Case study: Optimal maintenance strategy for 138kV SF$_6$ Circuit Breaker

Problem description:

How frequently should planned maintenance be carried out on HV circuit breakers?

In this case, a large electrical transmission company was seeking to reduce costs by optimizing their maintenance strategy whilst maintaining network performance and managing risks. The organisation had observed no evidence of degradation under the current (OEM recommended) 10-monthly maintenance routine and wished to investigate options for extending the interval.

Results and benefits:

The study revealed that the optimal interval for CB testing was at around 5 years, rather than the existing 10 month interval. This represents a net 75% reduction in total cost/risk business impact. For the population of 200 such circuit breakers in similar duty, this yields a saving of £900,000 per year.

Sensitivity testing to the extremes of optimistic & pessimistic risk and cost assumptions showed that the result was robust within a range of +/- 1 year of the 5 year cycle, and just +/-10% effect on the cost/risk impact.

The ‘what if?’ studies also revealed that, of the various failure modes considered, only one group had a significant impact on the testing strategy (red line in graph above). Furthermore, these failure modes included risks introduced by testing, as well as those increasing with time and normal usage.

100-140kV transmission lines are commonly used to connect generation stations with load centres. Circuit breakers are used for load switching and for disconnecting the lines in fault conditions. These breakers use various technologies, such as air, oil or sulphur hexafluoride gas (SF$_6$), as an arcing control medium.

There are many circuit breakers in service in a typical network; they are highly reliable and normally remain passive until called upon to operate for switching or in fault conditions. Dormant or hidden failures are therefore a concern, and functional tests and checks for leaks are periodically required to ensure that the breakers are fit to operate when needed.

Historically, the deterioration of a circuit breaker has been mainly manifested in wear of the contacts. And this is often inferred from the cumulative number of operations and the energy dissipated during the opening operation.

However modern equipment, such as the SF$_6$ models, suffer minimal contact erosion, even under heavy fault duty. So the reliability of the equipment and need for routine maintenance are focussed more on the operating mechanism.

The study we performed

We used the SALVO Process to provide the structured navigation and evaluation discipline to ensure all factors, stakeholders, data uncertainties and scenarios were explored, quantified and evaluated on a consistent and auditable basis.

This process was supported by real-time cost/risk modelling and ‘what if?’ calculations using the DST Maintenance Evaluator™ tool.
This study involved a small team comprising inspectors, operations, maintenance and process safety personnel. It needed just 2 hours to build the ‘base case’ scenario, using the SALVO storyboard for maintenance strategy optimisation. The study used DST Maintenance Evaluator™ software to model the risks and costs and operational options available, and calculate the optimal strategy. This enabled the team to use range-estimated data, to evaluate the impact of different decision factors, costs and risk assumptions, and to explore alternative scenarios instantly.

The study, including testing for sensitivity to all sources of data uncertainty, revealed the optimal strategy was to carry out circuit breaker testing every 60 months, taking account of opportunities to align the work to the nearest 12 month interval for planning purposes.

Finally, the SALVO Process decision-recording stage ensured the documentation of all assumptions, scenarios explored, uncertainties, sensitivity analysis and implications for alternative strategies, providing a clear audit trail for why the maintenance interval of 5 years is optimal.

Like other modules in the DST Asset Strategy Evaluator™ suite, the tool provides:

- A structured logic, with clear ‘storyboard’ checklist to ensure all factors are considered.
- Disciplined process to capture and quantify the knowledge of cross-disciplined teams, including their uncertainty.
- State-of-the-art analytical algorithms to evaluate the life cycle cost, risk and performance of decision options.
- Sophisticated, extremely rapid sensitivity-analysis to identify which assumptions have what effect upon the decision.
- Rapid creation and evaluation/comparison of multiple scenarios, enabling the study team to compare alternatives and explore ‘what if?’ ideas - instantly.