HVPD
High Voltage Partial Discharge

Our Knowledge is Your Power

HVPD Mini™ Monitor Case Study
Online Partial Discharge Monitoring Of Medium Voltage Switchgear

4-Channel Portable Online Partial Discharge Monitor

Continuous, Remote Access Insulation Condition Monitoring of 3.3 kV – 45 kV Cables & Switchgear

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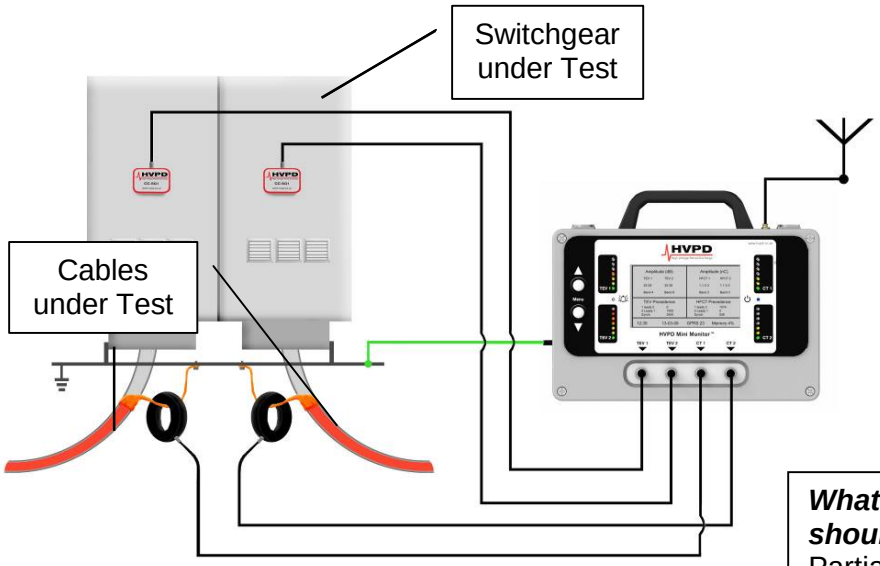
Introduction to the HVPD Mini™ Partial Discharge Monitor



	PD Level Bands	
	TEV (dB)	HFCT (pC)
1	<6	300
2	12	600
3	17	1,100
4	25	2,600
5	30	5,500
6	35	8,500
7	>40	>12,000

Figure 1: Illustration of HVPD Mini™ Monitor in Substation

What is Partial Discharge and why should we test for it?
Partial Discharge activity is produced by the localised electrical breakdown of a portion of the insulation between two electrodes that does not completely bridge the gap between them. PD activity is indication of 'incipient' faults in the insulation and is widely regarded as the best *'early warning'* indicators of the deterioration of medium and high voltage insulation.

The HVPD Mini™ Monitor is a portable, 4-channel, remote-access *Online* Partial Discharge (PD) Monitor for medium voltage (3.3 kV to 45 kV) cables and metal-clad switchgear. The system has been designed specifically for continuous, on-line PD monitoring of in-service cables and plant without the need for an outage for sensor installation. The unit is a portable, stand-alone device which uses a built-in mobile GPRS modem for remote download of PD monitoring data to a centralised database. The HVPD Mini™ Monitor is suitable for both temporary and permanent installations and is best utilised as part of a structured PD test and monitoring scheme such as the HVPD 4-Phase Asset Management Plan (refer to HVPD for details). The primary application of the monitor is for the PD monitoring of either paper (PILC, PICAS) or polymeric (XLPE and EPR) power cables and metal-clad air-insulated or solid-insulated switchgear in the medium voltage range (3.3 kV to 45kV).

The HVPD Mini™ Monitor has been designed for use with two types of non-invasive PD sensor, these being the High Frequency Current Transformer (HFCT) and Transient Earth Voltage (TEV) sensor. These sensors have been carefully chosen as they can be attached safely with the plant 'live'. The split-core, HFCT sensors are attached around the earth connections of the power cable at the switchgear to detect PD pulses emanating from along the cable and the TEV sensors are attached magnetically to the outside of metal-clad switchgear to detect the electromagnetic radiation from PD sites within the switchgear panel and cable box. PD signals are measured by the sensors and are processed by the HVPD Mini™ Monitor's embedded hardware. The system utilises the *synchronous* capture of signals from both the 2x HFCT channels and the 2x TEV channels for signal 'precedence' measurements i.e. 'which pulse came first'. This allows for the automatic localisation of the source of the PD signals on cable feeders and switchgear panels.

