11 months of mitigating risk

Partial discharge, a major cause of electrical failure in the industry, has always been hard to detect until it becomes a problem. However, a pilot of a new detection system by INEOS and EA Technology validated the system, delivered savings for INEOS, and netted the partners the Innovation Award at the IAM Awards 2018.

by Graham Earp

IAM Awards 2018: Innovation award winner

Aware of the issue of partial discharge in electrical networks, INEOS suspected that it may be occurring somewhere within one or more of 18 critical 33kV underground feeder cables on its Grangemouth site. But, in line with industry standards, there was no way to be sure without periodically taking the critical high voltage (HV) cables out of service, physically disconnecting them, and then performing conventional very low frequency (VLF) cable testing. This results in unwanted disruption to both the HV connections and the operation of the plant.

INEOS is a multinational group specialising in petrochemical production. Grangemouth in Scotland is one of its largest manufacturing sites. Home to a crude oil refinery and INEOS' Olefins and Polymers business, Grangemouth requires about 140 megawatts of electricity and 550 tonnes per hour of extra high pressure steam for normal operations. To support this, INEOS operates a combined heat and power (CHP) plant, served by its own private electricity distribution network.

The cables considered as part of the pilot were the ones linking the CHP plant to the main electricity distribution substation. If any one of these 18 cables were to fail, it would disrupt the operation of the CHP plant, which could have a domino effect across the entire site.

With this in mind, INEOS routinely disconnects and tests the cables once a year. This is no small undertaking; it involves temporarily shutting down CHP operations at Grangemouth, which requires considerable preparation and planning.

Early warning

Partial discharge is a breakdown of a small area of insulation that is subject to high voltages. The breakdown does not span the whole distance between the two insulated electrodes – hence "partial". It can be caused by poorly made or poorly installed insulation, or by wear and tear. Once partial discharge starts, it will inevitably degrade the insulation until eventually it fails.

When partial discharge occurs, it emits a very brief, high-frequency pulse of electrical current. The pulse races along the cable away from the discharge location. When it reaches the end of the cable, it is reflected back the other way.

To EA Technology, a consultancy serving the power industry, this small side effect of partial discharge represented an opportunity. Sensors attached non-invasively to cables could continuously monitor for these pulses. Engineers could be alerted to the signs of partial discharge while the cables were still in operation, without the need for a shutdown or to excavate the cables to perform a manual inspection.

EA Technology had a prototype solution based on the pulse monitoring method, known as CableData™ Monitor. INEOS had the electrical network and were keen to embrace innovative technology. The two companies therefore decided to work together on a joint pilot study, using the CableData™ Monitor to test INEOS' 18 critical cables at Grangemouth.

EA Technology installed and commissioned the CableData™ Monitor in partnership with INEOS' power systems engineers, attaching radio frequency current transformer (RFCT) sensors to the 18 cables. These sensors simply wrap around the earth straps at the ends of the cables like a cuff, without breaking the insulation or interfering with the connections.

The sensors connected to a series of measurement nodes installed in the primary substation, which in turn fed the continuously monitored data to a central hub where it was stored and processed. EA Technology's partial discharge experts could then access and assess the collected data from the hub over the 4G mobile network, using a specially designed web interface.

When it came fully online in October 2016, the CableData™ Monitor seemed to confirm the INEOS team's suspicions. The system detected minute high-frequency current pulses in three of the 18 cables.

Monitor or replace?

By measuring how much time elapses between the original pulse and its reflection from the ends of the cable, it is possible to pinpoint where along the length of the cable the partial discharge is taking place. Using this technique, the team narrowed down the source of the partial discharges to a set of relatively recently installed cable joints.

This was somewhat unexpected. Wear and tear over time means that partial discharge is generally more likely in older components. But it was also good news. EA Technology's experience detecting and measuring partial discharge had taught the team that joints can withstand higher levels of partial discharge than cables themselves, and can withstand them for longer.

