Capturing the relationship between component condition and power system reliability – transformers vs. circuit breakers

Challenge and objective

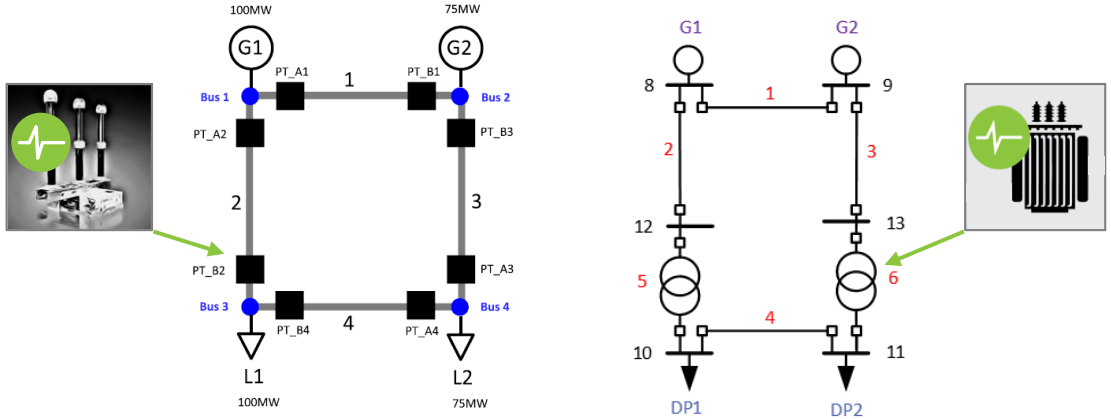
- The VulPro project has developed methodologies for analysing reliability of supply that take into account the technical condition of power system components. Initial work considered power transformers, building on an existing health index model.
- To complement the work on transformers, the PhD study in the project has focused on high-voltage circuit breakers (HVCBs) and on how their technical condition impact reliability of supply.
- An important question then raised was: How should the technical condition of circuit breakers accounted for in reliability of supply analysis? Can other component types be treated in a similar way as power transformers?

What have we learned?

- HVCBs have different failure mechanisms from power transformers and have two distinct failure modes that are related to their technical condition:
  i) failure to trip on command and ii) tripping without a command.
- How probabilities of such failures depend on condition can be estimated using existing data.
- The fault statistics available for calibrating CBs probability to fail to trip on command is particularly scarce, making this estimate relatively uncertain.
- Compared to transformers, circuit breakers have a different role in the power system as part of protection systems for transmission lines. This means that some HVCB failures (not tripping on command) lead to the simultaneous occurrence of two or more outages.
- For HVCBs, no failure database of scrapped components could be used to translate health indices to failure rates, and the HVCB failure method instead had to rely on a database of planned and unplanned outages (with a flag that an outage had occurred but no time stamp).

Implications and recommendations

- The VulPro methodology for integrating component condition and component reliability models in reliability of supply analysis can be applied to different types of components.
- However, it must be considered how different types of components have different roles in the power system (e.g., power transformers vs. high-voltage circuit breakers (HVCB)).
- For HVCBs, the influence of substation topology should be considered in future work.
- A database of scrapped HVCBs and/or time stamps on exactly when outages occurred would have improved the accuracy of component reliability models for HVCBs.
- Degradation models for transformers and HVCBs should be further improved.
- There is a great need to develop degradation and reliability models for other components such as power cables and overhead power lines, for which few models are available today.



[1] J. A. Grant, I. B. Sperstad, J. Foros, and V. V. Vadlamudi, "Health index calculation using failure modes, effects, and criticality analysis for high-voltage circuit breakers," *in ESREL 2023*, 2023, doi: 10.3850/978-981-18-8071-1_P128-cd.

[2] J. A. Grant, H. Toftaker, S. Perkin, I. B. Sperstad, and V. V. Vadlamudi, "High-voltage circuit breaker condition-dependent failure rate with covariates," *in 2024 Annual Reliability and Maintainability Symposium (RAMS)*. IEEE, 2024, doi: 10.1109/RAMS51492.2024.10457806.

[3] J. A. Grant, I. B. Sperstad, V. V. Vadlamudi, S. Perkin and E. S. Kiel, "The impact of high-voltage circuit breaker condition on power system reliability indices", *IET Generation, Transmission & Distribution*, vol. 18, no. 23, pp. 3980–3994, 2024. doi: 10.1049/gtd2.13333.