An instantaneous display of the peak PD level is given for each of the 4 channels of the unit via colour-coded 7-level LED arrays. The unit's LCD display shows the peak level and signal 'precedence' for the past 24 hour period. The logged data is stored locally on the unit's inbuilt flash memory for either local download (through a USB connection to a laptop PC) or remote upload of data to a remote FTP server with the inbuilt GPRS modem. Data can be viewed on a PC with the HVPD MiniReader© software for Microsoft® Windows®.

Background

HVPD's new HVPD Mini™ Monitor on-line partial discharge monitoring technology has been developed under the OFGEM IFI (Innovation Funding Initiative) funding from 2x UK Utilities ('Customer A' and 'Customer B') over the 2 year period from December 2007 to December 2009. The HVPD Mini™ Monitor development project was completed in December 2009 when extended, 6-month field trials were completed in the 11 kV and 33 kV distribution networks of Customer A in South East UK and in Customer B in Scotland.

The field trials have been conducted within the 33 kV and 11 kV electricity distribution networks of both Customer A and Customer B with deployments of 10 units being made to provide continuous PD monitoring over 6 months at both primary and secondary switchgear (RMUs) in both networks.

The on-line partial discharge monitors have been designed with inbuilt GPRS modems, which allow remote connection and data download via the 3G mobile phone network. By using a mobile phone SIM card from a local mobile phone service provider, the PD monitoring data can be downloaded at a low cost to a secure, data centre FTP server or alternatively to the HVPD Wide Area Network Monitoring Database FTP server at HVPD's offices in Manchester, UK.

For further information on the data hosting, data basing and reporting options available please contact HVPD at info@hvpd.co.uk.

Case Study – Continuous On-line PD Monitoring of MV Switchgear

High levels of PD activity were initially detected on the customer's 11 kV GEC VMX Switchgear in the Grid Primary 132 kV / 11 kV substation using the Transient Earth Voltage (TEV) sensor within the handheld PDSurveyor™ system (Figure 2) during a routine walk-by inspection. This PD activity was found to be intermittent in nature.

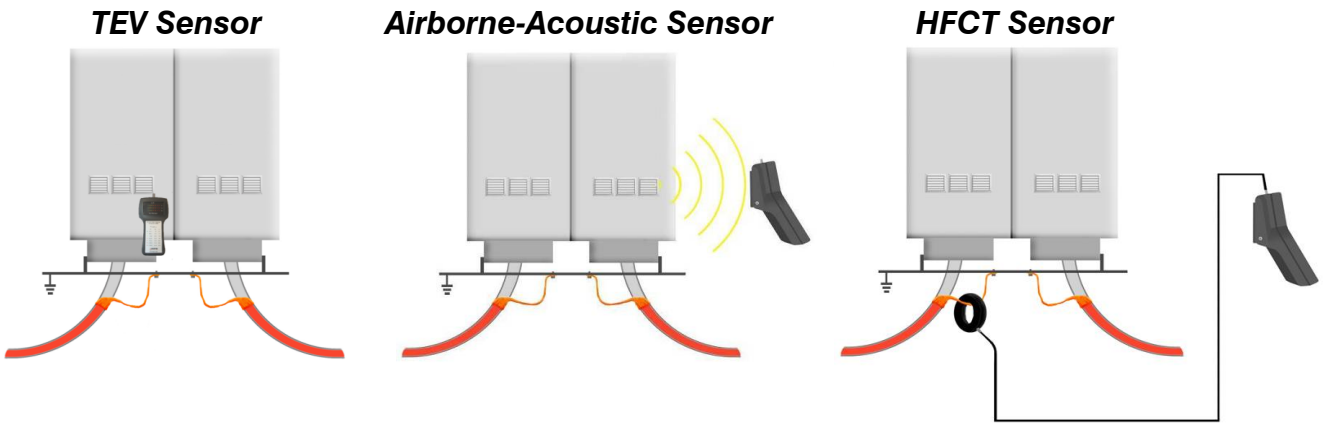
Figure 2: The HVPD PDSurveyor™ - TEV PD Detection on Cable Terminations and Switchgear

The PDSurveyor™ allows for very rapid *walk-by PD* screening of both MV switchgear and cables with a 'typical' 16-feeder primary indoor substation requiring around 20 minutes to complete a 'look-see' PD survey. This testing takes around 1 minute per panel and cable circuit to check the PD levels of the cables and switchgear with most of the time taken up attaching and removing the HFCT sensors between circuits.

