1. SCOPE

The following document gives technical guidance and acts as a basic guide for the usage of the EA Technology (EATL) UltraTEV, UltraTEV+ and Partial Discharge Locator (PDL) devices in testing for Partial Discharge activity on high voltage equipment.

2. ISSUE RECORD

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5. DISTRIBUTION

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6. CONTENTS

1. SCOPE **1**

2. ISSUE RECORD **1**

3. ISSUE AUTHORITY **1**

4. REVIEW **1**

5. DISTRIBUTION **1**

6. CONTENTS **2**

7. INTRODUCTION **3**

7.1 PARTIAL DISCHARGE 3
7.2 CASE STUDIES 4
7.2.1 Insulation in 11kV Cable-End Box *4*
7.2.2 Cable Bushing *5*
7.3 DETECTING PARTIAL DISCHARGE 5
7.3.1 Detecting Surface Discharge *6*
7.3.2 Detecting Internal Discharge *6*

8. USAGE GUIDES **6**

8.1 USING THE ULTRATEV 6
8.1.1 Testing *7*
8.1.2 Checking Switchgear *7*
8.2 USING THE ULTRATEV+ 8
8.2.1 Testing & Calibration *8*
8.2.2 Measuring PD *8*
8.3 USING THE PARTIAL DISCHARGE LOCATOR (PDL) 10
8.3.1 Testing & Calibration *10*
8.3.2 Locating PD *11*

9. INTERPRETING RESULTS **12**

9.1 ULTRATEV 12
9.2 ULTRATEV+ 13

10. APPENDIX: **14**

10.1 POSSIBLE SOURCES OF ERROR 14
10.2 FLOW CHART FOR PARTIAL DISCHARGE INSPECTION PROCESS 15

7. INTRODUCTION

7.1 Partial Discharge

Partial discharges (PD) are electrical discharges that occur in an otherwise insulating media but do not completely bridge the gap between two points of differing potential. PD can be considered in two forms:

- Surface discharge – Surface discharges normally occur from the effects of the weather on outdoor equipment or the corona effect. These discharges produce Ozone and Nitrogen gasses which, when combined with moisture, produce Nitric acid. This acid then attacks both the insulation and surrounding metalwork.

  The result is tracking on the surface of the insulation. These carbon tracks electrically reduce the effectiveness of the insulation causing the process to accelerate to eventual flashover. The action of this acidic atmosphere can often be seen as rust on the metalwork and corrosion of copper surfaces (light blue/turquoise stain).

- Internal discharge – Within all insulating materials there are small voids, often microscopic in size. High voltage across the insulation produces electrical stresses which can cause these voids to charge up like small capacitors. When sufficiently charged they discharge with a small spark across the void.

  This discharge action progressively erodes the voids making them bigger. As these voids increase in size the energy in each discharge increases. During this process carbonisation of the inner surface of the void also occurs. The resultant carbon from this progressively builds up to make the void conductive. This increases the electrical stress on the next void and the process repeats itself. After time there may be sufficient conductive voids throughout the insulation to cause failure.

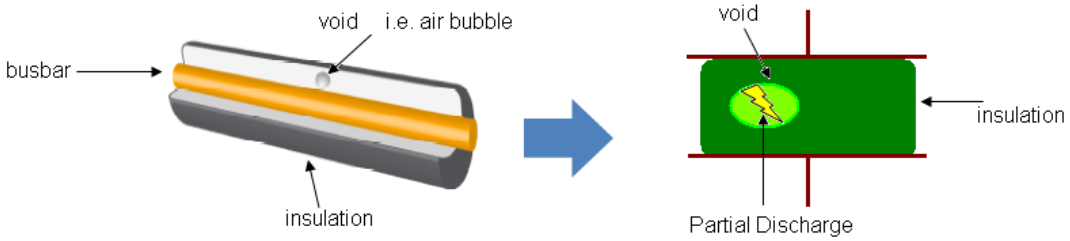


Figure 1 – Internal Discharge

7.2 Case Studies

Partial discharge contributes to around 85% of disruptive failures in HV and MV assets[1]. Therefore it is important to understand what visual evidence there can be of PD activity in equipment and why it is happening.

7.2.1 Insulation in 11kV Cable-End Box

As shown in the diagram below, partial discharge activity was discovered in a cable sealing end box. Upon inspection, a white powder (Aluminium Oxide) was present between two cable cores that were too close together. This showed that there was partial discharge activity. If the problem is not resolved the insulation can degrade enough such that a flashover occurs between the cable cores.

