REPORT

Partial Discharge Survey Examples of MV and HV Assets

Private and confidential

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Safer, Stronger

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Executive summary

Background to this Sample Report

This report provides actual customer examples of partial discharge surveys that were done and the subsequent report with data and recommendations for customers to review as part of the overall evaluation of EA Technology's products and services.

Scope and Objectives

The scope of the report covers the following:

- Sample survey of 66kV, 11kV and 3.3kV substation assets.

The objective is to:

- To show customers that by using our partial discharge instruments that they will be able to Identify discharging components and help target maintenance activity to rectify defects and remove potential sources of failure that could cause unexpected outages and downtime.

Conclusions

Below are actual customer conclusion examples that would be in a report that EA Technology LLC would provide a customer after a Partial Discharge survey was done at their facility. The reader can use the information in this report to see how using EA Technology Instruments such as the UltraTEV Plus^2 which is a non-invasive PD measurement instrument can be used as part of a regular non-invasive condition assessment maintenance program.

C1. Non-destructive corona found on ABS1 inside SR001 substation.

C2. Ultrasonic surface discharge activity detected on center phase of 66kV CB1. This activity was not present after a day of rain in the area – this proves that the surface discharge activity was caused by surface contamination from the atmosphere.

C3. Non-destructive corona found on ABS3 inside SR001 substation

C4. A rusty nut and bolt at the base of the polymeric 66kV dropper insulator above TX021 on the north phase was located. This nut and bolt is emitting ultrasonic surface discharge activity.

C5. Behind the VT chamber on CB6 inside the SR001 substation, an ultrasonic surface discharge source was detected. Likely a ‘contact’ or ‘floating metalwork’ type issue.

C6. An internal void type discharge of a low level was detected coming from the HV cable chamber of CB9 inside SR001 substation.

C7. Non-destructive corona found on CB-Q100 on top of TX045 substation.

C8. Non-destructive corona found on Rotary switch S100 on top of TX045 substation.

C9. A low level ultrasonic source of discharge was found coming from within the TX074 11kV Cable Box.

C10. An ultrasonic surface discharge source was detected from above the crutch of HV cable head termination 54100. On closer inspection, it can be seen that two of the three HV phases are crossed over in very close proximity to one another. This is likely to cause a point of high electrical stress which can cause surface partial discharge at this point. After a day of rain, the surface discharge source was no longer present.

C11. An ultrasonic source of surface tracking was detected coming from behind the HV CB at TX009. A visual confirmation has found the likely source. It was seen that the ‘B’ HV connection on the 11,000/110V voltage transformer was covered in green verdigris.

Recommendations

The following is actual recommendations our engineers have made based on the findings mentioned above. The report will provide details and results along with recommendations. These findings are very typical of things that EA and our customers find when they perform non-invasive condition assessment surveys with our equipment.

R1. The corona found on ABS1 inside SR001 is of no concern as it is in open air.

R2. The surface discharge activity on 66kV CB1 is unlikely to have caused any damage to the porcelain insulation system of the circuit breaker. At the next available shutdown, it is recommended to closely inspect the porcelain for any signs of damage.

R3. The corona found on ABS3 inside SR001 is of no concern as it is in open air.

R4. The rusty nut and bolt on the polymeric insulator above TX021 may be deteriorating and likley losing its mechanical strength. At the next available outage, it is recommended to replace the nut and bolt, replace any other faulty assets in its vicinity. Also, as polymeric insulation is more susceptible to surface damage than porcelain, the base of the polymeric insulator should be closely inspected for signs of degradation – replace if any degradation found.

R5. Although not urgent, it is recommended that at the next available outage, the VT chamber panel on CB6 inside SR001 substation should be removed and all HV assets within this chamber be inspected for signs of a ‘contact’ or ‘floating metalwork’ type discharge. This may be poor HV connections somewhere in the panel. Clean the inside of the panel and all assets within. Repair / replace any damaged assets as required.

R6. As the PD source within the HV cable chamber of CB9 is an internal void type discharge, it is unlikely that a visual examination will find any defects. However, recommend a visual examination of this chamber if an outage allows. Recommend re-test in one years’ time to compare any changes.

R7. The corona found on CB-Q100 on top of TX045 substation is of no concern as it is in open air.

R8. The corona found on Rotary switch S100 on top of TX045 substation is of no concern as it is in open air.

R9. It is recommended that at the next available outage, this 11kV cable box be inspected for any signs of surface tracking on all HV assets within. Check all clearances to earth straps also. If any signs of tracking are found on the cables, plan to re-terminate the cable. Check for closely crossed phases and the gaps between this insulation.

R10. The HV cable head termination 54100 should be closely inspected at the next available outage. Attention should be paid to the area where the two phases cross one another. If any signs of surface tracking are found, plans should be put in place to re-terminate the HV cable.

R11. It is recommended that at the next available opportunity, the 'B' HV contact on the VT inside TX009 substation be cleaned up with plans to be replaced. If this is not possible, consider replacement of the VT. Also, the cast resin insulation around the HV contact should be closely inspected for signs of surface tracking. If this is the case, plans should be put in place to replace the VT as the damage is not repairable. Inspect the rest of the HV chamber as the VT contact may not be the only source of PD.

Contents

Appendices

1. Background & Introduction

This report provides customers with examples of a PD survey was carried out on the 66kV, 6.6kV and 3.3kV assets using the UltraTEV Plus2 and UltraTEV Locator instruments.

This report details the results of the partial discharge survey.

2. Overview of Detection of Partial Discharge Activity

2.1 General

Partial discharges are electric discharges that do not completely bridge the electrodes. The magnitude of such discharges is usually small; however, they can cause progressive deterioration of insulation that may lead to eventual failure.

Non-intrusive partial discharge detection provides a fast and simple to use test for identifying potential sources of insulation failure, that could result in the loss of supply to customers and a serious health and safety issue to staff and other personnel.

A partial discharge emits energy in the following ways:

Electromagnetic:
- Radio
- Light
- Heat

Acoustic:
- Audio
- Ultrasonic

Gases:
- Ozone
- Nitrous Oxides

The most practical techniques for non-intrusive testing are based on the detection of the radio frequency part of the electromagnetic spectrum and ultrasonic emissions.

2.2 Electromagnetic Discharge Activity

When partial discharge activity occurs within high voltage switchgear insulation it generates electromagnetic waves in the radio frequency range which can only escape from the inside of the switchgear through openings in the metal casing. These openings may be air gaps around covers, or gaskets. The signal can travel through other insulating materials or components, however, the signal attenuation increases with each surface or medium that it traverses. When the electromagnetic wave propagates outside the switchgear it also impinges on the metal casing of the switchgear producing a transient voltage on the external metal cladding of the switchgear. The Transient Earth Voltage (TEV) is a few millivolts to a few volts and lasts only a short time with a rise time of a few nanoseconds.

The partial discharge activity may be detected non-intrusively by placing a capacitive probe on the outside of the switchgear while the switchgear is in service.

2.3 Airborne Ultrasonic Discharge Activity

Acoustic emission from surface discharge activity occurs over the whole acoustic spectrum. Using an instrument to detect the ultrasonic part of the acoustic spectrum has several advantages. Instruments are more sensitive than the human ear, are more directional, are not operator dependent and operate above the audible frequency.

The most sensitive method of detection uses an airborne ultrasonic microphone centred at 40 kHz. This method is very successful at detecting surface discharge activity provided there is an air passage between the source and the microphone. When there is no or very limited air path, a contact ultrasonic microphone can be used to detect ultrasonic activity through the metalwork of the switchgear.

When undertaking ultrasonic surveys, it is important that environmental conditions are also measured. The presence of moisture in the atmosphere can have a direct effect on the presence of surface discharge.

3. Partial Discharge Instrumentation

3.1 UltraTEV Plus2

The UltraTEV Plus2 is a hand held instrument used for the detection and measurement of partial discharge in switchgear, cables and terminations, overhead insulators, and more. Both TEV and surface discharges can be detected and are displayed as numerical values on a color screen. The instrument also has the ability to display the number of PD pulses per cycle, severity levels, maximum levels for internal discharges, and a numerical value for ultrasonic emissions, which can be heard with the supplied headphones. Finally, the instrument has built in Algorithms used to analyse TEV and Ultrasonic measurements and advise the user if either internal or surface partial discharge is present.

