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# Addressing Noise Sources During Online PD Testing

Timothy Erwin

National Sales Manager, EA Technology LLC

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# Agenda

- Review: What is PD?
- Example 1: Noise (?)
- Example 2: Power inverters and different technologies
- Example 3: Dry-type transformers
- What can we do to avoid these problems?
- What did we learn?

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## EA Technology Group

- Originally established as R&D Center for the UK Electricity Industry. Privatized in the early 1990s.
- Provides research, strategic engineering consultancy, HV asset condition assessment services, specialized instrumentation and asset management software and consulting.
- Discovered the TEV effect in 1978 and developed the first practical detection method in 1982
- Instrumental in the development of PAS-55 and ISO-55000
- Maintains a large forensic investigation lab equipped with the latest technology and staffed by highly experienced scientists.

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# Is Partial Discharge Real?

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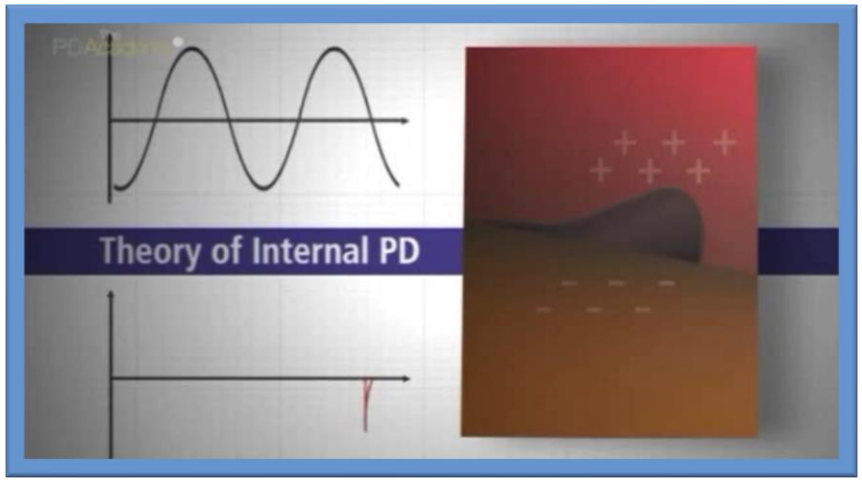
# What is Partial Discharge?

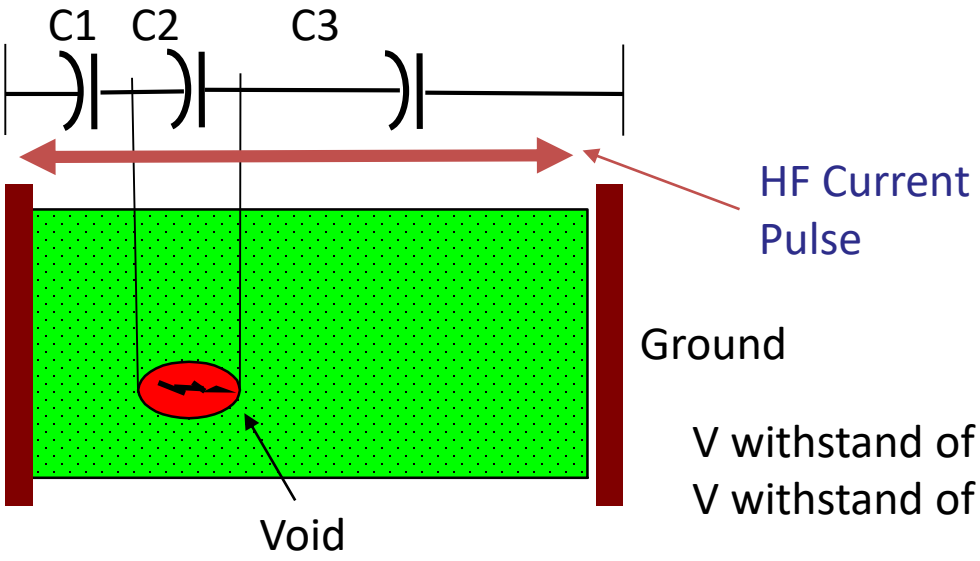
**PD** failure process

- Multiple causes
- Starts small
- ALWAYS gets worse
- Leads to FLASHOVER




**PD is the inability of a portion of the insulation to withstand the electric field applied to it**

**Partial Discharge** - A flashover of part of the insulation system due to a localized electric field greater than the dielectric withstand capability of that part where the overall insulation system remains capable of withstanding the applied electrical field.




V withstand of C2 < applied field
V withstand of C1&C3 > applied field

**One effect of this flashover is a high frequency current pulse that travels through the capacitance of the insulation (C1 & C3)**

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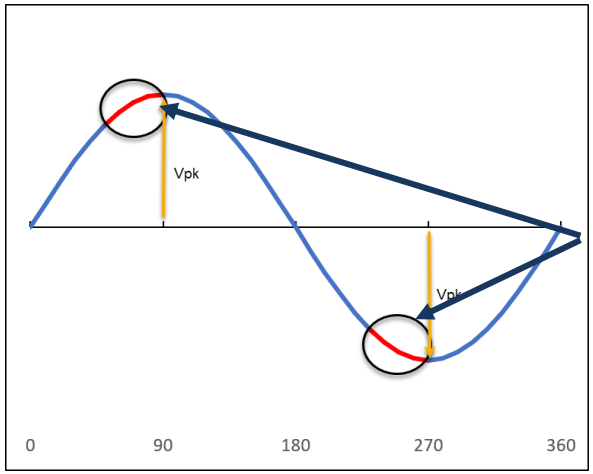
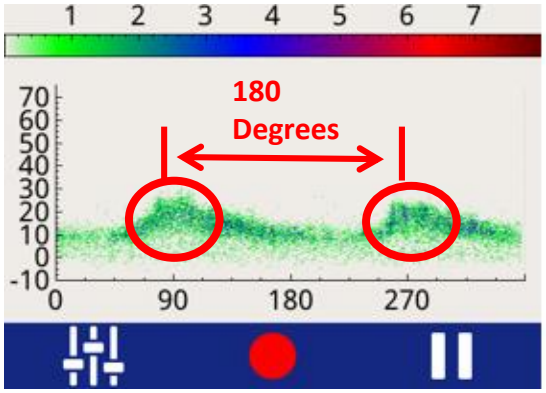
# Phase Resolved Plots




Partial Discharge tends to occur on the rising edge of the voltage sine wave. As such, PD impulses tend to be synchronized to the AC waveform and 180 degrees apart.

Phase Resolved plots show PD impulses on a power system cycle so groupings 180 degrees apart can be seen.



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# Online test classifications

- Ultrasonic/Acoustic testing – through louvers, vents, contact sensors, and parabolic dishes (Audio over 20KHz)
- TEV testing – Makes use of the Transient Earth Voltage phenomenon to safely detect internal discharge from outside cabinets
- RFCT testing* - By attaching RFCT to cable ground straps, the PD current can be safely measured on live cables
- RF Testing – Specifically designed directional and non-directional radio receivers can pickup the EMI generated by PD

  * installing RFCT on live cables requires opening the HV compartment and appropriate safety measures

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# Types of PD

- **Internal discharges** occurring in defects, voids or cavities within solid insulation (TEV, UHF, RFCT, IR)

- **Surface discharges** occurring across the insulation surface (Ultrasonic, UHF, RFCT)

- **Corona discharge** occurring in gaseous dielectrics in the presence of inhomogeneous fields (Corona Camera, Ultrasonic, UHF,)

- **Contact discharge** occurs on floating metal in high field conditions (TEV, Ultrasonic, UHF)