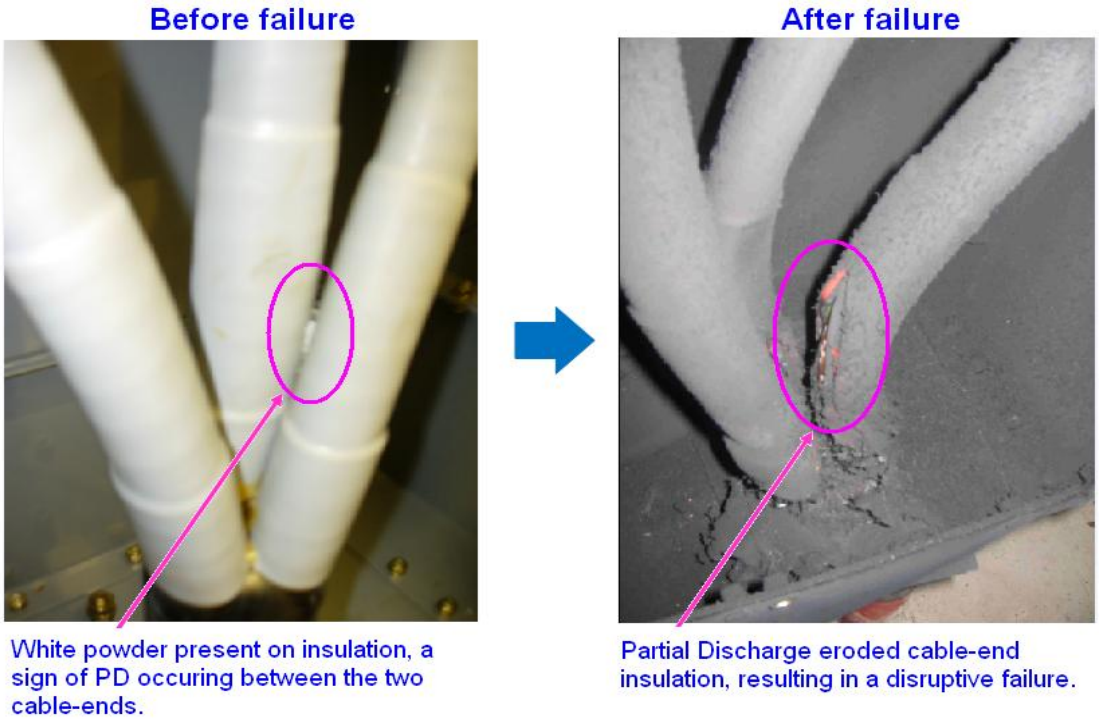
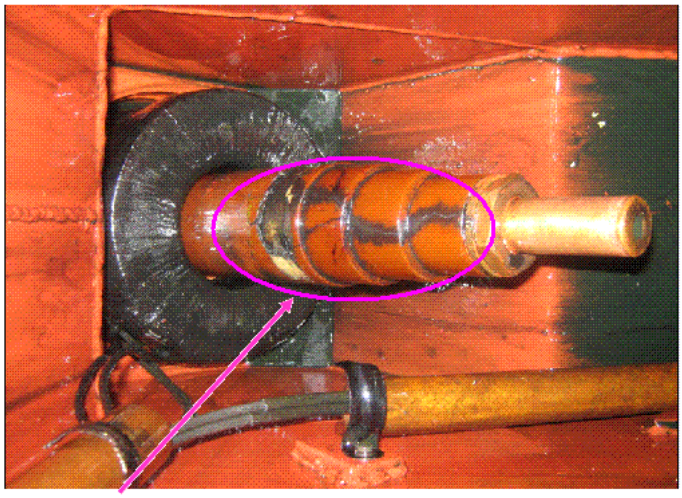


