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RESOURCE ADEQUACY METRICS AND THEIR APPLICATIONS

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April 20, 2020

1.0 INTRODUCTION

The New York State Reliability Council, LLC (NYSRC) Executive Committee formed the Resource Adequacy (RA) Working Group in December 2019 with the following objective: "Ensure that Executive Committee members are aware of current practices and proposals for resource adequacy metrics." This report responds to one action required for meeting this objective, to "gather information on current practices and proposals for resource adequacy metrics." Other actions are outlined in the Conclusions and Recommendations, Section 5 of this report.

The New York Control Area (NYCA) will be undergoing significant changes that will present challenges for maintaining reliability. One of these challenges is to ensure that resource adequacy is maintained recognizing the anticipated future replacement of traditional generation with intermittent energy-limited resources, primarily wind and solar. Although resource adequacy in NYCA has been assessed for many years by the New York Power Pool (NYPP) and now by the NYSRC and the New York Independent System Operator (NYISO), the advent of a future system composed of intermittent energy-limited resources makes resource adequacy assessment even more critical as a technical tool for evaluating reliability. Therefore, it is important to have a basic understanding of the different types of resource adequacy metrics currently used for such evaluations, not only for NYCA, but nationally and globally.

Many electric power systems, notably in North America, Western Europe, and Australia, probabilistically evaluate resource adequacy using some form of metrics and related reliability criteria. NYCA and many other electric power systems have utilized one of these metrics, Loss of Load Expectation (LOLE), as its resource adequacy metric for many years. The history of this metric is provided in Appendix A.

This report provides: (1) definitions of five commonly used resource adequacy metrics, (2) a survey of metrics used in North America and around the world, (3) application of various metrics in NYCA, and (4) Working Group conclusions and recommendations.

After beginning this effort, the NYSRC learned that Northeast Power Coordinating Council (NPCC) will be evaluating the applicability of alternative resource adequacy metrics. The information provided in this report will serve as important background information for this analysis.

2.0 RESOURCE ADEQUACY METRIC DEFINITIONS

Below are definitions and applications of the common resource adequacy metrics used in the electric power industry for resource adequacy assessments.[1]

[1] The metric definitions in this section are largely based on the North American Electric Reliability (NERC) publication, *Probabilistic Adequacy and Measures*, July 2018.

LOSS of LOAD HOURS (LOLH)

LOLH is generally defined as the expected number of hours per time period (often one year) when a system's hourly demand is projected to exceed the generating capacity. This metric is calculated using each hourly load in the given period (or the load duration curve).

LOSS OF LOAD EVENTS (LOLEV)

LOLEV, also known as loss of load frequency, is defined as the number of events in which system load is not served in a given time period. A LOLEV counts the expected frequency of continuous LOLH.

LOSS OF LOAD EXPECTATION (LOLE)

LOLE is defined as the expected number of days per time period (usually a year) for which the available resource capacity is insufficient to serve the demand at least once per day. LOLE counts the days having loss of load events, regardless of the number of consecutive or nonconsecutive loss of load hours in the day. Industry experts utilize various techniques from evaluating only the daily peak hour, subset of daily hours, or all daily hours.

LOSS OF LOAD PROBABILITY (LOLP)

LOLP is defined as the probability of system daily peak or hourly demand exceeding the available resource capacity during a given period. The probability can be calculated either by using only the daily peak loads (or daily peak variation curve) or all the hourly loads (or the load duration curve) in each study period.

EXPECTED UNSERVED ENERGY (EUE)

EUE is the summation of the expected number of megawatt hours of demand that will not be served in a given time period as a result of demand exceeding the available capacity across all hours. EUE is an energy-centric metric that considers the magnitude and duration for all hours of the time period, calculated in megawatt hours (MWh).

Many systems in North America, although not using EUE as a reliability criterion, calculate EUE in their probabilistic studies. EUE is very useful in estimating the size of loss of load events so the planners can estimate the cost and impact of the loss of load events. Use of the EUE metric may also provide insights for assessing the reliability of evolving systems with high levels of intermittent energy-limited resources.

