HV Cable Management – doing it digitally

Graham Earp, Principal Consultant Engineer, EA Technology
Thomas Faulkner, High Voltage Distribution Engineer, British Steel

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Summary

Demonstrates how digital technology is being used to detect the presence of Partial Discharge (PD) on underground High Voltage (HV) electricity supply cables

- What is PD?
- Detection, location and monitoring

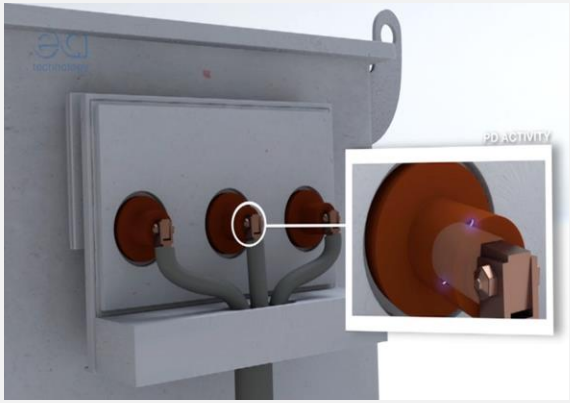
- Case study
- Benefits

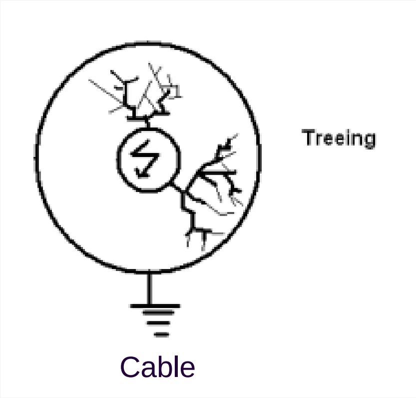
What is PD?

An electrical discharge that only partially bridges the insulation between conductors

Internal Discharge

- No visible signs





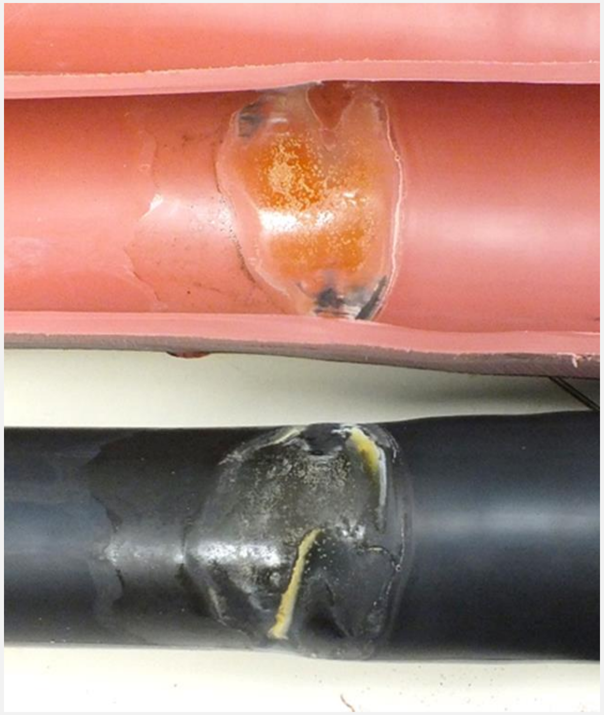
Surface Discharge

- Visible signs

PD activity in cables

- Erodes the cable insulation
- Major cause of electrical failure

- Detection & monitoring:
  - Early warning
  - Reliability
  - Safety



XLPE Cable PD Damage

Paper Insulated Cable PD Damage

Transient earth voltage detection

Technique mainly used for metal-clad HV switchgear and plant

- HF transient signals from discharge sources
- Travel over switchgear surfaces
- Detected using capacitively coupled probes on the switchgear metalwork