3.2 UltraTEV Locator

The UltraTEV Locator can be used in single probe mode for TEV magnitude measurements, or double probe mode to accurately locate the source of PD activity using the time of flight technique. The UltraTEV Locator can measure PD magnitude over a large range with high accuracy and is the benchmark instrument for the assessment of partial discharge activity.

4. Interpretation of Results

The interpretation of results is aided by the use of EA Technology's partial discharge measurements database that contains over 15,000 records of surveys of switchgear and other electrical assets using partial discharge detection equipment. A judgement has been made that the top 5% of the switchgear and other assets requires further investigation. It is possible to interrogate the database to determine the criteria for further investigation of different subsets within the data e.g. for particular types of switchgear, different voltage ratings, particular manufacturers etc.

The level for further investigation of ultrasonic measurements is determined more by the knowledge that a source has been found than by the amplitude of the measurement. This is because the amplitude is very dependent on the size of the opening through which the airborne ultrasonic signal can pass and a clear direct line path between the source and the opening. A source is deemed to be found if movement of the ultrasonic microphone across the opening and angling the probe towards and away from the opening shows that the source is within the switchgear.

It is important that the following additional criteria are taken into consideration. Any one of these factors may result in a further investigation being carried out at levels below the general criteria.

- Switchgear component
- History of failures
- Circuit importance
- Level of Risk

5. Results and Discussion

The following section provides an example summary and discussion points on assets where partial discharge activity was detected and not detected on actual customer assets.

Substation	Result Sheet		Comments
		Surface HV assets (Substations)	
SR001 Substation outdoor		TEV	All clear at time of test
		Ultrasonic	Sources of ultrasonic discharge detected – action recommended Sources of corona detected – no concern
SR001 Substation indoor		TEV	Minor PD source detected – retest 1 year
		TEV + Ultrasonic	Potential Contact problem
SR004 Substation		TEV + Ultrasonic	All clear at time of test
SR005 Substation		TEV + Ultrasonic	All clear at time of test
SR006 Substation		TEV + Ultrasonic	All clear at time of test
SR008 Substation		TEV + Ultrasonic	All clear at time of test
TX036 Substation		TEV	All clear at time of test
		Ultrasonic	All clear at time of test
TX045 Substation outdoor		TEV	All clear at time of test
		Ultrasonic	Sources of corona detected – no concern
TX045 Substation indoor		TEV + Ultrasonic	All clear at time of test
		Surface HV assets (Transformers)	
TX012		TEV + Ultrasonic	All clear at time of test
TX017		TEV + Ultrasonic	All clear at time of test
TX028		TEV + Ultrasonic	All clear at time of test
TX030		TEV + Ultrasonic	All clear at time of test
TX034		TEV + Ultrasonic	All clear at time of test
TX039		TEV + Ultrasonic	All clear at time of test
TX046		TEV + Ultrasonic	All clear at time of test
TX047		TEV + Ultrasonic	All clear at time of test
TX052		TEV + Ultrasonic	All clear at time of test
TX053		TEV + Ultrasonic	All clear at time of test
TX062		TEV + Ultrasonic	All clear at time of test
TX063		TEV + Ultrasonic	All clear at time of test
TX065		TEV + Ultrasonic	All clear at time of test
TX066			Not energized at time of test
TX067		TEV + Ultrasonic	All clear at time of test
TX068			Not energized at time of test
TX074		TEV	All clear at time of test
		Ultrasonic	Sources of ultrasonic discharge detected – action recommended

Surface HV assets (Link Boxes)			
CL001		TEV + Ultrasonic	All clear at time of test
CL003		TEV + Ultrasonic	All clear at time of test
Surface HV assets (Air Break Switches)			
ABS0		TEV + Ultrasonic	All clear at time of test
ABS5		TEV + Ultrasonic	All clear at time of test
ABS6		TEV + Ultrasonic	All clear at time of test
ABS7			Not energized at time of test
ABS9		TEV + Ultrasonic	All clear at time of test
ABS10		TEV + Ultrasonic	All clear at time of test
ABS012		TEV + Ultrasonic	All clear at time of test
ABS19		TEV + Ultrasonic	All clear at time of test
ABS062		TEV + Ultrasonic	All clear at time of test
TX036 ABS		TEV + Ultrasonic	All clear at time of test
TX045 ABS		TEV + Ultrasonic	All clear at time of test
TX046 ABS		TEV + Ultrasonic	All clear at time of test
TX047 ABS		TEV + Ultrasonic	All clear at time of test
TX067 ABS		TEV + Ultrasonic	All clear at time of test
TX068 ABS			Not energized at time of test
TX066 ABS			Not energized at time of test
Surface HV assets (Motors and Generator Cable Boxes)			
CV701 Drive 1		TEV + Ultrasonic	All clear at time of test
CV701 Drive 2			Not energized at time of test
CV701 Drive 3		TEV + Ultrasonic	All clear at time of test
GEA1		TEV + Ultrasonic	All clear at time of test
GEA2		TEV + Ultrasonic	All clear at time of test
GEA3		TEV + Ultrasonic	All clear at time of test
Surface HV assets (Cable head terminations)			
5698		TEV + Ultrasonic	All clear at time of test
5797A		TEV + Ultrasonic	All clear at time of test
5797B		TEV + Ultrasonic	All clear at time of test
5798		TEV + Ultrasonic	All clear at time of test
53106		TEV + Ultrasonic	All clear at time of test
54100		TEV	All clear at time of test
		Ultrasonic	Sources of ultrasonic discharge detected Action required
Underground HV assets (Transformers)			
TX005		TEV + Ultrasonic	All clear at time of test
TX006		TEV + Ultrasonic	All clear at time of test
TX007		TEV + Ultrasonic	All clear at time of test
TX009		TEV	All clear at time of test
		Ultrasonic	Sources of ultrasonic discharge detected Action required

5.1 Assets Where Further Action is Recommended

The following are the assets where partial discharge was found and where the nature, location or type of discharge detected would lead to a recommendation from EA Technology to further investigate. The Example Customer, with more knowledge on the criticality, consequence and risk of failure together with the availability of outage opportunities would be able to better determine when any investigation or remedial work should be carried out.

5.1.1 SR001 Substation (Outdoor)

Inside the SR001 Substation outdoor switchyard, no TEV (internal PD) type discharges were detected. Most of the TEV data collected from the grounded structures throughout the yard indicated that there is a medium level of surface discharge / floating metal in the area. All assets scanned are unlikely to have any internal type PD because the UltraTEVPlus2 showed no indication of this during the scan.

TX022 was de-energised during this scan, also both CB4 and ABS3 were in the open position.

After scanning for TEV activity, all assets were scanned with the ultrasonic dish, two sources of ultrasonic discharge and two sources of corona were detected within the switchyard:

1. SR001 Substation (Outdoor) – ABS1

The south and center phase insulators on ABS1 were emitting ultrasonic activity that is consistent with non-destructive corona activity. See Table 1Figure 1. Table 1Figure 2 is the trace captured during the scan and does not indicate PD. Given the nature of the exposed metalwork, metallic sharp points and the single cluster of activity on the phase resolve plot, this source is classed as non-destructive corona – no action required.