Figure 2 – PD in a Cable End Box

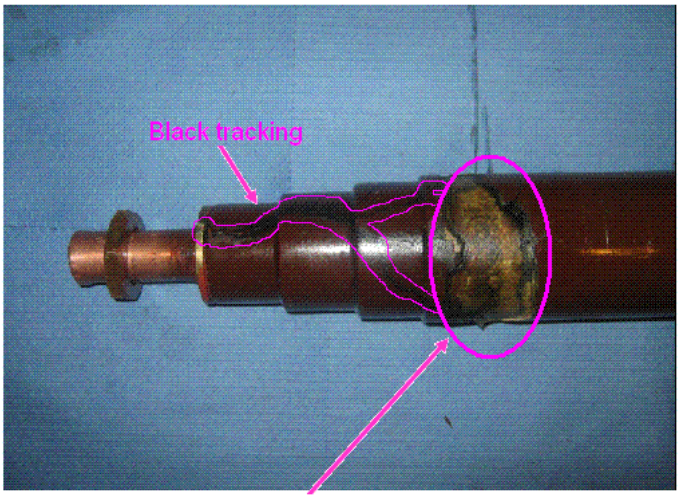
[1] http://www.pd-academy.com/default.aspx

7.2.2 Cable Bushing

In the figure below, it can be seen that there is “treeing” (or tracking) present in the HV bushing. This problem was not detected and, as can be seen by the severity of the treeing in the second picture, a flashover occurred as a charge passed from the metallic screening in the cable bushing to the current transformer.



Black tracking (or "treeing") has occured due to Partial Discharge. The most likely cause is impurities within the insulating oil.



PD activity was so severe that it burned through layers of the bushing to expose the metallic screening. This led to a flashover to the connected CT.

Figure 3 – PD in Cable Bushing

7.3 Detecting Partial Discharge

The energy magnitude of partial discharge is normally very small. Non-intrusive methods of measuring the partial discharge on equipment is vital for SPEN as insulation and equipment with high levels of PD can result in a disruptive failure leading to health and safety risks and potential loss of supply to customers.
Identifying PD can indicate deteriorating insulation long before failure, thus providing an opportunity to take appropriate rectification measures.

EATL has developed a number of easy-to-use instruments which provide TEV (Transient Earth Voltage) measurement and ultrasonic discharge detection. This document looks at the basic use of the UltraTEV and UltraTEV+ handheld meters and the Partial Discharge Locator as well as the actions to be taken based on the measurement results.

The UltraTEV handheld meter will be used to conduct surveys on switchgear in Primary, Secondary and Grid indoor substations for partial discharge during routine inspection visits.
When no or minimal amounts of PD are detected, confidence in the serviceability of the equipment will be improved. When high levels of partial discharge are identified (above 30dB), the problem must be investigated and the safety risk established. It should be noted that other sources of PD may be detected by the available monitoring devices and guidance on the identification of these sources is provided in Appendix 10.

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These handheld measurement units contribute to the information used in prioritising plant refurbishment and replacement programs as well as supporting SPEN's Asset Risk Management programme. This programme relies on a robust level of condition information to extend plant life and prevent failures through early identification and intervention.

7.3.1 Detecting Surface Discharge

Surface discharges can be located by ultrasonic detection where there is an air path from the point of discharge. The UltraTEV+ can be used to detect surface discharge on units at a distance using the UltraDish attachment and headphones.

7.3.2 Detecting Internal Discharge

Internal discharge can be detected by TEV mode using the UltraTEV, UltraTEV+ and PDL. The probe(s) must be held completely perpendicular to the unit of inspection, with the top screen making full contact with the unit.

8. USAGE GUIDES

8.1 Using the UltraTEV

The UltraTEV handheld meter is used in routine substation inspections to check for potential PD sources. The meter itself is easy to use and has a simple and effective reading method. After the UltraTEV meter is switched on (and after testing functionality) the meter can be used to inspect an entire unit with care being taken to ensure the accuracy of the readings.