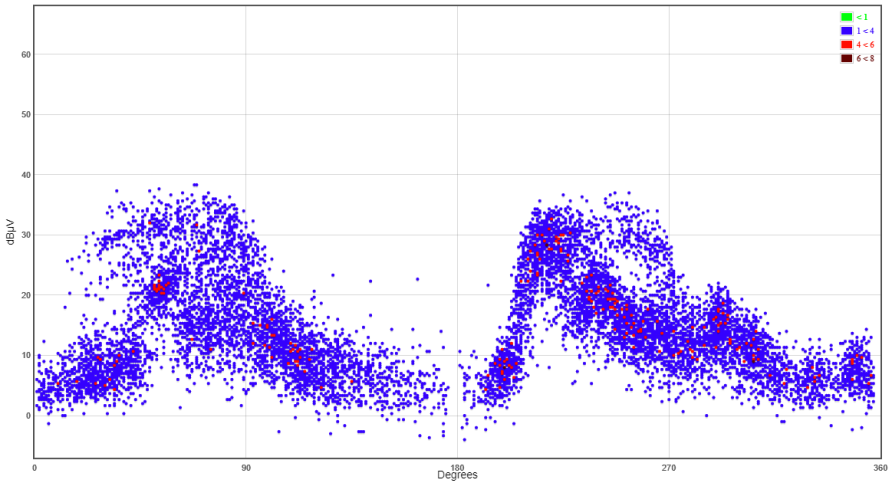
# Surface PD – Flexible microphone

- 11kV HV Cable phases too close to insulated plastic boot
- Can be just heard with naked ear

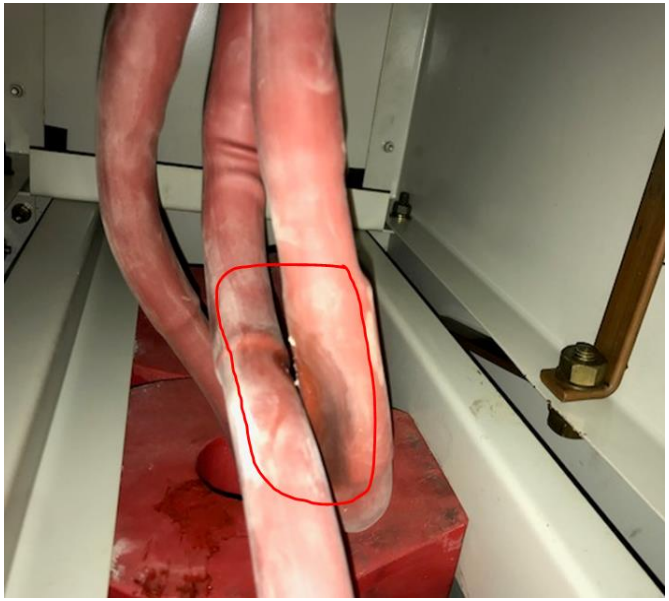
| Metadata | |
|---|---|
| Panel Number: | 2 |
| Asset Name: | |
| Component: | Cables |
| Sub Location: | Red 1 |
| Insulation: | XLPE |
| Switch Position: | Closed |
| Comments: | White discharfe seen on red heatshrink at base of white cover |

| Measurement | |
|---|---|
| Measurement (dBµV): | 24 |
| Ultrasonic Accessory: | Flexible Microphone |
| Ultrasonic Classification: | PD |
| Classification Certainty (%): | 94 |
| Phase Reference Locked: | True |

Graph Control



# Surface PD, Crossed phases – Contact Probe

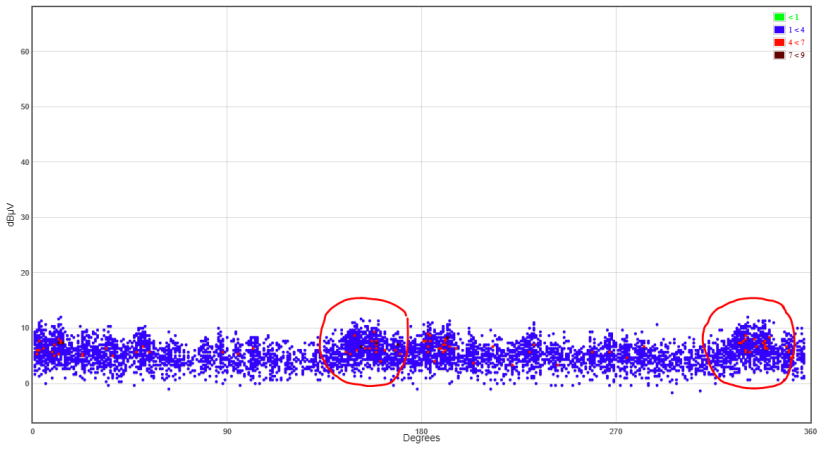


- 11kV HV Cable phases too close – crossed phases
- Can see 180 degree clustering
- Difficult to determine from single reading but obvious on site as only difference in switchboard

| Metadata | |
|---|---|
| Panel Number: | 4 |
| Asset Name: | |
| Component: | Lower Busbars |
| Sub Location: | |
| Insulation: | |
| Switch Position: | Closed |
| Comments: | Back panel bus section |

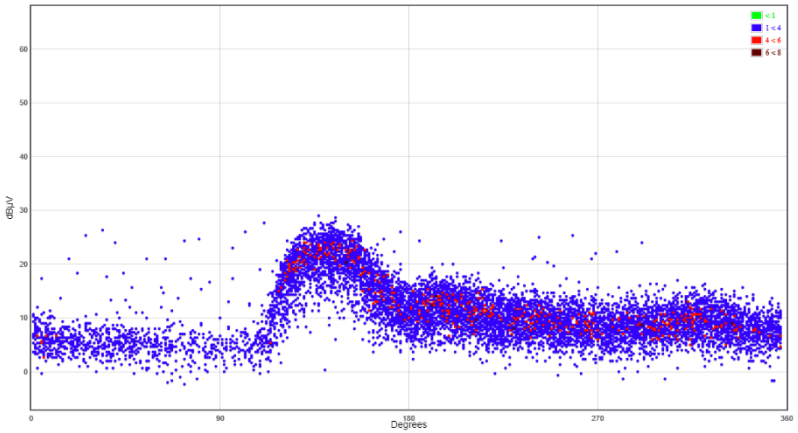
| Measurement | |
|---|---|
| Measurement (dBµV): | 1 |
| Ultrasonic Accessory: | Contact Probe |
| Ultrasonic Classification: | PD |
| Classification Certainty (%): | 76 |
| Phase Reference Locked: | True |
| Phase Reference Source: | Photo |

Graph Control



# Corona / Surface PD – Flexible Microphone

- 11kV connection at rear of CB spouts, poor insulation interface
- Note white build up, also rust and green verdigris
- Corona with some surface PD – can be seen in phase resolved pattern
- Corona tends to have a ‘deeper’ sound

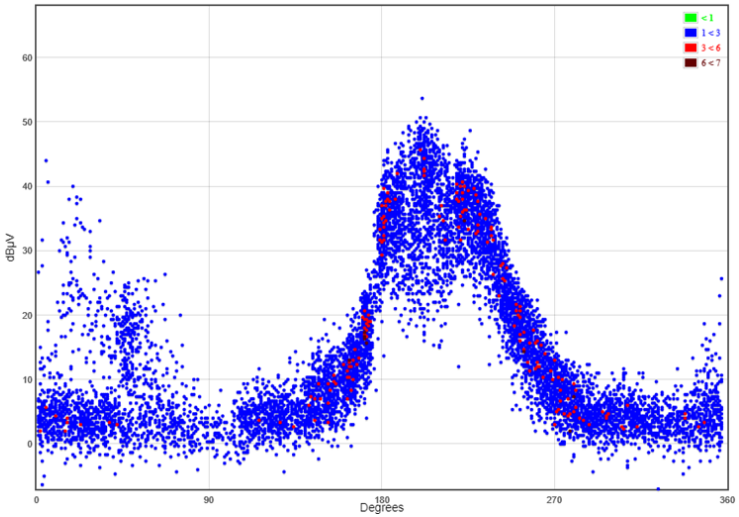



# Corona, 132kV Isolator - Ultrasonic

- 132kV isolator, sharp point into air
- High ultrasonic
- Note one peak of activity on one half of sine wave

| Metadata | |
|---|---|
| Panel Number: | 2 |
| Asset Name: | 132kV Tx Isol |
| Component: | Upper Busbars |
| Sub Location: | |
| Insulation: | |
| Switch Position: | Closed |
| Comments: | White ph on Tx side corona |

| Measurement | |
|---|---|
| Measurement (dBµV): | 36 |
| Ultrasonic Accessory: | UltraDish |
| Ultrasonic Classification: | PD |
| Classification Certainty (%): | 64 |
| Phase Reference Locked: | True |
| Phase Reference Source: | E Field |