Figure 1 ABS1

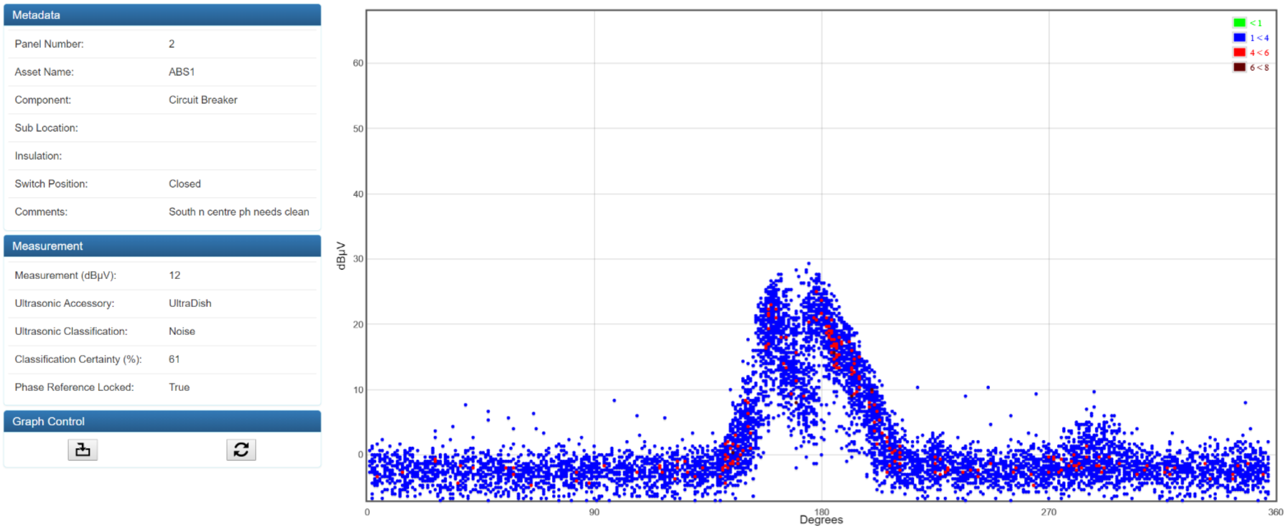

Figure 2 Ultrasonic trace from ABS1 showing Corona Discharge

2. SR001 Substation (Outdoor) – CB1

An ultrasonic source of surface discharge was detected on the middle of the center phase bushing on CB1. See Figure 3. With readings up to 12dBuV which was also phase resolved (activity 180 degrees apart,) this is classed as a strong surface discharge source. See Figure 4. To rule out any internal type PD happening within the 66kV CB. Given that the construction of the CB being porcelain, surface contamination is highly unlikely to degrade the insulation system, however, at the next available shutdown, it is recommended to inspect the CB at this point of discharge.

Two days later, this CB was revisited after heavy rains the previous day. Another ultrasonic scan was performed and all of the ultrasonic activity had disappeared. This confirms the above recommendation – all clear.

Figure 3 CB1

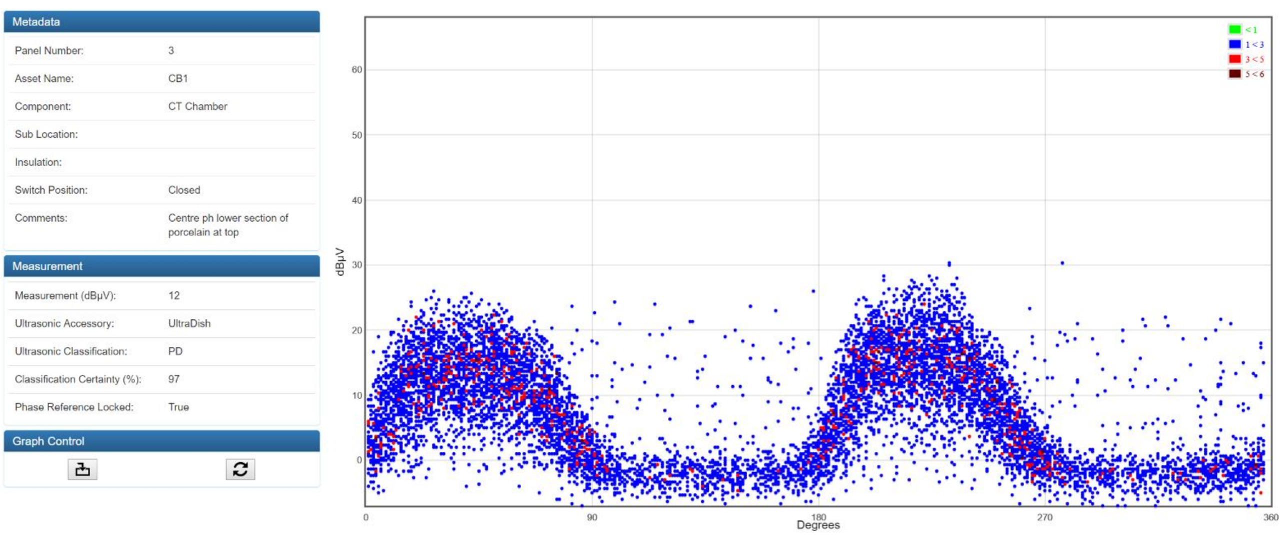

Figure 4 Ultrasonic trace from CB1showing surface discharge activity

3. SR001 Substation (Outdoor) – ABS3

An ultrasonic source of non-destructive corona was detected on the top of south phase insulator of ABS3. See Figure 5. The trace in Figure 6 is consistent with corona activity. Given the nature of the exposed metalwork, metallic sharp points and the single cluster of activity on the phase resolve plot, this source is classed as non-destructive corona – no action required.

Figure 5 ABS3

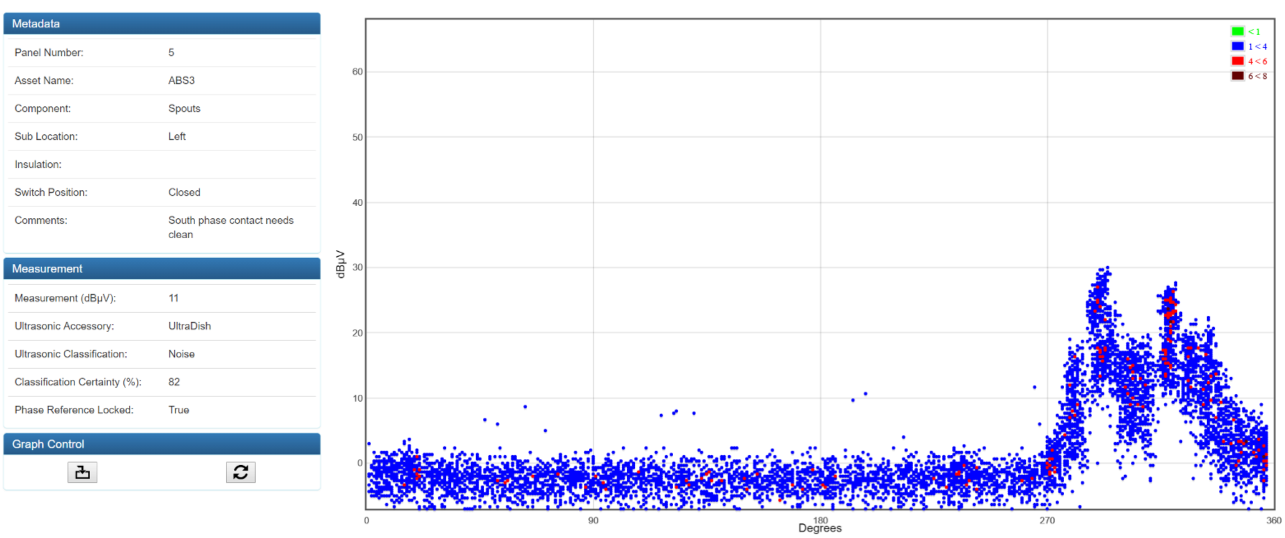

Figure 6 Ultrasonic trace from ABS3 showing corona activity

4. SR001 Substation (Outdoor) – TX021 North phase 66kV dropper

There was ultrasonic surface discharge detected from the HV side of the north phase, 66kV dropper at TX021. See Figure 7. Upon closer inspection with binoculars, it could be seen that the nut and bolt that is holding the conductor clasp are rusty. This is likely giving the surface discharge activity that has been detected. Figure 8 is showing a trace consistent with surface PD. The polymeric insulation on the HV dropper may also be deteriorated because of the activity of the bolt.

Recommend a close inspection of the polymeric insulator and replacement of the metallic hardware at the end of the insulator.

