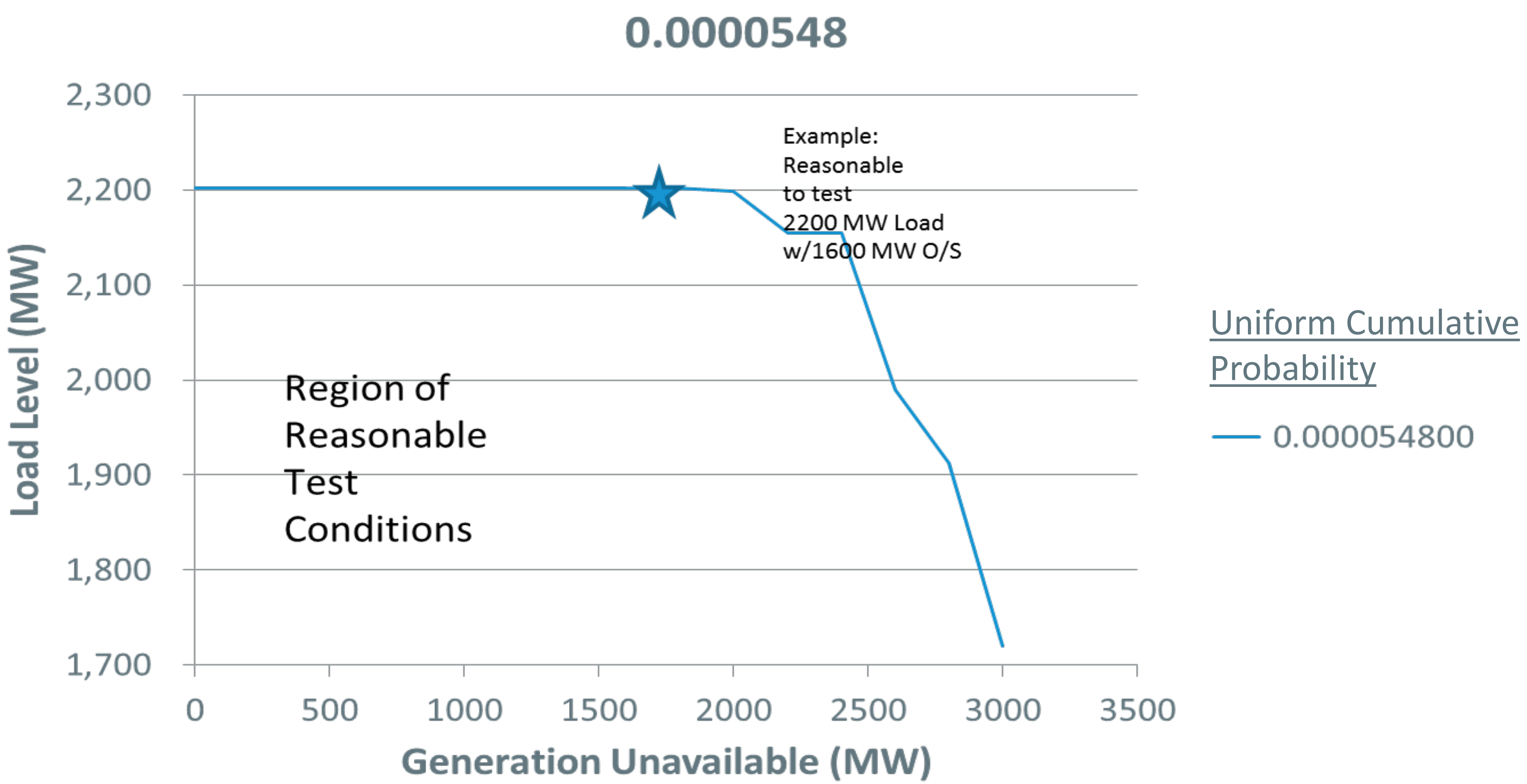
- In a reliable system, resource adequacy requirements are met while maintaining transmission system security. (Every resource unavailability/load condition that meets resource adequacy requirements should also meet transmission security requirements)
- A likelihood (probability) of load and generation unavailability that's comparable to the resource adequacy criteria should establish the boundary of reasonable system conditions for which system security should be maintained.
- System aggregate LOLE criteria - 1 days/10 years
  - 1 days/10 years ~ .000274 probability
- Sub-sections of the system must meet a more rigorous threshold (i.e.; lower LOLE) in order for the system aggregate LOLE to meet .1 day/year (assuming sub-section stresses are driven by independent resource unavailability) (See Appendix III).
  - Example - 1.05 days/10 years used for LRA ~ .000288 probability
- Potentially many more study areas than FCM zones
  - Need lower threshold probability than LSR
- Suggest that the cumulative probability of load and unavailability threshold could be 1/5 to 1/10 of the System aggregate threshold ~ .0000548 - .0000274

