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Clarifying the Interpretation and Use of the LOLE Resource Adequacy Metric

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RELIABILITY | RESILIENCE | SECURITY




Agenda

- Introduction
- Historical background
- LOLE and related definitions
- Converting between timescales
- Conclusions

Acknowledgements

- IEEE Resource Adequacy Working Group
- NERC's Probabilistic Analysis Working Group
- Writing Team (many authors)

Clarifying the Interpretation and Use of the LOLE Resource Adequacy Metric

IEEE Resource Adequacy Work Group (RAWG), many authors[1]

I. INTRODUCTION

The loss of load expectation (LOLE) metric has a long history in power system reliability assessment, and today represents the most common basis for quantifying the resource adequacy of a power system [1]. As adequacy assessment methods have evolved over time, however, LOLE's definition and use has been adapted in different and sometimes mathematically inconsistent ways, often leading to confusion and inconsistent applications. While these issues are not generally new, they remain prevalent in industry practice, particularly as they relate to the interpretation of the common "1 day in 10 years" rule of thumb for acceptable shortfall risk as applied in North America.

Introduction

The raining analogy

Abdul stroked his beard gently, "Our weather bureau has existed only 100 years. But I can tell you that in that whole time we have had only 10 days of rain."

"Really!" said George excitedly. "Then you would expect rain only one day in ten years."

“Which ten years?" "Any ten years."

Abdul consulted his record book. "Well, I don't know about that -- it says that from 1884 to 1893 we had two days of rain. I really wouldn't want to predict."

"I know, I know," George said. "But on the average“.

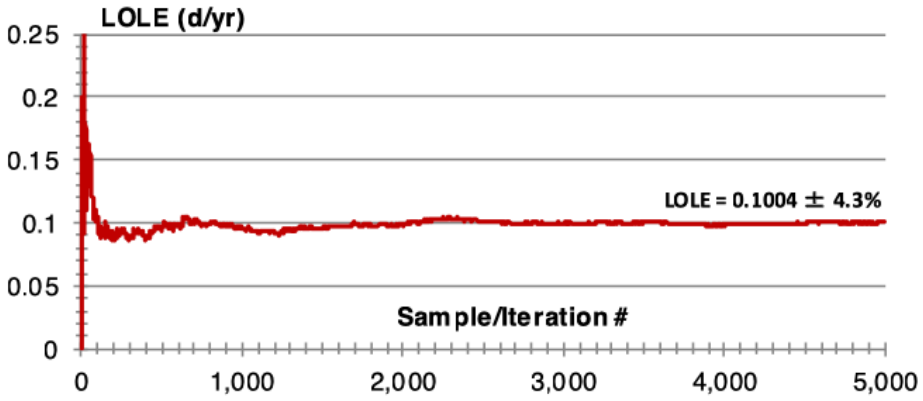
“Yes, I suppose so. I'm not much of a mathematician."

"It's really simple. You could even say you expect rain a tenth of a day year -- that's only 2.4 hours per year."

"No -- I couldn't say that, because we only count days of rain. On some day it could rain 1 hour or 12 hours, and we'd count it one day.

The loss of load expectation (LOLE) resource adequacy criteria

- The loss of load expectation* (LOLE) metric has a long history in power system reliability assessment, **and today represents the most common basis for quantifying the resource adequacy of a power system** [1].
- As adequacy assessment methods have evolved over time, however, **LOLE's definition and use has been adapted in different and sometimes mathematically inconsistent ways**, often leading to confusion and inconsistent applications.