Figure 7 **North phase 66kV dropper at TX021**

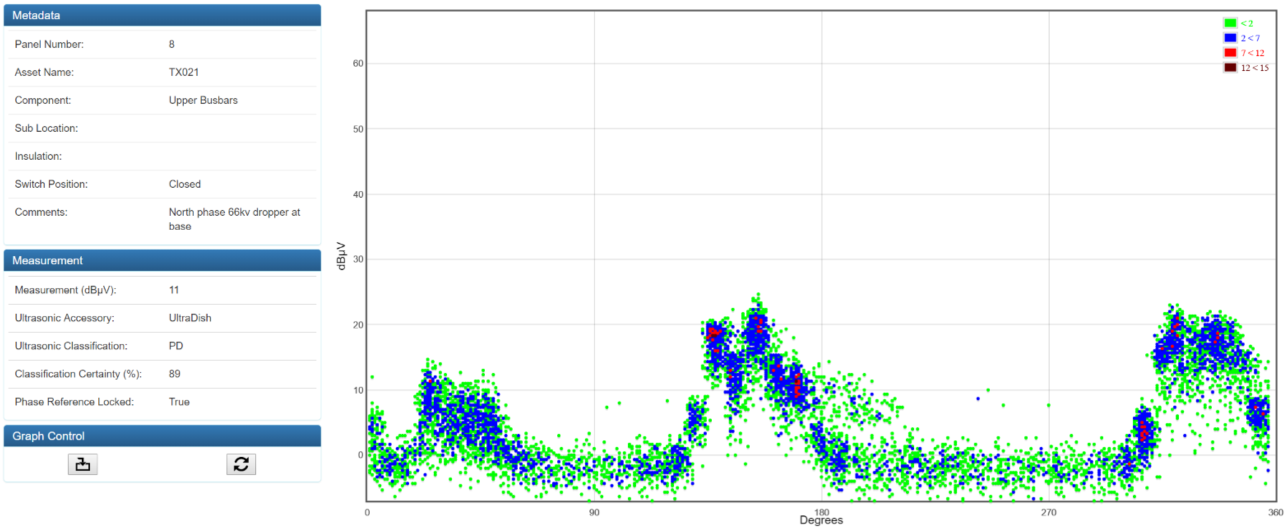

Figure 8 Ultrasonic trace from North phase 66kV dropper at TX021 showing surface PD activity

5.1.2 SR001 Substation (Indoor)

A potential source of partial discharge was detected from within the CB6 VT chamber. From examining the ultrasonic trace in Figure 9 and the TEV trace in Figure 10, the source detected does not indicate an internal void type discharge. It is more likely a ‘contact’ or ‘floating metalwork’ type discharge. Figure 10’s trace is typical of contact type discharge where there are two flat lines of activity, 180 degrees apart. The activity that causes this trace is tiny sparks that flash across a physical gap between two conducting assets as the volts rise and fall per sin wave. The amplitude of the trace won’t go above a certain level because the cause is tiny sparks across a gap of a certain length. Usually this type of activity does not cause any damage when it is not load related but it is always a good idea to investigate as it could indicate a poor HV connection and also because the contacts may be getting damaged from the constant sparking. This may be the contacts on the VT, HV fuses (if any) or any of the HV assets within this chamber not having the best connection. Check all clearances also. A crackling noise can be heard coming from behind the panel that also helps confirm it. This source is not a matter of urgency. Recommend inspect during the next maintenance period.

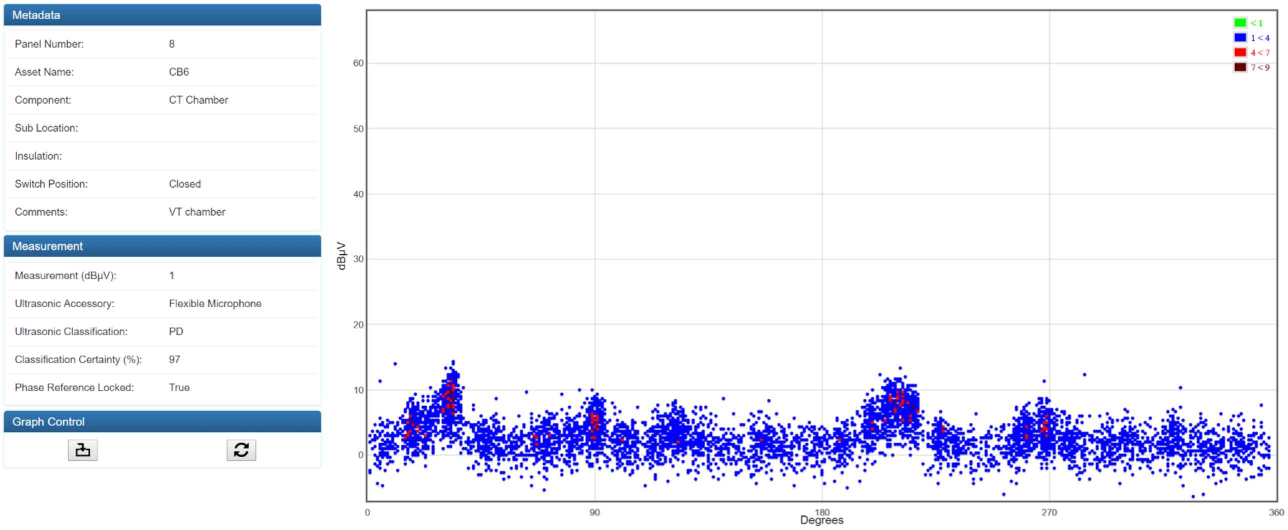

Figure 9 Ultrasonic results from CB6 VT chamber showing PD surface activity

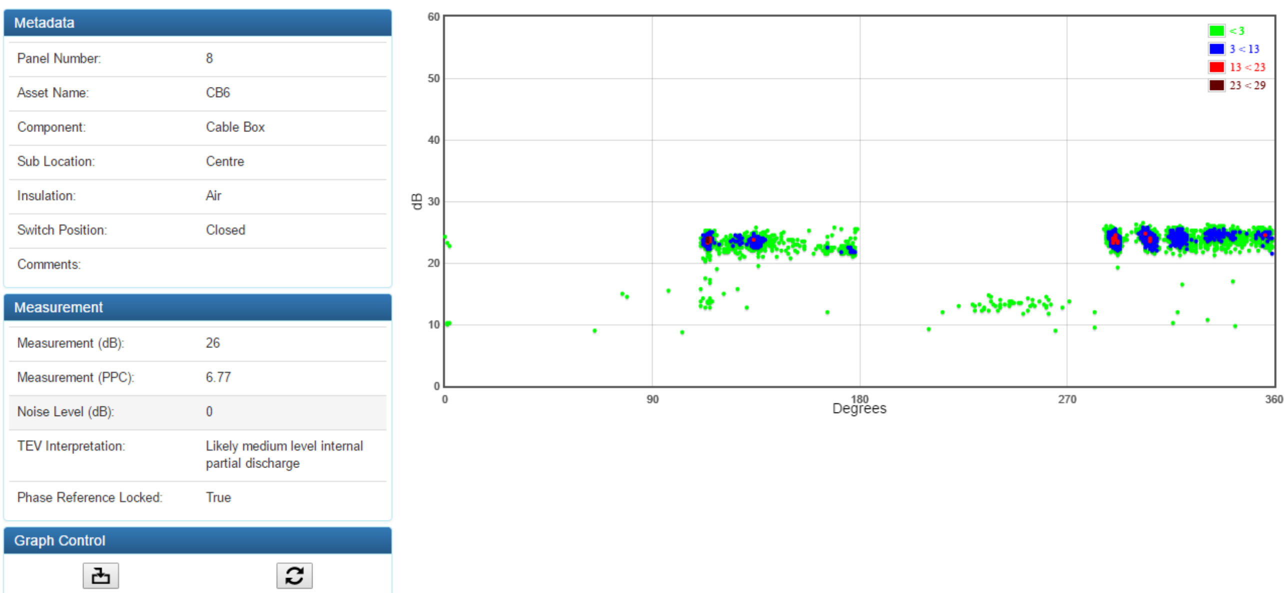

Figure 10 TEV results from CB6 VT chamber showing internal PD activity

5.1.3 SR001 Substation (Indoor) – CB9 HV Cable Chamber

A minor source of internal PD has been detected from within the CB9 HV cable chamber. See Figure 11. This source is around 15dB and 2 pulses per cycle. It is at a low level at the moment so is of no concern in the near future. Recommend retesting in one years' time to compare results and look for any changes in amplitude. The PD trace is consistent with internal void type discharge. A visual inspection during the next shutdown period would be a good idea also but unlikely to see anything wrong as the activity is consistent with internal void type PD. No ultrasonic noise could be heard here which likely rules out surface tracking.

