



# Condition Assessment of MV/HV Cables

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## Executive summary

### **What are the issues/problems that lead to the development of on-line testing systems used for Condition Assessment of Cable Assets?**

There is a growing concern about the increasing age and reliability of Medium and High Voltage (MV/HV) distribution networks, together with considerable pressure to implement the most cost-effective management of network assets. Therefore asset managers around the world have a very real need to understand the condition of their aging Medium and High Voltage (MV/HV) cable assets, to help with their management and ultimately improve network reliability.

The strategy of moving toward maintaining and replacing assets only when strictly necessary (Condition Based Maintenance) can help considerably in meeting these needs. Implemented correctly, this approach can deliver significant cost savings, while keeping reliability and quality at the required level for electrical assets. To do this, asset managers need accurate information at their fingertips in order to make informed decisions.

### **Why is this a problem if it isn't managed?**

PD is the primary cause of failures in cables, however, replacing and maintaining underground cable circuits, particularly with the need for excavation, can be very expensive, hence network managers need evidence to justify maintenance/replacement actions. Having information regarding the presence, severity and location of PD helps to make smarter informed decisions when planning and conducting repairs. Knowing the location of PD activity can also reduce the cost of repair through more accurate excavation limited to the area of interest.

EA Technology's unique experience can be used to identify the following potential issues:

- Degradation of the cable and cable joint insulation.
- Mechanical damage to the cables and cable joints.
- Condition of the cable.
- Suitability of the existing cable joints and termination kits.
- The location of potential failure points.

## 1.1 Health index for Cables

Working with many owners and operators of high voltage equipment, EA Technology has developed a process for deriving and populating health indices for a wide range of HV assets. The intention is to combine relevant information in order to provide a means of ranking equipment by proximity to end of life. The final number for each piece of equipment is normalised onto a scale of 0 to 10; 0 representing the best condition and 10 the worst condition. The detailed formulation of a health index for each population of equipment is specific to that population, based on the available condition information and the background history of the units in the population. The formulation is designed such that increasing values represent increasing levels of degradation and probability of failure (POF). However, this is not a linear scale. By design the relationship between the health index and the probability of failure is a cubic relationship. Individual items of equipment with a health index of  $<4$  are in 'good' condition with a very low probability of failure, that would not be expected to deteriorate significantly in the short or medium term. Values in the 4-7 range indicate 'moderate condition' with a low current probability of failure, but at risk of significant deterioration in the medium term. Values  $>7$  indicate 'poor' condition with a significantly increased probability of failure that will continue to increase relatively quickly in the short term.

In general terms assets in 'good' condition (HI  $<4$ ) would be expected to continue to operate satisfactorily for the foreseeable future (to have a long remnant life) and do not require any significant change to existing operation and maintenance.

Assets in 'moderate' condition (HI 4-7) are not at immediate risk but may become increasingly unreliable in the medium term (5-10years). Assets in this condition are potentially candidates for life extension measures, enhanced maintenance, refurbishment etc.

Assets in 'poor' condition (HI  $>7$ ) are at risk in the short term, this risk will increase relatively quickly. Significant investment (replacement) is required to prevent unacceptable probability of failure. For electricity network assets this is often effectively End of Life (EOL).

Having derived the initial health index, the HI in future years can also be estimated based on the understanding of the degradation processes and the rates at which these proceed. Definition of end of life for assets will vary depending on the application and operational considerations. However, the approach is based on identifying units where the probability of failure is significantly raised, i.e. those with a health index of greater than 7. The actual end of life, and therefore the remnant life, of an existing unit will depend on the level of risk acceptable to the owner. In the present case any cable with a health index of greater than 7 would be deemed to be approaching end of life.

This approach enables integrity analysis in conjunction with relevant background information to be used for maximum effect to assist in the management of the electrical assets. It will prioritise the assets in need of remedial treatment or replacement and considers the most appropriate method of managing the asset population.

