



**High Voltage Partial Discharge Ltd**  
Empress Business Centre  
380 Chester Road  
Manchester  
M16 9EA,UK

## **HVPD Multi™ - Permanent 16-Channel PD Monitor Summary Guide**

**May 2009**



**High Voltage Partial Discharge Ltd  
Manchester, UK**

Tel: + 44 (0) 161 877 6142

Fax: + 44 (0) 161 877 6139

e-mail: [info@hvpd.co.uk](mailto:info@hvpd.co.uk)

Web: [www.hvpd.co.uk](http://www.hvpd.co.uk)

## INTRODUCTION

This document describes the functionality, usability and applications of the new 16-Channel **HVPD Multi™ Permanent Monitor** from High Voltage Partial Discharge (HVPD) Ltd. The HVPD Multi is a 16 Channel, portable device suitable for the measurement and monitoring of *Partial Discharge* (PD) activity in medium voltage cables and plant in the voltage range of 6.6kV to 45kV. The unit is suitable for the PD monitoring of a wide range of in-service MV plant including MV cables, switchgear and rotating machines.



**Figure 1: The HVPD Multi™ Permanent 16 Channel Monitor**

### What is PD and why do we test for it?

Partial Discharge (PD), as its name would suggest, is an electrical discharge that occurs across a *portion* of the insulation between two conducting electrodes, without completely bridging the gap. Partial Discharges can occur in voids in solid insulation (paper, polymer etc), gas bubbles in liquid insulation or around an electrode in a gas (corona).

Partial Discharge activity can initiate under normal working conditions in MV or HV equipment which has not been installed correctly and where the insulation condition has deteriorated with age and/or has been aged prematurely by thermal over-stressing. PD can also be observed, on occasion, with the commissioning of new equipment due to improper installation, poor design and/or workmanship (this is seen particularly in cable joints and terminations which are made-up on site). After initiation, the PD can propagate and develop into electrical trees until the insulation is so weakened that it fails completely with breakdown to earth or between the phases of a 3-phase system.

It is known that whilst some discharges can be extremely dangerous to the health of the insulation system (e.g. discharges within polymeric cables and accessories) other types of discharge can be relatively benign (e.g. corona into air from outdoor cable sealing ends). It is necessary therefore, when testing for PD, that the Test Engineer is able to ascertain the type of discharge present and its origin.

***Failure of High Voltage insulation is the No. 1 cause of HV system failures with IEEE statistics indicating that electrical insulation deterioration causes up to 90% of electrical failures of certain high voltage equipment. On-line PD testing of HV plant gives advance warning of pending insulation failure thus allowing the plant owner to take remedial action during planned outages. Unlike off-line testing, on-line PD testing and monitoring gives an accurate picture of the plant's health and performance under service conditions***

### **Medium Voltage Cable and Plant Asset & Risk Management**

PD testing is particularly important where MV plant has a high 'criticality'. This may be due to its age, historical failures or the consequences of its failure (position in the distribution network). Identification of the 'critical plant' within the plant owner's HV network can be achieved quickly and easily using HVPD's on-line PD Test and Monitoring technology to provide an 'early warning system' for incipient faults.

On-line PD monitoring allows for analysis trends in PD activity to be observed over time. This may reveal correlation with environmental (temperature, humidity etc) or service conditions (changes in load etc). As PD activity is often present well in advance of insulation failure it is possible by observing its development that strategic decisions can be made about refurbishing and renewal programmes.

The HVPD Multi has been developed to meet the market demand for a PD *monitoring unit*. Critical MV plant items and circuits can be monitored for partial discharge gathering critical information with respect to insulation condition and maintenance scheduling.

### **Benefits of Permanent PD Monitoring**

- It is truly a predictive test, indicating insulation degradation in advance of the failure (the detection of 'incipient' faults)
- It is a non-intrusive test, requiring no interruption of service and is performed under normal operating voltage and load
- It is a non destructive test i.e. it does not test to failure or adversely affect the equipment under test
- It does not use any over voltages and thereby avoids exposing the tested equipment to higher voltage stresses than those encountered under normal operating conditions

- Trending can be accomplished by storing results to allow comparison with future tests
- Monitoring an MV cable network On-line PD is relatively inexpensive compared with the cost of multiple plant replacement.