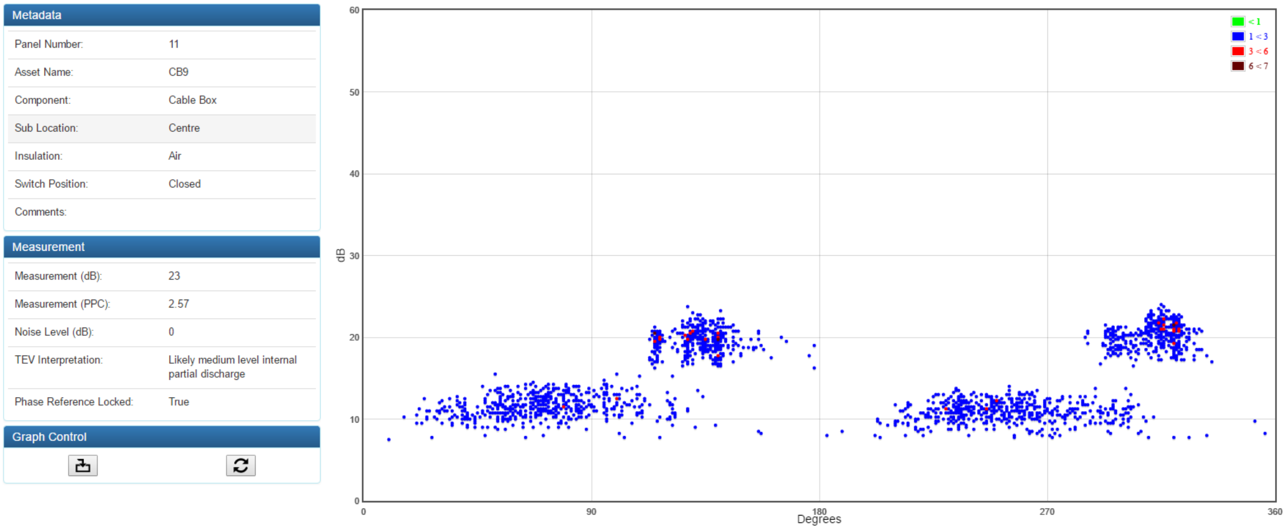

Figure 11 **Internal PD results from CB9 HV Cable Chamber**

5.1.4 TX045 Substation (Outdoor)

On the roof of the switch room inside TX045 substation, there are two sources of corona activity present.

1. TX045 Substation (Outdoor) - 66kV CB-Q100

Corona activity was detected at the top of the two CB bushings as seen in Figure 12. This is of no concern as corona on outdoor switchgear is non-destructive.

Figure 12 **66kV CB-Q100**

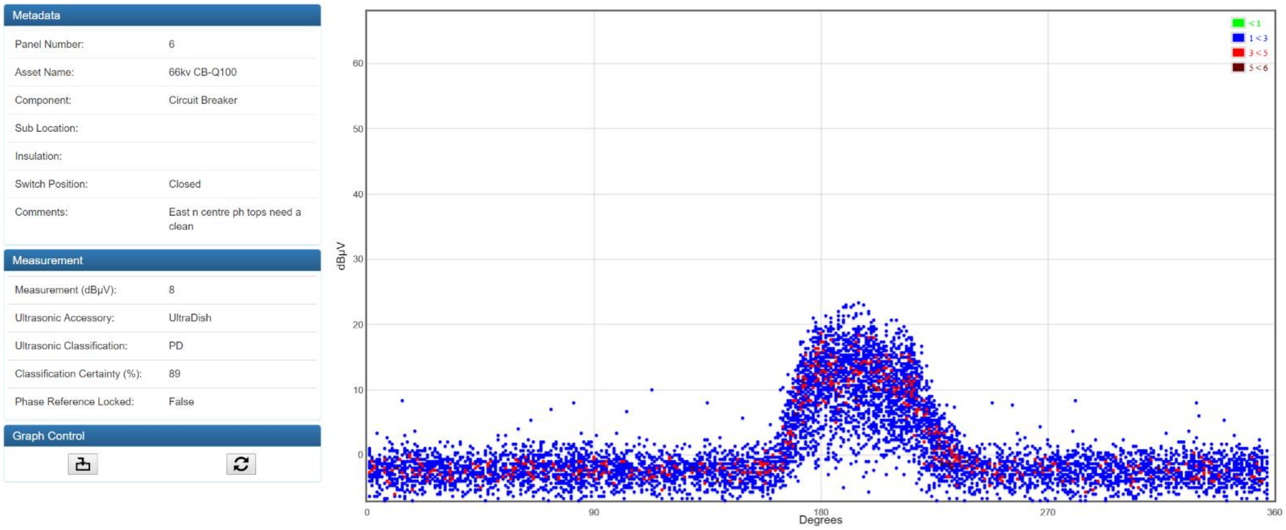

Figure 13 Ultrasonic results from 66kV CB-Q100 showing corona activity

2. TX045 Substation (Outdoor) – 66kV Rotary Switch-S100

Corona activity was detected at the top of the rotary isolator bushing as seen in Figure 14. This is of no concern as corona on outdoor switchgear is non-destructive.

Figure 14 66kV S100 Rotary Isolator

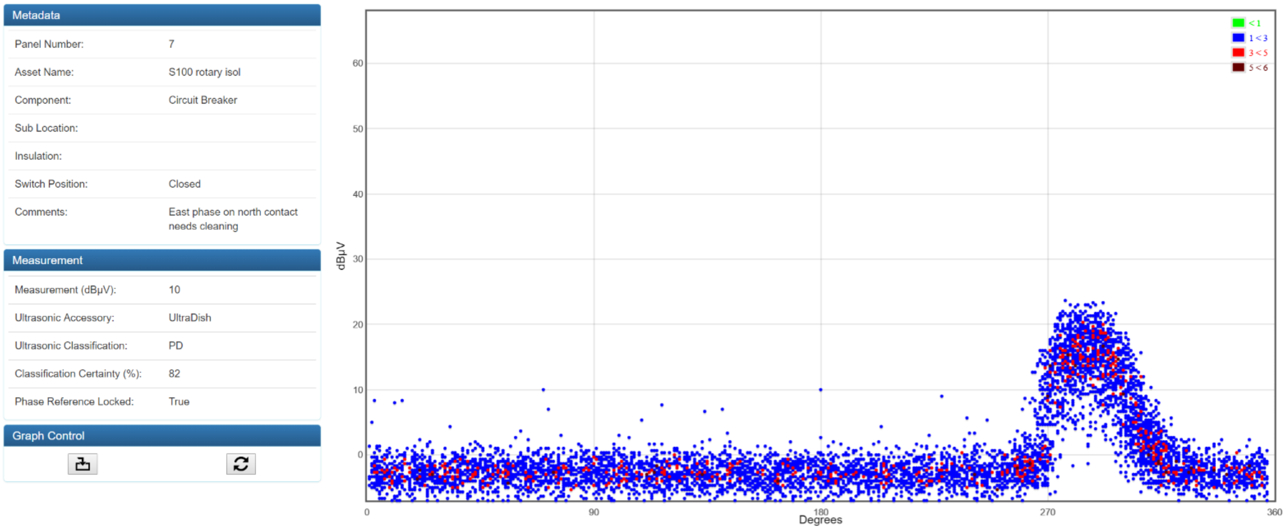

Figure 15 Ultrasonic results from 66kV S100 Rotary Isolator showing coronoa activity

5.1.5 TX074 11kV Cable Box

There was an ultrasonic source located to within the 11kV Cable Box of TX074 using the Ultra Contact Probe. It gave readings on average of 0dBµV (the scale starts at -7dBµV.) This indicates a low level but the HV asset ideally would not be making any noise at all. The audible noise recorded sounds like surface tracking somewhere on the HV assets. Recommend inspect during the next maintenance period. Look for signs of tracking on all HV assets especially the HV conductors. Check all clearances are adequate also.