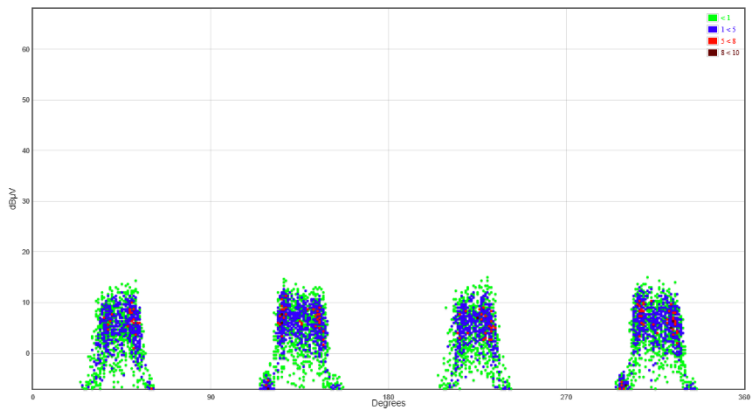
# Magnetic Transformer Vibration, Contact Probe

- 11kV Transformer magnetic vibration noise detected with contact probe – no problem detected
- Sound goes away when metal plate is physically leant on – stops vibrating
- Note 4 clusters of activity in phase resolved plot, not indicative of PD

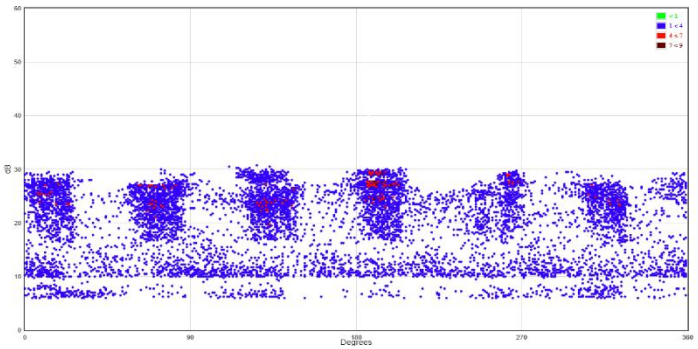
| Metadata | |
|---|---|
| Panel Number: | 1 |
| Asset Name: | Tx |
| Component: | Cable Box |
| Sub Location: | Centre Right |
| Insulation: | Air |
| Switch Position: | |
| Comments: | Possible vibration, goes away when touching metal with hand |

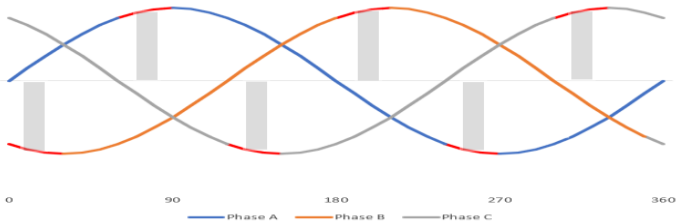
| Measurement | |
|---|---|
| Measurement (dBµV): | 2 |
| Ultrasonic Accessory: | Contact Probe |
| Ultrasonic Classification: | PD |
| Classification Certainty (%): | 74 |
| Phase Reference Locked: | True |
| Phase Reference Source: | Manual |

Graph Control




# Noise, Industrial- TEV


- Industrial noise from factory load - 212.41 PPC count
- No PD signals can be detected

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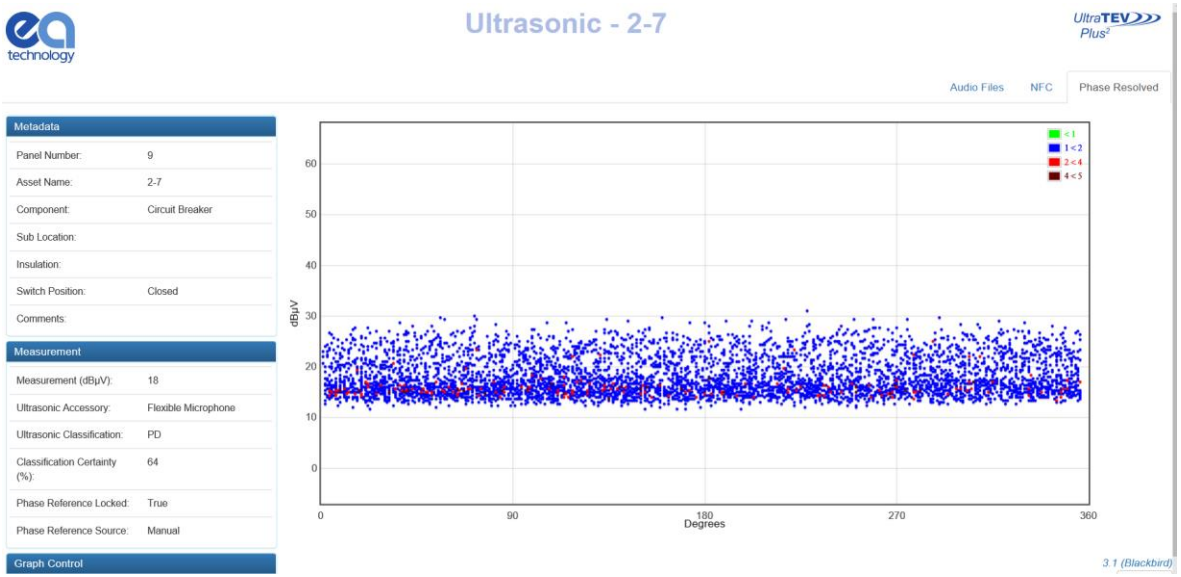
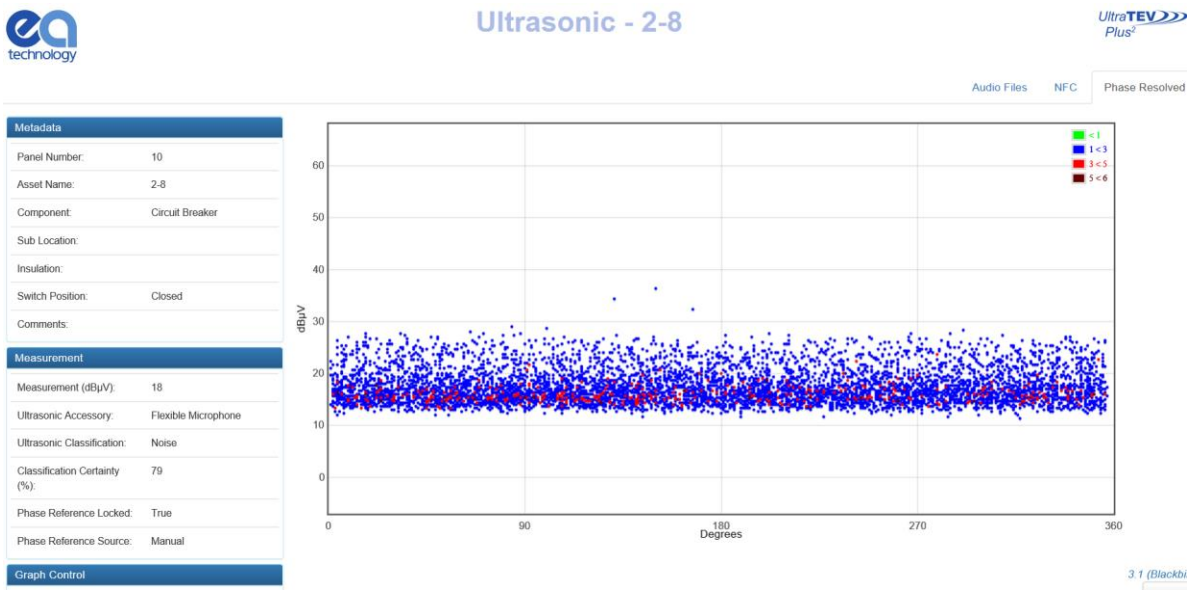
# Example 1: NOISE(?)