Proposed Approach To Develop Study Base Cases

Boundary of Reasonably Stressed System Conditions, Assuming a Cumulative Probability Threshold of .0000548

Example: Load - 2200 MW 50/50; 2213 MW 95/5

Generation - 3000 MW Installed: 2@1000 MW, 2@500 MW; EFORd-5%



Questions

APPENDIX I

Considerations for Resource Unavailability in Transmission Planning

Resource Unavailability Modeled in Consideration of Many Different Situations – Examples

- Long duration unplanned outage (e.g., Stator, GSU failure, fire)
- Short duration unplanned outage (e.g., Tube leak, high wind)
- Sudden outage (e.g., any turbine trip, intermittent fault)
- Common mode outage
  - Sudden
  - Long duration
- Failure to start when called on
- Failure to be at the required output when needed (e.g., units that start, but sit at min and miss the whole peak)
- Failure to stay running after started
- Fuel supply unavailability
- Common mode fuel supply failure
- Avoidance of RMRs
- Failure to meet contractual service obligations
- Unanticipated temporary shutdown (e.g., unit stops operating for business reasons)
- 0 MW audited SCC (3 years of 0's to be automatically retired)
- Unit physically unable to operate
- Announced Retirement
- Unannounced Retirement
- Static Delist
- Limited Energy units (e.g., emissions restrictions)
- Regulatory shutdown (e.g., NE nukes 1996-1998)
- Scheduled Maintenance
- Maintenance overrun
- Derate due to ambient air/water conditions
  - Including full shut down
  - Difference between output at 90 degrees and 100 degrees
- Intermittency
  - Seasonal
  - Daily
  - Hourly

Deterministic Transmission Planning

- Base Conditions
  - Network topology (static)
  - Generation availability (base condition(s) vs. contingency: different planning philosophies)
  - Power transfers (static vs. consequence of other conditions)
  - Load Forecast (static)
- Reasonable Stress
  - ISO New England Planning Procedure No. 3 requires
    - With due allowance for generator maintenance and forced outages, design studies will assume power flow conditions with applicable transfers, load, and resource conditions that reasonably stress the system

Deterministic Transmission Planning - Reasonable Stress

- Generation availability (base condition(s)) - Some reflection of the probability of unavailability
  - Number and location of generators assumed unavailable in base case(s)
  - Consideration for intermittent and low capacity factor units
  - How many base cases?
- Power transfers (semi-static)
  - Can result from generation unavailability assumptions
  - Can be specifically modeled to reflect system transfer objectives (reliability, economics, policy) and obligations
- Load Forecast (static)
  - Examples: Peak (50/50, 90/10); X % of Peak, based on load duration

Deterministic Transmission Planning Contingencies

- Transmission and generation
  - Single element, multi-element, Extreme Contingencies
- Tested as discrete events (e.g.; N-1, N-1-1, EC)
- Some implicit consideration of probabilities
  - Example: NERC TPL Standards (Transmission Planning)
    - Single element outages – “non-consequential” load loss generally not allowed
    - Multi-element outages – “non-consequential” load loss allowed
    - Extreme Contingencies – cascading outages allowed

Resource Contingency Modeling to Represent Sudden Events
- Normal/Design Contingencies