"Normalized EUE" is the total expected firm load shed due to supply shortages (MWh) as a percent (%) of the total system net energy for load, and therefore represents an overall percentage of system load that cannot be served.

3.0 SURVEY OF RESOURCE ADEQUACY METRICS AROUND THE WORLD

This section documents variations in how alternative resource adequacy standards are used and interpreted in existing power system entities in North America, Western Europe, and Australia. Appendix B is a summary of risk metrics and corresponding resource adequacy criteria targets established by these entities.

As shown in Appendix B, the majority of entities in North America conducting resource adequacy studies use the LOLE metric with corresponding 1-in-10-year resource adequacy standard targets. The survey also shows that, in addition to the LOLE metric, the Manitoba Hydro and Saskatchewan Power systems also use LOLH and EUE metrics for their resource adequacy studies, although no criterion targets are provided. Several other systems in North America also calculate EUE in their probabilistic studies in addition to using the LOLE metric for their resource adequacy criterion.[2]

Appendix B shows that the LOLH metric is used in six Western European countries, with the loss of load duration criterion target ranging from three to eight hours per year. A normalized EUE target of 0.002% is used in Australia. This is the only EUE criterion that we could find from our survey.[3]

In summary:

- **The majority of North America markets use the LOLE metric as the basis of their resource adequacy criteria.**
- **Many countries in Western Europe use the LOLH metric as the basis for their resource adequacy criteria.**
- **Australia uses the EUE metric as the basis for its resource adequacy criterion.**

Although the majority of North American regions rely on the same resource adequacy standard, it should be recognized that there are regional differences in resource adequacy models and assumptions. Examples are as follows:

- Loss of load event definitions, e.g., frequency of shedding firm load after depletion of operating reserve vs. frequency of initiating Emergency Operating Procedures (EOPs).
- Neighboring area emergency assistance; e.g., detailed external models vs. use of a tie benefit equivalent.
- Load forecast uncertainty; e.g., including economic forecast uncertainty or only weather uncertainty.
- Models; e.g., GE-MARS vs. SERVM (used by SERC).

These differences in study assumptions and models can substantially affect the installed reserve margins necessary to achieve the chosen reliability targets. However, within the NPCC interconnected Areas, modeling differences are minimized by a requirement within the NPCC

[2] The NERC publication, *Probabilistic Adequacy and Measures*, July 2018, reported that a NERC survey showed that 20 entities in North America calculate EUE in their probabilistic studies.

[3] See Footnote 6.

resource adequacy criterion that specifies those factors that must be modeled or represented in each NPCC Area's resource adequacy study.[4] Further, the resource plan of each NPCC Area is assessed annually to ensure that proposed resources meet NPCC resource adequacy planning requirements.

4.0 APPLICATION OF VARIOUS METRICS IN NYCA

GE-MARS has the capability to calculate the LOLH and EUE metrics as well as the LOLE metric. Accordingly, we requested NYISO staff to determine LOLH and EUE reliability measures, with the LOLE fixed at 0.1 days/year, from the NYCA 2020 Installed Reserve Margin (IRM) Study base case. A comparison of these NYCA metric measures with metric measures and criteria used elsewhere is depicted in Table 1 below:

Table 1
Metric Comparison: NYCA vs. Other Markets

	LOLE	**LOLH**	**EUE**	**Normalized EUE[5]**
NYCA 2020 IRM Base Case	**0.1 days/year**	**0.34 hours/year**	**235 MWh/year**	**0.00015%**
US and Canada	0.1 days/year	--	--	--
Western Europe	--	3 to 8 hours/year	--	--
Australia	--	--	--	0.002%

The LOLE metric as currently used in New York only considers the frequency of which a shortage might occur, and does not take into account of the duration and magnitude of the shortfall. Use of the LOLH and EUE metrics would allow the duration and magnitude risk characteristics, respectively, to be calculated. This would be particularly useful as NYCA evolves to a system with more intermittent energy-limited generation resources. The NYISO is also reviewing the application of all three metrics to compare reliability impacts of resource options under its Reliability Planning Process.[6]

[4] The NPCC resource adequacy criterion, in addition to requiring a LOLE of 0.1 day/year, requires that each Area in their resource adequacy studies make "due allowance for demand uncertainty, scheduled outages and deratings, forced outages and deratings, assistance over interconnections with neighboring Planning Coordinator Areas, transmission transfer capabilities, and capacity and/or load relief from available operating procedures."