### **MV Plant that can be monitored for PD**

Most items of plant present in a cable network can be monitored for partial discharge activity, these include the following:

- Cables and Cable Accessories (terminations and joints)
- Switchgear (Solid Insulated, AIS and GIS)
- Instrument Transformers (Voltage and Current)
- Power Transformers and Bushings
- Motors and Generators
- Surge Arrestors
- Capacitors

### **Background to the Technology**

The HVPD Directors (Dr Lee Renforth and Dr Ross Mackinlay) have built-up significant experience in the application of *on-line PD testing and cable PD mapping (location)* over a period of 10+ years. The application of the new on-line PD test technology began in the UK in 1998 when the first series of on-line PD tests with portable, 'spot-test' equipment were carried out on in-service, 11kV paper-insulated (PILC) cables in the London Power (now EDF Energy) Network. These tests were *the world's first* on-line PD tests to be carried out on in-service MV cables using ferrite-based, inductive high frequency current transformers (HFCTs). The promising results from this early development work was taken on to develop the HVPD Longshot™, 4-Channel Synchronous PD Spot Tester which was brought to the market in 2003.

The new on-line technique for insulation condition testing of *in-service cables* has been made possible by the development of a new type of *inductive* PD sensor, the split-core, clip-on High Frequency Current Transformer (HFCT). The HFCT sensors are normally attached to the earth bar/strap of the cable termination under test, with no outage required. The initial work in 1998 to 2002 focused on the PD testing, PD mapping (PD site location) and PD monitoring of older (50-60 years old) in-service, underground paper-insulated cables (PILC). The business driver behind this decision was stated in the paper presented at the CIRED 2001 Conference by Cliff Walton of London Power Networks, as follows [1]:

*“Some 98% of the supply incidents that occur in London, arise from cable systems and terminations (rather than transformer and switchgear failures). Network performance statistics also indicate that incidents on the 11kV (& 6.6kV) MV systems affect the most customers. LPN have recently commenced installing live line multi-functional monitoring equipment on 300 higher fault rate feeder circuits. Preliminary results of live line condition monitoring have shown very encouraging results in being able to detect and locate failure BEFORE it occurs.”*

Over the 8 year period since the above was reported LPN/EDF Energy have presented a number of papers at CIRED (in 2003, 2005, 2007 and now 2009) on the further development of this on-line PD monitoring technology and methodology. Today, EDF Energy have over 1,000 of their 11kV cable feeders being monitored using the latest web-enabled, remote-access PD monitors. The data from these monitoring systems is being used to support a condition-based asset management decisions by the company.

Further to discussions held with both utility and industrial customers who had purchased the HVPD Longshot™ 4-channel PD test unit between 2003 and 2007, it became apparent that there was a market need for a complementary portable *PD monitoring technology* that could be left in the substation if any PD was detected during an on-line PD surveys with PD spot-test units such as the HVPD Longshot™ unit. The question arose, ‘*Once we detect PD what should we do next?*’. The answer to this is ‘*To remotely monitor the PD activity to ensure it doesn’t get any worse and prepare an action plan for repair!*’.

It was requested by our customers that the PD monitoring solution should be able to monitor *wide-area underground cable distribution networks* by automatically detecting any PD activity in cables, switchgear and other MV plant, whilst simultaneously rejecting ‘noise’. Another request was that the system should be able to remotely download PD test and diagnostic data over a 3G Mobile network and/or a standard LAN connection (when this is available in the substation). It was also requested by the customers interviewed that the monitor should be able to make a measurement of the *Cumulative PD Activity* in the cable or plant under test which would provide a measure of the destructive energy from the PD activity. It was proposed that this would be achieved by measuring both the PD Magnitude levels (in pC’s or dB’s) and PD Pulse Rate (‘count’). By combining these two measurements it is then possible to provide a ‘Cumulative PD’ activity measurement in the PD data capture and analysis software.