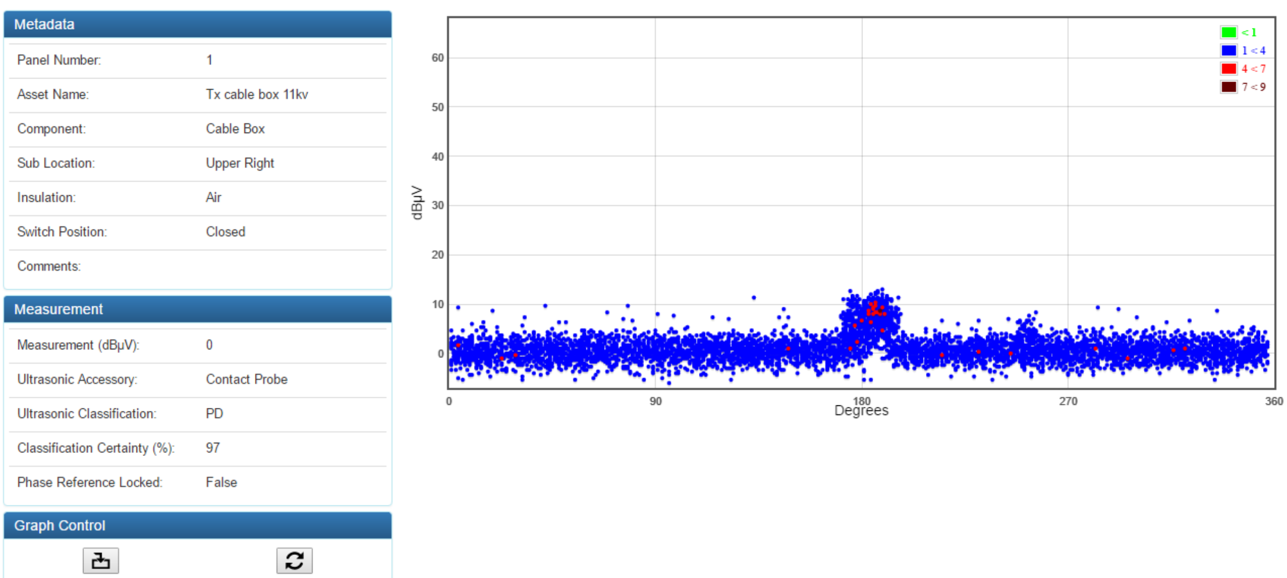

Figure 16 Ultrasonic trace from TX074 11kV Cable Box

5.1.6 HV Cable head termination 54100

On Tuesday 13th September, surface discharge was detected at the crutch of HV Cable termination 54100. See Figure 17 and Figure 18. This is indicative of a build-up of contamination on the termination. Upon closer inspection of the HV termination, it can be seen that the center phase and east phase conductors are crossed between each other and are in very close proximity to each other – likely touching, just above the crutch. This creates a high electrical stress point between the two conductors.

The next day, the area had a full day of rainfall.

We revisited this cable head termination the next day after the rain stopped, rescanned the termination for signs of ultrasonic activity and none could be detected.

This tells us that the termination is prone to a build-up of contamination from the atmosphere, and the contamination will likely be washed off during a decent downpour of rain. Also, there could be white deposits of Nitrous Oxide which is a by-product of PD that may have been sitting between the two conductors where they are likely touching at the high electrical stress point. This could have also been washed off during the rains.

It is recommended at the next available outage to closely inspect the termination for any surface discharge activity between the crossed phases. If any damage is visible, the damage is not repairable. Plans should be put in place to replace the HV termination. Also inspect the ground / bonding connections to make sure they are tight and clean.

There were five HV cable terminations tested in this area: 5698, 5798, 5797A, 5797B and 54100. All HV cable terminations were clear of ultrasonic and TEV activity except 54100.

Figure 17 **Cable head termination 54100**

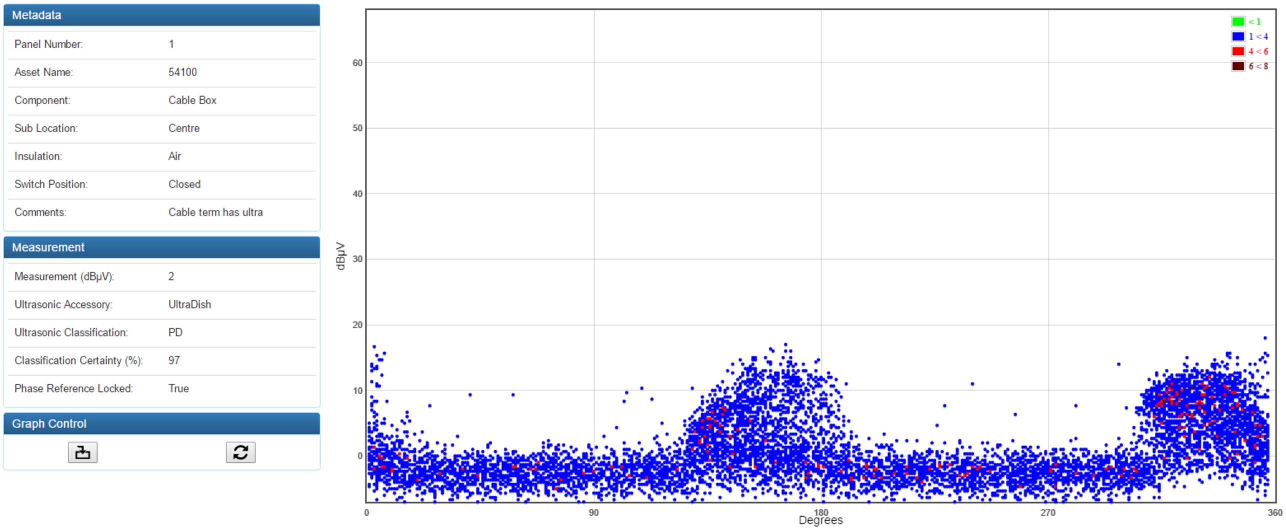

Figure 18 Ultrasonic results from Cable head termination 54100 showing Surface PD Activity

5.1.7 TX009

An ultrasonic discharge source was detected coming from behind the HV CB at TX009. Upon visual inspection of the HV chamber, it was picked up that the 'B' HV connection on the 11,000/110V voltage transformer was covered in green verdigris. This contact is very likely the source of ultrasonic activity. This contact needs to be cleaned and ideally replaced. If there is any surface tracking visible on the cast resin part of the VT, the VT should be planned to be replaced. The whole HV chamber should be inspected for any other evidence of surface tracking – the VT connection may not be the only source.

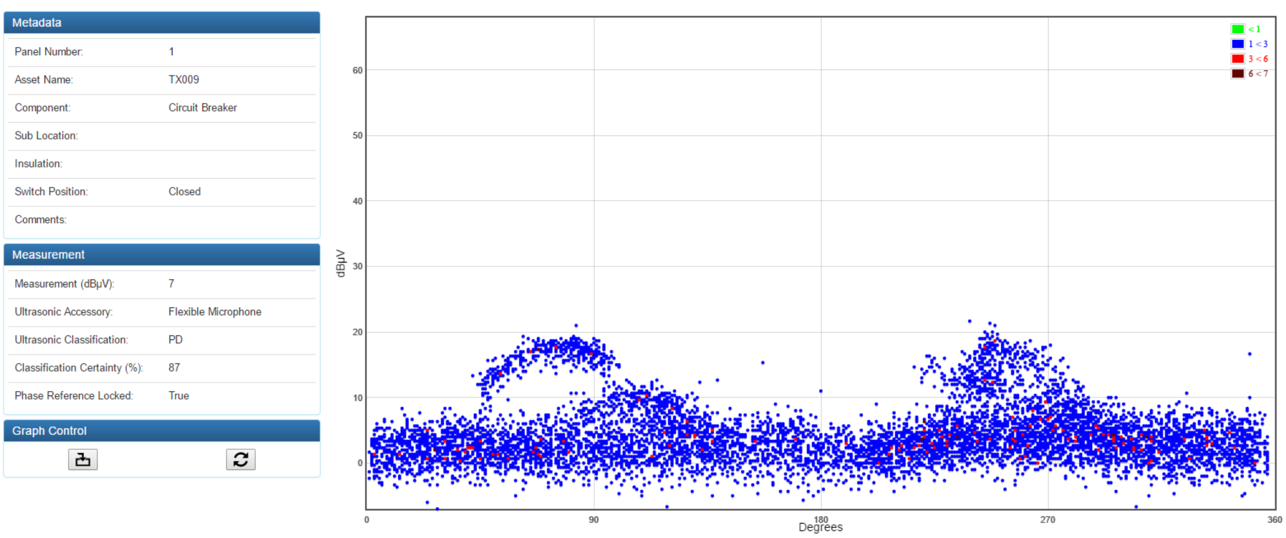

Figure 19 Ultrasonic data recorded from TX009 showing PD activity

6. Conclusions

C1. Non-destructive corona found on ABS1 inside SR001 substation.