It is known that this type of GEC VMX switchgear has a well documented history of PD activity occurring in both the switchgear housing 'spouts' and the VTs mounted on the rear of the switchgear. This has been identified by a Health & Safety alert document published by the Ministry of Defence in the UK which can be found at the following web link:

www.ogc.gov.uk/documents/HealthandSafetyAlert022005.pdf

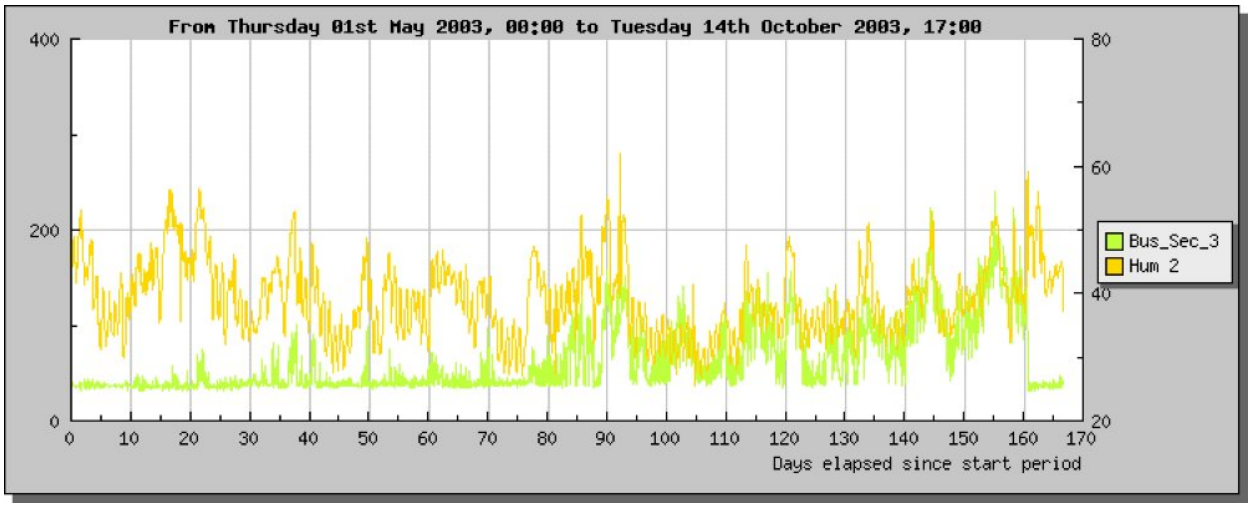
The PDSurveyor™ is a simple, easy-to-use, handheld PD scanning device suitable for testing indoor, medium voltage (3.3 – 45 kV) cables and plant. The unit has 2x built-in PD sensors, the TEV and Acoustic for Switchgear PD testing and a connection for an external High Frequency Current Transformer (HFCT) for Cable PD testing. The HFCT sensor is used to get an instant indication of PD activity in MV cables with, uniquely for a handheld unit, PD measurements made in pico-Coulombs (pCs) using an integrator circuit.



Whilst this rapid screening indicates the possibility that PD is present, it is not a diagnostic test and thus any results must be assessed further in detail to diagnose the *precise nature* of the activity. This is achieved using a *diagnostic* PD test unit, such as the HVPD Longshot™ Test Unit, which uses the *'EventRecogniser'* software module to automatically record, diagnose and differentiate partial discharge from and AM RF interference and other noise.

Plant Monitored: 11 kV GEC/Alstom VMX Air-Insulated Switchgear

It is known that this type of air-insulated switchgear has a well documented history of PD activity occurring in both the switchgear housing 'spouts' and the VTs mounted on the rear of the switchgear. This PD activity is known to be closely related to levels of humidity in the substation as is illustrated below in this extended PD vs. Humidity monitoring trial.