[5] The normalized EUE % for NERC was calculated by dividing the MARS calculated year 2020 unserved energy, 235 MWh (from the 2020 IRM base case), by the NYISO's "Gold Book" NYCA 2020 energy forecast, times 100.

[6] In his presentation, *Analyzing Loss of Load Events*, presented at the NERC Probabilistic Analysis Forum on December 12, 2019, Mike Welch of the NYISO presented ways the NYISO was reviewing the LOLE, LOLH,

As depicted in Table 1, when compared to the LOLH and EUE criteria used in Western Europe and Australia, respectively, NYCA's LOLH and EUE reliability results, based on the NYCA's LOLE criterion, appear to be more stringent than resource adequacy criteria used outside the US and Canada. However, as pointed out in Section 3.0, when comparing the IRM results from different entities, differing modeling assumptions must be recognized.[7]

5.0 CONCLUSIONS AND RECOMMENDATIONS

The NYSRC Resource Adequacy Working Group prepared this report to identify and define probabilistic resource adequacy metrics used in the electric power industry in North America and other parts of the world.

As a result of our review we concluded that consideration should be given to studying LOLH and EUE, in addition to the LOLE metric, in future IRM and resource adequacy assessments. This would provide the NYISO and NYSRC with a better understanding of the frequency, duration, and magnitude of potential future power supply shortfalls particularly as NYCA evolves to a system with more intermittent energy-limited resources. To illustrate the value of recognizing metrics in resource adequacy assessments, in its latest Long-Term Reliability Assessment NERC indicated it will be enhancing its reliability assessment process by expanding probabilistic approaches and incorporating energy adequacy metrics in future assessments.[8]

RECOMMENDATIONS

The current 0.1 days/year LOLE criterion used in NYCA is consistent with that used by other NPCC Areas and most of the other North American regions, and the Working Group does not recommend a change to that criterion. However, the Working Group recommends that the NYSRC Executive Committee approve the following actions:

1. As concluded earlier, it would be helpful when assessing resource adequacy, particularly of a system with a high percentage of intermittent energy-limited resource capacity, that the values for all three metrics, LOLH and EUE, as well as LOLE, be calculated. The Working Group therefore recommends that the NYISO and the NYSRC consider whether the 2021 IRM Study should calculate all three metrics and report them to the Executive Committee. Also, if time permits, we further suggest that a sensitivity case be run that examines the

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and EUE metrics to compare reliability impacts of planning options, with respect to the timing of loss of load events, how frequently they are occurring, how long they last, and the energy deficit from the event.

[7] An interesting reason as to why the US and Canada may have more stringent resource adequacy criteria than used in other countries is provided in the Australian Review Panel report, *Reliability Standards and Reliability Settings Review*, published in April 2010, that proposes that countries that appear to have more stringent standards (than Australia) generally have characteristics, such as larger system size and higher levels of interconnections that would make a higher standard less costly to achieve.

[8] Source: NERC Publication, *2019 Long-Term Reliability Assessment.*

reliability risks for each of the three metrics for a high intermittent renewable resource scenario compared to that of the present resource mix.

2. The NYSRC RA Working Group and NYSRC Executive Committee should monitor the following ongoing NYISO efforts to better understand the possible impacts of the recently enacted Community Leadership and Community Protection Act (CLCPA) in New York State. These efforts include CARIS process, 2020 RNA, and announced NYISO Grid in Transition Study by The Brattle Group.

3. The Working Group recommends that the NYSRC support and actively participate in the planned NPCC evaluation of the applicability of alternative resource adequacy metrics that is scheduled to be initiated in 2020.

