Universal, Hand-held On-Line Partial Discharge (PD) Surveying Tool for Insulation Condition Testing of High Voltage Plant

The unit is powered by an internal 7.2V Lithium-Iron rechargeable battery and is supplied with an external AC Mains to 7.5V Battery Charger and Carry Case. On full charge the battery will last for a total of 10 hours of continuous usage. The battery has sufficient charge for operation when the 'ON' LED on the front display panel is lit continuously. A low battery warning is provided to the user when the 'ON' LED starts to flash. This is an early warning to the user that the unit requires a re-charge.

The unit is switched 'ON' and 'OFF' by the User by pressing the RED button on the back of the unit (as shown below in Figure 5). When switched ON the unit will operate for 5 minutes and then will switch-off automatically, this feature being used to ensure that the unit is not left on for long periods. Whilst in 'normal' use it is typical for the unit to last several days up to a week without need for a re-charge, it is recommended that the unit is re-charged every other day to ensure a healthy battery voltage and charge is maintained.

Figure 5: PDSurveyor™ 'ON/OFF' button and Battery Charger Socket

2.0 How It Works

The PDSurveyor™ incorporates ***three*** individual partial discharge sensors and corresponding measurement circuits which are designed to pick up different types of PD activity in different types of HV plant, as follows:

CT - Cable PD Circuit – Cable PD is measured using the external, split-core, **High Frequency Current Transformer (HFCT 100/50) sensor** which *is clipped around the earth strap of the cable to be tested*. Cable PD pulses are generally in the frequency range of between 200kHz – 4MHz and are typically monopolar in shape. The unit measures the charge content of the Cable PD pulses in picoCoulombs (pC's) by using an integrator circuit to measure the area underneath the monopolar pulse.

TEV Circuit – **Transient Earth Voltage** (TEV) PD signals are generated by internal partial discharges in 'local' HV equipment including switchgear, cable terminations, motors and transformers. TEV signals are in a higher frequency range of between 4MHz – 100MHz and are normally oscillatory in shape (as opposed to monopolar for cable PDs). The unit has a built-in TEV sensor which is placed against the equipment under test to measure these signals. The resultant PD signals are measured in dB (decibels), as is the convention for on-line switchgear testing.

AA – Airborne Acoustic Circuit – Acoustic/Ultrasonic PD signals are generated by partial discharges into air and are detected using the unit's built-in 40kHz airborne acoustic (ultrasonic) sensor ('line-of-sound' to the pd site is required). The PDSurveyor™ sensor is very useful when testing Air Insulated Switchgear and has been designed with high sensitivity to pick-up small discharges into air which are inaudible to the human ear. The resultant PD signals are measured in dB (decibels) as is the convention for measuring acoustic signals.

The outputs of each of the above measurement circuits are displayed on the PDSurveyor's display screen which consists of 3x rows of 7 x colour-coded LEDs, 1 row for each sensor. The PD levels vs Plant Condition / Action to be taken for each LED are shown overleaf in Figure 2. These range as follows:

LED 1 – Green (Plant OK)

LEDs 2 & 3 - Yellow (Moderate PD – Monitor)

LEDs 4 & 5 – Orange (Moderate to High PD – Investigate Source of PD)

LEDs 6 & 7 - Red (High PD – Test & Restrict Access).

3.0 Scope of Supply

The PDSurveyor™ is supplied complete with a **Split-Core, High Frequency Current Transformer Sensor (Type HFCT100/50) and 2m-long BNC Cable** which is connected to the top of the unit as shown below in Figure 3. The unit is supplied complete with a Mains Battery Charger, Soft Shoulder Carry Case and User Manual.

Figure 3: PDSurveyor™ shown with the HFCT 100/50 Sensor and 2m BNC Co-axial Cable

The Transient Earth Voltage (TEV) Sensor and the Airborne Acoustic (Ultrasonic) Sensor are built into the back of the PDSurveyor™ housing as shown below in Figure 4.