HVPD Ltd and our UK Electricity Distribution Network Operator (DNO) partners (EDF Energy, Scottish Power and Scottish & Southern) agreed in October 2007 that a new design portable, remote-access multiplexed 16-channel monitor should be developed, the HVPD Multi Monitor

It was agreed that the new monitor would be a multiplexed system suitable for testing up to 16x cable feeders at primary substations. The unit should have 16x single channels and should be capable of detecting both ‘cable PD’ (using HFCT sensors) and ‘local PD’ using TEV (Transient Earth Voltage) sensors or a combination of these two. The purpose of the monitor, being to provide remote access, continuous PD monitoring of both cables and switchgear using the on-

line PD sensors which can be attached to the cable terminations and the switchgear when they are 'live'. For reasons of health and safety, it was agreed that in all cases these portable PD sensors should only be connected to the earth leads, earth connections or earthed metal-clad switchgear under test.

Over the same period from 2007 to date, HVPD have also developed the complementary 4-Channel HVPD Mini Monitor™ (for use at RMU's and secondary switchgear) which has been designed for use in conjunction with the HVPD Multi Monitor™ unit to provide *Wide-Area Distribution Network PD monitoring*. This new range of PD monitor technology is presented in the form of *portable*, remote-access PD monitors which can be moved around both large and small MV distribution networks to carry out short-term monitoring of PD activity (typically for periods of 1 week per substation). Through the use of portable PD monitors, moved around networks and positioned at both primary and secondary substations (for 1 week per sub), it is possible for *Wide-Area Distribution Network PD monitoring* to be achieved at a fraction of the cost of installing permanent systems.

### **Why Use the Multi?**

The HVPD Multi™ Monitor unit has been designed as a stand-alone, remote-access PD monitor for permanent PD monitoring of PD activity in the *medium voltage cables and switchgear*. The unit is suitable for permanent installation in electricity distribution substations to log and trend PD data on the MV cables, switchgear and other MV plant to which the on-line PD sensors are attached. The data obtained from this continued monitoring provides extremely useful data with respect to plant replacement and maintenance decision making.

### **HVPD Multi™ – Product Features**

The HVPD Multi™ Permanent Monitor is a 16 channel multiplexed monitoring device which is capable of monitoring and analyzing PD sensor information from 24 hours to 12 months. The unit is of rugged construction and is designed to be mounted on the wall in substation environments for long periods of time. The unit is remotely controllable and data can also be interrogated remotely.

### **The HVPD Multi™ and the 4 Phase Approach**

In conjunction with the PD condition-monitoring technology for electricity distribution plant, HVPD have also developed a complementary *On-line PD Test methodology* for the application of the technology, focusing resources to those items of plant and cables most in need of repair or replacement. The HVPD Condition-Based, 4-Phase Asset Management approach (refer to Figure 2 below) has been designed to support condition-based asset management decisions for the utility and industrial MV plant owners, using the on-line PD test and monitoring condition data generated by the complete range of on-line PD test and monitoring technologies.



**Figure 2: HVPD’s recommended 4-Phase PD Test and Monitoring Approach**

*\* It is recommended that the HVPD Multi™ Permanent Monitor unit is used as part of a structured, condition-based asset management plan and is used in conjunction with a synchronous, multi channel unit using higher specification diagnostic PD test and/or monitoring technology (such as the HVPD-Longshot© PD Test Unit or the range of PD monitors including the Mini Monitor from HVPD Ltd). HVPD recommend the 4-Phase PD Test and Monitoring plan is adopted.*








HVPD have developed, through discussions with our utility and private network clients, a cost-effective alternative to the wholesale deployment of permanent monitoring systems which is to utilize portable PD monitors, moved between different substations to monitor for a week at a time. This requires significantly less capital investment, for example, assuming a 1000 substation network, with 80% monitoring utilization per unit (of 40 weeks per annum) this would around 25x portable units at a capital price of £750k (or £750 per substation). Of course, these portable monitors would require test technician resources, to install and de-commission the portable monitors to move them between substations on a weekly basis. With 25 units, 3x test technicians would be required at an estimated cost of £300k per annum and with analysis, database and reporting labour costs estimated at a further £150k a total cost operating cost of £450k per annum (or £450 p.a. per substation) is estimated.