APPENDIX A

HISTORY OF THE ONE-DAY-IN-TEN YEAR LOLE CRITERION IN NORTH AMERICA AND NEW YORK

The idea of using probability methods for determining IRM requirements goes back to the early 1930s. Several papers were published on this issue through 1950 without suggesting a specific LOLE index, although ranges of possible criterion levels were suggested during the late 1940s. During the 1950s, suggested LOLE index values were presented in a fairly narrow range, e.g., from one day in five to one year in 15. Around 1960 some publications suggested using a one day in ten years LOLE index, but without specifically quantifying the reason for its justification. Since 1960, the LOLE index of one day in ten years has been widely recognized by the electric industry in North America.

A 1981 US Department of Energy (DOE) report noted that system reliability criteria have been established on the basis of historical reliability levels that provided trouble-free service in the past. To our knowledge there have been no technical analyzes in North America to justify the one day in ten-year index, but to accept it as a universal standard that has provided acceptable service reliability.

Prior to formation of the New York Power Pool (NYPP), New York's upstate and downstate utilities during the mid-1960s separately used the one day in LOLE ten criterion to develop Upstate New York (UPNY) and Southeast New York (SENY) IRMs. They were determined to be 12% and 14%, respectively. Later, the NYPP also adopted the one day in ten-year criterion, which initially provided an 18% non-coincident peak IRM requirement for each utility[9]. The Northeast Power Coordinating Council also adopted the one day in ten-year criterion.

During the early 1970s, low generation availability required several 5% and 8% voltage reductions during the summer period, mostly in NYC. Because of NYS Public Service Commission (NYSPSC) and consumer complaints about the large number of voltage reductions, the NYPP Planning Committee considered using a maximum number of voltage reductions – 5 per year – as the LOLE criterion. LOLE studies showed this value correlated to a LOLE of one day in ten years. Therefore, it was decided not to change the LOLE criterion. Since then, to our knowledge, the NYPP and NPCC did not seriously re-evaluate the LOLE criterion. It has been very rare since 1970 that the actual IRM has been equal to or was lower than the required IRM. In 1999 the NYSRC adopted the LOLE index of one day in ten years as one of its Reliability Rules.

[9] This utility IRM requirement resulted in a 22.0% NYCA installed reserve on its coincident peak.

APPENDIX B

SURVEY OF RESOURCE ADEQUACY METRICS AND CRITERIA AROUND THE WORLD

	Metric	Criterion
North America - NERC Regions[10]		
NPCC – All 5 Areas[11]	LOLE	0.1 days/year
MISO	LOLE	0.1 days/year
MRO - Manitoba Hydro	LOLE/LOLH/EUE	0.1 days/year[12]
MRO – SaskPower	EUE	--
PJM	LOLE	0.1 days/year
SERC – All 4 Areas	LOLE	0.1 days/year
SPP	LOLE	0.1 days/year
TRE-ERCOP	LOLE	0.1 days/year
WECC – All 6 Areas	LOLP	0.02%[13]
Western Europe[14]		
Great Britain	LOLH	3 hours/year
France	LOLH	3 hours/year
Belgium	LOLH	3 hours/year
Netherlands	LOLH	4 hours/year
Ireland	LOLH	8 hours/year
Portugal	LOLH	8 hours/year
Australia[10]	Normalized EUE	0.002%

[10] Source: NERC Publication, *2019 Long-Term Reliability Assessment*, Table 4, pages 42-43.

[11] Certain NPCC Areas have supplemental resource adequacy criteria that may be more stringent than NPCC's 0.1 days/year LOLE criterion.

[12] This criterion applies to the LOLE metric. Related criteria were not provided by NERC for the LOLH and EUE metrics for both MRO Areas.

[13] A 0.02% LOLP is approximately equivalent to a LOLE of 0.1 days/yr.

[14] Source: *Renewable and Sustainable Energy Reviews,* June 2019. The other Western European countries and Japan use various types of deterministic or other probabilistic methodologies and criteria for setting IRMs.