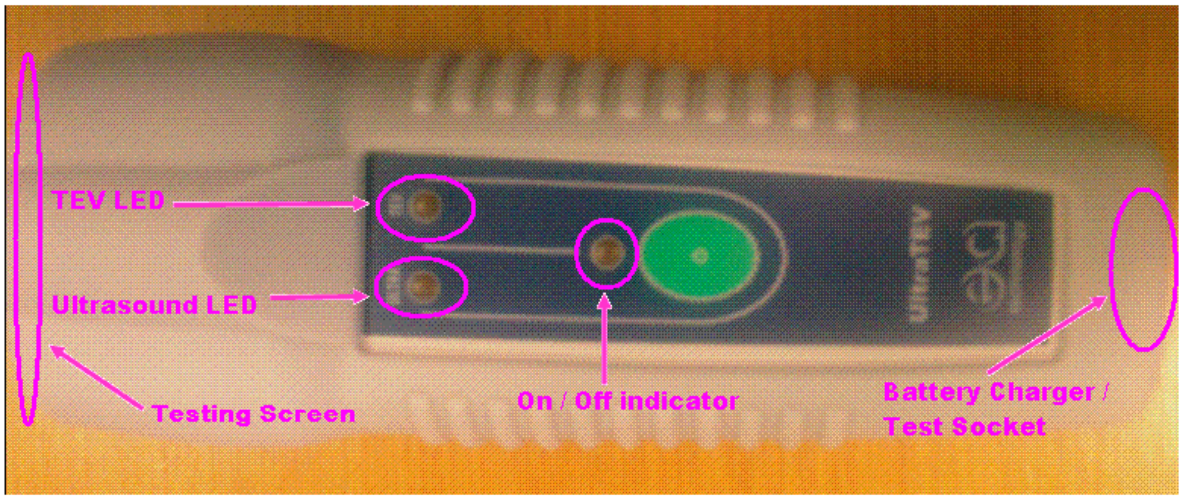


Figure 4 – UltraTEV handheld meter

8.1.1 Testing

The UltraTEV meters are required to be calibrated once a year internally by the Compliance Group in SPM.

To check the functionality of the UltraTEV device, the test cable provided can be used. The cable is plugged into the bottom of the device (as shown in Figure 4) and the test unit screen held firmly on the UltraTEV testing screen. This should make both of the LED's turn red, showing that the unit is fit for use.

8.1.2 Checking Switchgear

When carrying out measurements, the blue test screen at the top of the meter should be held completely flat against the switchgear for several seconds, to ensure that the meter has taken an accurate reading. The UltraTEV uses both TEV and ultrasound sensors **simultaneously**. The "TEV" LED (as shown in Figure 4) will light up green, amber or red. The "Ultra" LED (Figure 4) will light up either green or red. Many combinations of LED's are possible but any red LED must be reported.

Before taking measurements on switchgear, a reading must be taken in open air. If the UltraTEV LEDs are green, then proceed to taking a reading on some unearthed metal work, such as a fire extinguisher or substation door. If the UltraTEV is also green for this, then proceed to inspecting the unit.

Each individual component of the switchboard under inspection should be checked with the UltraTEV. For example, circuit breaker, CT chamber, VT, Cable Box, Cables. If any of the LEDs are red without the meter actually being used on live plant, then it is likely that there is background noise present in the substation.

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8.2 Using the UltraTEV+

The UltraTEV+ meter should be used to give a measure of PD on HV equipment. The display on the UltraTEV+ gives an indication of the safety of the equivalent reading, using a traffic light system; green for nominal conditions, amber for above-average conditions and red for conditions of concern.