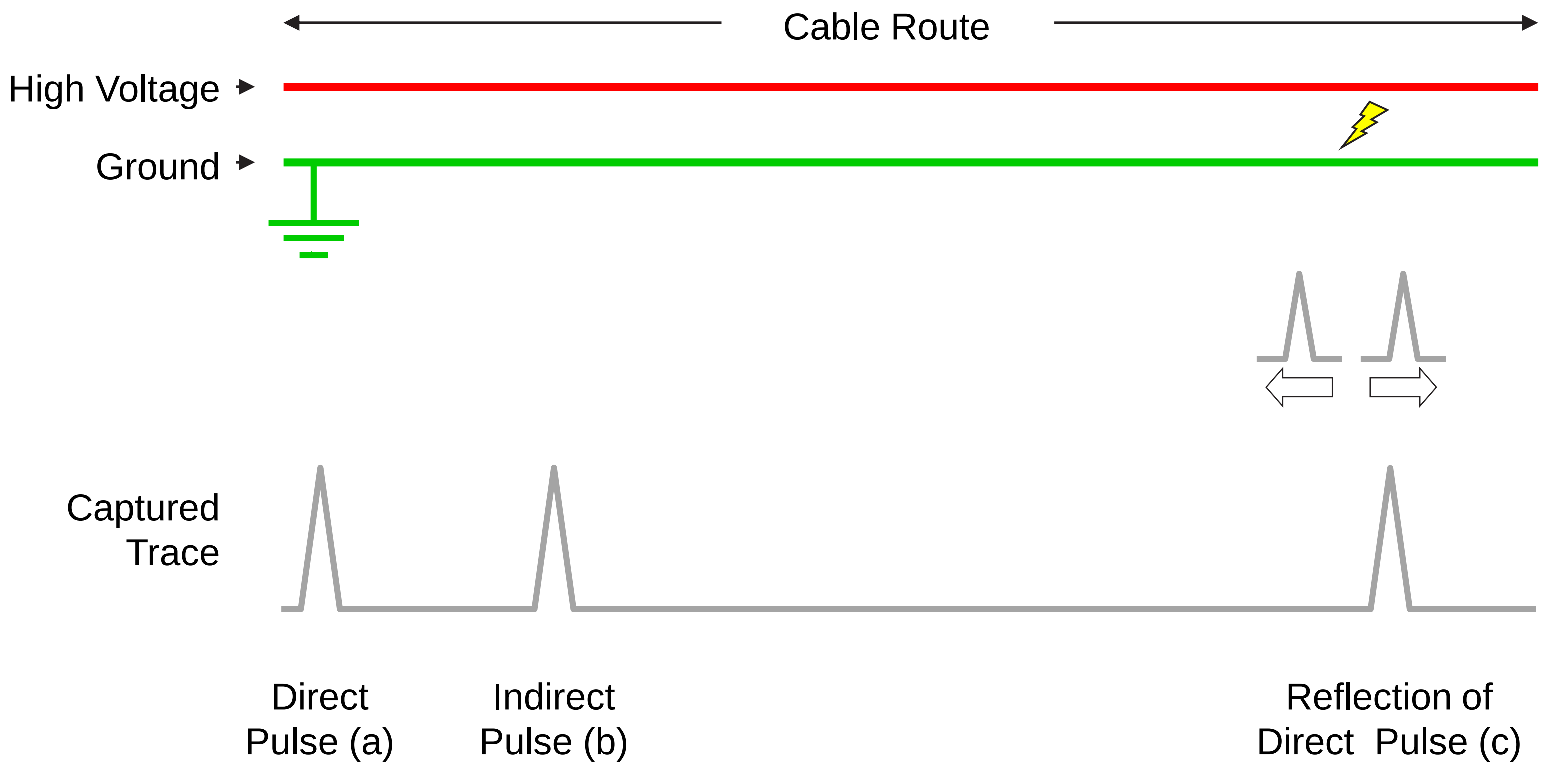
Widely used and understood

- Hand-held instruments – spot measurement
- Permanent monitoring
- On-line (equipment energised)

On-line monitoring PD in cables less common than in other types of plant and equipment

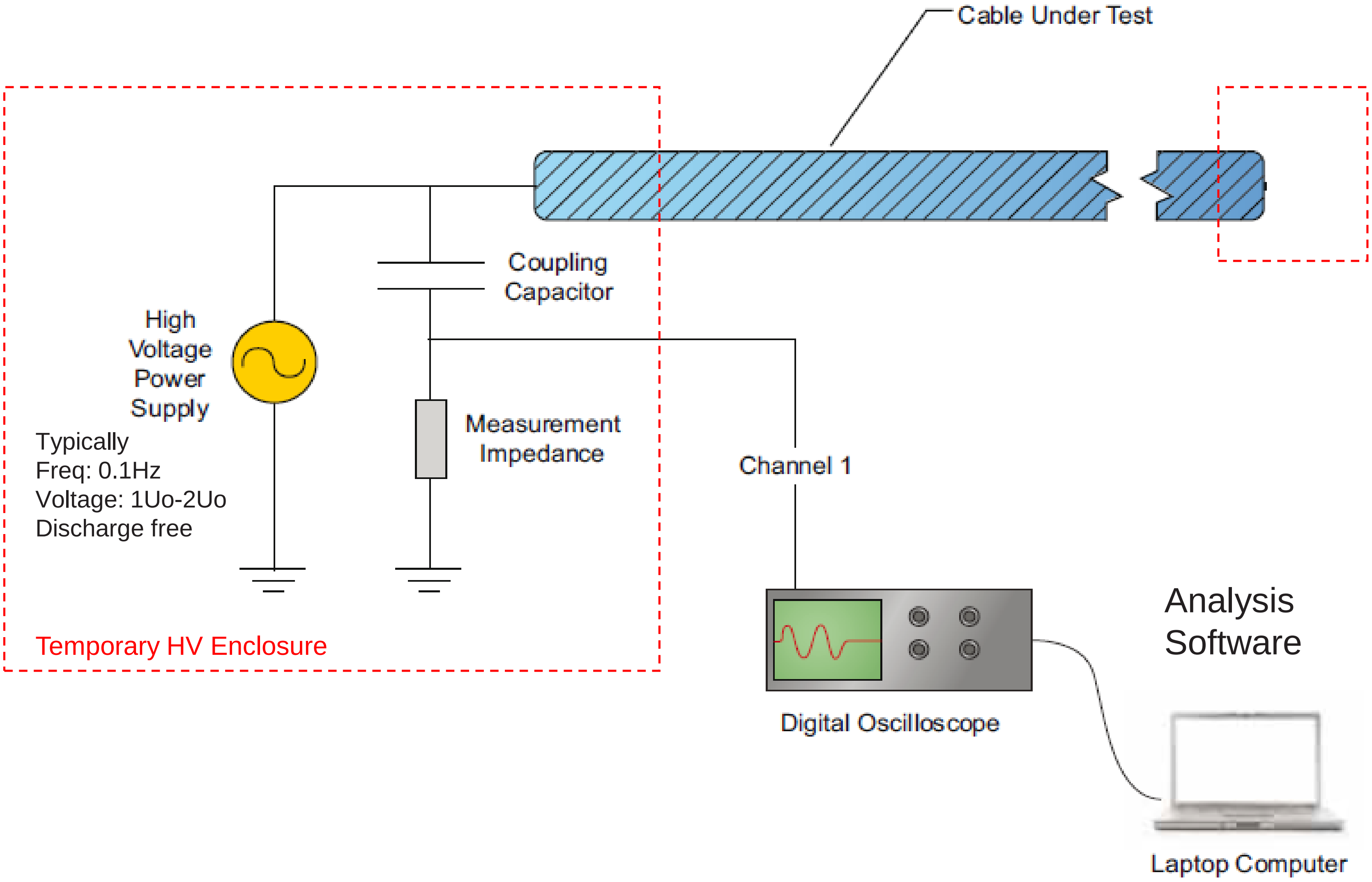
Cable PD

PD produces a very short duration pulse which travels away from the discharge location



Traditional “offline” VLF test

(Very Low Frequency)



