The impact of high-voltage circuit breaker condition on power system reliability

Challenge and objective

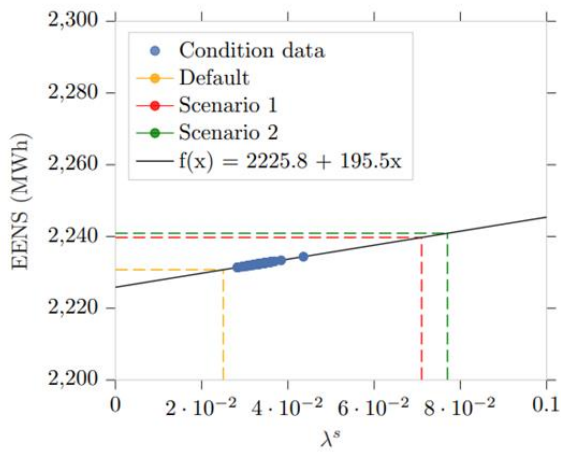
- How can high-voltage circuit breaker (HVCB) condition data be integrated into power system reliability analysis?
- How does the condition of an HVCB influence the likelihood of the HVCB tripping without a command or failing to trip on command?
- What are the effects of unwanted and missing HVCB operation on the system-level reliability indices?
- What are the sensitivities between the reliability indices and the HVCB condition parameters?

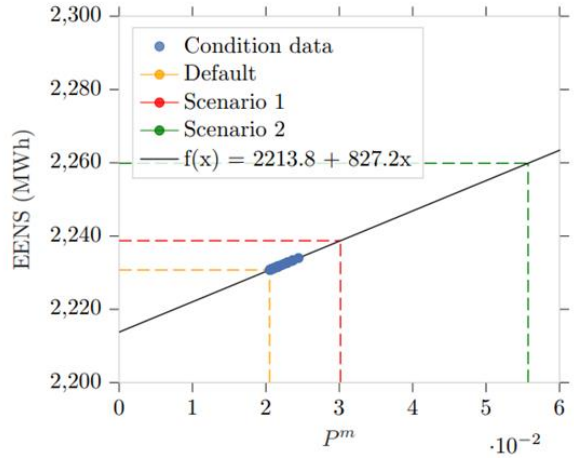
What have we learned?

- The condition data of HVCBs can be utilised to assess the deterioration of failure mechanisms. The weight that these failure mechanisms contribute to the health index can be justified through a framework employing failure modes, effects, and criticality analysis.
- The Cox Proportional Hazards Model can be used to facilitate the transformation of health indices into the HVCB condition-dependent reliability parameters of Pm (probability of failure to trip) and λs (trip without a command rate) while considering the effect of covariates.
- Trip coil current measurements can account for a higher fraction of the weight of the failure mechanisms that contribute towards λs (92\%) than Pm (39\%). As a result, λs could potentially vary by 184.07% compared to default values found in the literature that do not account for the HVCB condition, while Pm could potentially vary by 47.13%.
- In a study using a 4-bus test system, it was found that λs had minimal impact on reliability indices despite its high variability, while Pm had a significant effect on reliability indices despite being less variable.

Implications and recommendations

- The methods enable the assessment of how the condition of high-voltage circuit breakers affects the reliability of a system.
- This can be used for decision support to enable condition-based and risk-based maintenance and renewal of high-voltage circuit breakers.
- The failure mechanism of failure to trip on command has a stronger influence on reliability of supply due to common-mode failures (multiple outages from a single line fault).
- Collecting data for HVCBs' failure to trip on command is therefore more important to assess how the reliability (and vulnerability) of a power system depends on HVCB condition.





[1] 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.