- "Typical" switchgear
- Breakers, busbars
- No motors or rotating equipment
  - PD Indication
  - Low certainty
  - No Phase Resolve Plot
  - Let's take a listen…

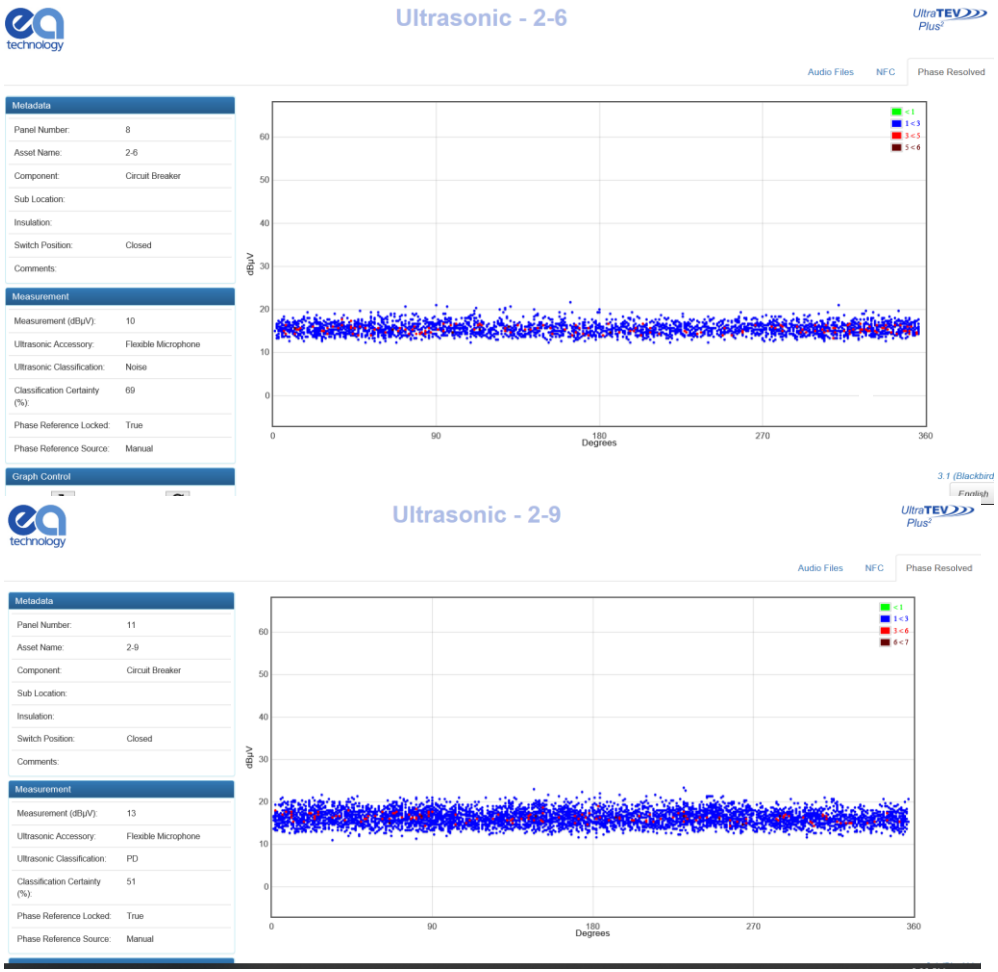
- That is something
- Not really electrical but close
- Sounds a little more mechanical




Neighboring cell:

- Similar levels and pattern
- Classified as **noise**
- Fairly high % certainty

Very similar sound




- Located midway on 9 section lineup
- Classified as Noise
- Levels similar. (All sections)
- Rotated microphone, levels stayed consistent

- End section of gear
- Near large floor circulating fan

- Audio is high pitched, well above 120 Hz
- Not like sections 7 and 8.
- Most likely from fan, possibly bearing noise

- High levels of background noise most likely caused by circulation fans and AC units within an isle's width of the gear.
- Because of mid summer temps we were unable to turnoff auxiliary fans.
- There is something at sections 7 and 8. Not necessarily PD, possibly loose metal or panel vibrating.
- Our work permit did not allow opening of energized equipment. Investigation is ongoing.
- UHF detector @ 800 MHz probably would have eliminated a lot of background noise giving better indication of PD

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# Example 2: Power inverters and different detection technologies

# Electronic switching inverters

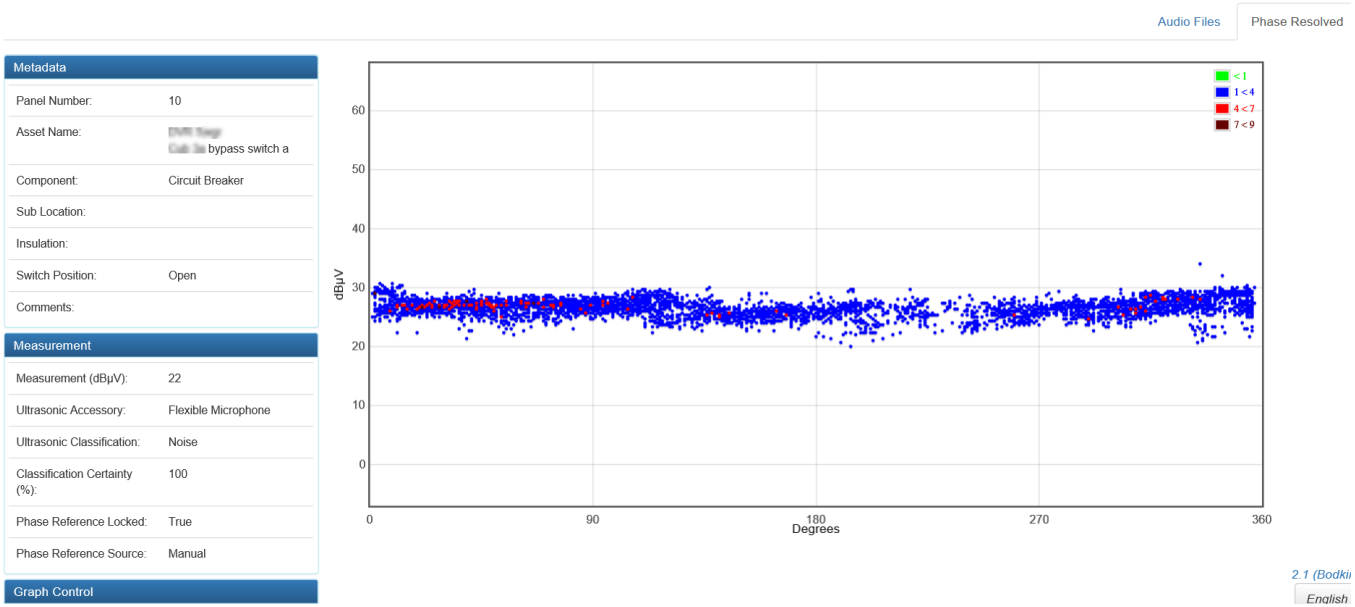
Locations with switching inverters are problematic as they tend to be very noisy in the spectrums where we look for PD.

Common in windfarms, solar farms and scientific manufacturing facilities that need very clean power

These locations also tend to be tight on space and utilize dry type transformers that also radiate their own noise signatures.