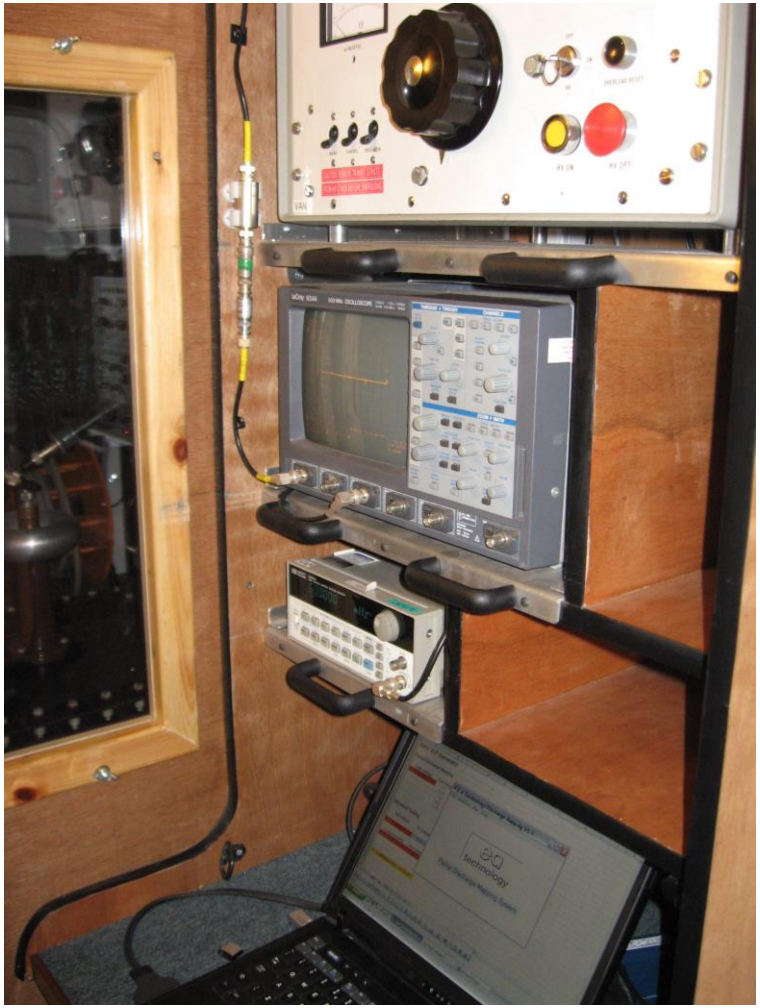
VLF test van

HV VLF power supply

VLF test van

Capacitive coupler

Control console



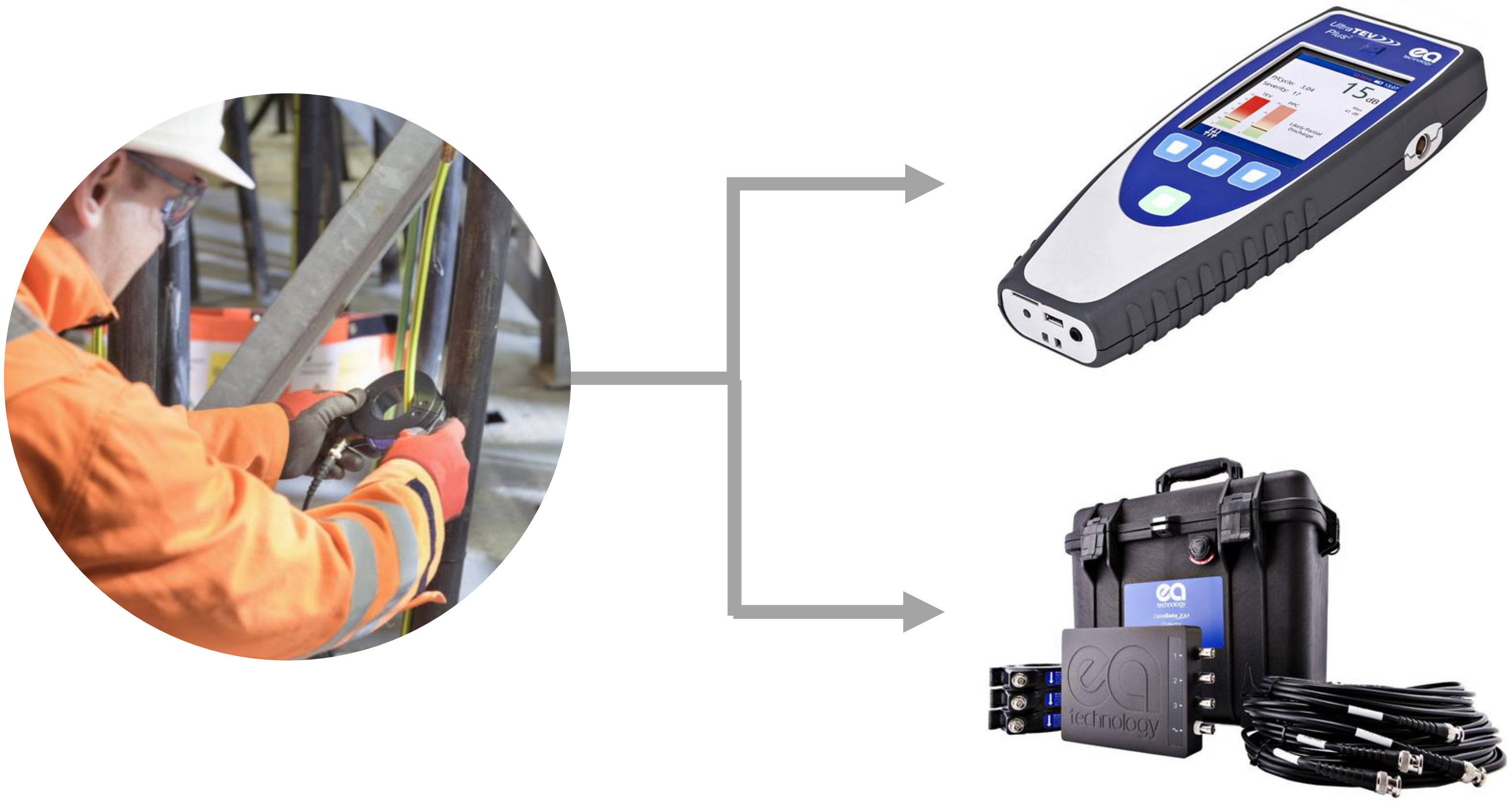
Alternative "online" approach

Radio Frequency Current Transformers (RFCTs) clip round earth straps

Current pulses are digitised and captured for processing and analysis