Such a reduced cost approach is being viewed favourably by the utilities we have spoken to as they want to look at portable systems which can be moved to 'points of strain' in the network such as 'worst performing circuits' and 'multiple faulted' cables. In the short-term, as curious utilities continue to investigate and explore the potential this new On-line test and monitoring technology, there is an interest from them in carrying out Pilot Projects on their networks, using portable monitoring technology moved around to monitor their 'worst performing circuits' which have been pre-selected by SPPS Asset Managers. This market pull from the marketplace is coming from an increasing awareness from electricity utilities and other HV plant owners of the potential safety and cost benefits which can arise from the application of the on-line PD test and monitoring solution.

### **The HVPD Multi™ – Scope of Supply**

The technology is supplied in its standard package with all accessories, as given in Table 1 below; complete with PD Sensors and BNC signal cables, optional HSDPA Modem for remote download of the PD monitoring data (this data is also stored on the unit's hard disk drive for 'local' download through the USB connection).

**Table 1: HVPD Multi Monitor - Standard Scope of Supply**

<p><b>1x HVPD 16-Channel Multi Monitor</b></p>	
<p><b>16x HVPD HFCT100/50 Portable Split-core Sensors</b></p>	
<p><b>8x HVPD CC-SG1 TEV Sensors</b></p>	
<p><b>16x 10m BNC Cables</b></p>	
<p><b>1x GPRS Antennae and 3m Cable</b></p>	
<p><b>1x Multi Monitor Reader© Software for an MS Windows based PC</b></p>	
<p><b>160GB USB Portable Hard Drive for local download and data backup</b></p>	

In order to apply HVPD smooth survey algorithm the HVPD Multi™ Monitor is based on similar data acquisition technology as the HVPD Longshot™ unit's Lecroy Waverunner measurement circuits, with data sampling rates of up to 100MS/s (mega samples per second)

## Applications

The HVPD 16-Channel Multi Monitor unit is the result of over 2 years of development by HVPD, in close collaboration with the utility and industrial end-users, is presented as an intelligent, stand-alone *PD monitor* for permanent PD monitoring of PD activity in the *medium voltage cables, switchgear and other plant (voltage range 6.6kV to 45kV)*.

## Key Features

- Continuous, permanent PD monitoring technology capable of *automatically* detecting and monitoring On-Line Partial Discharge (PD) activity in all types of medium voltage (MV) cables and switchgear.
- The monitoring system is able to capture the PD signals On-Line, without outages of the 50/60Hz HV power supply.
- The system employs a wideband measurement across the frequency range of 200kHz up to 50MHz. No hardware filters are employed which can 'blank-out' or 'mask' real PD's.
- The HVPD Multi Monitor has a data-acquisition rate of 100MS/s (mega samples per second) which is equivalent to 2 Million Samples per 50Hz power cycle, at a rate of 1 sample per 10ns. This high data acquisition rate enables very detailed analysis of the pulses received to be made in the diagnostic software.
- The system can *automatically differentiate* pulses received into 3x types ('Cable PD', 'Local PD' and 'Noise') using the '*SmoothSurvey*©' diagnostic software module which is able to filter out noise whilst preserving the pd pulses, based on pulse-shape and frequency analysis
- The unit can be set-up to remotely monitor (via the HSDPA (3G mobile phone) network when there is no LAN connection in the substation) any PD activity which has been detected during surveying tests using PD 'Spot-test' equipment.
- The standard supply package includes 16x HFCT sensors for 'Cable' PD detection and 8x 'TEV' sensors for 'Local' PD detection. This allows up to 16x Feeder cables to be monitored, 8x switchgear panels

