



Data Development and Composite Probabilistic Adequacy Evaluation

Final Project Report

S-104G

Power Systems Engineering Research Center
*Empowering Minds to Engineer
the Future Electric Energy System*



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Project Team

James McCalley, Project Leader
Iowa State University

Graduate Student

Elijah Goossen
Iowa State University

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For information about this project, contact:

James McCalley, jdm@iastate.edu; 515-294-4844

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For additional information, contact:

Power Systems Engineering Research Center
Arizona State University
527 Engineering Research Center
Tempe, Arizona 85287-5706
Phone: 480-965-1643
Fax: 480-727-2052

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Executive Summary

The reliability of the bulk power system has traditionally been assessed based on whether the time frame is operational, operational planning, or long-term planning, and based on whether the motivating concern is for transmission system performance or an adequate supply of generation to meet the load. Standard TPL-001-5 of the North American Electric Reliability Corporation (NERC), a standard for long-term planning, specifies seven types of contingencies, denoted P1-P7, and minimum performance requirements for each. Because TPL-001-5 generally requires a higher performance level for more likely contingencies, it is philosophically risk-based; however, it is deterministic in its implementation in that performance for a given contingency is either satisfied or it is not. Although TPL-001-5 is a planning standard, its essence is applied in operations as well, where performance following single component (so-called “N-1”) outage must be satisfactory. On the other hand, long-term evaluation of resource adequacy has long been assessed probabilistically, based on the probabilistic metric loss of load expectation (LOLE), with a general performance requirement guideline that LOLE be less than 0.1 day per year. We have also developed an approach called risk-based security assessment (RBSA) which applies a probabilistic measure to transmission system performance.

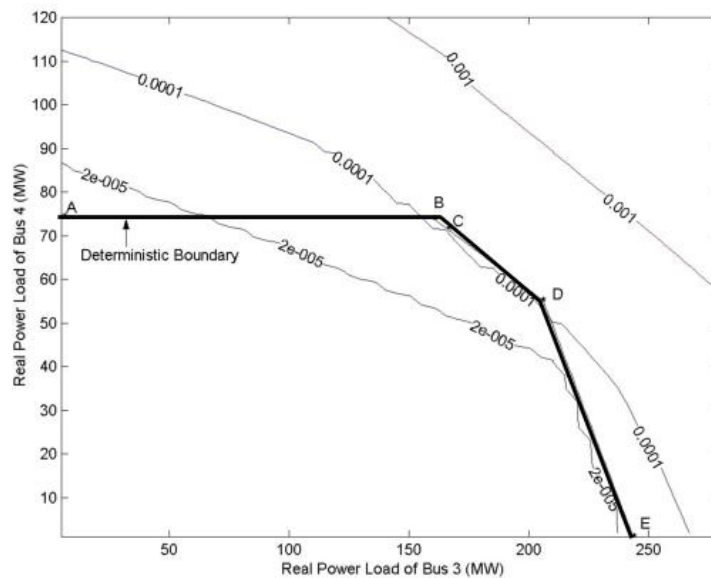
In this study, these three approaches, deterministic transmission assessment, probabilistic resource adequacy evaluation, and RBSA were compared. The deterministic transmission assessment approach and RBSA were illustrated on a utility subsystem; the power flow solver PSS[®]E was used for the deterministic approach, and in-house software was used for RBSA. Resource adequacy evaluation was evaluated on a US subregion using the Monte Carlo approach encoded within GE-Vernova’s application GE-MARS.

There were three main takeaways from this project.

1. ***Contingency probability estimation:*** A key tool necessary for probabilistic evaluation of transmission performance or of resource adequacy is the contingency probability estimation tool (CPET). CPET operates on the NERC databases Generation Availability Data System (GADS) and Transmission Availability Data System (TADS) to compute contingency probabilities for either short-term assessment as performed in real-time operations or in operational planning, or for long-term assessment as performed in long-term planning. These probabilities are essential for resource adequacy evaluation; they are also essential for risk-based transmission contingency evaluation. CPET has the ability to use GADS and TADS data characterizing only the geographical area of interest. In addition, if outage data for the geographical area of interest is sparse, CPET is capable of “borrowing strength” from outage data of other regions by appropriate statistical methods to increase the precision of the resulting estimates.
2. ***Risk-based security assessment:*** RBSA provides a metric to reflect the risk associated with an operating condition stemming from multiple contingencies, their occurrence probability, and the severity of the post-contingency system performance. This metric may be applied when the post-contingency performance problem is overload, undervoltage, voltage instability, or transient instability. We illustrated its use in this report for contingencies resulting in overload and undervoltage. The RBSA was originally intended to be used on-line, and we envision its initial trial to be done side-by-side with a conventional Energy Management System contingency processor. Although the RBSA

evaluation illustrated in this report is specific to an operating condition, it can also be deployed within a production cost simulator to provide cumulative risk and therefore to evaluate the performance of a long-term plan.

3. **Risk-aware decision-making:** The deterministic approach for evaluating system performance for contingencies can result in operational, operational planning, or long-term planning decisions that are risk-inconsistent. This means that some operating conditions identified as acceptable (secure) can actually be of higher risk than other operating conditions identified as unacceptable (insecure). The thick path A-B-C-D-E in the nomogram below represents the boundary between secure and insecure operating conditions based on the deterministic approach, for a particular power system. The thin lines represent contours of constant risk, where it is clear that points A and E have lower risk levels than points B, C, and D.



Our main conclusions in this project are that (i) CPET is a foundational tool for both resource adequacy analysis and for transmission system performance evaluation; (ii) the RBSA approach offers an approach to unify operations and planning transmission performance evaluation; and (iii) RBSA should be deployed side-by-side with an EMS contingency evaluator; it should also be built into a production cost simulator.

Project Publications:

- [1] Elijah Goossen, James McCalley, and Shayan Behzadirafti, “Data development and probabilistic adequacy evaluation,” to appear, Proc. of the North American Power Symposium, Oct. 26-28, 2025.

Student Theses:

- [1] Elijah Goossen, “Data development and probabilistic adequacy evaluation,” Masters of Science Thesis, Iowa State University. Graduated May, 2025.