INNOVATIVE ASSET MANAGEMENT AND TARGETED INVESTMENTS USING ON-LINE PARTIAL DISCHARGE MONITORING & MAPPING TECHNIQUES

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ABSTRACT

An increasing proportion of medium voltage (MV) cables in the UK have been installed for more than 40 years. If nothing or too little is done to replace this ageing asset, an increasing fault rate can be expected with more customers being interrupted. An increase in operational cost is also likely to occur due to the increasing number of repairs required. Network automation and remote control have significantly reduced the duration of customer interruptions but have not addressed the problem of fault incidence or provided a way to target cable replacement.

INTRODUCTION

On-line partial discharge (PD) monitoring and mapping equipment (on-line condition monitoring) are becoming of increasing interest amongst electricity distribution companies, as they offer an easy way of assessing the condition of cables. The emergence of this new market is seeing an increasing number of manufacturers and research organisations developing this technology, which they hope will assist to better manage and renew ageing underground cable networks.

The introduction of the "Innovation Funding Incentive" (an allowance that can be used to fund specific research projects) by the regulator of Great Britain (OFGEM), has enabled EDF Energy Networks to accelerate developments in many areas of the distribution network.

The outcome of several years of research, development and field experimentation is the development of the Advanced Substation Monitor (ASM, Fig 1) and a web based analysis interface (Fig 2).

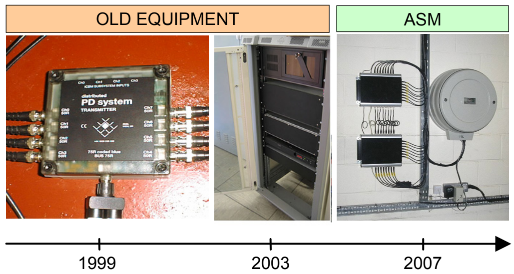

Fig 1: Equipment evolution

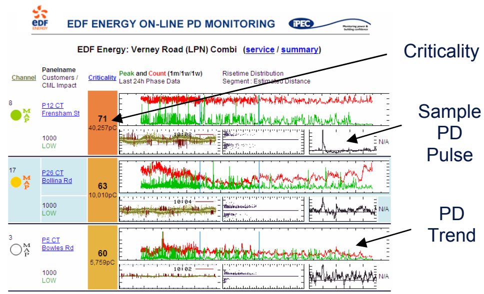

Fig 2: Web based Analysis software

These new tools combined with existing spot testing and mapping methodologies [1] (both on-line and off-line), can significantly contribute to asset management excellence.

LATEST RESULTS

The value and the potential of the technology have already been proven as a number of incipient faults on the EDF Energy network have been detected in advance, and cable replacements successfully carried out before failure. The success of this "preventive replacement" approach was demonstrated by analysing the defective cable sample (or joint) and also checking that the discharge activity had disappeared once the circuit had been reenergised.

The red trace on Fig 3 shows the discharge activity on a feeder section in south London.

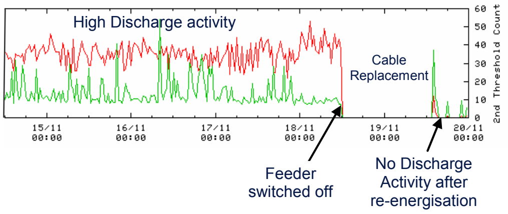

Fig 3: Preventive cable replacement

The circuit was switched off, a targeted repair carried out and the feeder re-energised. No discharge activity could be detected afterwards, which proved the success of the intervention. Many other "high discharge" cable sections have recently been identified and are currently being investigated.

On-line condition monitoring is only one of the solutions available to asset managers. The benefits of deploying this technology are potentially substantial and need to be fully understood before it can be used as best practice.

TECHNOLOGY BENEFITS

Below is a list of the areas that could be impacted once on-line partial discharge monitoring and mapping techniques have been adopted:

Financial

- Reduction in operational expenditure (OPEX) due to the cost savings of repairing faults;
- Better control of capital expenditure through targeted cable replacements;
- Deferment of capital expenditure by avoiding premature replacement of underground medium voltage cables.

