RESOURCE ADEQUACY METRICS

AND THEIR APPLICATIONS

A Final Report

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Prepared by

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1. Introduction

This is the third and final report of a series of NYSRC Resource Adequacy Working Group (RAWG) reports on applications of reliability metrics. Previous reports have defined the three metrics -- Loss of Load Expectation (LOLE), Loss of Load Hours (LOLH), and Expected Unserved Energy (EUE)[1] -- provided a survey of entities using these metrics, provided metric results from recent ICS studies, and discussed the potential value of using all three metrics in IRM and resource adequacy applications. The RAWG has also reviewed, along with NYISO staff, several ICS IRM studies results along with their associated metrics.

This report further discusses the key finding in the earlier reports, that the use of multiple reliability risk metrics - LOLE, LOLH, and EUE - in New York Control Area (NYCA) resource adequacy assessments and IRM requirement studies would be of benefit. The report also introduces the use of *risk profiles* that provide "pictures" of loss of load events. Risk profiles communicate a clearer understanding of the reliability outcomes of alternate resource scenarios, including extreme weather event scenarios. Next, the report lists several applications for the use of the three metrics in NYSRC and NYISO studies, followed by a discussion of NYSRC's LOLE criterion. Finally, the report provides recommendations, including NYSRC reliability rule and policy changes to incorporate use of these metrics.

2. The Benefits of Using Multiple Metrics

Today, the range of types of resource options and applications in New York Control Area (NYPA) is expanding. Using just the current LOLE metric -- which provides only loss of load event frequency -- a system that has rare but very large events could appear to have the same level of reliability as a system with more frequent, smaller events. Moreover, increasing intermittent renewable resource and extreme weather events are future types of resource adequacy applications that can potentially provide many different types and variations of shortfall events. Therefore, understanding the size, frequency, and duration of potential shortfalls will become more important. This supports RAWG recommendation to supplement the currently used LOLE

[1] These reports can be found on the NYSRC web site at: https://www.nysrc.org/reports3.html. Brief definitions of these metrics are as follows:

LOLE: The number of events in which system load is not served in a given time period. This metric serves as NYSRC's resource adequacy criterion, as follows: "The loss of load expectation of disconnecting firm load due to resource deficiencies shall be, on average, no more than 0.1 days per year." The NYSRC Reliability Rules Subcommittee is presently drafting a revision to this criterion that would not change the present procedures or models for calculating reliability metrics.

LOLH: The expected number of hours in a given time period (often one year) when a system's hourly demand is projected to exceed the generating capacity.

EUE: The expected amount of energy (MWh) that will not be served in a given year.

criterion metric with the LOLH and EUE metrics in all resource adequacy assessments, IRM studies, and NYISO Planning Studies.

Others in the industry have determined that the three metrics can be used in a linear function to calculate, with very good accuracy, the other two metrics; but only for families of scenarios with fixed load or fixed resources.[2] Our own reviews of study results have verified this observation.

3. Risk Profiles: Pictures of Loss of Load Events

Providing a "picture" or a profile of loss of load events would make the application of multiple metrics more understandable and meaningful. To illustrate the use of *risk profiles,* below are four examples shown in Table 1. In all cases, the NYCA system meets the LOLE criterion of 0.1 days per year or one loss of load event every 10 years.[3] For the purpose of illustrating the use of risk profiles, Table 1 examines reliability measures and metrics over a 10-year period from recent Installed Capacity Subcommittee (ICS) studies.

Table 1
Risk Profiles for a 10-Year Period for Selected ICS Studies

LOL Event Characteristic	Metric	2021 Base Case	2022 Base Case	2022 Sensitivity: NYCA Isolated	High Renewable Case
IRM		20.7%	19.6%	28.2%	42.9%
Number of LOL Events in 10 years	LOLE	1 event	1 event	1 event	1 event
Number of Hours per Event	LOLH	3.7 hours	3.4 hours	3.0 hours	3.3 hours
Unserved Energy per Event	EUE	244 MWhr	207 MWhr	163 MWhr	208 MWhr
Average Load Shortfall per Event		66 MW	61 MW	54 MW	63 MW

Table 1 shows that, relying only on the LOLE metric, the four recent cases selected appear to have same level of reliability in that they all have one loss of load event every 10 years; but by including all three metrics, we arrive at different reliability conclusions -- the loss of load durations of the four cases ranges from 3.0 to 3.7 hours per event while the unserved energy value ranges from 163 MWhr to 244 MWhr per loss of load event.

Table 1 also shows a "4th metric," load shortfall. A question raised by NYSRC Executive Committee members during past discussions of NYCA IRM studies has been: "How much load is expected to be dropped with this IRM during a one day in 10-year criterion event?" Up to now we have not been able to answer this question, but now with use of the LOLH and EUE metrics we are able to estimate shortfalls by dividing the EUE's unserved energy by the LOLH's hours duration. This

[2] Source: Fazio & Hua, 2019, "Three probabilistic metrics for adequacy assessment of the Pacific Northwest power system." at https://www.sciencedirect.com/science/article/pii/S0378779619301713.
[3] See footnote 1 for the entire LOLE criterion.

result provides an "average MW shortfall" measure. Recent technical papers on reliability metric applications[4] have calculated a "maximum shortfall," which may be a better measure; however, programming is needed to calculate the maximum shortfall measure from GE-MARS output. RAWG will discuss with NYISO staff the feasibility of calculating maximum shortfall from GE-MARS output.