**The term "expectation" is used in the mathematical sense, e.g., the long-term average value*

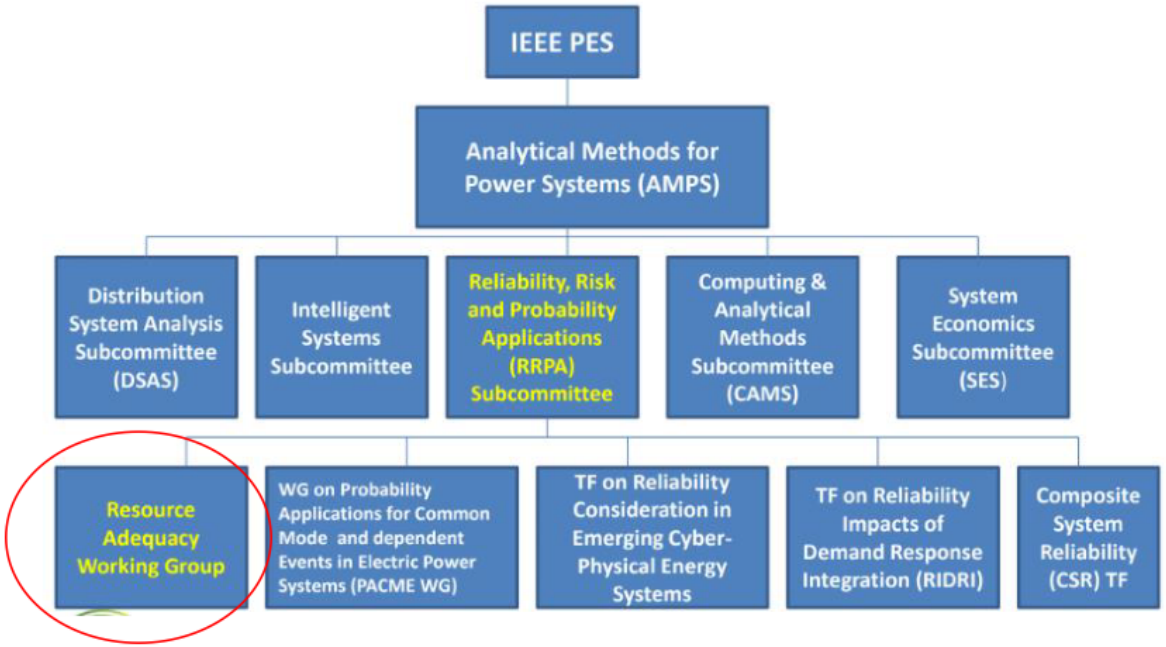
IEEE RAWG recent efforts

- To help address this problem, the IEEE PES Resource Adequacy Working Group (IEEE RAWG, operating under the Reliability, Risk and Probability Applications Subcommittee of the Analytical Methods for Power Systems Committee) is seeking to clarify the **mathematically-correct interpretation of LOLE** relative to other related metrics and terms.

RRPA Subcommittee

Scope:

– *" The RAWG reviews industry and academic probabilistic resource adequacy assessments, discusses probabilistic resource adequacy techniques, and shares expertise and experiences".*



Historical background

Probabilistic resource adequacy assessments

- Probabilistic resource adequacy assessment had been discussed as early as the 1930s [6]
- In 1947 Calabrese published one of the first papers [7] dealing with the metric that would come to be known as LOLE.
  - Calculated the expected (mean) count of the number of days in which daily maximum load would exceed available capacity.
- Billinton and Chu [1] chronicles the discussion and adoption of this "average count of shortfall days" metric in industry, and the eventual coalescence around 1 day in 10 years (0.1 days per year) as an acceptable level of risk through the 1960s.

Definitions

"expected total number of days of loss of load"

"fraction of time during which loss of load may be expected to occur"

"loss of load duration"

Recent developments

- Improved computational capabilities & increasing penetrations of variable generating resources (which can shift periods of system shortfall risk away from peak load hours) have motivated adequacy assessments at higher temporal resolution than the historical daily peak analysis
  - This allows for the quantification of the **expected count of hours** (rather than days) experiencing shortfall.

- A common adaptation of the historical "1 day in 10 years" criteria to **hourly** assessments has been to interpret it as "24 hours in 10 years", based on the premise that the original criteria referred to a full day's duration of shortfall.

LOLE and related definitions

LOLE and Related Definitions

- An **"event-period"** is a general period of time during which, at some point, system resources are insufficient to meet all demand
  - An **"event-hour"** is an event-period lasting one hour
  - An **"event-day"** is an event-period lasting one day (during which at least one event-hour occurs)
  - An **"event-year"** is an event-period lasting one year (during which at least one event-day occurs)

- An **"adequacy event"** (event) is a set of event-periods that are contiguous at the highest available level of temporal resolution

LOLE as a counting measure

Using these definitions, the IEEE RAWG hopes to remind practitioners that LOLE is a **counting measure**:

"The expected count of event-periods per horizon (e.g., 1 event-day per 10 years, 3 event-hours per year, 1 event-year per 20 years)."

This definition emphasizes that one cannot simply perform a unit change on the event periods (e.g., by equating 1 event day with 24 event-hours)

Special cases of LOLE

- **Loss of load hours (LOLH)**, the expected count of event-hours per horizon (e.g. 3 event-hours per year).
- **Loss of load days (LOLD),** the expected count of event-days per horizon (e.g. 1 event-day per 10 years)
- **Loss of load years (LOLY)**, the expected count of event-years per time period (e.g. 1 event-year per 20 years)

Reporting LOLE

- In North American studies, “LOLE” is often implied to be LOLD, with results in terms of event-hours labelled as LOLH instead [5].

- In European studies, “LOLE” typically implies the LOLH criterion [9]. The LOLY criterion is used by the Northwest Power and Conservation Council.

- **The IEEE RAWG does not consider one of these definitions to be more “correct” than any other. LOLE can be reported in terms of any kind of event-period (and horizon), as long as those units are clearly specified.**

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Distinguishing LOLE from similar metrics

- LOLE is not a measure of total shortfall duration, as shortfalls may be shorter than the event periods, they occur in.

- Only in the special (but common) case where the LOLE event-period is equal to the period of study can a direct numerical equivalence be made.

- LOLE does not count the number of adequacy events. For this, one should calculate the loss of load events (LOLEV, sometimes called loss of load frequency, LOLF), the expected count of adequacy events per horizon (e.g., 1 event per 10 years, which is not the same as 1 event-day per 10 years).