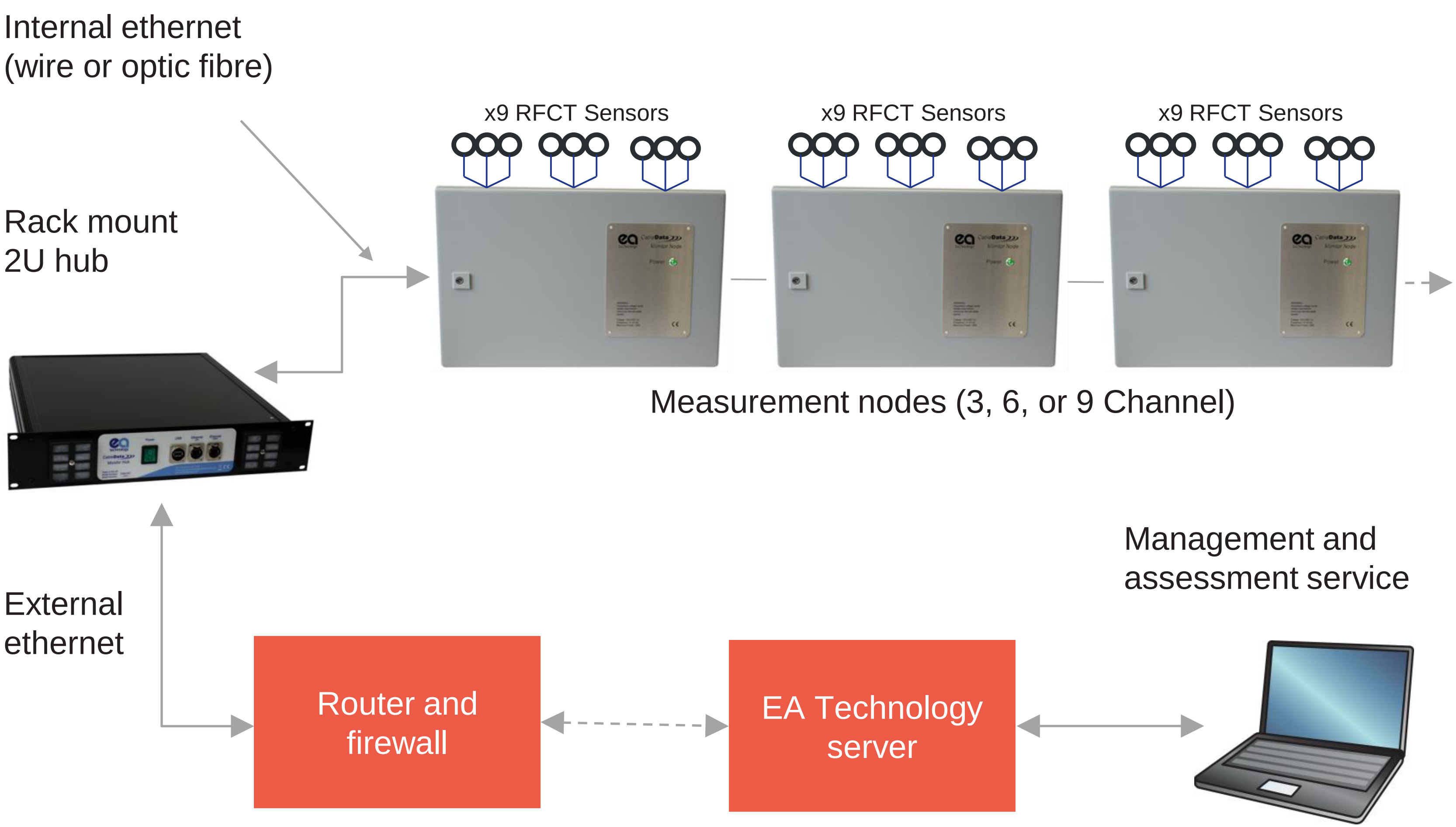
Digital hand-held/portable instruments

Spot measurements



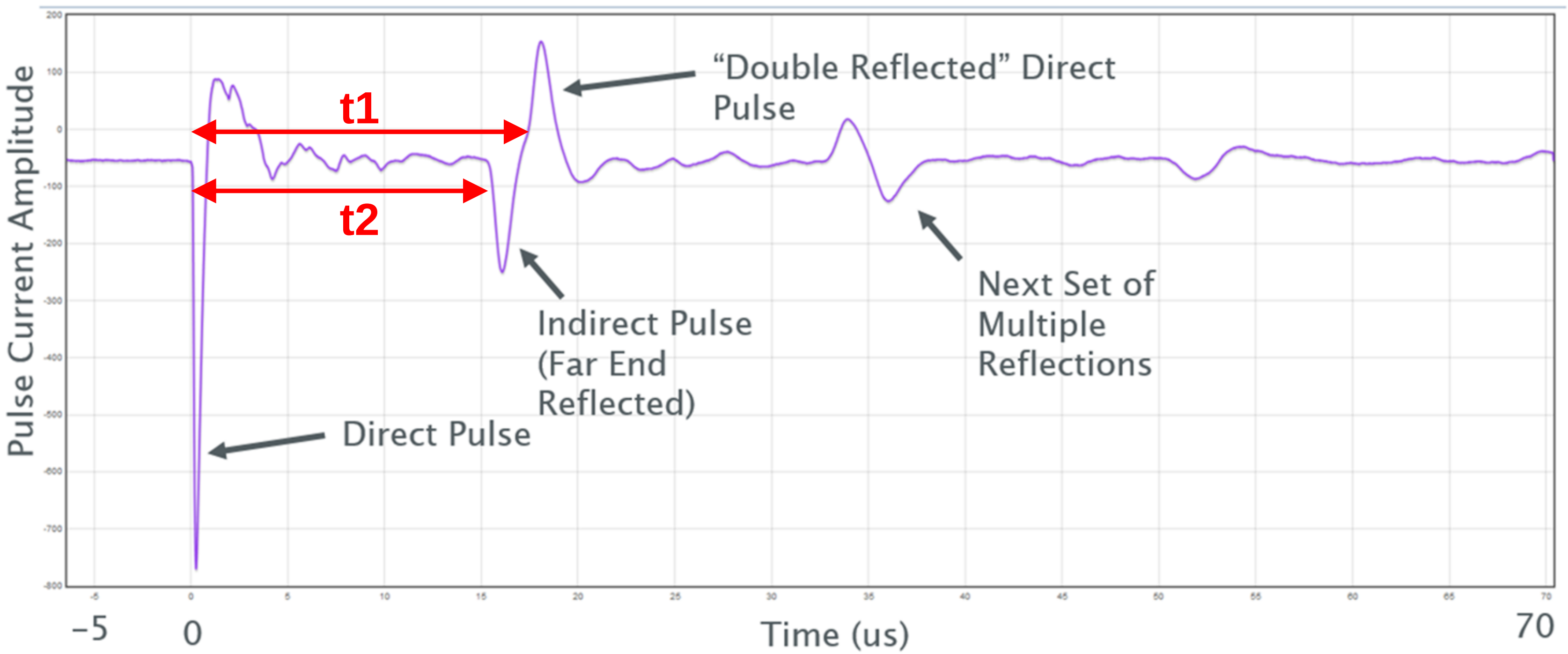
CableData monitor system

24/7 continuous monitoring



Digital waveform capture

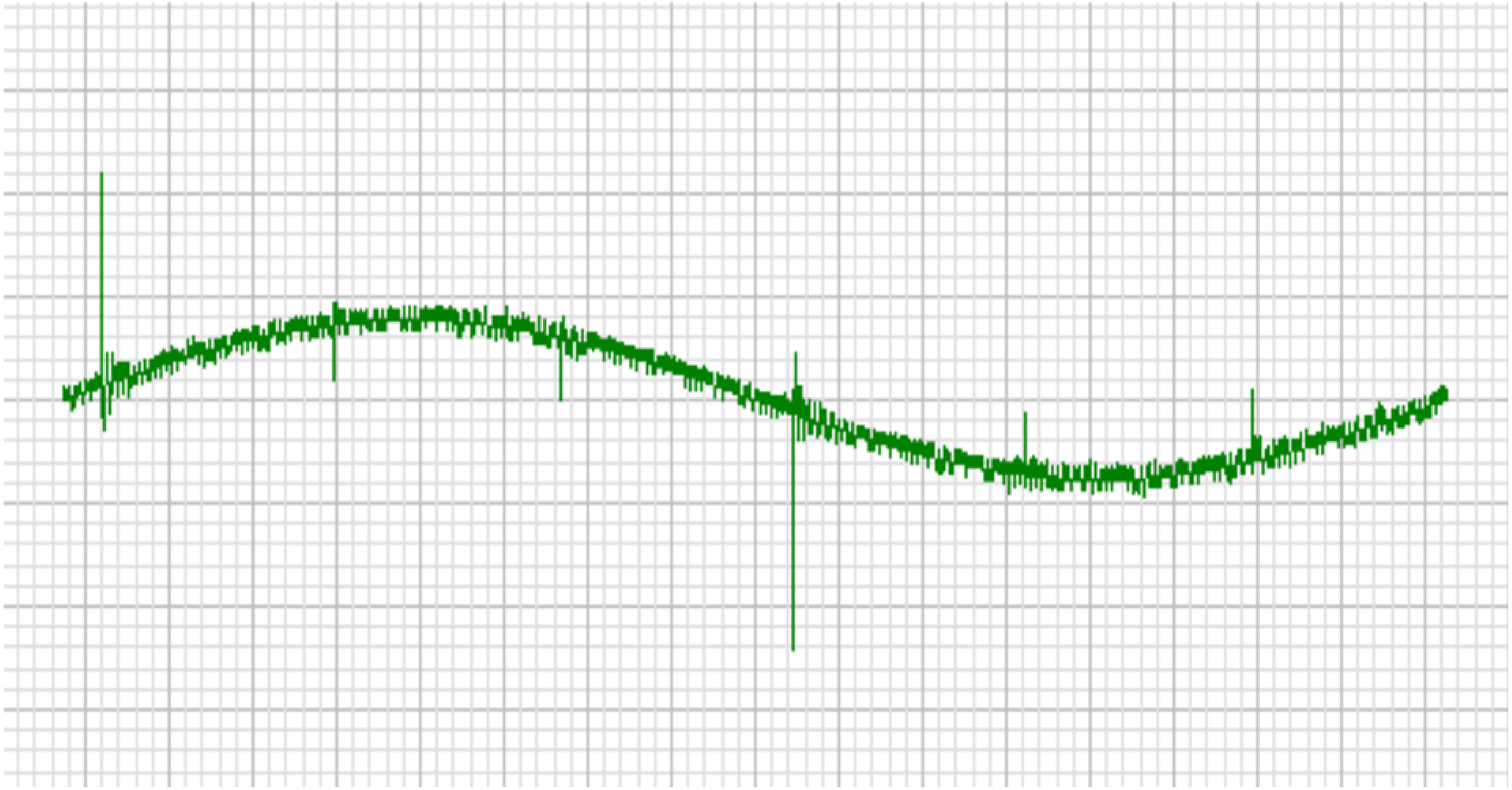
Can be used for PD location



t1= Time for direct pulse to travel 2x cable length
