Is resilience different from reliability?

C. Singh

ECE Dept

Texas A&M University

In the past few months, I have listened to several talks trying to distinguish reliability and resilience. A colleague brought the latest note [1] to my attention. It looks to me that most of the people trying to distinguish reliability and resilience do not have sufficient knowledge in the indices, models and methods that have been developed in power system reliability literature. Therefore, instead of answering this question, I would like to provide a description of the indices that have been used in power system reliability evaluation and then let the reader answer this question himself or herself.

Reliability is measured or calculated in terms of indices using models and methods that are different at different levels. For example, the way we quantify reliability at the distribution level is different from the way we do at the composite system level (generation and transmission). Ref 1 for example talks about IEEE Std 1366, which is applicable to distribution level.

We know that power system reliability is generally considered to have two aspects, adequacy and security. Adequacy generally does not consider the sudden disturbances and dynamics whereas security does. However, it is important to remember that the only reason dynamic aspects have not been historically included in adequacy is computational complexities. Otherwise, there is no reason why dynamic aspects should not be considered in evaluating adequacy. Actually, there have been attempts to include transient stability and effect of protection failures in the calculations of reliability indices. The point is one has to differentiate the current usage in industry from the potential usage if sufficient understanding, computational power and efficient tools were available.

Now there are three basic attributes of reliability [2], frequency of failures, and duration of failures and magnitude of load loss and there are indices that relate to these three attributes.

Frequency deals with the number of failures in a specified time period. Duration of failures is a function of restoration and resiliency. Therefore, if the system bounces back from failure fast then the duration will be reduced.

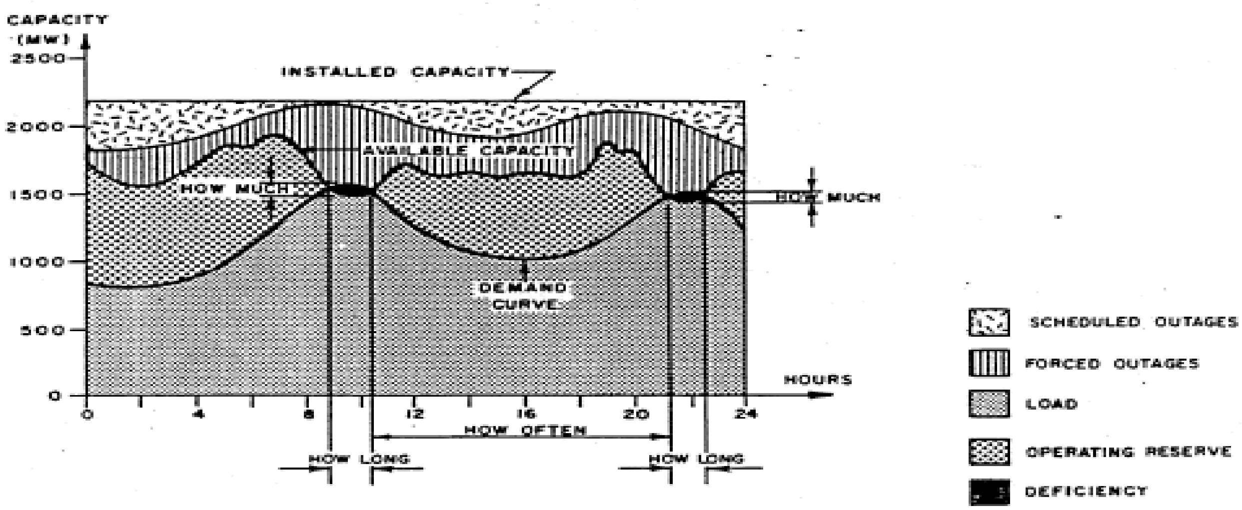
There are five indices that have been used [2] at the composite system level and these fall into three categories:

1. Loss of Load Expectation (LOLE): There are two versions,
    - DLOLE (daily loss of load expectation) is the expected number of days per year on which insufficient generating capacity is available to serve the daily peak load
    - HLOLE(hourly loss of load expectation) is the expected number of hours per year when insufficient generating capacity is available to serve the load
    - The LOLE depends on failure rate as well as how long it takes to restore the system. For example system x may have twice the failure rate of system y but if the duration of failures in y is reduced to half, then HLOLE will be the same. So for higher failure rate in the system, one could compensate by reducing the time to restore. However, even though HLOLE will stay the same, the frequency of failures will increase and some loads are sensitive to failures even of smaller durations.
2. Frequency and Duration of Capacity Shortage Events (F&D)
    - Frequency of generating capacity shortage events is defined to be the expected (average) number of such events per year.
    - Duration is the expected length of capacity shortage periods when they occur.
    - F&D indices use hourly load information and thus reflect the influences of daily load cycle shape.
    - F&D methods model unit parameters more fully than those models used in LOLE.

- F&D indices are conceptually superior to LOLE and LOLE can be derived from F&D indices. They have, however, greater data requirements.

3. Expected Unserved Energy (EUE)
    - The EUE index measures the expected amount of energy, which will fail to be supplied per year due to generative capacity differences and/or shortages in basic energy supplies.

These various attributes are shown pictorially in the following figure.



Loss of Load Expectation captures both the number of failures as well as duration and EUE captures depth of load loss in addition. If the system bounces back faster then the LOLE will decrease and so will EUE. The expected unserved energy captures the duration as well as magnitude. Therefore, reliability is not only binary but various shades of loss are also captured.

The point is that the picture is more complex than some portray simply as the frequency of failures. Within the broad context of reliability defined by these indices, resiliency would appear as a component of reliability. Resilience relates to restorability and speed of restoration. Although the failure rate and restoration time may not necessarily depend on each other but indices like LOLE and EUE would capture both. For example if resilience were improved, LOLE and EUE would be improved. Ref [3,4] for example show the importance of considering repair and restoration in calculating reliability.

Note: This is a developing document and not the final one. Therefore, the ideas expressed here may evolve with time.

References:

1. Aaron Clark-Ginsberg, What is the difference between reliability and resilience, https://www.researchgate.net/publication/320456274_What's_the_Difference_between_Reliability_and_Resilience

2. C. Singh, Course Notes in Power System Reliability:

https://chanansingh.engr.tamu.edu/

3. Jiang, Kai, and Chanan Singh. "Reliability modeling of all-digital protection systems including impact of repair." *IEEE Transactions on Power Delivery* 25, no. 2 (2010): 579-587.

4. Liu, Yong, and Chanan Singh. "A methodology for evaluation of hurricane impact on composite power system reliability." *IEEE Transactions on Power Systems* 26, no. 1 (2011): 145-152.