C2. Ultrasonic surface discharge activity detected on centre phase of 66kV CB1. This activity was not present after a day of rain in the area – this proves that the surface discharge activity was caused by surface contamination from the atmosphere.

C3. Non-destructive corona found on ABS3 inside SR001 substation

C4. A rusty nut and bolt at the base of the polymeric 66kV dropper insulator above TX021 on the north phase was located. This nut and bolt is emitting ultrasonic surface discharge activity.

C5. Behind the VT chamber on CB6 inside the SR001 substation, an ultrasonic surface discharge source was detected. Likely a 'contact' or 'floating metalwork' type issue.

C6. An internal void type discharge of a low level was detected coming from the HV cable chamber of CB9 inside SR001 substation.

C7. Non-destructive corona found on CB-Q100 on top of TX045 substation.

C8. Non-destructive corona found on Rotary switch S100 on top of TX045 substation.

C9. A low level ultrasonic source of discharge was found coming from within the TX074 11kV Cable Box.

C10. An ultrasonic surface discharge source was detected from above the crutch of HV cable head termination 54100. On closer inspection, it can be seen that two of the three HV phases are crossed over in very close proximity to one another. This is likely to cause a point of high electrical stress which can cause surface partial discharge at this point. After a day of rain, the surface discharge source was no longer present.

C11. An ultrasonic source of surface tracking was detected coming from behind the HV CB at TX009. A visual confirmation has found the likely source. It was seen that the 'B' HV connection on the 11,000/110V voltage transformer was covered in green verdigris.

7. Recommendations

R1. The corona found on ABS1 inside SR001 is of no concern as it is in open air.

R2. The surface discharge activity on 66kV CB1 is unlikely to have caused any damage to the porcelain insulation system of the circuit breaker. At the next available shutdown, it is recommended to closely inspect the porcelain for any signs of damage.

R3. The corona found on ABS3 inside SR001 is of no concern as it is in open air.

R4. The rusty nut and bolt on the polymeric insulator above TX021 may be deteriorating and hence losing its mechanical strength. At the next available outage, it is recommended to replace the nut and bolt, replace any other faulty assets in its vicinity. Also, as polymeric insulation is more susceptible to surface damage than porcelain, the base of the polymeric insulator should be closely inspected for signs of degradation – replace if any degradation found.

R5. Although not urgent, it is recommended that at the next available outage, the VT chamber panel on CB6 inside SR001 substation should be removed and all HV assets within this chamber be inspected for signs of a ‘contact’ or ‘floating metalwork’ type discharge. This may be poor HV connections somewhere in the panel. Clean the inside of the panel and all assets within. Repair / replace any damaged assets as required.

R6. As the PD source within the HV cable chamber of CB9 is an internal void type discharge, it is unlikely that a visual examination will find any defects. However, recommend a visual examination of this chamber if an outage allows. Recommend re-test in one years’ time to compare any changes.

R7. The corona found on CB-Q100 on top of TX045 substation is of no concern as it is in open air.

R8. The corona found on Rotary switch S100 on top of TX045 substation is of no concern as it is in open air.

R9. It is recommended that at the next available outage, this 11kV cable box be inspected for any signs of surface tracking on all HV assets within. Check all clearances to earth straps also. If any signs of tracking are found on the cables, plan to re-terminate the cable. Check for closely crossed phases and the gaps between this insulation.

R10. The HV cable head termination 54100 should be closely inspected at the next available outage. Attention should be paid to the area where the two phases cross one another. If any signs of surface tracking are found, plans should be put in place to re-terminate the HV cable.

R11. It is recommended that at the next available opportunity, the ‘B’ HV contact on the VT inside TX009 substation be cleaned up with plans to be replaced. If this is not possible, consider replacement of the VT. Also, the cast resin insulation around the HV contact should be closely inspected for signs of surface tracking. If this is the case, plans should be put in place to replace the VT as the damage is not repairable. Inspect the rest of the HV chamber as the VT contact may not be the only source of PD.

Appendix I Investigation of surface discharge activity

Evidence of surface discharge activity evidence should be visible on the surface insulation and metallic components. In most circumstances it can be easily observed using a strong light source, however for early stage discharge activity a magnifying glass may be required.

Inspection of components normally requires an outage however some switchgear models have inspection windows around the switchgear and therefore an initial inspection can sometimes be carried out with the switchgear in service.

For general investigations the presence of white powder in the base of the switchgear or on horizontal surfaces is a good initial indication that a discharge source is present within a particular switchgear panel. A subsequent closer examination of adjacent components often then reveals the precise location. Evidence of activity is often identified by the presence of white powder, carbonisation, tracking, nitric acid looking like condensation and staining of metallic surfaces, etc.

The following section describes the procedures for investigation of specific components such as the cable box, circuit breaker spouts, VTs and bus sections. Note however that some points are applicable to investigations carried out on most components

Discharge activity detected within cable box / terminations

Since surface partial discharge activity most often occurs at surface interfaces, cable terminations are one of the most common areas for discharge activity to occur. Problems can often arise due to poor installation practice, in particular where the cable stress relief sleeving has been cut back too far and/or the phase cables have been crossed. Under these circumstances discharge activity can occur between the phases. Detection and subsequent identification of discharge activity in this region nearly always results in the cable box being re-terminated. This is because the cable sheath is permanently damaged and if allowed to remain in service will ultimately fail.

The cable box should be inspected (using a strong light source) looking for evidence of surface discharge activity, with particular attention being paid to the polymeric surfaces of the terminations. Often white powder (nitrous oxide) is observed between the cables, generally at the crutch of the cable around the stress relief sleeving. This is formed due to chemical breakdown of the insulation during the early stages of discharge activity. At more advanced stages a nitric acid (Nitrous Oxide combined with humidity) solution is formed, looking like condensation on the surfaces of internal components. This acid formation leads to significant staining and corrosion of the steel box and copper components.

Discharge activity detected within circuit breaker spouts

Partial discharge activity often occurs within the circuit breaker spouts due to surface contamination, misalignment of circuit breaker or manufacturing defects. Surface discharge activity is most common for resin rather than porcelain insulation due to its increased sensitivity to surface contamination.

Surface discharge activity in the spouts is best detected from the front of the switchgear with the panel door open to improve the air path. By careful use of the instrument, the discharging phase can often be identified.

Prior to any investigation of partial discharge activity consideration should be given to the de-energisation and racking out process. Failure of switchgear tends to occur during the switching and racking out process due to the creation of electrical transients in the system. Furthermore, since partial discharge activity has been detected within the spouts, there is an increased risk of plant failure and danger to operational personnel. For safety reasons therefore, consideration should be given to remote switching of the circuit breakers. Also, where high levels of activity have been detected it would be prudent to de-energise the switchboard remotely prior to any switching operation.

Once de-energised the circuit breaker spouts and contacts should be visually inspected using a strong light source and signs of partial discharge activity should be noted such as:

- The presence of green verdigris on the non plated area of the isolating contact.
- Black staining on the resin surface of the spout moulding.
- Mottling of the metallic surfaces.
- Formation of nitric acid, which looks like condensation on the surface of the spout.
- Evidence of carbon tracking and tree formations.

The extent of the remedial action will depend upon the results of the visual examination. Minor sources of discharge activity caused by surface contamination such as dust and moisture may be successfully removed by simply cleaning the insulation using an appropriate cloth and cleaning fluid. However, it should be noted that discharge activity often returns within the same location and in such cases can rapidly increase in severity over a relatively short period of time. More advanced deterioration i.e. surface etching and carbonisation of the cast resin surfaces may require components such as spouts, contacts and sometimes the entire removable truck to be replaced.