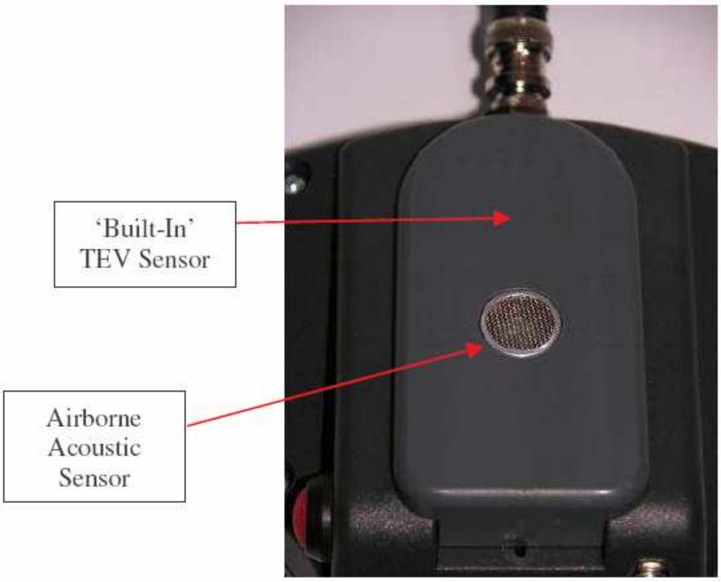

Figure 4: PDSurveyor™ Rear Sensor Plate with TEV and Acoustic Sensors

4.0 Applications

The **PDSurveyor™** can be used to test **High Voltage Cables, CTs, VTs, Switchgear, Rotating HV Plant and Transformers.** Some examples of these applications and tips for use are given in this section.

4.1 PD Screening of Medium Voltage (MV) Cables

The On-Line Partial Discharge (PD) testing of Medium Voltage cables (6.6kV to 132kV) originated in the UK in the late 1990's through the use of split-core High Frequency Current Transformer (HFCT) sensors which are attached around the earth strap of the cable at the switchgear or transformer with the equipment 'live'.

The techniques employed in the new On-line PD test techniques have evolved from Off-line PD testing of cables (with a VLF or other external HV Power Supply) which was pioneered in the UK, Germany and Netherlands in the 1980's. The move across to on-line pd testing over the past few years has been led by customer requests to avoid cable outages for insulation condition testing (for the Off-line test the cable needs to be isolated at both ends and the portable HV power supply applied).

The test set-up is inherently safe as the PDSurveyor™ is connected to the cable under test via the HFCT 100/50 sensor which is connected around the earth strap after it is 'brought-off' the cable (as is illustrated in Figure 3 below). An alternative to this is to connect the larger HFCT sensor (HFCT140/100) around the core of the cable (after the earth screen has been 'taken-off). The connection options for HFCT sensors are given in Appendix 1.

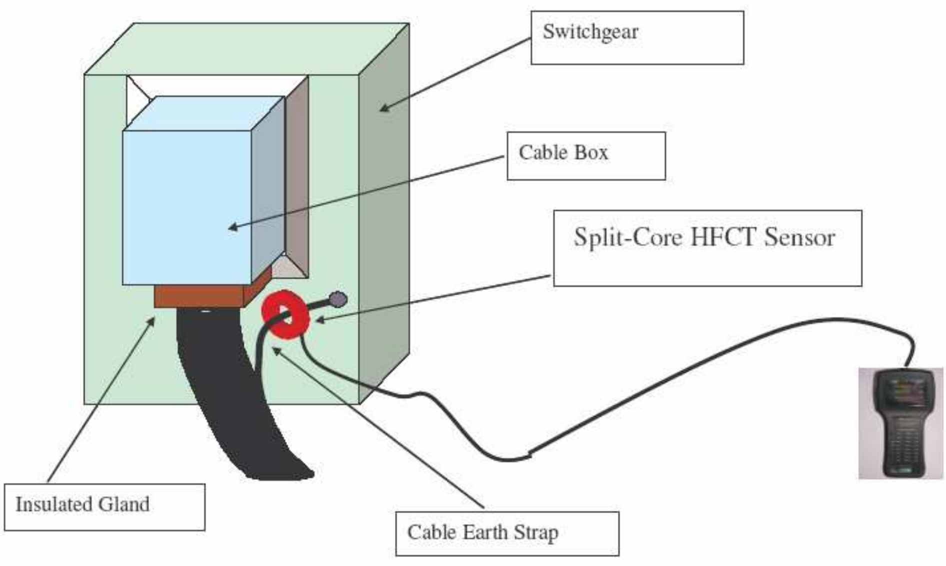

Figure 6: HFCT Connection on Earth Strap for On-Line PD Testing of MV Cables with the PDSurveyor™

PD Levels for Cables

The indicative figures for PD Levels vs. Condition given in Figure A1.5 show that for **Paper Insulated Lead Sheathed Cables (PILC)**, discharge below 3000pC can be considered as being within acceptable limits (green), between 3000pC and 6500pC is a cause for some concern with some monitoring recommended (yellow), between 6500pC and 10000pC is a higher level of concern with regular monitoring and re-testing recommended (orange) and anything above 10000pC (red) should be considered as being on a trend to failure and the problem should be investigated further to pinpoint the location of the PD activity (using a High-Spec PD Diagnostic Test System such as the IPEC OSM-Longshot© PD Spot Tester and Cable Mapping tests followed by repair/replacement).