The findings of the specified test results provided will be detailed in a written report for each site. The reports will include:

- All Test results.
- Interpretation of results.
- Health Indices and End of Life analysis for each asset.
- Recommended remedial actions and intervention strategy.

This information will assist in the management of the MV/HV cable equipment involved and is designed to make the management and operation of electricity assets more efficient, reliable and safe, at lower cost.

Clearly, the consequences of cable asset failure could lead to a serious disruption of network operation which, in turn, reinforces the importance of condition assessment. The data and information provided from the test results provided will assist with:

- Optimising a replacement strategy based on condition and strategic importance.
- Ensure compliance with Statutory Requirements, Regulations, Standards and Security.
- Establish the environmental conditions of the selected cables which, if adverse, can have a drastic impact on the performance of the cable.

EA Technology is an expert with Risk-Based Investment Planning of Asset Replacements. We can help you identify the lowest cost option for investment in cable and all types of utility assets, based on the forecast outcomes of different investment scenarios. We use the latest asset condition assessment techniques, combined with advanced computer modelling, to find the best return for your investment.

## Features

- Balances condition, performance, risk and cost factors to optimise investment decisions
- Delivers clear investment options, with evidence to justify decisions
- One-off service or ongoing investment management relationship

## Benefits

- Learn how much life in years is left in your cables.
- Calculate the best time and place to invest in replacements
- Maximise return on investment
- Reduce total capital expenditure

## 1.2 Condition Assessment with the Cable Data Collector (CDC)

Online PD testing identifies the location of PD in live medium voltage cables, along the cable route, providing quick, safe and non-disruptive testing. PD activity leads to deterioration and subsequently failures in high voltage insulation. This is particularly important for cables which often are not considered as part of the asset base as they lie often hidden underground within a plant. Cables are a critical part of the asset base and should always be considered when upgrading a network installation

The Cable Data Collector (CDC) is a portable instrument designed to allow the detection and possibly location of partial discharge in medium voltage cables. It is functionally similar to VLF cable mapping, but there are differences in how it operates that can offer significant advantages depending on network configuration.

The CDC instrument consists of both the data-gathering hardware and separate data analysis software (CDAS). Useful assessment information can only be obtained by using CDAS, as if CDC is sold as a stand-alone instrument it relies upon sending data to others who possess a CDAS licence

PD activity present on the cables will be measured using special high frequency inductive sensors (RFCT) on the cable shield grounding strap (see Figure 1). These can be used on single or three phase insulated cables up to several kilometers in length. This will allow the detection of small high frequency signals produced during the partial insulation breakdown. The signals will be captured and stored on the EA Technology CDC (see Figure 2).

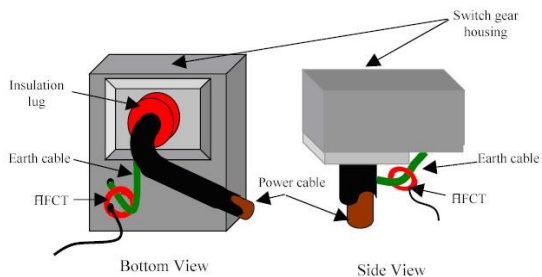


Figure1 Cable CT Attached to Ground Strap



Figure 2 Cable Data Collector

Signals are further filtered by the instrument itself and then digitally processed using

The CDC is able to measure and record the magnitude and angular position of each discharge event on the systems voltage waveform. Events will also be grouped by the software package in terms of their signature similarities. The magnitude, signature and phase resolved plots will then be analyzed to determine the degree of PD activity present on the cable.

Two pieces of software are available; the CableData Collector Application and the CableData Analysis Suite. The CableData Collector software communicates with the instrument allowing data to be captured and stored quickly and easily ready for offline analysis using the CableData Analysis Suite which captures data to be imported, analyzed and reported on. Data is output to a single zip file for easy storage and portability between processing machines. Software is supported by Microsoft Windows, supporting Windows XP though to Windows 8. The CableData Analysis Software displays waveform and phase resolve event data on interactive charts, providing the ability to map discharge



activity along the cable length. A built in report generation tool allows reports to be created from imported data.