t2 = Time for pulse to travel from source to far end and back to source point

In this example the cable is around 1.4km long and the source is close to the near end of the cable

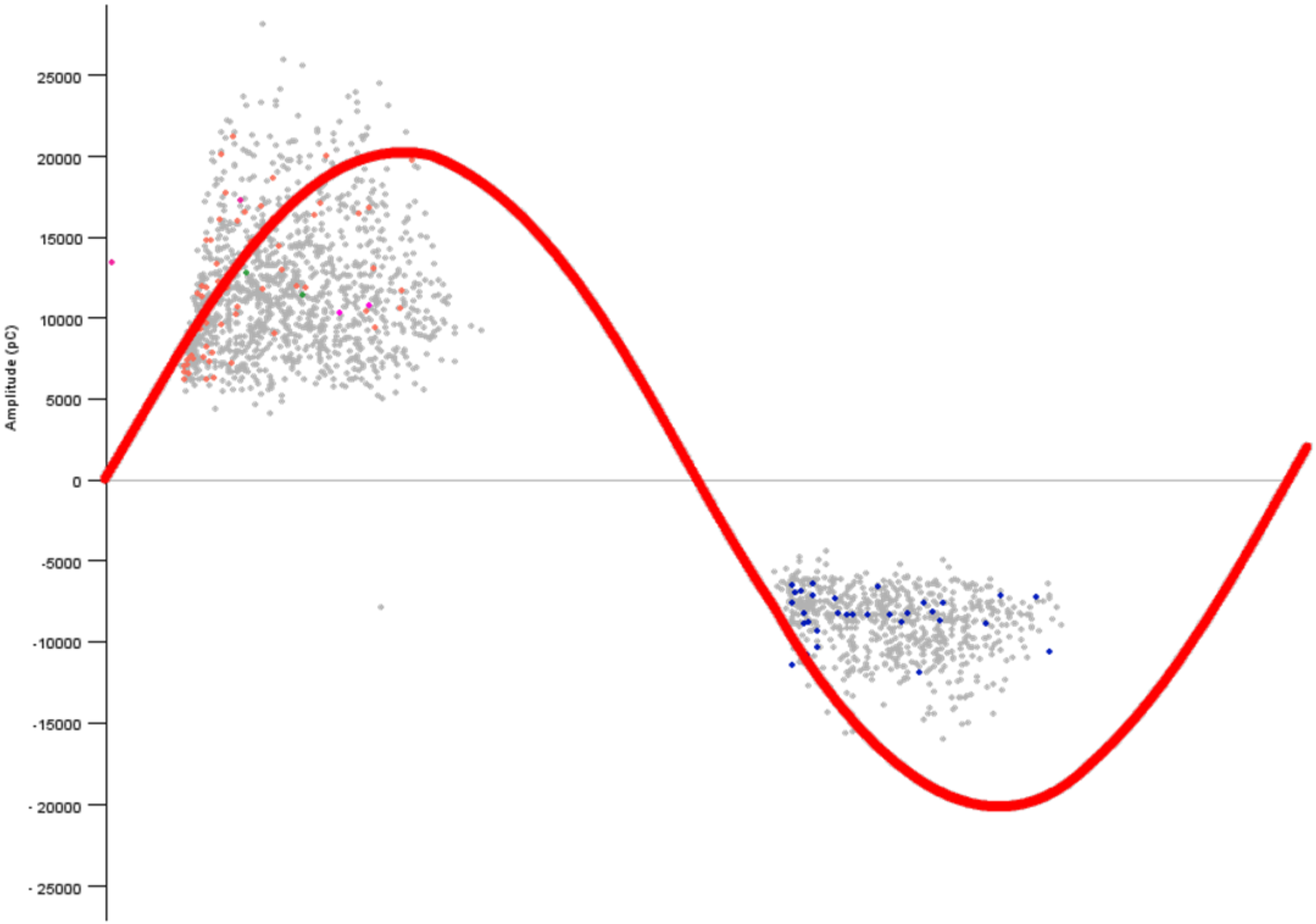
Cable PD – phase reference



- Useful in recognising PD activity
- Can help differentiate between genuine PD and interference/noise
- Automated processing