Operate in the range of 10’s to 100’s KHz

# Example 1: Scientific manufacturing facility in room with switching inverters




Ultrasonic

- Background levels in room high
- Significant noise level
- Gain could be masking lower level PD

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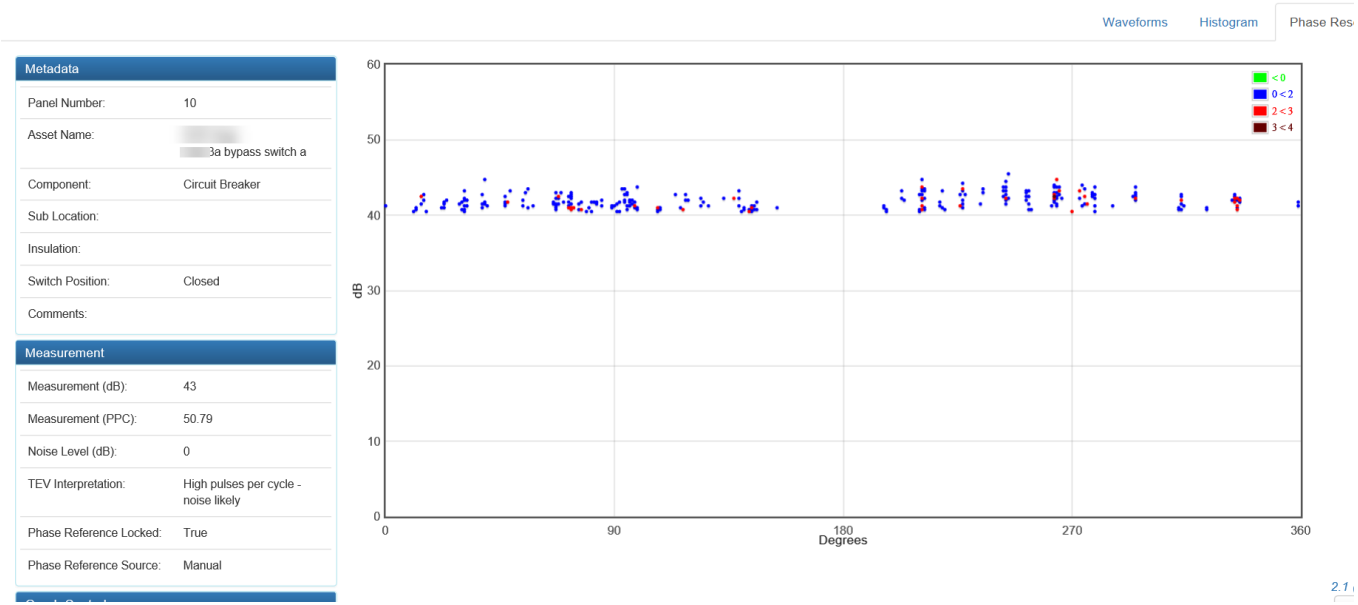
# Example 1: Scientific manufacturing facility in room with switching inverters



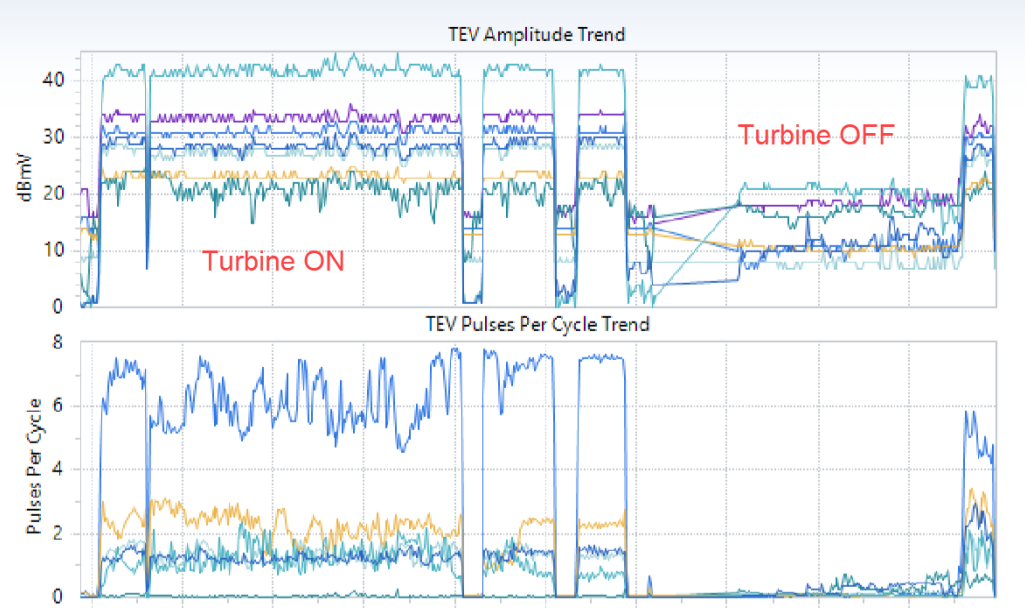

TEV:

- High levels 43 Db
- High Pulse Per Cycle count - 50.79
- Within background levels of 39Db and 41.15 PPC

Example 2: Wind Turbine with known PD in basement mounted transformer

- Transformer had been tested with off-line equipment and it was determined that there was PD on at least one winding
- Testing with multiple online technologies was performed including
  - TEV
  - Ultrasonic
  - RFCT on transformer incoming, tail and chassis ground straps
  - Radiometric (RF) PD Detector
- Different test equipment was used for the TEV and Ultrasonic, RFCT on cable straps and the RF PD detector.
- Tests were run with the turbines generating and with them off and transformer back fed from the 33Kv side. This allowed a comparison of the affect of the inverters when generating.

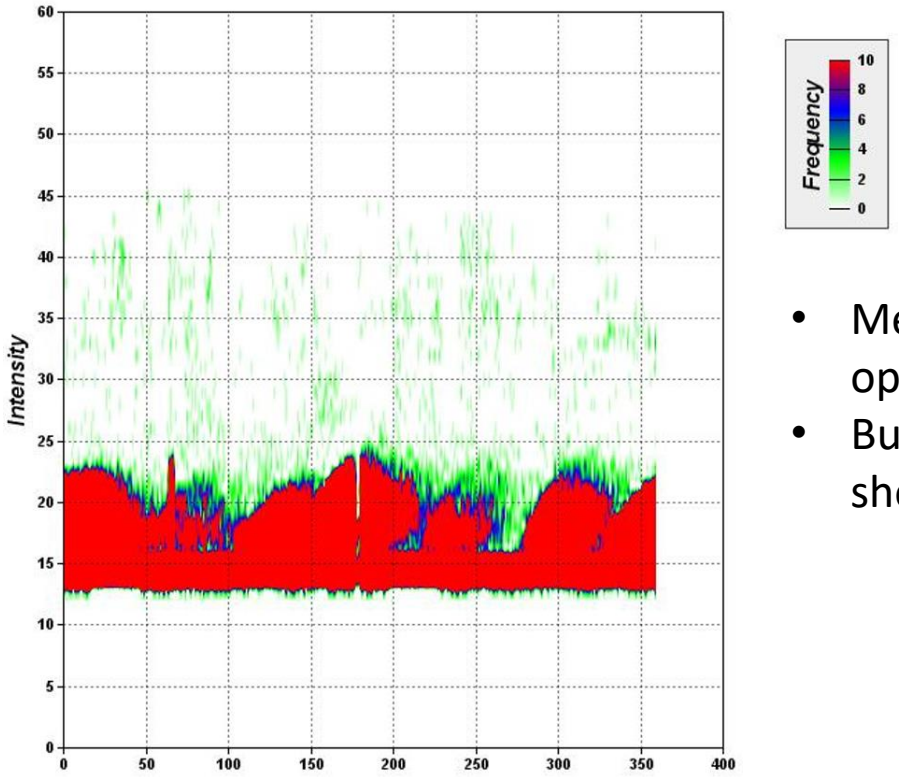
# TEV: Sample Average amplitude and PPC over 24 hours




- When turbine is on amplitudes are high
- When turbine is off (windspeed dropped) amplitudes drop. From 20-42 dBmV to 0-16 dBmV.
- Alarm threshold is 29 dBmV
- Full time monitoring or planned interruption of turbine operation would be necessary.

Measurements are recorded on 3 types of probes- internal and external types and an antennae at multiple locations near each winding

# **TEV:** Phase resolved plot- Probe on transformer panel.




- Measurements with inverters operating will not allow TEV detection
- But with inverters stopped the PRP shows PD.