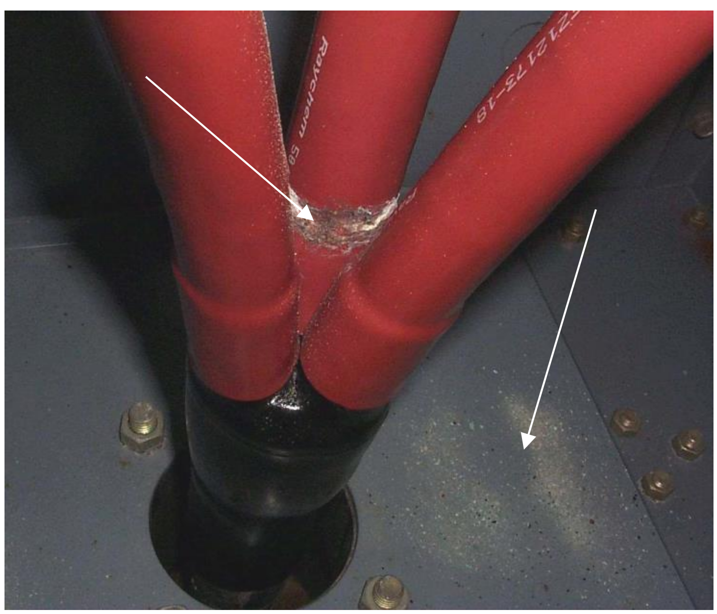

Figure 1 **Surface discharge activity between cable phases.**

Note that white power in the base of the cable box or on horizontal surfaces is a good indication that discharge activity is present within switchgear.

Figure 2 Evidence of advanced discharge activity within an 11kV switchgear air insulated cable box.

Note the extensive rusting of steel box due to the formation of nitric acid within box as a result of partial discharge activity.

**Figure 3 Discharge activity between cable phases within an air insulated cable box.
Note white powder deposit on polymeric surfaces.**

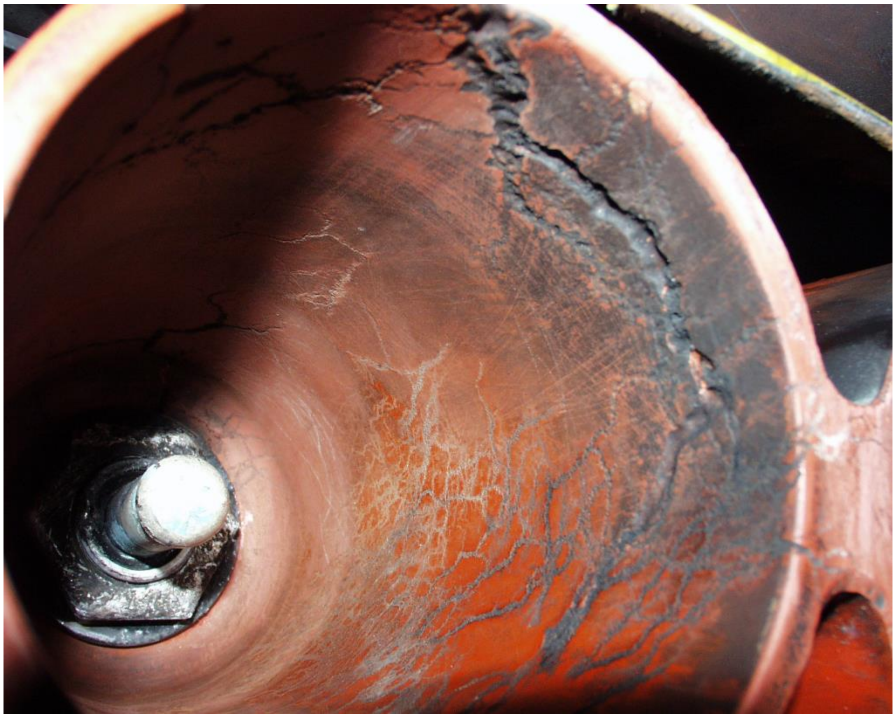

Figure 4 Advanced surface discharge activity within the resin spout of an 11kV circuit breaker.

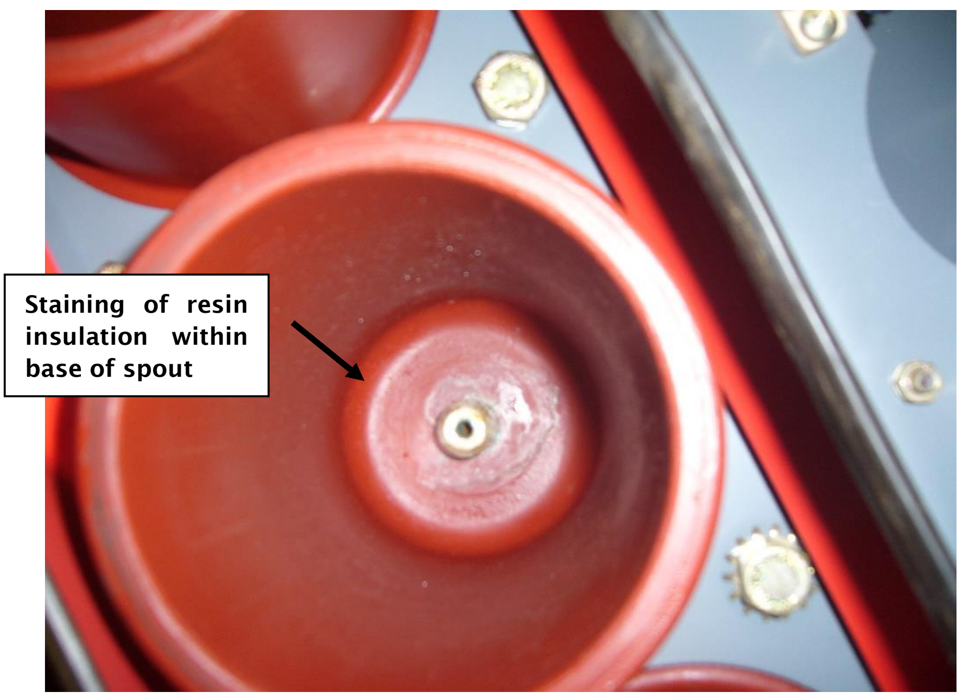

Figure 5 Staining of resin insulation within 11kV circuit breaker spout caused by the effects partial discharge activity

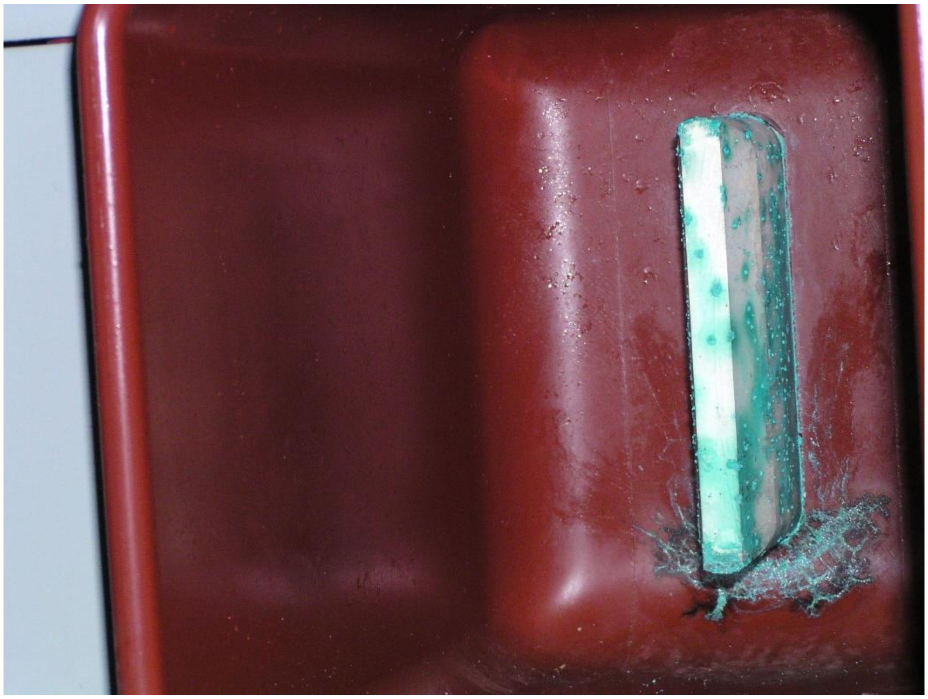

Figure 6 Evidence of surface discharge activity within fixed portion resin spout of an 11kVcircuit breaker.

Figure 7 Evidence of discharge activity within a porcelain contact cluster of an 11kV circuit breaker.
Note the green corrosion product on the surface of the contact cluster.

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