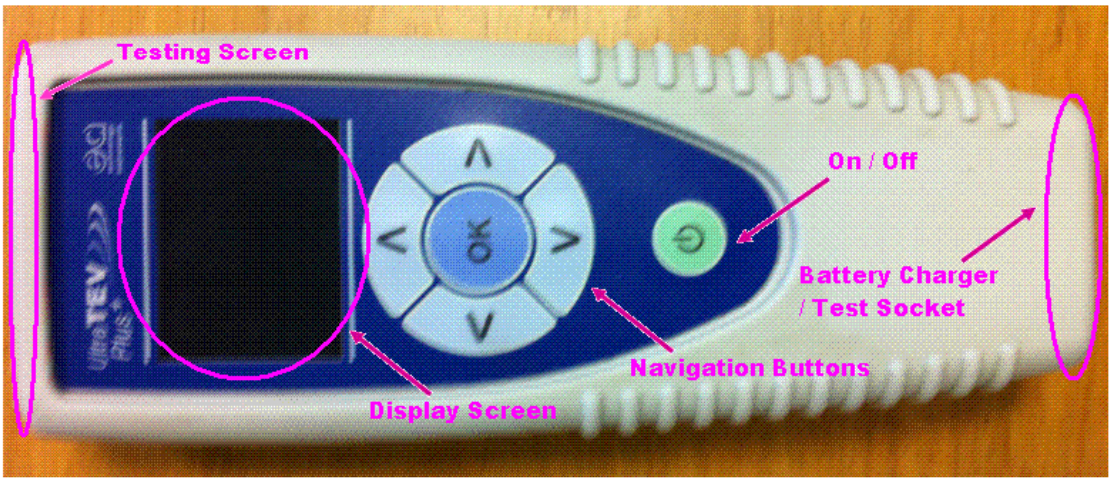


Figure 5 – UltraTEV+ Handheld Meter

8.2.1 Testing & Calibration

The UltraTEV+ comes with a testing unit that can be plugged into the battery charger/testing socket (shown in Figure 5). Slowly moving the test unit towards the UltraTEV+ testing screen will show the functionality of the UltraTEV+ meter. That is, as it approaches the meter (in **continuous mode**) the display will move from green, through to amber and, when the test unit is directly on the screen, red. As seen in Figure 6.

Similar to the UltraTEV, the UltraTEV+ has an auto calibration feature such that as it is switched on, it should be ready to use.
However, to compensate against background noise, the UltraTEV+ meter should be used to measure the readings on an isolated piece of metalwork (such as the substation door) in the substation three times. These values should be noted and averaged so that this value can then be subtracted from future measurement in order to negate the effect of background noise.

8.2.2 Measuring PD

The meter must be switched on in an open air environment so it performs an accurate self test. After this auto-calibration a menu is displayed showing two modes: **TEV mode** and **Ultra mode**. Both of these modes can be used to inspect the plant but for testing of internal PD, preferably, TEV mode is used.

The UltraTEV meter is normally used in **continuous mode**. Within this mode, the reading on the meter changes as it moves across the plant, so the operator can locate the point of highest PD activity.

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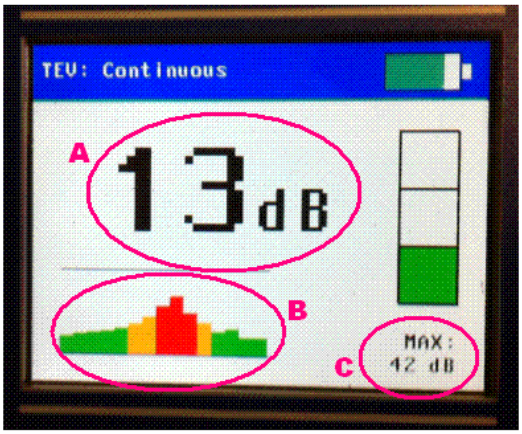


Figure 6 – UltraTEV+ Screenshot in Continuous Mode

The meter must be held flat against the surface of the equipment under investigation, such that the entire testing screen at the top of the meter (blue screen) is in contact with the metalwork of the equipment. i.e. the UltraTEV+ should be held completely perpendicular to the inspected unit with the testing screen making full contact.

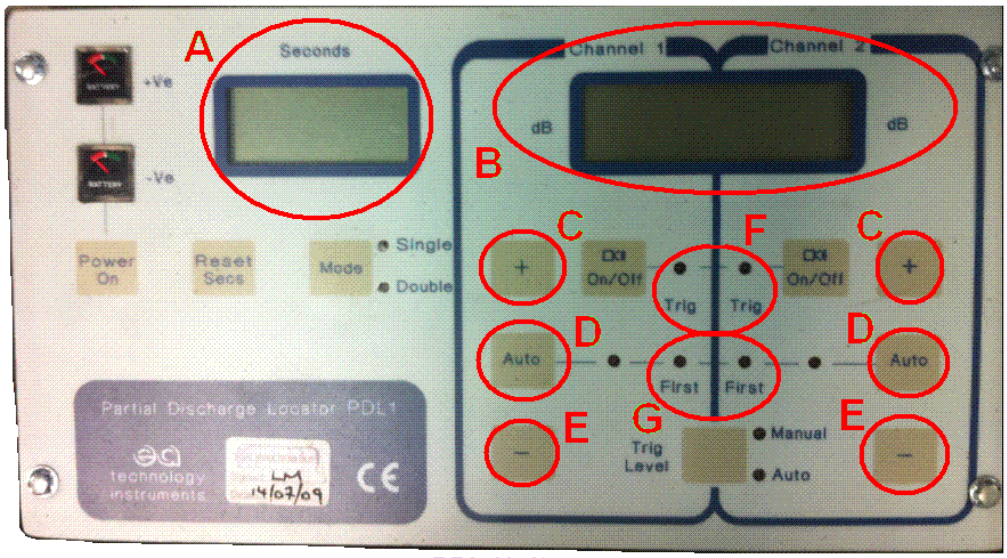
The current PD reading is displayed (**A** in Figure 6) with the history (**B** in Figure 6) showing where the largest readings have occurred and the maximum total reading from the session is displayed in the bottom corner (**C** in Figure 6). From looking at Figure 6, it can be seen that the peak reading of 42dB occurred as the meter was moved along the unit. The meter can then be used to track back to the potential source of the PD.