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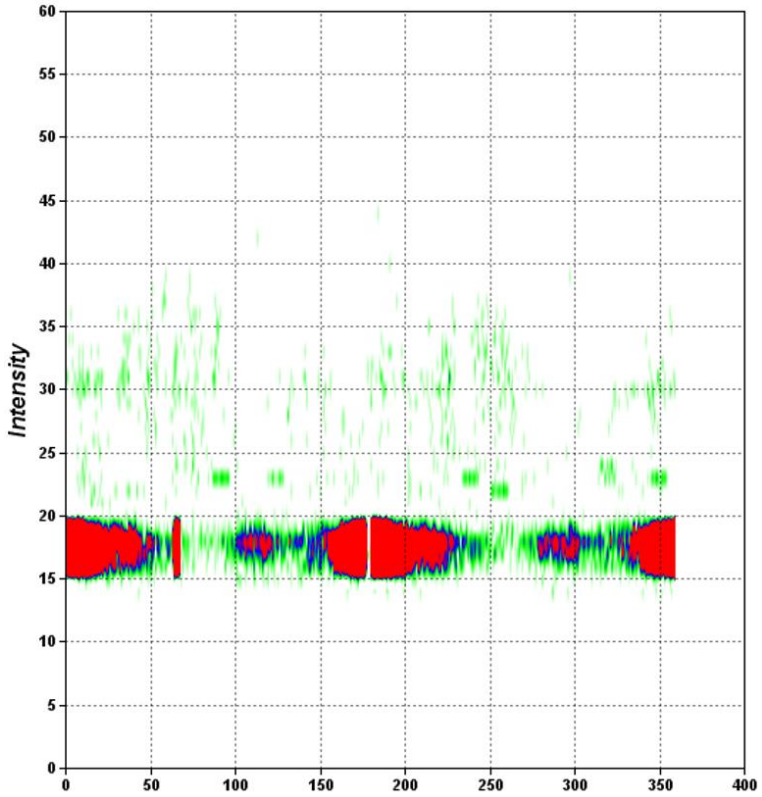
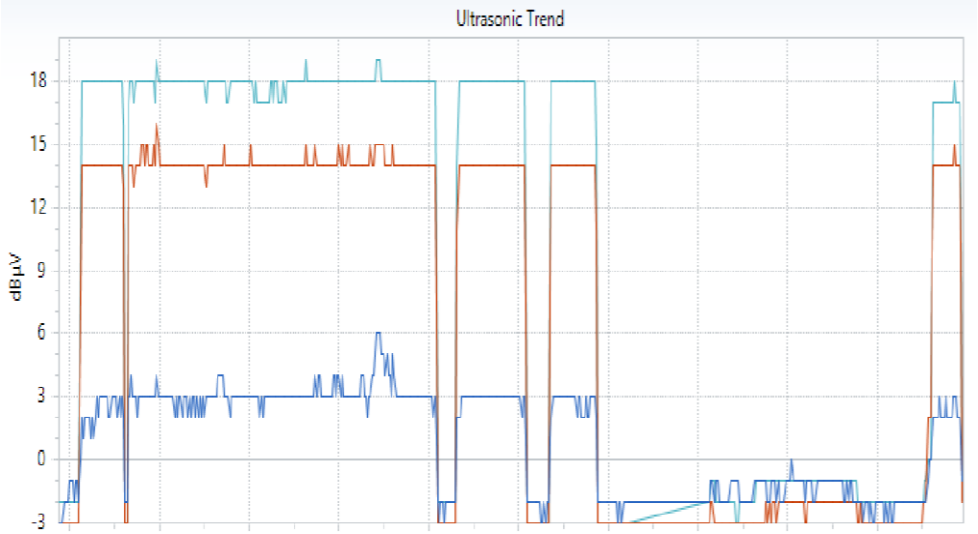
# **TEV:** Phase resolved plot- Probe on transformer panel.




Clear PD pattern with turbine stopped, inverts off.

# **Ultrasonic:** Average amplitude over same 24 hours as TEV




- Similar trend as TEV
- Low levels of U.S. activity when inverter was off suggest it is not possible to use U.S. as a method of PD detection in transformers

Because the transformers have solid resin insulation there is no airpath out, so ultrasonic internal PD detection is not possible with airborne sensors.

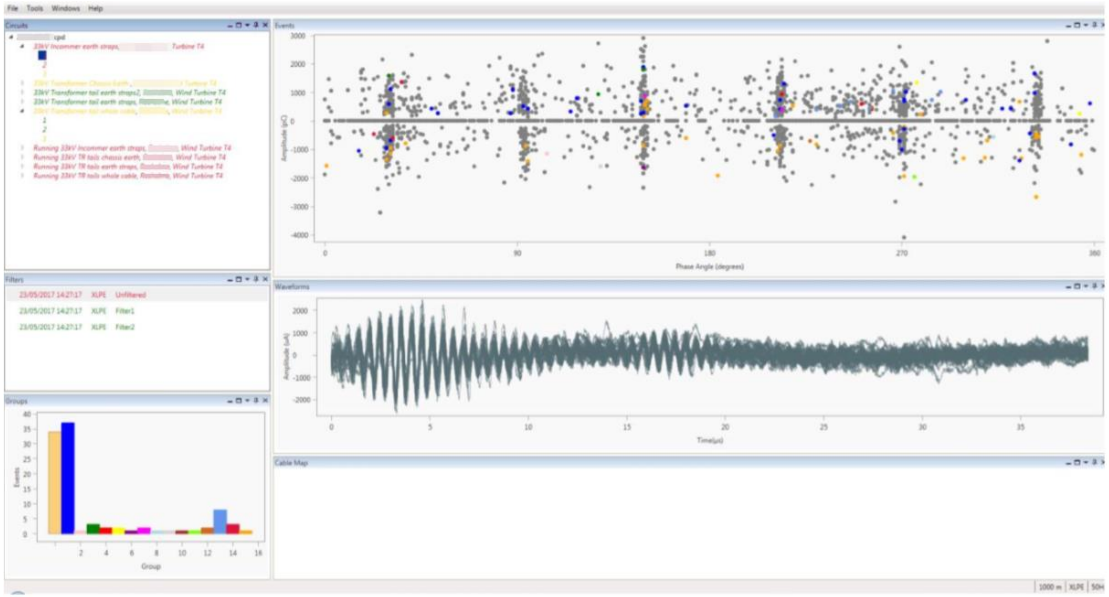
# Cable testing- RFCT

RFCT

Incoming 33 kv interconnect cables

Transformer Tails

# Incoming cable winding #1 – Turbine off



- Inverter noise
- No PD Pulse

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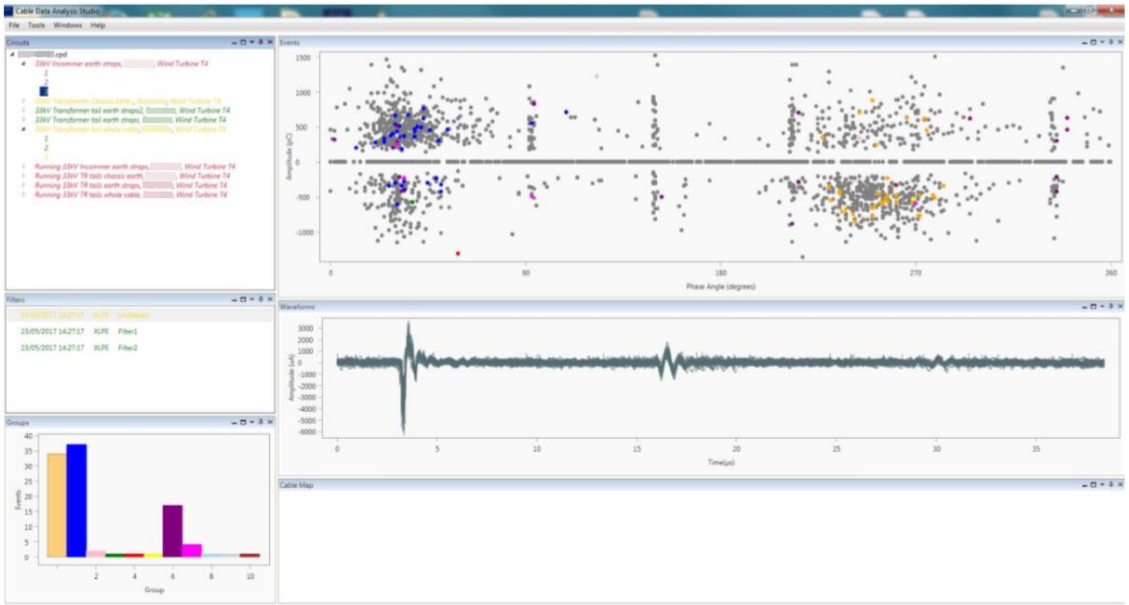
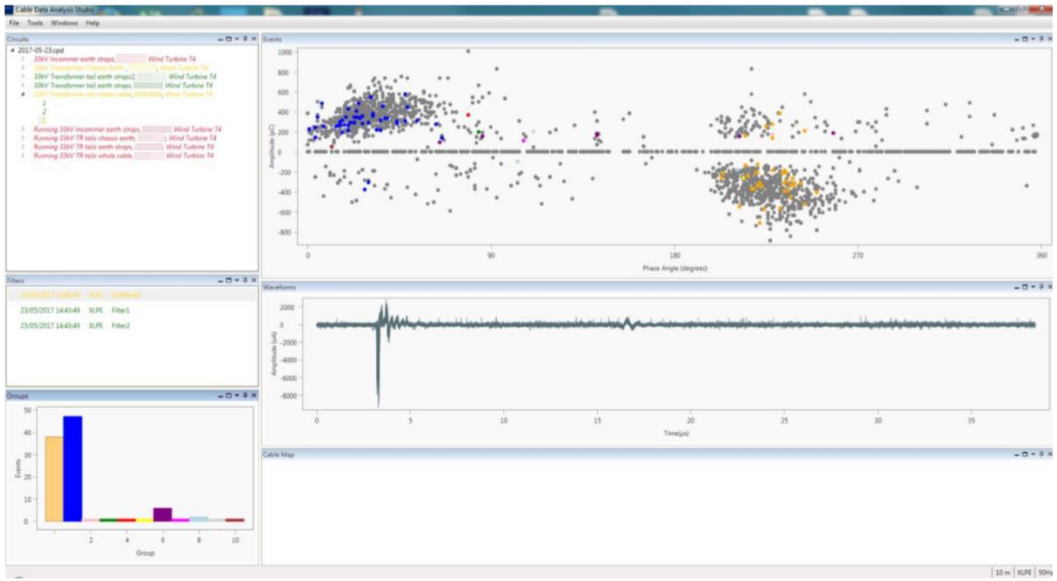
# Incoming cable winding #3- Turbine off