- Related problems must be addressed
- Representative situations:
  – Sudden outage (e.g.; any turbine trip, intermittent fault)
  – Sudden common mode outage (e.g.; Mystic 8&9)
  – Failure to start when called on
  – Failure to reach desired MW when needed
  – Failure to stay running after started
  – Sudden outage precipitated by a failure which then results in a long-term outage

Resource Contingency Modeling to Represent Sudden Events - Extreme Contingencies

- Evaluate mitigating measures for related problems
- Representative situations:
  - Sudden outage of all generating units at a generating station
  - Loss of one generator followed by loss of another generator, without system adjustments between outages (N-2)
  - Loss of two generating stations

Modeling of Reasonably Anticipated Conditions in Base Cases

- Related problems must be addressed
- Representative situations:
  – Short-mid duration unplanned outage (e.g.; tube leak)
  – Long duration planned (unplanned?) outage
  – Range of anticipated seasonal performance
  – 0 MW audited SCC
  – Unit physically unable to operate (e.g.; Millstone 1)
  – Announced retirement
  – Scheduled maintenance
  – Maintenance overrun
  – Derate/full shut-down due to ambient air/water conditions
  – Static delist request
  – Limited energy units (e.g.; emissions restrictions)
  – RMR avoidance (?)

Modeling of Unusual/Uncommon Conditions in Base Cases
- Extreme System Conditions

- Evaluate mitigating measures for related problems
- Proposed representative situations:
  - Common mode fuel supply failure
  - Fuel supply unavailability

Scenario Analysis – Modeling of Possible Future Conditions in Base Cases

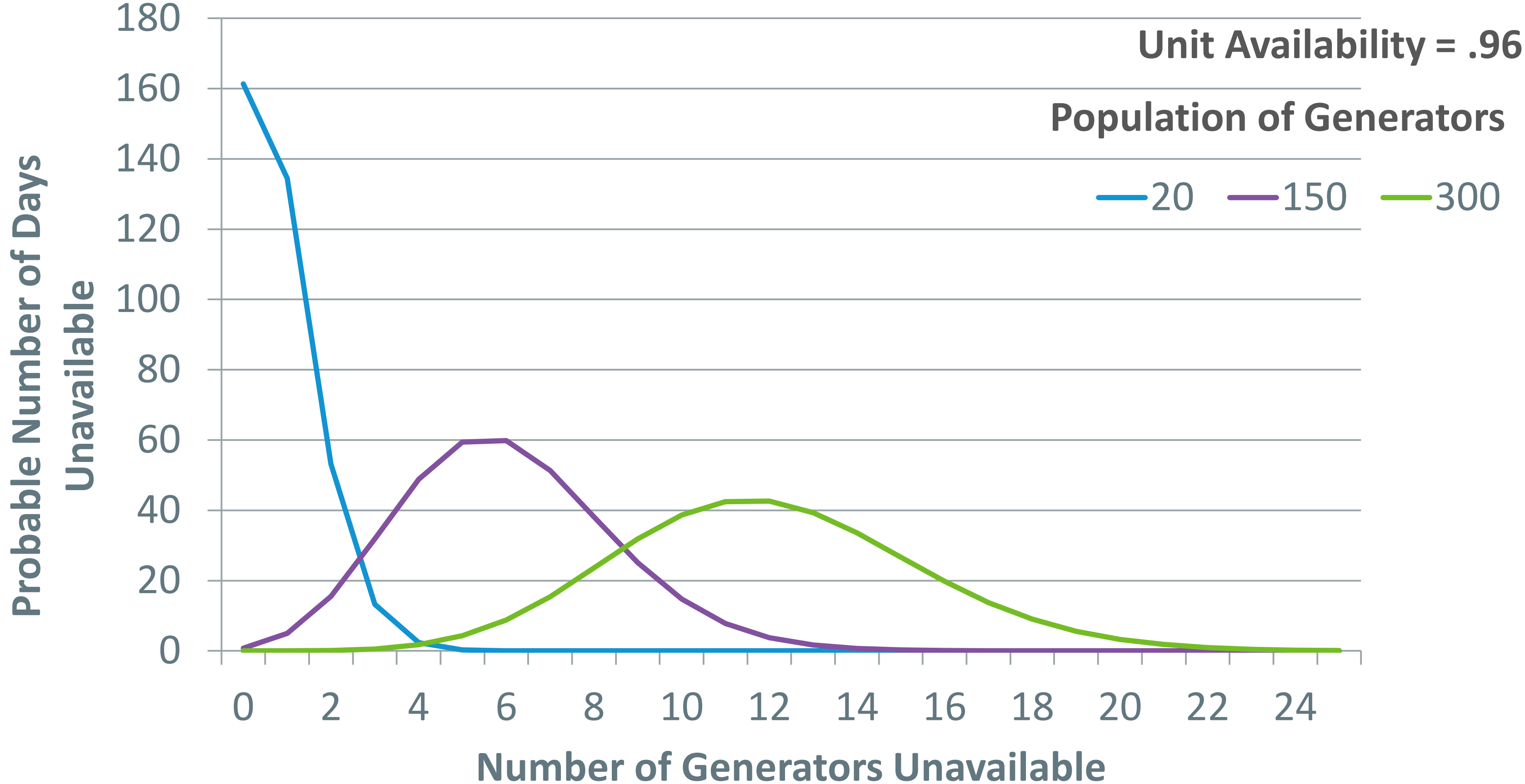
- Consider which problems should be mitigated/addressed based on cost, risk, etc.
  - Region needs to develop criteria and guidelines regarding thresholds of acceptability
- Representative situations:
  - Long(est) duration unplanned outage (e.g.; generator stator, GSU failure)
  - RMR avoidance (?)
  - Common mode outages
  - Unanticipated temporary shutdown (e.g.; financial shutdown)
  - Unannounced, relative to planning horizon, retirement (e.g.; Salem Harbor)