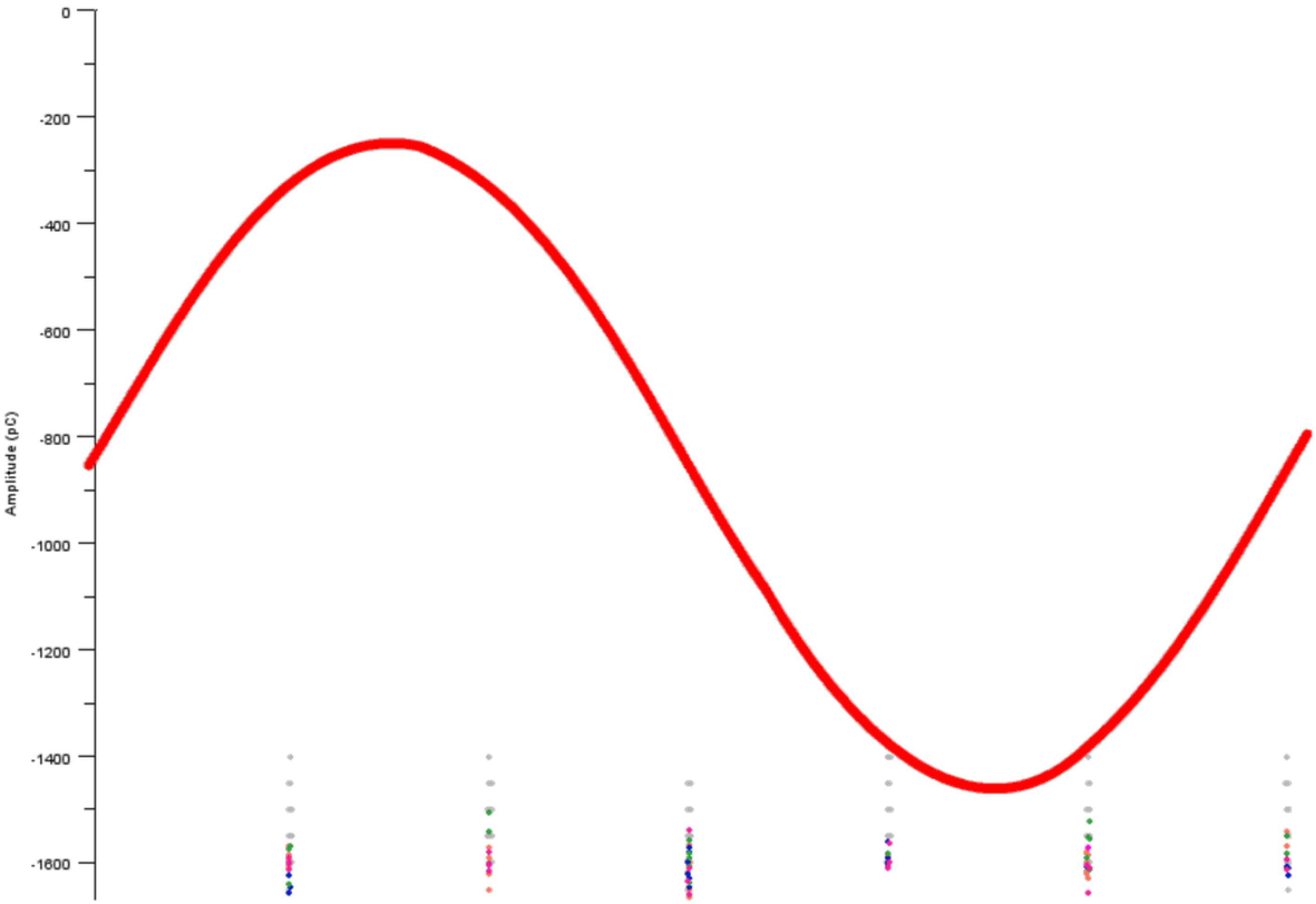
Phase resolved PD plot

Genuine PD

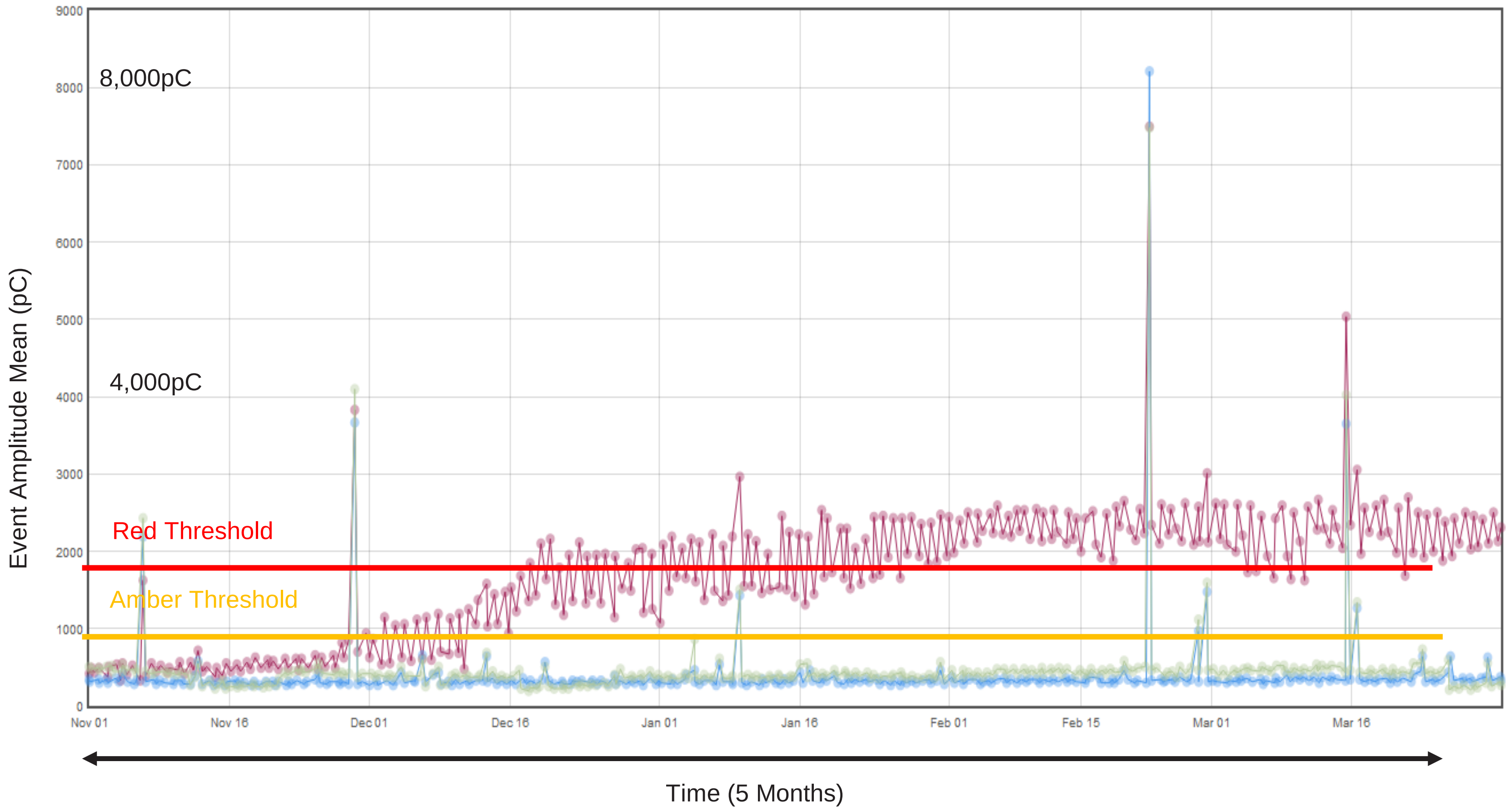


Phase resolved PD plot

Three phase machine noise



Time trending - event amplitude mean



Cable PD classification

Cable details: circuit name/No. cable type etc

PD classification for each phase

Comments on PD activity and trend

Recommendations for remedial action

Skegoneill S/S (Left to right panels)				Est Actual PD Level				
Panel	Circuit Name	Cable Type	Circuit Number	L1	L2	L3	Comments	Recommendations
SK2	Dargan Road S/D TX1 Landfill	XL	186	[illegible]	700	1,180	XLPE only cable. L1 phase plot and waveforms look like PD. Reflections present. L2 mainly noise, L3 could be cross coupling from L1 as the phase plot position and profile are similar.	Location may be possible with cable information. Further investigation and remedial action required.
SK3	Herdman Channel Rd HVC	XL/OL	172				Not monitored	
SK4	Whitehouse TXB	XL/MS	90	5,000	3,000	6,400	Phase plots and waveforms look like PD on all phases. Reflections present. L1 and L3 phase plot profiles different indicating separate sources. L2 could possibly be cross coupling from both L1 and L3. Event Amplitude Mean levels rose gradually on all phases between November 2017 and February 2018, but have then fallen back to near original levels by May 2018.	Location may be possible with cable information. Further investigation and monitoring required. Possible remedial action.
SK5	TXB						Not monitored	
SK6	Belfast North Main	XL/OL	110				Not monitored	
SK7	Dunmore	OL	142				Not monitored	
SK8	Buss Section						Not monitored	
SK9	Dunmore	XL/MS	79A	1,000	1,600	800	L2 phase plot and waveforms look like PD but no reflections present. L1 and L3 could have low level PD present or could be cross-coupling from L2 as the phase plot position and profile are similar but with the inclusion of more noise.	Location not possible due to lack of reflections. Further monitoring required and investigate if PD worsens.
SK9	Dunmore	XL/MS	79B	800	1,200	800	Possible low level PD activity on L2.	Continue to monitor.