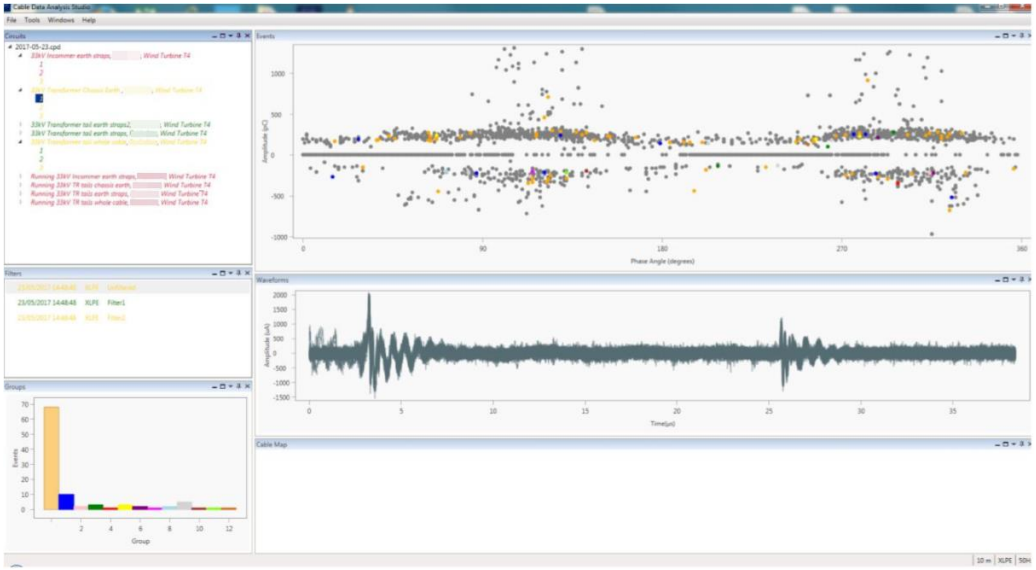
- Inverter noise
- Good PD cluster
- PD Pulse (6K pC)
- Reflected Pulse @ 12.7 ms

# Transformer tail winding #3- Turbine off



- No inverter noise
- Good PD cluster
- PD Pulse (9K pC)
- Reflected Pulse @ 12.7 ms

# Transformer chassis earth- Turbine off



- No significant PD Clusters
- Waveforms hazy with significant ringing
- Possible reflection at about 22.5ms

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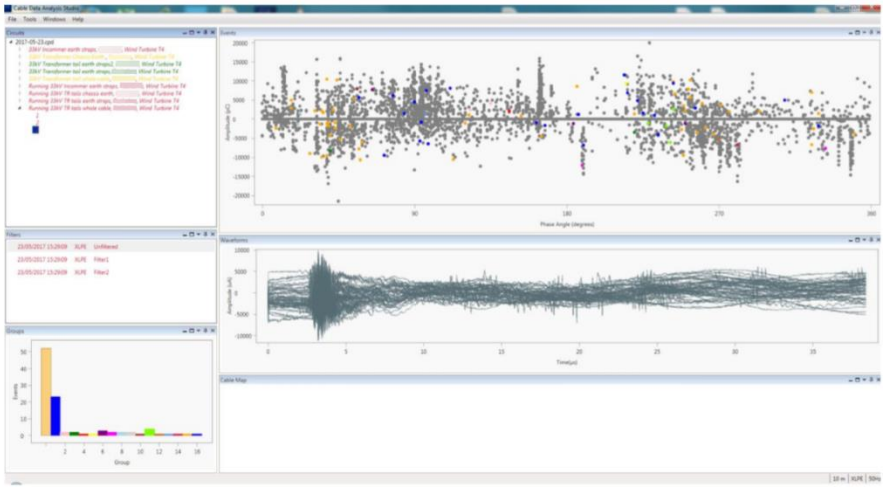
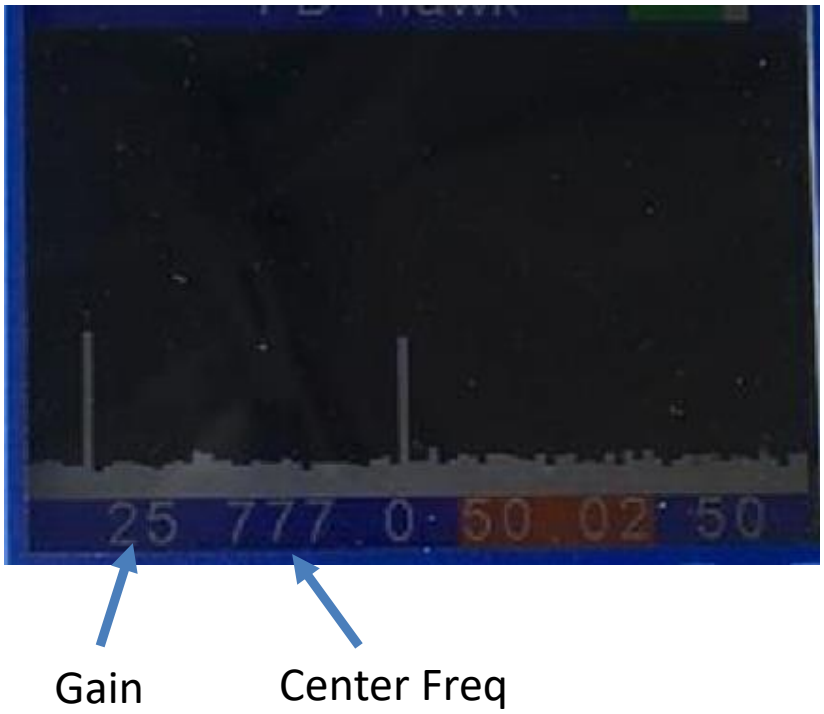
# Transformer tail winding #3- Turbine generating



Note levels of noise introduced by the turbine generating.