Converting between timescales

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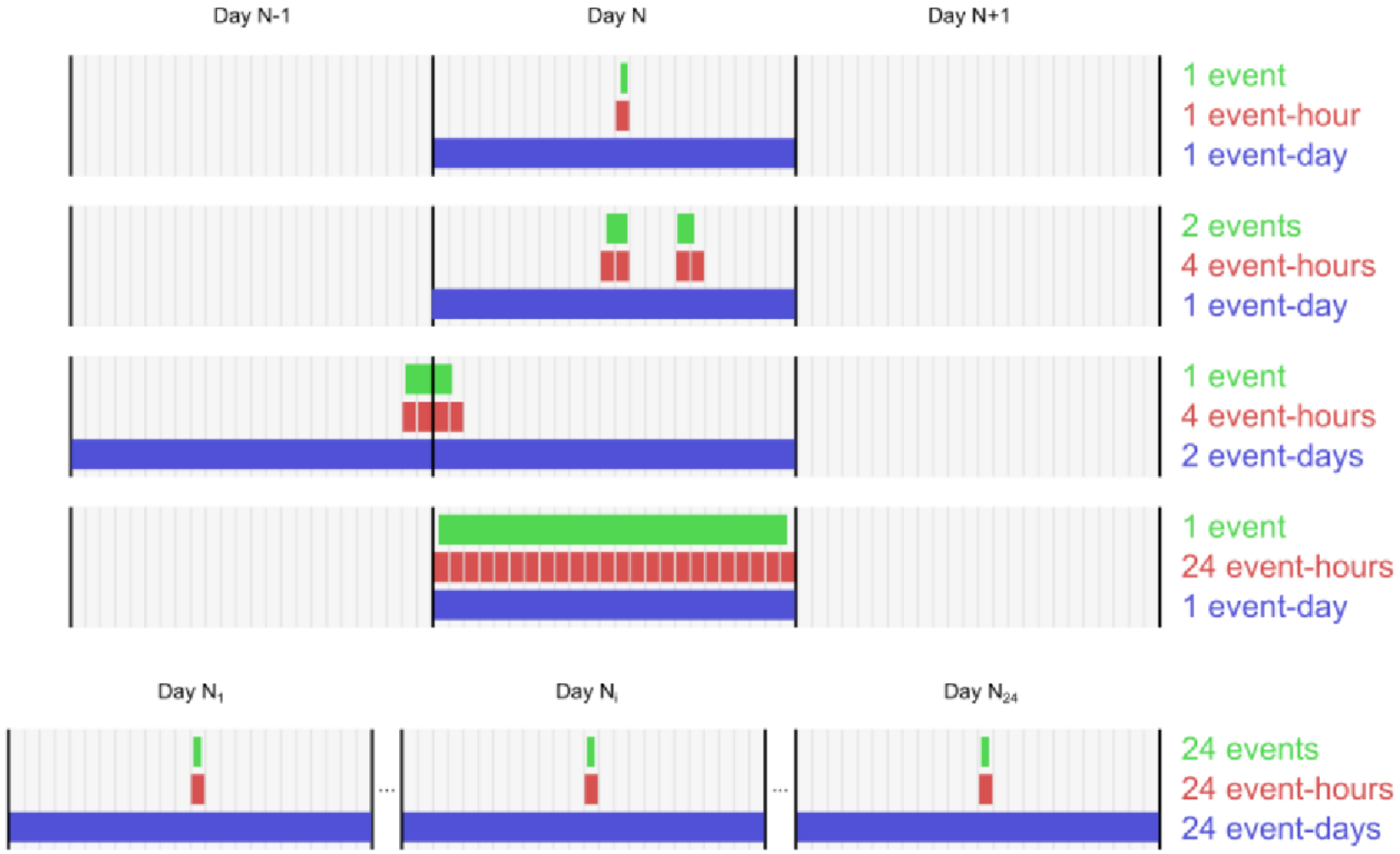
Event-days to Event-Hours LOLE

- A common source of confusion is how an LOLE adequacy criterion in terms of event-days per year is translated into a criterion for event-hours per year.

- For example, a common conversion equates the “1 day in 10 years” shortfall threshold to “24 hours in 10 years” or “2.4 hours in 1 year”.

- While it is not inherently wrong to use 24 event-hours per 10 years for an adequacy criterion, doing so implies a less reliable system than targeting 1 event-day per 10 years.

Exact conversions between criteria



Conclusions

- We hope to remind practitioners that a 1-day-in-10-year adequacy requirement for LOLE is not equivalent to a 2.4 hours/year requirement for LOLE/LOLH

- We recommend expressing LOLE results in terms of expected counts of "event-periods" (event-hours, event-days, etc.) per horizon in order to avoid the common misconception that LOLE and related metrics provide a measure of expected total shortfall duration

- The IEEE RAWG also recognizes the importance of using **multiple different metrics** to understand system adequacy [2,3].

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Questions and Answers