SK10	Belfast North Main	XL/MS	109A	800	1,500	900	Low level PD activity on L2. This cable failed at 11:22 on 16/4/18. There was no significant build-up of PD beforehand. It has not been possible to retrieve the failed cable section to determine the cause of failure.	Continue to monitor.
SK10	Belfast North Main	XL/MS	109B	800	800	800	Possible low level PD activity on all phases but not large enough to be of concern.	Continue to monitor.
SK11	TXA						Not monitored	
SK12	Whitehouse TXA	XL/MS	89	4,380	[illegible]	3,000	Phase plots and waveforms look like PD on all phases. Reflections present. Phase plot profiles different for all three phases indicating separate sources. L2 has the largest source and may have multiple sources on the same cable. Event Amplitude Mean levels rose gradually on all phases during November and December 2017 but have recently reduced slightly.	Location may be possible with cable information. Further investigation and remedial action required.
SK13	Herdman Channel Rd HVC	XL/OL	171				Not monitored	
SK14	Dargan Road S/D TX2	XL	187	1,000	1,440	940	XLPE only cable. L2 phase plot and waveforms look like PD with reflections. Could also be possible cross coupling from nearby cable XL/MS 89. Phase plot profiles on L1 and L3 are similar which suggests cross coupling from L2 and/or cable XL/MS 89.	Location may be possible with cable information. Further investigation and monitoring required. Possible remedial action but advisable to repair XL/MS 89 first and then review CDM data.

Case Study - British Steel

Using partial discharge monitoring to pre-empt destructive fault conditions

Thomas Faulkner, High Voltage Distribution Engineer, British Steel

IAM Asset Management Conference 2019, Liverpool

Why is it important we prevent high voltage failures?

- Risk to personnel
- Voltage depressions
- Production loss
- Asset damage

Why is the 33kV network important?

- 33kV is the primary electricity distribution voltage for the site
- A cable fault can lead to a voltage depression affecting many users
- A voltage depression associated with a cable fault cleared by protection within 0.25 seconds caused major operation disruption
- Operational loss costs circa £1,000,000 can be incurred due to such an event

Developing cable fault

Initially confirmed by TEV measurement on steel armouring on central power station interconnector cable