Table 2 below illustrates another example of using metrics to provide a good picture of loss of load events. For example, limiting the metrics to only the LOLE metric for examining the recent California and Texas loss of load events could lead one to the conclusion that the two events were similar: one or two loss of load events over a two or three-day period. However, the dramatic discrepancies in the LOLH and EUE measures show how reliance on the LOLE metric alone could skew the characterization of an event and have serious implications for decision-making. Accordingly, The RAWG recommends that this type of multiple metric analysis using risk profiles be done for NYSRC evaluations of extreme weather events and other applications.

Table 2
Illustration of Using a Risk Profile to Get a Good Picture of Recent Loss of Load Events[5]

LOL Event Characteristic	Metric	California Aug 2020	Texas Feb 2021
Number of Events	LOLE	2 events	1 event
Number of Days	LOLE	2 days	3 days
Number of Hours	LOLH	6 hours	71 hours
Unserved Energy	EUE	2,700 MWh	990,000 MWh
Max Shortfall	-	1,072 MW	20,000+ MW

Risk profiles similar those shown in Tables 1 and 2 should be prepared for major loss of load events that may impact the NYCA and other systems in the future, as well as for comparing reliability outcomes for alternate resource plans.

4. Extreme Weather Event Applications

We have previously pointed out that use of multiple metrics will be valuable for examining extreme weather impacts in resource adequacy assessments. The NYISO assessed one type of extreme weather event, an *extended wind lull*, in its 2021-30 Comprehensive Reliability Plan (CRP). The NYISO's wind lull study examined 18 extended wind lull event scenarios which considered loss of all off-shore or land-based wind facilities for one full week due to wind lull

[4] One such paper that discusses "maximum shortfall" was submitted to the 2021 NERC Probabilistic Analysis Forum, *Beyond 1-day-in-10,* by Derek Stenclik of Telos Energy.
[5] Based on a paper submitted to the 2021 NERC Probabilistic Analysis Forum, *Beyond 1-day-in-10, by* Derek Stenclik of Telos Energy.

events.[6] These wind lull scenarios were simulated using GE-MARS which included the calculation of all three metrics.

In the tables below we have chosen one of the NYISO's wind lull scenarios from the 2021-30 CRP to illustrate the application of multiple metrics for extreme weather assessments. This scenario assumes loss of all off-shore wind facilities -- with an assumed nameplate capacity of 6,098 MW in Zones J and K -- for one full week during the week with the highest offshore wind capacity factor. Table 3A provides details of the NYISO staff's study results taken from NYISO 2021-30 CRP's Figure 76.

Table 3A
Metric Data for Extreme Weather Scenario:
Loss of 100% of Offshore Wind Capacity Due to an Extended Wind Lull

LOL Event Characteristic	Base Case (No Wind Lull LOL events)	Wind Lull Case (All LOL events)	Wind Lull Case (Wind Lull LOL Events Only)
LOLE (days/yr.)	0.10	0.26	0.16
LOLH (hr./yr.)	0.291	0.849	0.558 (0.349 per LOL event)
EUE (MWhr)	85.7	289.9	204.2 (127.6 per LOL event)
Max OSW capacity available during the week designated for lull event	5,602 MW	0 MW	0 MW

From the data in Table 3A, we have prepared loss of load risk profiles for the extended wind lull scenario which are shown in Table 3B.

Table 3B
Loss of Load Event Risk Profiles for Extreme Weather Scenario:
Loss of 100% of Offshore Wind Capacity Due to an Extended Wind Lull

Loss of Load Event Characteristic	Metric	Base Case (Non- Wind Lull Event)	Wind Lull Event
Event Frequency	LOLE	1 event /10 yr.	1.6 events/10 yr.
Number of hours per event	LOLH	2.9 hours	3.5 hours
Unserved energy per event	EUE	857 MWhr	1,276 MWhr
Average shortfall per event		296 MW	365 MW
Customer cost from wind lull event		--	$ 64 million

By examining the number hours, unserved energy, and average shortfall of loss of load events in Table 3B, it is observed that, besides having a significant cost impact, loss of load events caused

[6] See NYISO 2021-30 CRP, Appendix E, *70X30 Scenario - Extended Wind Lull* for details of the NYISO's wind lull study, including study scope, assumptions, and results. The modeling assumptions for the wind lull scenario selected for this report are more fully described in this report.

by wind lulls result in a longer duration, more unserved energy, and greater shortfall than non-wind lull loss of load events. This type of information is an example of the benefit of quantifying the size, frequency, and duration of loss of load events when examining the reliability impacts of extreme weather events. Table 3B also shows customer cost impacts, assuming a cost of unserved energy of $50 per KWhr.[7]