Equipment for On-Line Cable Testing is small, portable, easy to use and rugged for use in industrial environments.

### 13 PD in Cables

Partial discharge in cables is of the 'internal' type, and therefore generates transient earth voltages (TEVs) – as is detected by other instruments of our manufacture. CDC detects the currents that are the underlying cause of TEV. PD degrades the insulation in cables just as it does in switchgear, and if left to progress will eventually damage the insulation to a point where it can no longer withstand its working voltage and failure will occur. Depending on the fault level, cable containment and other factors this failure may be catastrophic, but in all cases that section of cable will be irreparably damaged and require replacement.

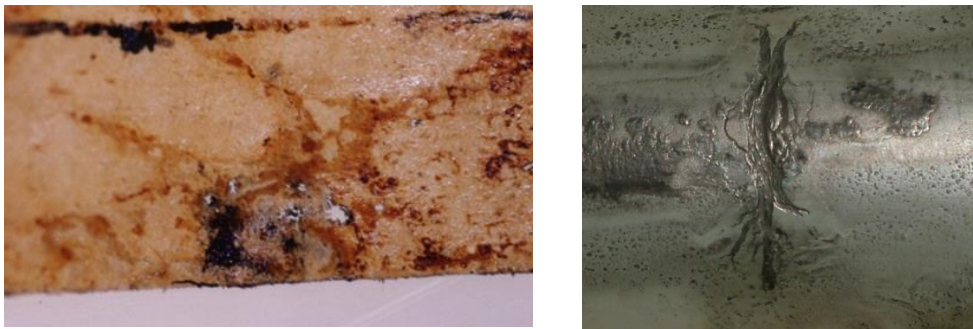


Figure 3 Degradation of cable insulation (left: paper, right: XLPE)

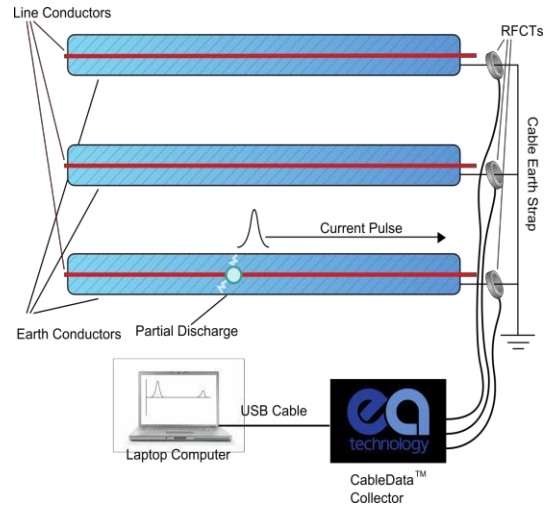
### 14 Principal of Operation

The CDC can only detect discharges to an earth that is accessible to the instrument's sensors – this is perfectly acceptable as at least some of the energy from a discharge will go to an accessible earth.

The signals that are present on the earth conductor are of very high frequency (up to several hundred megahertz) and very small magnitude (perhaps only a few volts at most but more commonly in the millivolt range).

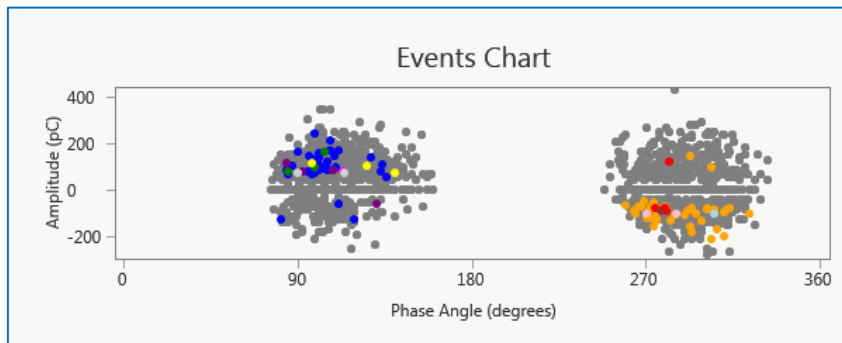
“In [electrical engineering](#), partial discharge (PD) is a localised [dielectric breakdown](#) of a small portion of a solid or fluid [electrical insulation](#) system under [high voltage](#) stress, which does not bridge the space between two conductors”

