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Ireland's ESB Networks worked closely with EA Technology on the development of the original UltraTEV Detector[™] and was the first network operator to adopt it as standard field equipment. Paul Shiel explains the application of the instrument which was the forerunner of successive generations of UltraTEV products and made possible a radical new approach to condition assessment based on measuring Partial Discharge (PD) activity.

Partial Discharge Signals Switchgear Condition

By Paul Shiel, ESB Networks, Ireland

In 2002, a post-fault forensic investigation revealed that an insulation failure was the root cause of a catastrophic failure of switchgear that occurred shortly after a switching operation. The failure was on a cast resin Ring Main Unit (RMU) that had been installed on ESB Networks' (Dublin, Ireland) 10kV distribution network for more than 20 years. An RMU is a node on the distribution feeder, usually at a distribution transformer, that has breakers on each side, to allow energisation from either direction. The failure resulted in the need for the utility to revisit the processes and procedures it had developed to manage the ageing switchgear population.

As a result of the failure, ESB placed an immediate operational restriction on all 250 substations equipped with the same type of switchgear. The restriction required that this type of switch only be operated after it had been de-energised by switching further up the line. The restrictions resulted in a severe disruption to customers' supplies and led ESB to experience major difficulties in managing network operations.

ESB is the owners and operator of the distribution network in the Republic of Ireland. As the licensed distribution system operator, it is responsible for the construction, maintenance and operation of the sub-transmission, medium and low voltage electricity network infrastructure. This responsibility includes overhead line and underground cable networks and substations installed to supply energy to Ireland's 1.8 million domestic, commercial and industrial customers.

Fault Cause Investigation

To resolve the problem and assist in the development of an operational protocol to help remove the restriction and reduce the disruption, ESB engaged the services of EA Technology Limited (Cheshire, England). EA Technology and ESB agreed that the cause of the fault was an insulation breakdown, which is known to occur in HV plant and equipment due to Partial Discharge (PD) activity. It was suggested that the use of a field-based PD detection instrument could have detected the PD activity before the failure.

PD measurement in HV/MV switchgear is an internationally recognised test procedure. IEEE Standard 1291 (issued in 1993), the Guide for Partial Discharge Measurement in Power Switchgear, states: 'Partial discharge measurements are an ideal method for evaluating switchgear apparatus with non self-restoring insulation. During a temporary over-voltage. During a high voltage test, or under transient voltage conditions during operation, partial discharges may occur on insulation of this type, which includes gas, liquid and solid materials. If these partial discharges are sustained due to poor materials design and/or foreign inclusions in the insulation, degradation and possible failure of the insulation structure may occur'.

In the UK, the Health and Safety Executive (HSE), the organisation responsible to the government for all aspects of workplace safety, has mandated that PD testing be carried out on all HV/MV switchgear, in its publication *HSE 230 Keeping Electrical Switchgear Safe* (issued 2002).

In practice, PD in HV insulation can be considered to take two forms: surface and internal. When surface PD is present, tracking occurs across the surface of the insulation, which is exacerbated by airborne contamination and moisture, leading to erosion of the insulation surface. Internal PD occurs within the bulk of the insulation materials and is caused by age, poor materials or poor quality manufacturing processes.

ESB Networks awarded EA Technology a contract to conduct field tests on the cast resin units in service, and agreed to pioneer the introduction and development of the EA Technology UltraTEV Detector[™].

Examination Protocol

The EA Technology UltraTEV Detector[™] is a handheld, field-based instrument, designed to detect both surface and internal PD activity. The instrument indicates with red, amber and green lights the presence or absence of PD at voltages up to 90kV. The instrument functionality was developed with ESB input to ensure that threshold settings – the levels at which the LEDs change colour – accurately correspond to the presence or absence of PD.



The UltraTEV Detector™ in use

A trial was suggested to test the protocol on a sample of cast resin units. Further non-intrusive checks were proposed for the trial, using two instruments developed by EA Technology: the MiniTEV for internal PD and a very sensitive ultrasonic detection instrument for surface PD. Following the non-intrusive tests, the switchgear would be de-energised, racked out and stripped down for detailed internal visual inspection. The operational restriction could be lifted on tested switchgear, once the internal inspection confirmed the test results.

Field Tests

The trial and test protocol satisfied ESB Networks' safety representatives, and 10 substations in Cork, southwest Ireland, were tested in November 2003. No detectable PD activity was identified in seven of the 10 substations. But for the remaining three, a very low level of ultrasonic activity was detected, below the UltraTEV Detector[™] threshold levels. As the results at all 10 substations were below the instrument's preset levels, the switchgear was isolated and prepared for internal inspection.