Quality of supply

- Reduction of the Customer Interruptions (CI) & Customer Minutes Lost (CML) by avoiding faults;
- Reduction in multiple interruptions by providing a better and more accurate "first diagnostic". This can also play a valuable role for the reputation of the company.

Environmental

- Organised cable replacement programme rather than emergency opening notices can reduce the environmental impact and the potential disruption that can be caused to the public.

Operational

- Versatile technology that can be used to monitor underground cable as well as other assets (e.g switchgear)
- Development of a robust cable replacement strategy and move towards a proactive condition based maintenance approach.

The extent of the benefits will mainly depend on how effectively the installations of monitoring equipment can be targeted.

DEPLOYMENT STRATEGIES

An ASM installed at a primary substation will have a limited detection zone as illustrated on Fig 4.

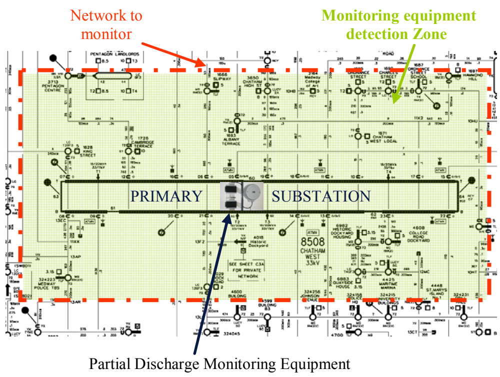

Fig 4: Network diagram showing the Primary substation network being monitored

Cable sections outside this detection zone can still be monitored but will require additional equipment to be deployed on remote parts of the network (Fig 5).

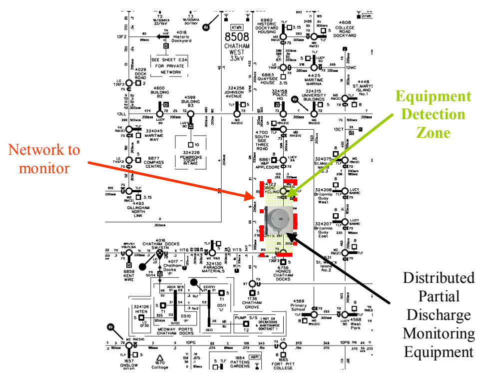

Fig 5: Network diagram showing a remote part of the network being monitored

Budget availability is likely to be different for electricity distribution companies around the world. As a result, different deployment strategies are likely to be adopted.

Several deployment scenarios along with their estimated cost and benefits are considered below. They have been developed using network performance information, historical fault data, partial discharge monitoring and mapping equipment present capabilities & EDF Energy Networks extensive experience with on-line condition monitoring technologies.

In the analysis below, it has been assumed that a fault would not necessarily have occurred during the year that discharge was first detected and a preventive repair carried out. The analysis instead assumes a 25% probability that it would have occurred in year 1, a 50% probability that it would have occurred the following year, and a 25% probability that it would have occurred during year 3. Fault location would be carried out using a mix of on-line and off-line PD mapping techniques.
A number of other assumptions (some of them specific to the GB network configuration) were also made.

Wide-scale deployment

This scenario assumes that around 40% of the primary substations are equipped with an on-line partial discharge monitoring equipment (ASM), and that two "distributed" ASMs are installed at strategic locations on each feeder (in order to expand the detection zone).

The estimated deployment cost for a company like EDF Energy Networks would be very high and estimated to be around £20M (€30M).

Table 1: Wide-scale deployment estimated benefits

OPEX savings	Rising to approx £2M/ Year from year 5
Potential Nº of Faults Avoided	Rising to approximately 350 Faults/Year (After 3 years)
Other benefits considered	Regulatory incentive for CI & CML (IIP)
Payback Period (Positive NPV)	Approximately 8 Years

The payback period would be very long and not be acceptable to UK asset manager operating within a 5 year regulatory period.

"Surgical" deployment

This scenario assumes that a very small number of ASMs are purchased and installed on the distribution network.

Table 2: Surgical deployment estimated benefits

OPEX savings	Negligible
Potential Nº of Faults Avoided	Negligible
Payback Period (Positive NPV)	Short

Such a deployment would be likely to only have a very limited overall impact. The main value would be that specific problems such as repeated failures can be dealt with efficiently.