The UltraTEV+ is mainly to be used to investigate a substation or unit, rather than being used as a device to locate the specific source of partial discharge.

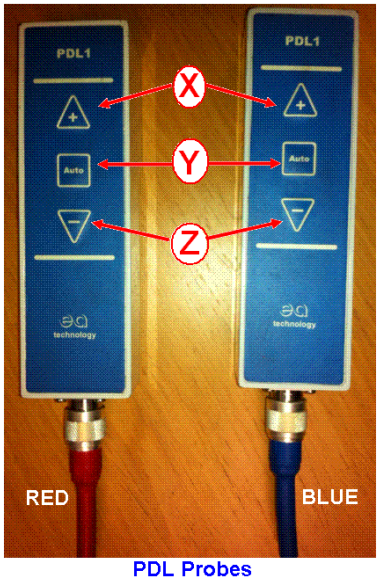
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8.3 Using the Partial Discharge Locator (PDL)

The PDL detects Partial Discharge using two ultrasonic probes to locate the source of partial discharge. When using the probes, they must be held at least 600mm apart while measuring. To locate the source of the partial discharge, the probes are held in position while the PDL main unit displays which probe detects the PD first. The probes can then be moved around the unit of inspection. This process is repeated as an iterative method until the source of the PD is located.



PDL Unit



PDL Probes

Figure 7 – Partial Discharge Locator Unit & Probes

8.3.1 Testing & Calibration

Once the PDL has been switched on at the side panel and the two probes have been connected into the “probes” input, the PDL can be tested and calibrated as follows:

The beepers can be used to indicate when a channel has been triggered. If the beeper sounds off when the PDL is turned on, it is a reaction to the surrounding noise. To stop the beeper increase the PDL attenuation using the “+” buttons on the main unit until the beeping stops or, alternatively, press the “on/off” button on each channel.

The PDL comes with a small test box which can be used to test the functionality of the probes. **This is not a method for calibrating the probes.** This will show whether the probes work and will allow the user to observe how the unit functions.

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Insert the two probes into the test box to activate the internal battery. When the unit is switched on, the default setting for the attenuation is 0 on each channel. As a result, both channels will have the "First" LED lit up (**G** in Figure 7). Pressing the "+" arrow on each of the probes (**X** in Figure 7) will increase the attenuation. This should be pressed enough such that only one "First" LED will remain consistently lit up.
Continue to increase the attenuation on both channels until the instrument is only just able to trigger. I.e. the next increase in attenuation will turn off the "Trig" LEDs. Take note of the values on the main display (**B** in Figure 7), in dB, once the instrument is just able to trigger.

Now press the "Auto" button on each probe (**Y or D** in Figure 7) and check if the automatic test gives the same values of dB obtained from the manual test.
Once the performance of the PDL is satisfactory, the unit can now be calibrated.

For calibration, the background noise can be compensated for by making two measurements; taking a measurement in air and a measurement on a piece of isolated metalwork, such as a substation door. The noise from these two tests can then be accounted for by pressing the "Auto" button on each probe (**Y or D** in Figure 7) **after each measurement**.

8.3.2 Locating PD

After testing and calibration the probes can be used with the front screen held perpendicular to, and completely on, the inspected unit. An accurate reading will be achieved after the probes are held steady for a minimum of 5 seconds on the plant. This can be checked by observing the timer on the main unit (**A** in Figure 7). From observing the "First" LEDs on the main PDL unit (**G** in Figure 7), the location of the source can be estimated by moving the probes along the plant.

The reading for each probe is displayed on the main display and these readings can be used to locate the source. That is, the smaller the differences between the readings on each channel, the closer the probes are to the source of the PD.

If the "First" and "Trig" LEDs are not flashing when inspecting the plant, pressing the "-" arrows on each probe (**Z** in Figure 7) will increase their sensitivity. The unit is ready to use when both channels' "Trig" LEDs (**F** in Figure 7) on the main unit are lit.