Internal inspections revealed evidence of PD activity in the switchgear installed in the three substations where the sensitive ultrasonic equipment identified PD activity. The area affected was the fixed copper contacts that exhibited verdigris growth with some resulting acid damage contributing to early stages on insulation degradation. The findings confirmed PD activity that ultimately could result in switchgear failure. Although difficult to estimate, consensus was that failure of these three units was unlikely to occur within 12 months. For these substations, the operational restrictions remained in place until maintenance or replacement was performed.



Example of surface partial discharge activity



Example of surface tracking



Example of verdigris growth

The testing and inspection field trials confirmed that the protocol was viable, providing a basis for the practical management of the 250 cast resin units on the network. Also, the trial proved that the threshold levels set for the UltraTEV Detector[™] were correct: sufficiently sensitive to detect dangerous levels of PD activity, but not so oversensitive as to cause an unmanageable number of substations to be subject to restrictions pending internal inspection.

Medium Voltage Switchgear Population

ESB Networks also has 5000 of another type of 10kV cast resin RMUs on its distribution network, which have suffered from disruptive failures in the past. During the trial in Cork, two of these units were also subjected to PD tests, and both produced red lights on the UltraTEV Detector[™], indicating the need for maintenance or replacement.

These findings led ESB Networks to consider incorporating the use of the UltraTEV Detector^M into the standard procedure prior to operating switchgear. It was considered that this discipline would significantly improve the safety and reliability of operational activities, in addition to identifying targets for the ongoing replacement programme. ESB Networks also included some new SF₆ gas insulated switchgear, ageing oil filled RMUs and some open cubicle substations in the trial.

Switchgear Operational Standards

ESB Networks has adopted the protocol developed and tested in the Cork field trials. The utility now issues all operational switching and inspection staff with an UltraTEV Detector™ for use prior to switching. Two models of the UltraTEV Detector™ were available: the first having a red/amber/green LED indication system and the later model having a red/green LED indication system. ESB Networks chose to deploy the later model and issued several of these to staff between May 2004 and March 2005.

During 2005 and 2006, ESB Networks staff completed more than 5000 inspections and the results have been analysed by switchgear category, namely: the 'cast resin' category accounts for 70% of tests completed; the 'other' category includes a range of equipment, for example terminations on SF_6 switchgear, oil filled RMUs and open cubicle substations. The results were:

Results of 5000 UltraTEV Detector™ readings		
Switchgear category	LED indication %	
	green	red
Cast resin	93	7
Other	95	5

The results demonstrated to ESB Networks that the majority of switchgear on its distribution network was in good condition: and as the positive results were targeted for maintenance or replacement, the number of red indications would decrease.

Safety Objectives Met

ESB Networks has confirmed its satisfaction with the results obtained following the introduction of this new procedure prior to switching. ESB has achieved its main objective of ensuring operational staff are not unknowingly exposed to potentially dangerous situations and that defective equipment can be targeted for removal or replacement. The use of the UltraTEV Detector[™] has resulted in an increase in ESB Networks' confidence in the continued safety of staff and the integrity of its switchgear asset management strategy.

The development and subsequent availability of the UltraTEV Detector[™] was instrumental in allowing ESB Networks to resolve and safely manage the removal of an operational restriction on 250 substations that contained cast resin switchgear. The disruption to ESB Networks' customers was minimised and the protocol developed between ESB Networks and EA Technology has been adopted nationally to include all switchgear.

Conclusion

ESB Networks was satisfied with the results of the first year survey, which produced the following results in relation to the UltraTEV Detector™:

- Identifies clearly which switchgear not to operate live
- Improves operational staff safety
- Shows the network is clear of operational restrictions
- Reports that no failures of cast resin switchgear have occurred due to PD since the protocol was adopted
- Enables accurate targeting of maintenance and replacement resources
- Establishes a cost-effective standard

The Author

Paul Shiel joined ESB Networks in 1980 and worked on load research before progressing to system studies and to the MV substation section, where he was responsible for maintenance and design policy. It was during this period in the substation section that the UltraTEV Detector[™] was incorporated into standard working practices. Since then, Shiel has been appointed to the overhead line section to manage the current major refurbishment programme of ESB's network. He has a bachelor's degree in engineering, a master's degree and is a member of Engineers Ireland. Email: <u>paul.shiel@esb.ie</u>