If left unchecked, partial discharge will always lead to electrical failure eventually. But the time it takes for the first partial discharge to degrade the insulation to the point of failure is less predictable, dependent on a multitude of external and environmental factors. It is not possible to categorically predict when a cable experiencing partial discharge will fail, only that it will at some point.

However, with continuous monitoring, it is possible to detect trends. In general, if the current pulses from partial discharge are increasing in magnitude over time and occurring closer and closer together, the cable is accelerating towards failure.

EA Technology's in-house partial discharge experts analysed the information gathered by the CableData™ Monitor in detail. Based on the trends, and the identification of the cable joints as the source of the partial discharge, EA Technology concluded that imminent electrical failure was unlikely.

The INEOS team considered the data and EA Technology's conclusion, and the informed decision was that the cables would be monitored closely until the next scheduled planned shutdown of the CHP.

Stay alert

So for the 11 months between the identification of the PD and the next scheduled shutdown, INEOS and EA Technology focused on monitoring and safely managing the risk.

INEOS put in place a number of precautions to manage and minimise the effects of a sudden failure, including:

- making sure that resources (personnel, expertise and materials) were immediately available to repair a failure
- making alternative provision for electricity and steam supplies in case of a failure shutting down the CHP plant
- keeping personnel safe by preventing access to the discharging cable joints while they were energised.

At the same time, EA Technology used the CableData™ Monitor to set up automated alerts. They defined parameters that would indicate an increasing likelihood of failure – pulses surpassing a certain magnitude, or increasing in frequency at a certain rate, for example – and instructed the system to issue alerts if its measurements crossed these pre set thresholds.

If the system issued an alert, members of the EA Technology team would immediately receive automated emails and text messages. They could then investigate the readings and report back to INEOS – and, if necessary, review the decision to keep the cables in service.

And the pilot has delivered positive outcomes. The data provided assurance that the cables remained in service without failing until the planned shutdown in August 2017.

The readings from the CableData™ Monitor allowed the joint team to plan how to deal with the discharging cable joints during the shutdown. They were removed from service, replaced, and the ex service joints forensically examined providing valuable information for elsewhere in the industry.

The examination revealed that partial discharge had indeed been taking place in the three joints, despite their relatively recent installation. Moisture had made its way in under the outer sealing sleeves, causing internal corrosion that led to partial discharge on the internal insulation and stress control tubing. The location and level of partial discharge was consistent with what the CableData™ Monitor had indicated. The system worked.

A successful pilot

By continuously monitoring the condition of these critical cables EA Technology and INEOS avoided either an unexpected failure or an unplanned shutdown to replace the degraded parts.

An unplanned shutdown of the CHP plant to repair or replace the joints could have had significant implications for production at Grangemouth.

The CableData™ Monitor also improved safety for INEOS' personnel. The system pinpointed the location of the partial discharge, so the company could restrict access to that area while the cables were energised, protecting its people.

With the CableData™ Monitor system installed and validated, the Grangemouth CHP plant no longer needs to be periodically shut down for traditional VLF cable testing. This means the company can avoid the lost production associated with planned shutdowns as well as unplanned ones, and provides security of energy supply for the site.

Following the success of the pilot project, INEOS expanded the CableData™ Monitor system to monitor all 117 cables in the 33kV primary distribution substation at Grangemouth. Improvements to future joint methodology have also been introduced based on the forensic findings.

After the three degraded joints were replaced and the cables were re-energised in September 2017, there was no longer any sign of partial discharge. Still, INEOS is continuing to monitor all 18 critical cables closely. The replaced cable joints were just three of many of the same type, all installed at the same time. The CableData™ Monitor provides INEOS with the peace of mind that these similar joints are not currently discharging – and that if they start to, the company will have enough advanced notice to manage them effectively.

About the author

Graham Earp is a Principal Consultant Engineer with EA Technology. He is currently responsible for evaluating and implementing innovative technologies for the detection of partial discharge in High Voltage plant and equipment – in particular the development of online HV cable monitoring applications and services.