It can also be noted from Figure A1.5 that the PD Levels vs Condition/Action indicative for **XLPE (Polymeric) Cables** are much at less than for the PILC cables due to the polymeric cables being much less resilient to PD activity than their PILC counterparts. For XLPE cables discharges below 250pC can be considered as within acceptable limits (green), between 250pC and 350pC is a cause for some concern with some monitoring recommended (yellow), between 350pC and 500pC is a higher level of concern with regular monitoring and re-testing recommended (orange) and anything above 500pC (red) should be considered as being on a trend to failure and the problem should be investigated further to pinpoint the location of the PD activity (using a High-Spec PD Diagnostic Test System and Cable Mapping tests followed by repair/replacement).

For **'Mixed' Cables** (a mixture of XLPE, PILC, EPR or other cable types) it is necessary to find where the source of the discharge is (position along the cable) before making any diagnostic decision. To achieve this it is necessary to apply Cable Mapping Technology (refer to IPEC Engineering for further information on IPEC's On-Line Cable PDMap© Cable Mapping Technology).

The respective PD Levels vs Condition for PILC and XLPE **Joints and Terminations** have also been given at the bottom of Figure A1.5. It can be noted that these PD Levels vs Condition/Action are slightly higher than for the cables themselves as these cable accessories typically have more insulation in them than the cables themselves and are thus generally more resistant to degradation from PD activity, hence the higher acceptable levels. This difference is particularly marked with XLPE Cable Accessories with PD levels of between 3 to 5x those of the cables themselves.

In the setting of the PD Levels vs Condition for the PDSurveyor™, IPEC Engineering have considered the PD levels discussed above and also statistical likelihood of PD occurring in the cable sections themselves versus PD occurring in the cable accessories. From work carried out by IPEC and HVSL over the past 10 years with HV Power Plant Owners in the UK, Europe and the Rest of the World it is evident that, ***with XLPE cables, over 90% of failures due to PD activity occur within the cable accessories*** whilst only 10% occur in the cable sections themselves. With PILC cables the percentage of cable failures in the accessories is less than the XLPE cables at around 70% with around 30% of failures occurring in cable sections.

The PD Levels vs Condition which have been programmed into the PDSurveyor™ (see Figure A1.6 overleaf) have been set based on combining the PD Level Data for PILC and XLPE cables given in Figure A1.5 with the statistical likelihood of occurrence of PD in either the cable sections or the cable accessories as mentioned above. It should be noted that for XLPE cables, if Cable PD of Level LED Yellow 2 or LED Orange 1 is detected, it is recommended that the source of the PD activity is located by the user using a High-Spec PD Diagnostic Test System such as the IPEC OSM-Longshot© PD Spot Tester and Cable Mapping tests.

MV Cable PD Levels vs Recommended Action

Cable type	PD level	Recommended action
PILC Cables	0pC – 3000 pC	Discharge within acceptable limits
	3000 pC – 6500 pC	Some concern, monitoring recommended
	6,500 pC – 10000 pC	Some concern, regular monitoring recommended
	> 10000 pC	Major concern, repair or replace

Cable type	PD level	Recommended action
XLPE Cables	0pC – 250 pC	Discharge within acceptable limits
	250pC – 350 pC	Some concern, monitoring recommended
	350pC – 500 pC	Some concern, regular monitoring recommended
	> 500pC	Major concern, repair or replace

PD Level for MV Cable Joints and Terminations

PILC Cables	XLPE Cables
0 – 4000 pC	0 – 500 pC
4000 pC – 6000 pC	500 pC – 1000 pC
6000 pC – 10000 pC	1000 pC – 2,500 pC
> 10000 pC	> 2,500 pC

Figure A1.5: ***Guideline*****, PD threshold levels for Medium Voltage Cables**

Figure 1: PDSurveyor™ being used to Test Air Insulated Switchgear

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