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WRITTEN STATEMENT OF IAN DOBSON
SANDBULTE PROFESSOR, IOWA STATE UNIVERSITY
FOR PANEL 1: 2015 STATE OF RELIABILITY REPORT
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Good morning Chairman Bay, Commissioners, and Commission Staff. My name is Ian Dobson and I am a professor of power system engineering at Iowa State University. Thank you for the opportunity to speak to you today about data for risk analysis and mitigation of cascading outages. Load loss caused by cascading outages is a significant reliability issue for which analysis methods are emerging. I will also discuss problems with the statistics of measures such as load loss.

Especially given its complexity, the bulk electrical system can be considered to be highly reliable and there is continuing progress towards maintaining this high reliability. However, and at the same time, historical blackout data from NERC shows that blackouts of all sizes do occur. This is called "heavy tails", since the largest blackouts, those in the upper tail of the distribution of blackout sizes, although rare, are much more likely than might be expected. That is, the largest blackouts are rare, but not vanishingly rare. The largest blackouts also have high cost to society so that, overall, their risk is substantial. Indeed the risk of the largest blackouts exceeds the risk of smaller blackouts. The largest blackouts typically involve cascading outages; these are long, complicated chains of dependent outages that propagate outages and load shed over a wide area. The risk of large blackouts is hard to analyze and mitigate, but it is not sufficient to only mitigate the more tractable smaller blackouts, because some (but not all) of the measures to suppress small blackouts can increase or eventually increase the chance of large blackouts.

In my opinion, the heavy-tailed pattern of reliability in which blackouts of all sizes occur but with larger blackouts rare can be entirely consistent with a well-run power grid. Indeed, complex systems analysis strongly suggests that conscientiously upgrading the grid when there is a real or anticipated blackout together with not over-spending on the grid can, over time, produce this pattern of reliability. This same pattern of grid reliability has been observed in other advanced economies worldwide.

It is also possible, especially now when the grid and the generation mix are changing rapidly, for large cascading blackouts to become more frequent than in the historical pattern of reliability, and this would be very undesirable. Therefore I would like to discuss aspects of the risk of cascading outages so that the current high reliability can be maintained.

A large majority of outages occur singly as an outage of one component and usually there is no load lost. The cause of the outage can be identified, and mitigation is usefully directed towards the most frequently occurring causes and outages. This is well exemplified many times in the 2015 State of Reliability Report. Longer cascading outages are different: there is an initial outage for some cause and then, more rarely but also more significantly, the outages propagate by a wide variety of other mechanisms. Although the outages of a long cascade can be explained (with both effort and hindsight) as a deterministic sequence after the cascade, the cascade typically involves unusual, rare, or poorly understood events. This is expected since careful engineering has already mitigated the most likely events. The chance of a particular long cascade is small, but since there are so many possible long cascades, occasionally one will happen. The longer the cascade, the more one is forced towards a probabilistic description, and the more one has to abandon the idea of a single cause of the cascade. After the initial outage, a number of chance events and operating conditions have to interact for the outages to propagate further. That is, there are many "causes" interacting in a complicated way to produce a long cascade. In particular, a root cause analysis that entirely attributes the long cascade to only the cause of the initial outage is generally not supported by the engineering or scientific realities. (In accordance with this, reports analyzing large blackouts recommend multiple different improvements to reliability practices.) Moreover, the mechanisms and causes involved in the initial outage and the subsequent propagations of outages are usually different. For example, a tree contact can cause an initial outage, which is then propagated via overloads and lack of situational awareness. One partial counter-example is weather, which can be a factor in both the initial outage and subsequent propagation. However, even if weather is a repeated cause during the cascade, other causes, perhaps under utility control, that make the outages more widespread may also be significant factors that merit analysis and mitigation. In particular, I support the Key Finding 1 in the 2015 State of Reliability Report that recommends: "… other metrics that report on BPS reliability (specifically load-loss events) that retain weather impacts should be developed." The low correlation (less than 0.1) between the transmission outage severity and the cause codes in Figures 3.5 and A.9 of the 2015 State of Reliability Report leaves open the possibility of finding other patterns in the cascade propagation that correlate more strongly with cascade impact. It remains important to continue to analyze and mitigate the initial outages that start all cascades, since this is indeed one of the effective mitigations, but the initial outages cannot be entirely eliminated, and quantifying and mitigating the different causes of the subsequent propagation of outages is also indicated. I also note with enthusiasm the detailed classification of various types of common mode and dependent outages in the 2014 TADS definitions.

The heavy-tailed pattern of reliability in which blackouts of all sizes occur poses challenges to monitoring the grid reliability with statistics. Conventional statistics can fail. For example, according to historical blackout data, the annual total or average blackout size, although often small, fluctuates randomly and sufficiently wildly so that it is neither representative nor indicative of grid reliability. Also it takes many years of data to experience enough larger blackouts to reliably indicate their distribution. These problems affect measures of blackout size such as load loss that contribute to the Severity Risk Index. To assess these problems, I would recommend that the empirical data for the cumulative distributions of these measures be collected for about 20 years, fitted with a curve, and then extensively resampled to provide model-free checks on and insights into the statistical performance of these measures.

There are also ways to avoid the statistical problems inherent in heavy tails. To monitor annual cascading performance, it would be better to monitor both the initial outages and the subsequent average propagation of outages, since these together govern the cascading and both can be meaningfully estimated annually since their statistics are not heavy-tailed.

The research, industry and regulatory community is starting to understand, quantify and mitigate the risk of cascading outages via models, simulations and analysis of data. In this process the systematic collection of detailed reliability data such as the previous work of the NERC Disturbance Analysis Working Group and the more recent work on TADS by the industry and regulators is extremely valuable and foundational. Increasing the automatic logging and processing of the data and coordinating the various reporting streams could be an opportunity to improve the data accuracy while minimizing the manual work filling out forms. For example in the 2015 State of Reliability Report it is exciting and useful that the TADS data can be linked to the load loss reporting.

It is particularly important to validate with real data, and improve where needed, the methods, models and simulations for cascading being developed by the community so that they approximate reality well and provide credible and useful tools for the industry. Reliability data is sensitive, but nevertheless allowing qualified researchers suitable access to some reliability data that is not in a summarized form is a key necessity for progress. Creative options such as more freely releasing old data should be explored.

The risk analysis of cascading outages, and particularly the rare long cascades that result in the most serious blackouts, pose significant challenges to data collection and analysis. However, I am optimistic that, given the data, the current state of the art can be extended to accommodate the monitoring and mitigation of large cascading outages.

Once again, I would like to thank the Commission for this opportunity to participate and I look forward to your questions and the discussions.