If the "First" LEDs are not flashing and the "Trig" LEDs are then the unit of inspection is experiencing no partial discharge.

If both of the "First" LEDs are lit at the same time it can mean one of the following:

- The time difference between readings at each probe is too small to resolve. i.e. the source of the PD is more or less in the middle of the two probes or the probes are too close together.
- There may be other sources of PD affecting the readings.
- The PDL is too sensitive.

The first scenario can be checked by moving the two probes further along the plant and checking if both of the "First" LEDs still light up at the same time.

For the second scenario the plant will have to be inspected in detail. If the PD is large, then it may be detected in adjacent switchgear, which must not be misinterpreted as another source. This can be checked and prevented by thorough investigation.

The third scenario can be resolved by increasing the attenuation on the probes. This can be done using "+" on each probe (**X** in Figure 7) until only one side displays the "First" LED.

The red and blue connecting cables to the unit can be used to remember which probe is closest to the potential PD source. The most commonly used technique is to always keep the "red" probe closest to the potential source (colours as highlighted in Figure 7).

9. INTERPRETING RESULTS

If the device reading is high, it is important to note the background reading levels of the site. When referred to the Zone Manager or Asset Management the information contained in this record may highlight information relating to experience gained from other PD surveys.

9.1 UltraTEV

Because the UltraTEV handheld meter gives a simple traffic-light reading, the results **may not** be definitive.

LED Colour	Interpretation	Response
Green Light	No action required.	Resurvey at next inspection.
Amber Light	No action required.	Resurvey at next inspection.
Red Light	Record in SAP.	Further investigation required.

9.2 UltraTEV+

The UltraTEV+ is mainly used to establish whether or not plant has any form of PD activity. After the point of the plant with the highest reading of PD has been located, the appropriate action will be taken according to the table below:

PDL Reading	Meaning[2]	Reaction	Conclusion
GREEN 0 – 20 dB	PD-related faults are unlikely to be developing.	No concern.	Discharges, if any, are most likely of no significance at this point in time. Monitor at inspections.
AMBER 20 – 30 dB	PD-related fault may be developing.	Some concern.	Readings are larger than average. Discharges may be occurring but noise may be contributing to results. Monitor at inspections.
RED 30 – 40 dB	PD-related fault is in the advanced stages of development.	Concern.	Discharges occurring. Zone maintenance should be contacted to confirm Red TEV and advise Technical Risk of findings.
RED 40 dB +	High probability of PD-related fault occurring.	**High priority**.	Large discharges occurring. Zone maintenance should contact Technical Risk.

[2] http://www.pd-academy.com/pdfaultdetection

10. APPENDIX:

10.1 Possible sources of error

There are many factors within a substation that can contribute towards misleading readings on the PDL, UltraTEV and the UltraTEV+. They can be affected by the following:

- DC fluorescent lighting
- Telecommunications (e.g. substation communication device or a mobile phone mast)
- High voltage overhead lines
- Vehicle ignition systems
- Battery chargers.

Note: Very high pulse rates for readings on the PDL (over 1,000) indicate background / external electromagnetic interference.

A problem noticed in the UltraTEV handheld unit is that when the battery is low, the meter can give spurious red LED readings. Because there is no battery level indicator on the UltraTEV this problem can be avoided by maintaining a high level of charge in the unit.

For equipment outdoors, rain and snow can cause interference as the droplets impinge onto surfaces at high potential a discharge occurs between the two just before contact.

Another possible source of interference or noise is the possibility of more partial discharge activity elsewhere on the tested unit. For example, there could be discharges occurring in the cable within the cable end box of the unit under test or another unit attached to the switchgear under inspection.
If this is the case it will either be identified by the Zone Maintenance team and failing that, the Asset Management team.

Be aware that for a large source of PD in equipment in a substation, the PDL and UltraTEV+ will pick up the ultrasonic and TEV readings from the source throughout the entire plant.

Obviously, some of these sources of noise cannot be prevented, and so must be taken into consideration when interpreting the results from the tests. Although most noise in the readings of a PDL or an UltraTEV+ will usually contribute only a small amount, there are cases in which the background noise could change the results from “amber” to “red”. If this were to happen it could lead to unnecessary modification or replacement of a plant or unit.

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10.2 Flow Chart for Partial Discharge Inspection Process

