Partial Discharge Monitoring in Transmission Assets

Powerlink Queensland and EA Technology Australia have formed a partnership to explore the benefits and use of online partial discharge monitoring to better influence real time operational decision making for plant experiencing partial discharge or degraded electrical insulation condition.

By Thomas Whyte - EA Technology & Brody Ward - Powerlink

Powerlink is responsible for connecting Queenslanders to a world-class energy future through the provision of high voltage electricity transmission services. Its network connects five million people and 238,000 businesses, spanning 1,700km from Cairns to the New South Wales border, encompassing voltages from 66kV to 330kV.

BACKGROUND

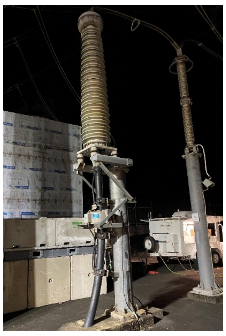
Infrequently, electrical utilities are exposed to disruptive failures of high voltage primary plant including cable terminations. To actively manage their assets and reduce the potential likelihood of failures, Powerlink implements a wide range of condition monitoring techniques to effectively manage their electrical assets.

With Partial Discharge a precursor to disruptive failure, they concluded that monitoring in real-time would provide many advantages to the safety of personnel, reliability of supply and maximising asset usage.

Due to this, Powerlink approached EA Technology Australia to provide a solution for the real-time monitoring of transmission assets. EA Technology worked together with Powerlink to install an online 24/7 monitoring system that could effectively be used in outdoor transmission yards. This partnership focused on an asset with suspect electrical condition issues, following this asset from the initial stages of monitoring through to decommissioning and forensic analysis.

The test subject of this project was a pair of 275kV oil filled cable terminations. DGA testing on the oil within the termination had previously indicated that partial discharge was occurring. Due to the criticality of the cable terminations, the monitoring system was installed as a risk mitigation system while replacement works could be planned.

THE HARDWARE



To monitor the pair of 275kV oil terminations, a modified version of the EA Technology Astute Monitor was used. This system is capable of capturing TEV, Ultrasonic and HFCT data. However, in an outdoor transmission scenario it was decided that the TEV testing method alone would be used.

The TEV sensors have the added benefit of including time of flight functionality. This allowed each TEV sensor to communicate and determine the origin point of the partial discharge signals. Due to this it was possible to determine the source of the partial discharge signals down to a specific phase of the terminations. It was also possible to add additional sensors to the monitoring system to act as aerials. These sensors were used to mask out external electromagnetic noise.

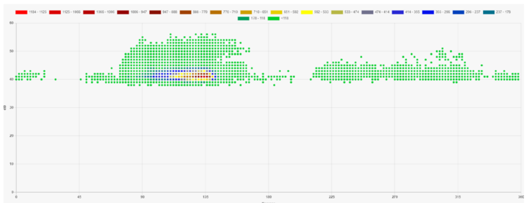
FINDINGS

The TEV test technique involves measuring the amplitude of Transient Earth Voltage pulses along with their frequency of occurrence with relation to the 50Hz sine wave. The amplitude is measured in dBmV. The pulses per cycle count (ppc) is the number of partial discharge events occurring during each 50Hz sine wave within the highest 10dBmV of TEV signal.

The project found that over the entire monitoring period, the amplitude of the partial discharge signals did not increase. However, the ppc count saw a significant increase over the period. The ppc raised from 6.5ppc in the first week of monitoring to 12ppc in the final week.

The increase in discharge rate without an increase in amplitude suggests that the defect causing the PD signals was evolving in time. Rather than the electromagnetic energy emitted by the defect becoming higher in amplitude – which is what we expect when the physical size of the defect becomes larger – the discharge events were occurring more frequently or over a larger area of the insulation, resulting in the increased ppc.