The PD monitor in the above example was equipped with a humidity sensor (yellow trace) so that the PD activity (green trace) could be compared to the humidity levels in the substation. Sporadic, low levels of PD activity were detected on the Bus Section 3 panel over the first 80 days of monitoring and at the 80 day point the PD activity increased and then closely followed the humidity levels. The panel showed a progressive increase in PD activity up to failure by surface flashover after 160 days It can be noted that the *'advance warning'* period from the inception of significant PD activity (Day 80) to eventual failure (Day 160) was 80 days.

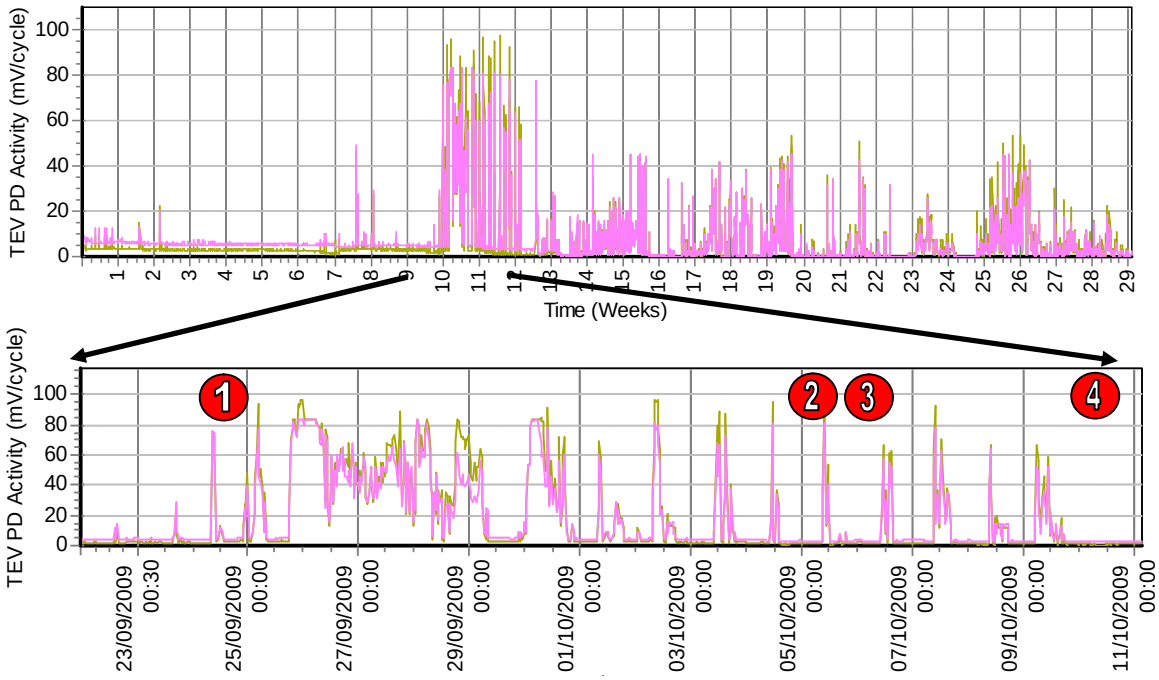
Continuous Switchgear PD Monitoring with the HVPD Mini™ Monitor

HVPD Mini™ Monitors Installed At Site

VMX 11 kV Switchgear

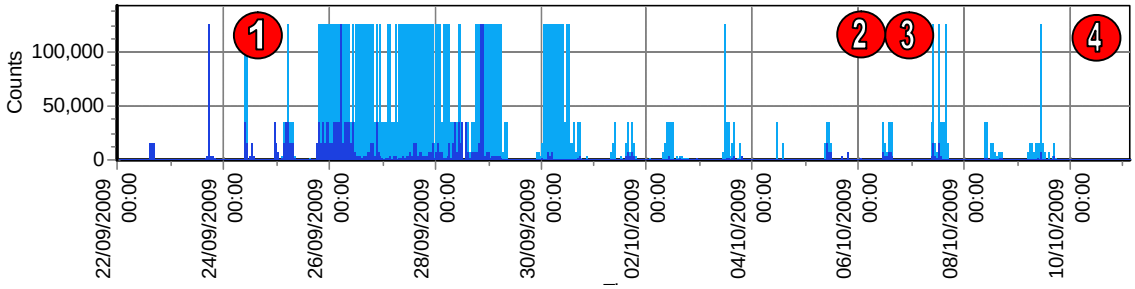
HVPD Mini™ Monitor TEV Activity (Local PD)