APPENDIX II

Examples of Probability Density and Cumulative Probability

Illustration 1

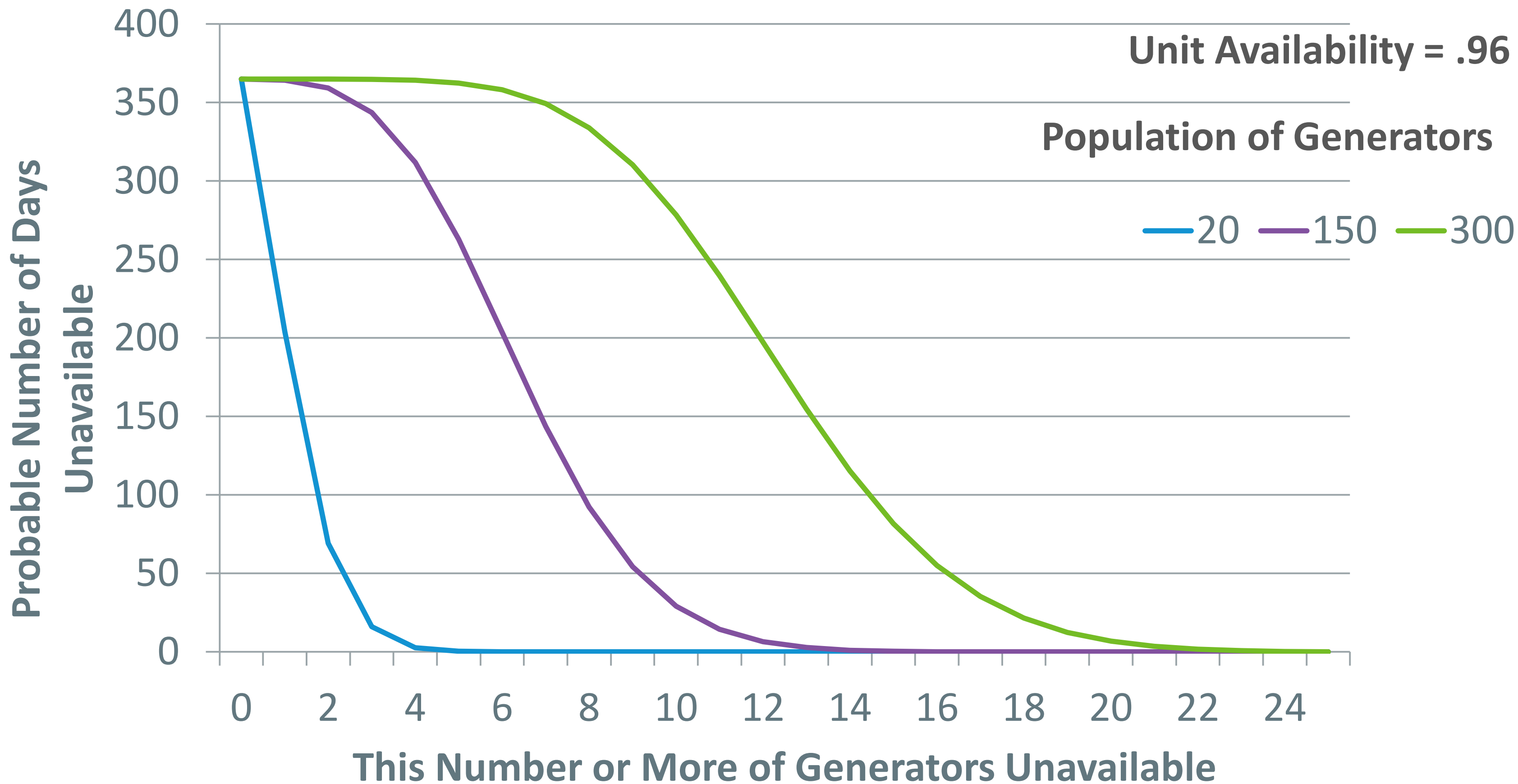
Example - Probable Number of Days of Having a Given Number of Generators Unavailable