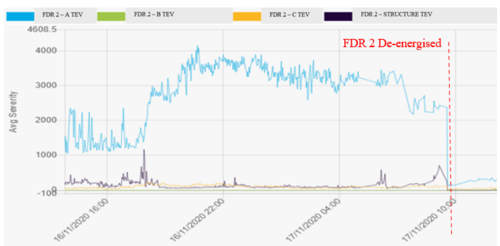
Analysis of the phase resolved partial discharge (PRPD) patterns over time shed more light on the defect type. The PRPD patterns show a very distinct set of partial discharge clusters.



The PRPD pattern shows one high level cluster of partial discharge activity located at approximately 130-degrees on the 50Hz sine wave. This cluster does not have a corresponding cluster with 180-degree separation on the sine wave. From this it can be concluded that the location of the defect is physically close to either the live or earthed portion of the insulation.

The cluster shape is also indicative of partial discharge occurring within oil. This led to the hypothesis that the discharge must be happening on the outside of the insulation, discharging into the oil. This cluster shape has been observed multiple times before, when defects have been found within transformer oil.

Once the appropriate replacements had been planned, the cable terminations showing the highest levels of partial discharge were de-energised, resulting in a complete drop in the amplitude and ppc count of the partial discharge.



FORENSIC ANALYSIS

Once removed from service, the cable terminations were broken down and a full forensic analysis was performed. The analysis included;

- Dissolved Gas Analysis
- External Visual Inspection
- Dismantlement of all sub-components and internal visual inspection
- Fourier Transform Infrared Spectroscopy (FTIR)
- Scanning Electron Microscopy with Energy Dispersive X-ray spectroscopy (SEM/EDS)

A visual inspection revealed a significant build-up of contaminants on the outside of the XLPE insulation, located just above the chamfered region of the termination. Electron microscopy found evidence of "micro pitting" along the chamfered region of the XLPE insulation. This is suspected to be the source of the partial discharge. It is hypothesised that this chamfered region was not correctly smoothed as part of the termination process, resulting in a rough surface for the electromagnetic fields to focus, resulting in PD activity. Over time the amount of partial discharge activity increased, discharging between the rough outer surface of the XLPE and the oil. This correlates with the PRPD patterns recorded by the PD monitoring system and the increase in acetylene in the oil identified during DGA testing of the oil.

THE BENEFITS OF PARTIAL DISCHARGE MONITORING

During the project, Powerlink has found that online PD monitoring can provide numerous benefits to utilities exploring a proactive risk-based approach to high voltage plant failure. Benefits may include increased site safety, reliability of supply, decreased risk of damage to nearby plant and financial and reputational risk factors.

During this project, the system was installed on six 275kV cable terminations within close proximity to each other which provide supply to a major load centre. As such, limited outage time was possible without compromising reliability or supply to customers.

Partial discharge monitoring data was analysed by EA Technology specialists and their conclusions were utilised by Powerlink engineers in real time to make dynamic decisions. Additionally, the alarm functionality was used to justify and rate the potential for explosive failure in real time. This allowed Powerlink to make effective operational decisions for personnel and where needed, implement electricity supply contingency plans.

Additional benefits of the implemented system such as non-intrusive installation, remote telecommunications, cloud serviced data and automated alarms proved increasingly useful as the evolution of the fault within the cable terminal progressed.

While the system does come at a financial cost to the operator, compared to intrusive methods of monitoring such as DGA analysis and financial burdens of explosive primary plant failure, the system on balance proved relatively inexpensive.

SUMMARY

Using 24/7 online partial discharge monitoring, it was possible to trend the degradation of the cable terminations which allowed Powerlink to act quickly when the partial discharge signals began to increase. Findings from the online partial discharge monitor data were supported by DGA testing whilst the asset was in service and then once the asset was removed from service, the corresponding forensic analysis.

The success of this project has seen Powerlink continue with the implementation of online partial discharge monitoring on multiple other assets, with the goals of providing a smarter and more reliable electrical network. T&D

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