TEV 1 | ***TEV 2***



Precedence Counts TEV Sensors

TEV 1 | ***TEV 2*** | ***Synch***



1) ***Large rise in TEV activity in week 10 (25th Sept 09) with sustained high level of TEV PD activity of 80 mV/cycle and above for 1 week also corresponding with significant increase in Precedence Counts which indicate TEV1 (Transformer 1 Panel) as the PD source***
2) ***Audible PD heard on visit to the substation by Customer's Engineer (5th Oct 09)***
3) ***Circuit breaker switched off and truck taken out of service for cleaning (6th Oct 09)***
4) ***Period of calm during week 12 (10th Oct 09) after maintenance with a significant reduction in Precedence Counts – However there remains at least one other PD source still present on the switchboard in the direction of TEV 1.***

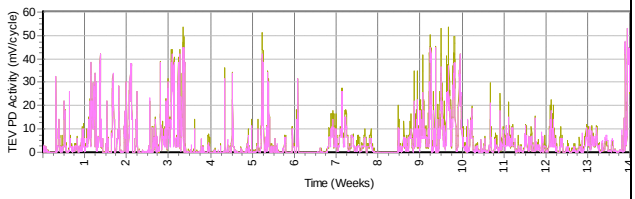
Circuit Breaker Truck Removed From Service - Signs of Surface Discharge Activity Evident

This circuit breaker truck was removed from service due to the early warning provided by the HVPD Mini Monitor and then the audible PD activity being heard on site by maintenance engineers during investigation. The photos above show clear signs of the onset of surface PD activity (black deposits) which are present on the lower portion of the switchgear 'spouts'.

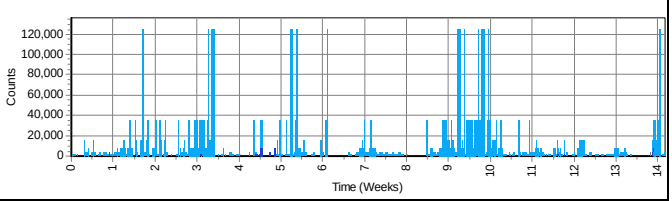
The High Levels of Local PD activity were located to the Circuit Breaker Truck of 'Transformer 1'. The 'spouts' of the truck were cleaned with a suitable solvent and the breaker put back into service.

Most Recent Monitoring Data (After Circuit Breaker Maintenenance)