The CDC instrument detects the discharge signals by using a radio frequency current transformer (RFCT) that is clipped around the earth at a safe and accessible location. By determining the magnitude of the pulses in the signal, the magnitude of the discharges can be derived. A basic diagram of this is shown below (Figure 4– note 3 RFCTs can be connected to the instrument simultaneously).

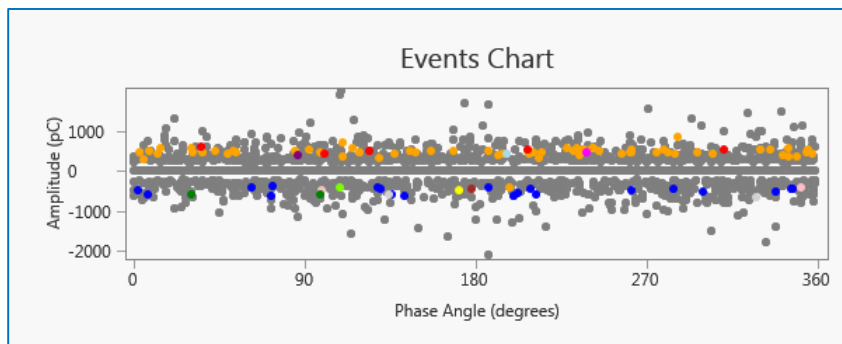


**Figure 4 Diagram of CDC operation**

A phase resolved plot attempts to display at which point in the 360° mains cycle a discharge occurred. 'Real' PD will often be gathered in cloud-like formations near the positive and negative peaks of the cycle (e.g. at around 90° and 270°) while other formations, such as a flat level, indicate an external source (Figure 5 and Figure 6 respectively).



**Figure 5 Phase-resolved plot showing true PD activity**



**Figure 6 Phase-resolved plot showing background noise**

## 15 Benefits of using the CDC for Cable Condition Assessment

Techniques using the CDC are the only way of dealing with cable degradation. Cables cannot be maintained or, as stated earlier, visually inspected. Electrical testing is the only option available to customers wishing to manage the risk of cable failure.

The advantages of CDC are: –

- No outage of the circuit to be tested is required.
- The rate at which cables can be tested is higher than for VLF cable mapping, and therefore the costs are lower. *Measurements can be taken in 5-10 minutes then analysis takes approximately 45 minutes. As such, all circuits on a switchboard can generally be surveyed in a few hours at most.*
- It can be used to make decisions regarding future management of the circuit, which may include partial/full cable/joint replacements, targeted VLF mapping, further electrical measurements, etc.

If you would like to learn more about cable condition assessment, health indexes, and the Cable Data Collector please contact us at 973-862-2759 and we would be happy to discuss your application.



# Global Footprint

We provide products, services and support for customers in 90 countries, through our offices in Australia, China, Europe, Singapore, UAE and USA, together with more than 40 distribution partners.



## Our Expertise

We provide world-leading asset management solutions for power plant and networks.

Our customers include electricity generation, transmission and distribution companies, together with major power plant operators in the private and public sectors.

- Our products, services, management systems and knowledge enable customers to:
- Prevent outages
- Assess the condition of assets
- Understand why assets fail
- Optimise network operations
- Make smarter investment decisions
- Build smarter grids
- Achieve the latest standards
- Develop their power skills