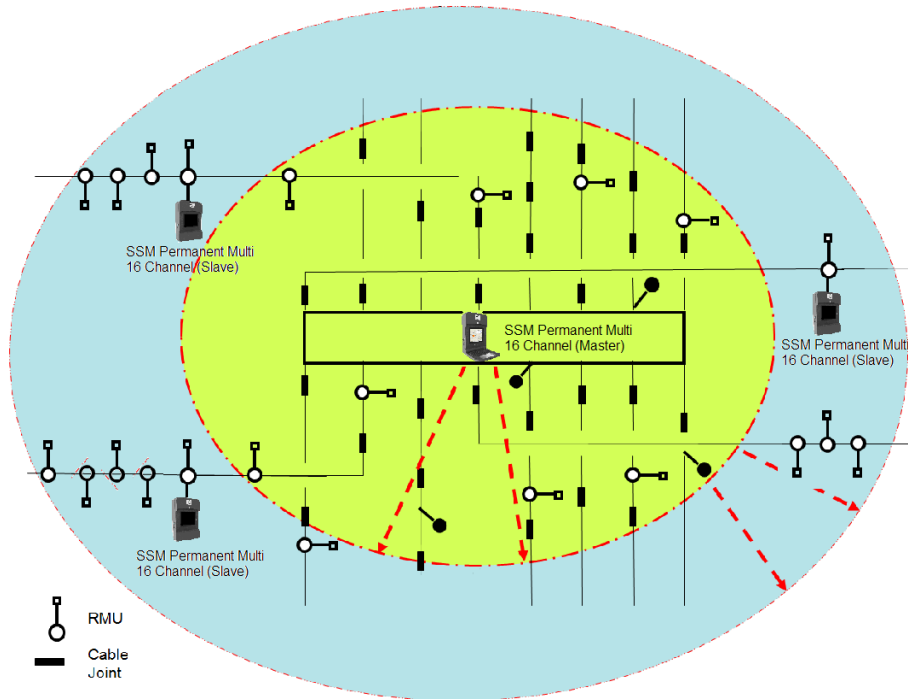
- 'Cable PD' pulses are measured in pico-Coulombs (pC's) and 'Local PD' are measured in decibels (dB's) as per On-line PD testing guidelines and practice.
- Measurements of both PD Magnitude & PD 'Count' (No. of pulses) are made to provide a measure of the 'Cumulative PD' activity across each power cycle analyzed.
- *Continuous, 24/7* PD Logging Capability with measurements taken every 20 minutes (72 measurements per day) with an individual measurement period of one cycle (16.67ms or 20ms).
- Stores up to 12 months of 16-channel PD monitoring data on local, 160GB hard drive memory.
- Downloads daily PD data every 24hrs via HSDPA modem (3G mobile) network.
- Generates a *Cumulative PD 'Criticality' Measurement* through data analysis in the PD Reader© pulse analysis software which measures the cumulative PD activity over each power period collected in each channel each 20-minute period.

### Monitoring of MV Cable Networks

HVPD recommend the use of a combination of both portable and permanent PD monitoring technology for a large utility or industrial medium voltage distribution networks (6.6kV-45kV) For wide-area distribution network PD monitoring the HVPD Multi is one of the units of choice.

The HVPD-Multi™ Permanent Monitor technology is designed for use in primary substations for temporary installations (to monitor up to 16x cable feeders using 16x HFCT sensors). For primary substations with less than 16x feeders it is recommended that TEV sensors are also used in conjunction with the HFCT sensors to detect any 'local' PD in the switchgear.

An Application for the HVPD Multi™ is the PD Monitoring of cables and switchgear at a primary substation. This is illustrated below in Figure 3. In this case a HVPD-Multi™ Monitor unit (with 16x HFCT split-core sensors attached to the earth connections of the cables) has been deployed to monitor 16x feeder cables. Further network coverage has been achieved by adding distributed 16 channel 'slave' units as required.



**Figure 3: Primary S/S Monitoring with a HVPD-Multi™ Monitor and expanded 'Slave' Units to give greater coverage**

**For further information please contact HVPD Ltd via:  
Tel: + 44 (0) 161 877 6142 or e-mail: [info@hvpd.co.uk](mailto:info@hvpd.co.uk)**