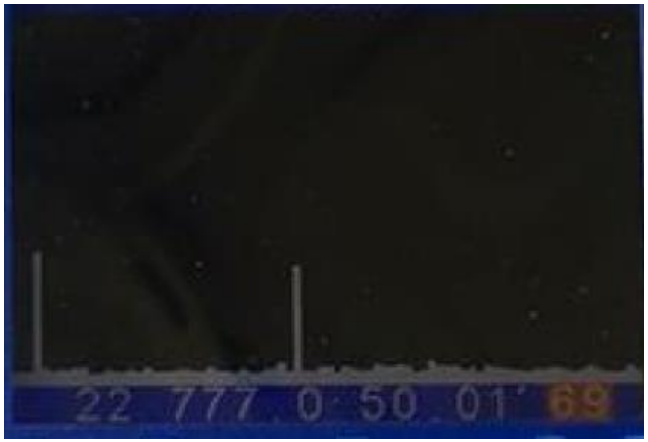
- No sign of grouping or clustering
- Waveforms characterized by bursts around the trigger point and significant noise on the rest of the waveform
- Filtering does not help significantly.

# UHF (RF) Test – Turbine generating




- Center Freq 777 MHz
- Inverter operating freq. usually 10's to 100's kHz
- Not effected by inverter noise

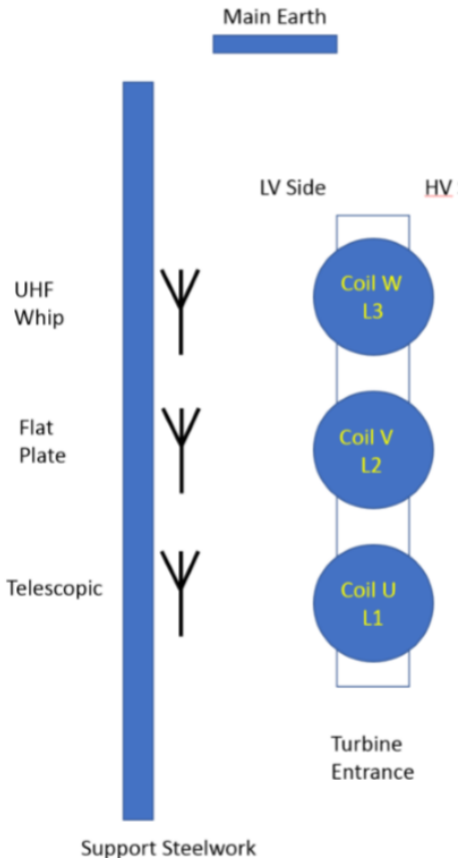
- UHF (RF) Test – Turbine not generating




- Little difference between turbines on and off
- Little apparent interference from inverters
- PRP was slightly unstable and not exactly 180$^{o}$
- This may have been caused by inception voltage different on positive and negative half cycles


When the HV transformer was de-energized the pulses stopped and the audio output went quiet.

# Sensor placement

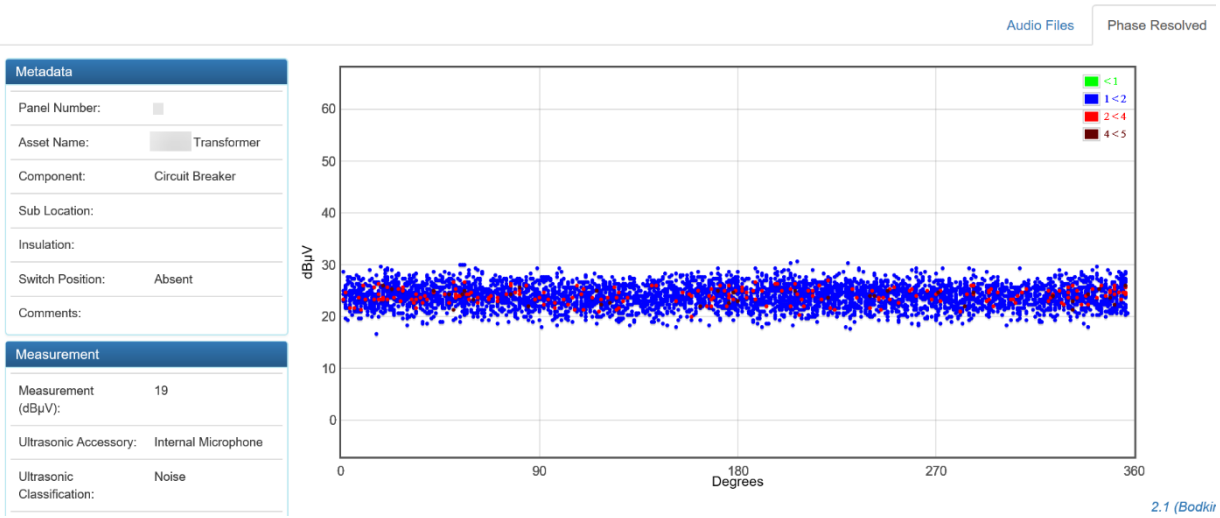

Main Earth
LV Side
HV
UHF
Whip
Flat
Plate
Telescopic
Coil W
L3
Coil V
L2
Coil U
L1
Turbine
Entrance
Support Steelwork

# Dry type transformers

Challenges:

- Vibrate at 2x system frequency (120Hz)- noisy
- Lack of dampening cause vibrations throughout transformer panels etc.
- Significant source of ultrasonic noise.
- Resin cast windings often dampen PD Ultrasonic emissions to the point its undetectable

# Ultrasonic Test




- High background noise
- Cannot hear anything on audio
- Cant really make a valid assessment

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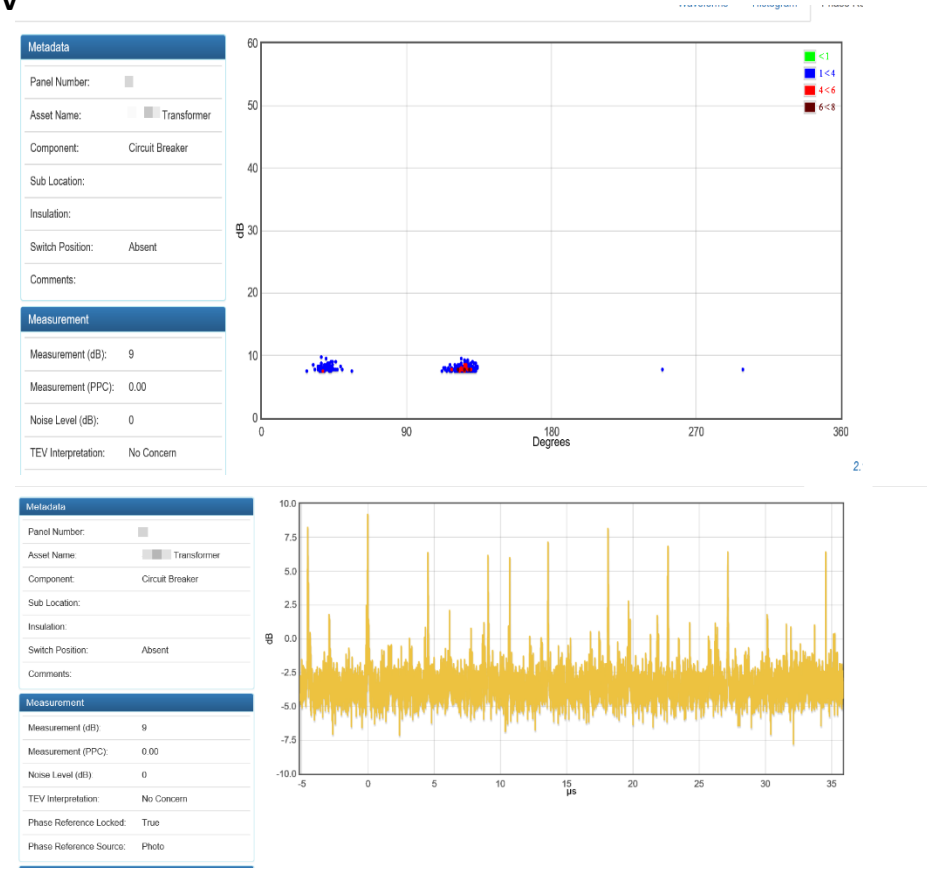
# TEV




- Clusters at 90 deg.
- Not synchronous to 60 Hz (0-PPC)

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## What have we learned?

- Know the equipment to be tested and understand the environmental impact.
- The use of different technologies, TEV, US, UHF, can provide different results, or supporting data for your conclusions
- Background measurements are valuable for determining if a measurement is real or noise.

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# Please Remember to Complete Your Evaluation Form

# Thank You!