Slide 15-"Review of Transmission Planning Assumptions and Methods", PAC Meeting, September 17, 2014

Illustration 2

Example - Probable Number of Days of Having Greater Than or Equal to a Given Number of Generators Unavailable

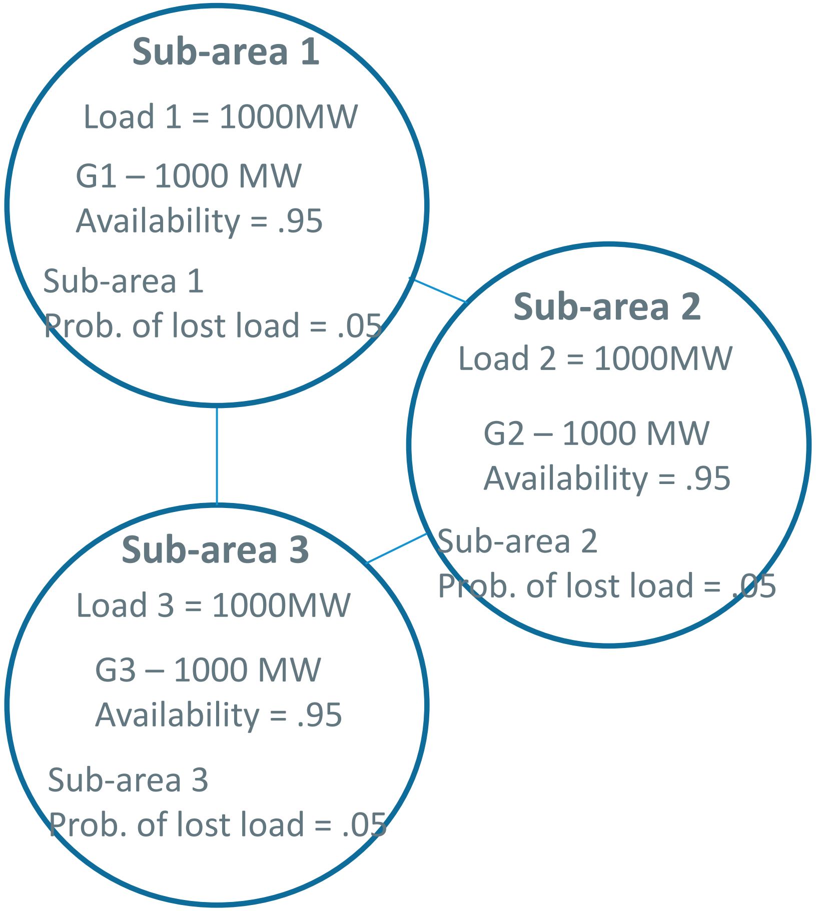


Slide 16-"Review of Transmission Planning Assumptions and Methods", PAC Meeting, September 17, 2014