Because this wind lull scenario's 0.26 days/yr. LOLE violates NYSRC's LOLE criterion, the NYISO also calculated compensatory capacity requirements, i.e., the "perfect capacity" needed to reduce the LOLE to 0.1 days/yr. The compensatory capacity needed in this case was determined to be 350 MW in Zone J.[8] Because compensatory capacity has the effect of reducing LOLE over the entire year, not just during a wind lull period, its capacity value is significantly less than the wind capacity lost during the week of the wind lull. Also, it should be recognized that in this case, by adding 350 MW of compensatory capacity to mitigate the reliability impact of a wind lull will not eliminate wind lull events entirely, just reduce their reliability impact sufficiently to meet the NYSRC LOLE criterion.

5. Future Metric Applications

Table 4 illustrates the types of NYSRC and NYISO applications that will benefit by applying multiple metrics. As discussed, use of metrics will provide more insights into frequency, size, and durations of shortfall events for providing better resource decisions for these applications.

Table 4
Examples of Future NYCA Multiple Metric Applications

Applications	Process	Entity
Sensitivity Studies	IRM Study	ICS
Parametric Studies	IRM Study	ICS
Renewable resource studies	Special Study	NYISO, ICS
Battery storage analyzes	Special Study	NYISO
Extreme weather event studies	Special Study	NYISO
Resource adequacy assessments	Reliability Needs Analysis (RNA) and Comprehensive Reliability Plan (CRP)	NYISO

[7] Multiple studies have developed estimates of the value of unserved energy to customers. The EPRI white paper, "Extreme Events, Natural Gas Fuel and Other Contingencies on Resource Adequacy" provides one such survey which shows the value of unserved energy for different classes of customers. We have weighed various values and arrived at a cost of unserved energy of $50 per KWhr for the purpose of this analysis

[8] See 2021-30 CRP Figure 71.

6. The LOLE Reliability Metric and its Application as NYSRC's Resource Adequacy Criterion

LOLE has served well as the metric for NYCA's "0.1 days per year" resource adequacy criterion[9] for multiple decades. Most North American systems use the 0.1 day per year LOLE criterion. Reliance on this metric, which specifies loss of load frequency, has been appropriate for past resource adequacy and IRM studies because shortfalls have shared similar characteristics, occurring during peak load events, and caused by randomly occurring forced outages of conventional fossil and nuclear generation.

As the NYCA increasingly relies on variable renewable energy and energy limited resources, the other metrics, LOLH and EUE, provide additional reliability information as they capture loss of load duration and total quantity of energy that is expected to go unserved. However, the LOLH and EUE metrics are single metrics that provide, just as LOLE, only one reliability risk measure. An advantage of the application of the LOLE metric for the NYSRC resource adequacy criterion is that it is consistent with its use as the NPCC resource adequacy criterion and that of NYCA's interconnected systems. Also, as stated above, it is currently the "North American Standard."[10] For these reasons, the RAWG agrees that the NYSRC should continue to utilize the LOLE metric for NYSRC's resource adequacy criterion, supplemented by measures of system risk from the EUE and LOLH metrics as discussed in Section 2.

7. Recommendations

The RAWG has the following recommendations:

1. The NYSRC and NYISO should calculate LOLE, LOLH, and EUE metrics in IRM and resource adequacy studies to provide multiple measures of system risk. Accordingly, NYSRC should establish a new Reliability Rule requiring NYSRC and NYISO to calculate, in addition to LOLE, the LOLH and EUE metrics in all IRM studies and resource adequacy assessments (RNA and CRP) as listed in Table 4. Accordingly, a new PRR should be prepared and NYSRC Policy 5 modified to incorporate all three metrics in NYSRC IRM and NYISO resource adequacy studies.

2. The LOLE metric should continue to serve as the basis for the NYSRC's resource adequacy criterion.

[9] See footnote 1 for the entire criterion.
[10] For details of this survey, see the RAWG's first report, *Resource Adequacy Metrics and Their Applications*, dated April 20, 2020.

3. Risk profiles as described in this report should be prepared for major loss of load events that may impact the NYCA and other systems in the future, as well as for comparing reliability outcomes of alternate resource plans and extreme weather event scenarios.

4. The NYSRC should form a permanent ad hoc NYSRC working group, "Resource Adequacy Advisory Working Group (RAAWG)." As NYCA transitions to a system with high variable renewable energy, maintaining reliability continues to be paramount. Therefore, during this grid transition the NYSRC must continue to maintain reliability standards that include resource adequacy requirements for ensuring sufficient resources for meeting reliability rules. This, coupled with extreme weather and uncertainty issues, makes resource adequacy a top NYSRC priority. In this regard, The RAAWG would monitor relevant resource adequacy assessments by the NYISO and other reliability entities, and advise the Executive Committee, RRS, and ICS, when appropriate, as to its insights regarding resource adequacy matters. It is intended that the RAAWG would only meet when necessary.