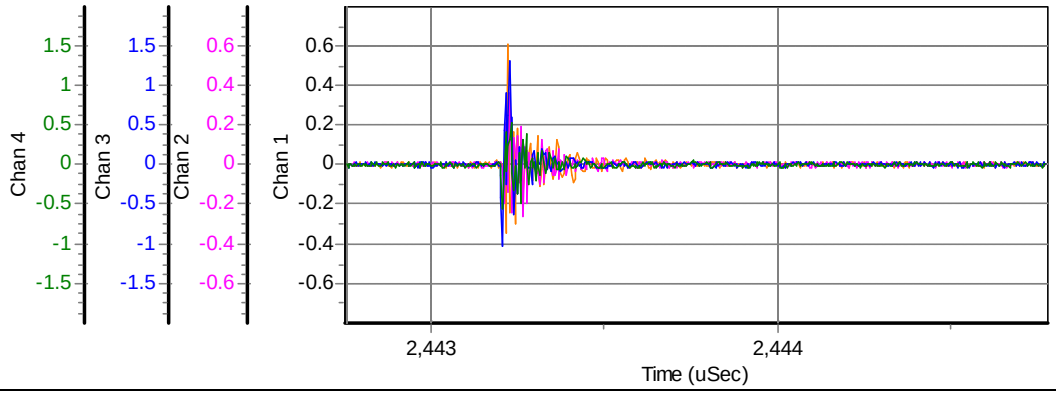
TEV Activity

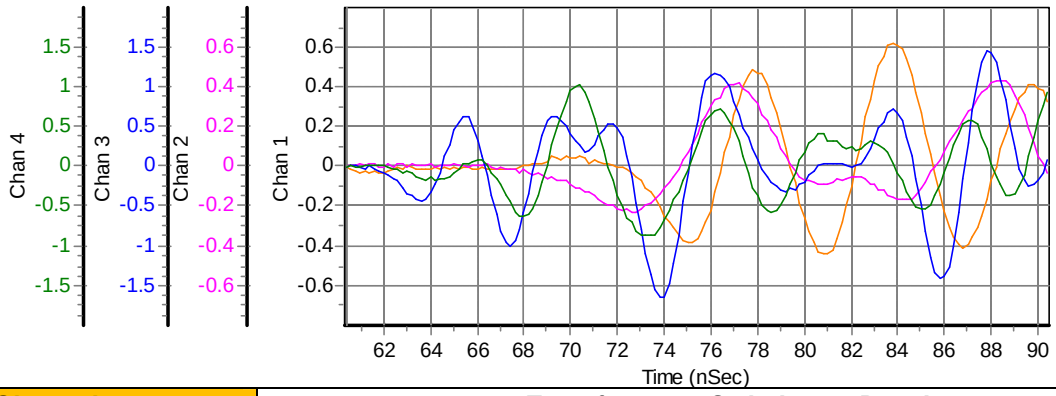


TEV Precedence



HVPD Longshot™ PD Spot Tester TEV Signals (Local PD Event)





Channel 1	**Transformer 1 Switchgear Panel**
Channel 2	**Transformer 1 Cable Box**
Channel 3	**Transformer 1 Truck Right (source)**
Channel 4	**Transformer 1 Truck Left**

HVPD Recommendations

The results of the PD testing and monitoring show that there are multiple sites of PD activity within the GEC VMX switchboard at the substation.

Transformer 1 Panel (Circuit breaker removed from service and cleaned)
The evidence of the photographs of the truck and the audible discharges which were heard by the Customer's Engineer on 9th Oct 2009 suggests the early stages of surface discharges are occurring on the 'spouts' on this circuit breaker truck. However, as there is presently no sign of any surface tracking on the spouts it can be ascertained that the switchgear is not in danger of imminent failure.

Action - it was recommended that the switchgear truck's 'spouts' were cleaned with a suitable solvent & inspected before being put back into service.
Since this maintenance action was carried out, the PD activity levels measured by the HVPD Mini™ Monitor units have dropped to between 20-40 mV/cycle which is significantly lower than the levels of 80-100 mV which were detected over the 2 week period between the 24th September and 9th October 2009. As the PD activity today is less than it was in this 2 week period, it can be argued that the switchgear is under less of a risk of failure than it was. However, this situation can change, as happened on the 24th September 2009, and it is thus advised that the PD activity in this substation is continuously monitored into the future to ensure PD levels do not rise again.

Overall Conclusion and Discussion

It is known that the deterioration of air-insulated switchgear insulation through surface tracking can be a slow process, with the insulation degradation process taking months and possibly years to fail through flashover. It is also known that this type of surface PD activity 'comes and goes' and is closely related to humidity (high humidity = high discharge) as has been shown in this Case Study. There are a number of options available to the plant owner in such a case including better control of the humidity in the substation using de-humidifiers and better temperature control. Whichever measures are put in place HVPD would recommend that continuous monitoring for PD activity be maintained when there is a history of surface PD activity.

Further Information:

The technology described in this Case Study has been presented by HVPD at the *CIRED 2009 Conference* in June 2009 in the following paper.

"DEPLOYMENT OF DISTRIBUTED ON-LINE PARTIAL DISCHARGE MONITORING DEVICES ON MEDIUM VOLTAGE ELECTRICITY NETWORKS"

This paper can be downloaded from the HVPD Website at the following link:

http://www.hvpd.co.uk/media/pdf/technical/HVPD-CIRED-2009-Paper-Jun-2009.pdf

For further information on this technology and its application please contact HVPD at:
info@hvpd.co.uk or call us on +44 (0) 161 877 6142.