APPENDIX III

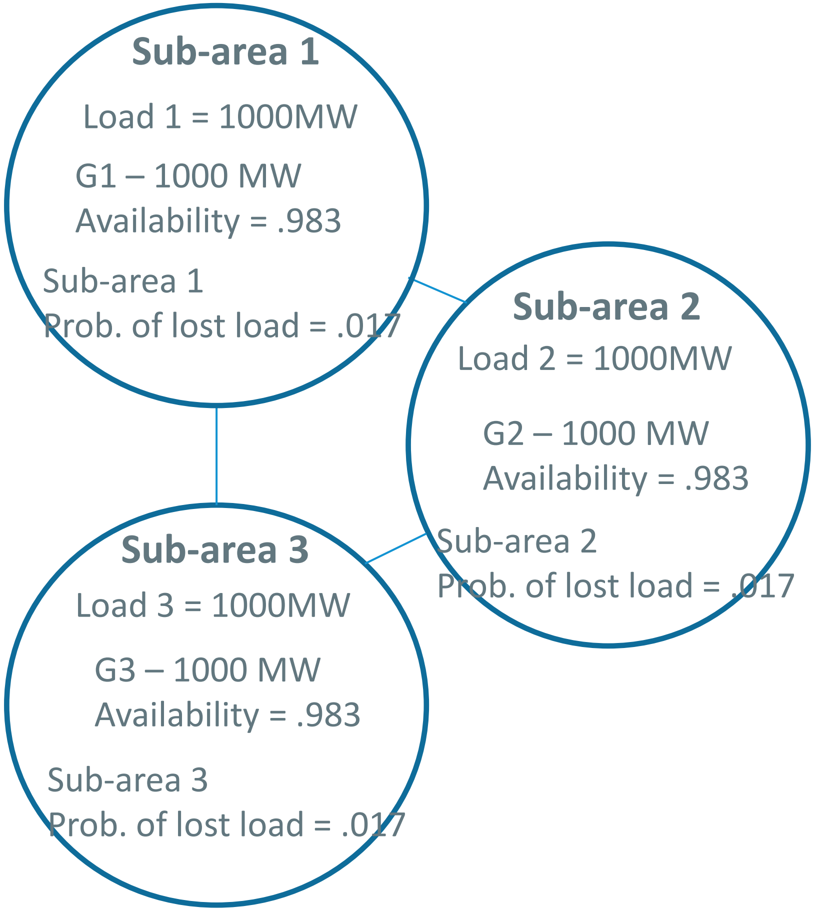
Sub-area Reliability(Adequacy) Impact on Regional Reliability (Adequacy)

Insufficient Sub-area Reliability (Adequacy) Compromises Aggregate Regional Reliability (Adequacy)



- The probability of lost load for each independent sub-area is .05
  - The entire sub-area load would be unserved, but for interconnections
- The probability of lost load for the entire system is .143
  - The probability that one or more 1000 MW generators is out of service [=1- (.95*.95*.95)]
  - There are more combinations of generation unavailability which are unreliable (one, two, or three generators out)
    - The amount of load at risk for each combination of generation unavailability will be different

Sufficient Aggregate Regional Reliability (Adequacy) Requires More Rigorous Sub-area Reliability (Adequacy)



- For the probability of lost load for the entire system to be no more than .05
  - The probability that one or more 1000 MW generators is out of service must be no more than .05
  - .05 = 1 – (.983*.983*.983)
- The probability of lost load for each independent sub-area must be no greater than .017
  - .017 = 1 - .983