Targeted deployment

This scenario assumes that around 10% of the primary substations are equipped with an on-line partial discharge monitoring equipment (ASM), and that two "distributed" ASMs are installed at strategic locations on each feeder. Some ASMs would be periodically redeployed as replacement schemes are carried out and sections of network become more reliable.

The estimated deployment cost for a company like EDF Energy Networks would be around £5M (€7.5M).

Table 3: Targeted deployment estimated benefits

OPEX savings	Rising to Approx £450K/ Year from year 3
Potential Nº of Faults Avoided	Rising to 125 Faults/Year (After 3 years)
Other benefits considered	Regulatory incentive for CI & CML (IIP)
Payback Period (Positive NPV)	3 Years

This scenario is likely to be the most effective as it is a good compromise between risk, cost and benefits.

Other solutions can be considered but they do not offer a satisfactory long term answer to the problem of an ageing MV network.

ALTERNATIVES

No deployment

Not doing anything can be expected to result in an increasing fault rate as the cables get older with more customer interruptions and an increase in operational expenditure due to the increasing number of repairs required.

Off-line testing

Off-line mapping is a well established technique and has been used for a number of years. This diagnostic technique alone cannot be considered to accurately target cable replacement and carry out preventive maintenance because:

- The requirement of an outage increases the risks on the network.
- It would take more than 40 years to cover the EDF Energy Networks MV cable network.
- It can be difficult to target circuits for testing.

Using off-line testing to support on-line condition monitoring methodology is believed to be a much more efficient approach.

Automation

Automation has been successfully deployed to reduce the impact of supply interruptions. Nevertheless, it does not reduce the number of faults, the number of interruptions experienced by customers, and does not help the identification of degrading sections of network.

Large-scale cable replacement

Large-scale MV cable replacement would be impractical (in terms of resource implications and public disruption) and very expensive, especially in central London.

ASSET MANAGEMENT PROCESSES

The successful implementation of new technologies often depends on how rigorous the integration into asset management procedures has been. In order to further assist the decision process and this integration, EDF Energy has been developing a cable replacement strategy based on a "Health index assessment tool" (Fig 6)

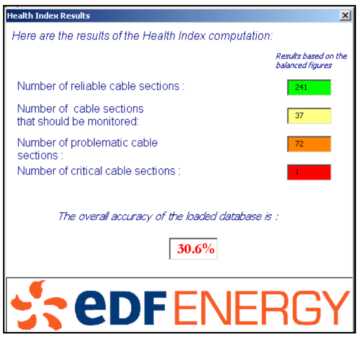

Fig 6: Health index tool: "Summary output"

It uses all the data that is available (e.g. fault data, type of cable, type of soil, historical fault data, date of installation, etc.) including the online condition monitoring data, in order to target investments.

CONCLUSIONS

The introduction of the Innovation Funding Incentive (IFI) in Great Britain has encouraged the distribution network operators and their suppliers to be more innovative as well as encouraging longer term thinking for asset managers.

EDF Energy Networks has recognised the need for improved knowledge on the condition of its ageing MV underground cable network and the need for a long-term cable replacement / investment strategy.

The on-line condition monitoring techniques are finally becoming "mature" and even if research on improving the technology, detecting defects and predicting failures is continuing, EDF Energy Networks has started to benefit from the technology. Consequently, the integration of this innovation into asset management processes has started.

From 2007, EDF Energy will be carrying out an extended "targeted deployment" trial, part of which will include integration into the control system (Fig 7).

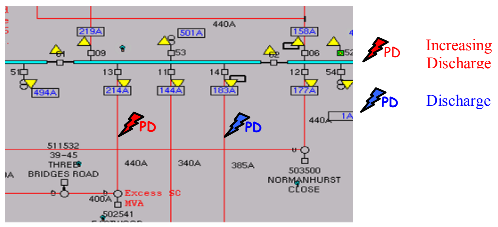

Fig 7: Network control diagram showing cable sections where partial discharge activity has been detected.

REFERENCES

[1] Matthieu Michel, 2005, "Comparison of Off-Line and On-Line Partial Discharge MV Cable Mapping Techniques ", *CIRED*