Cable PD site trial

Cable PD detection equipment used to Iinvestigate further

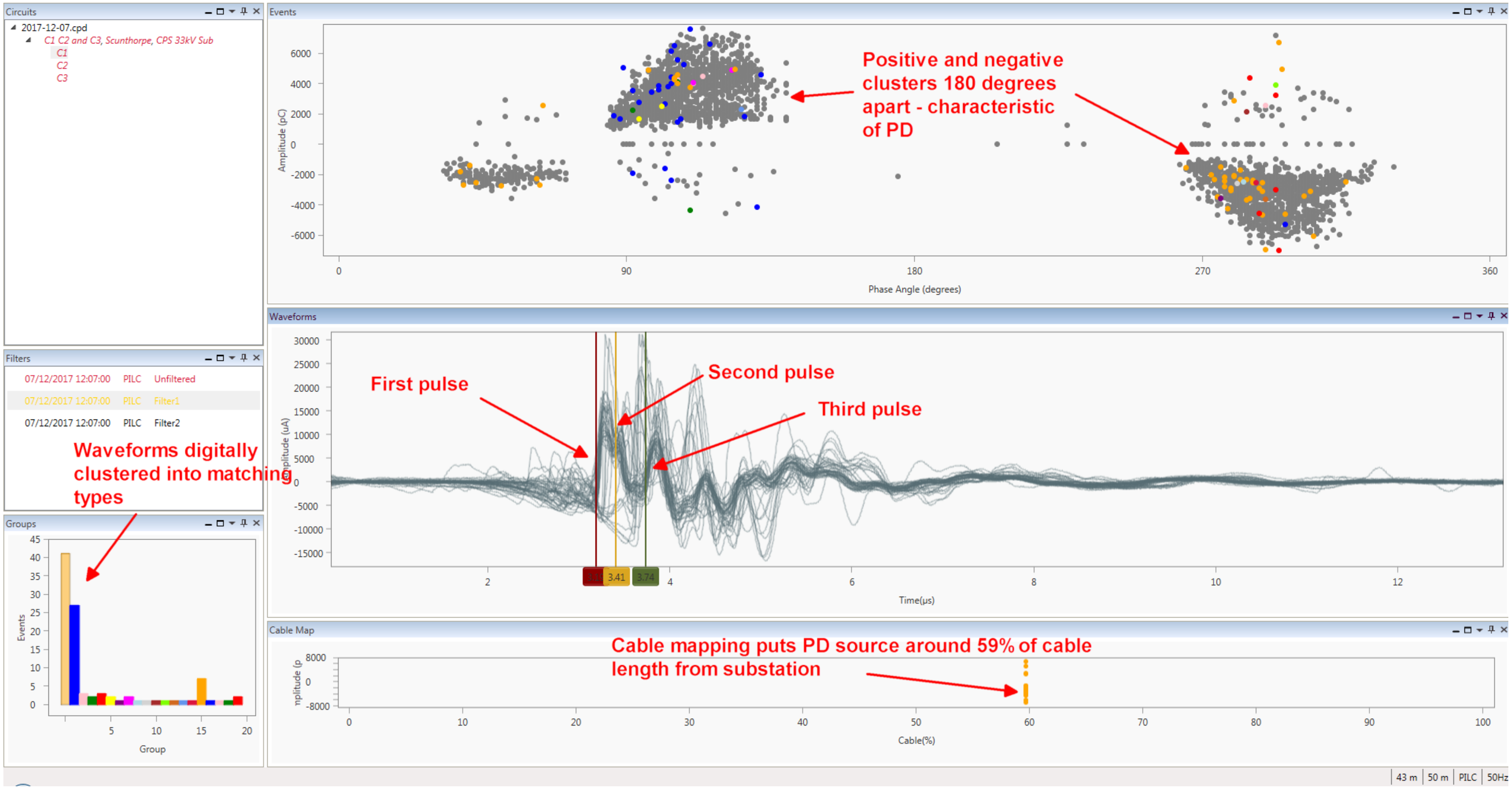
Sensors → Digitisation → Analysis

RFCTs fitted to cable earth strap

CableData Collector

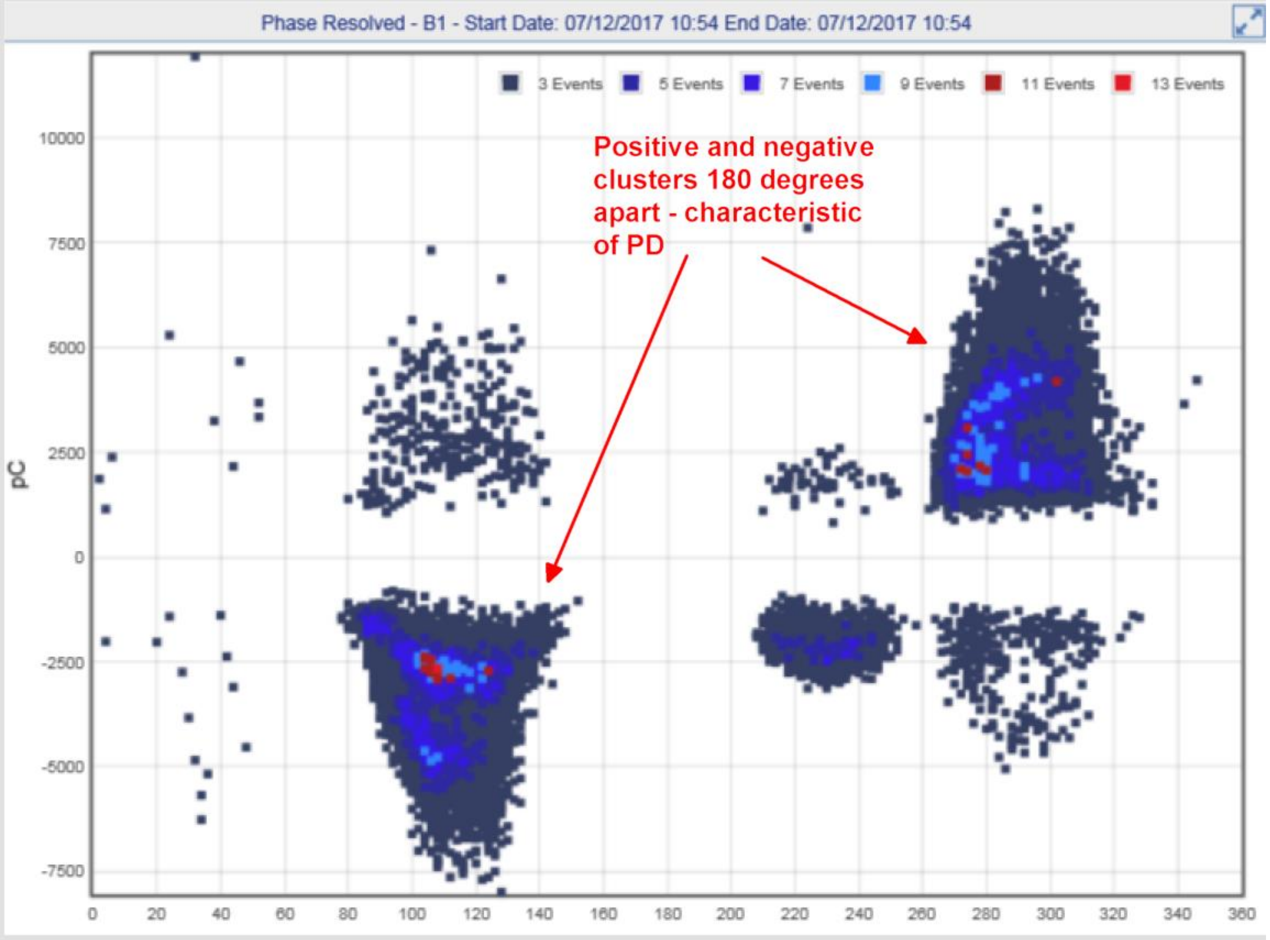
CableData Monitor

CableData collector analysis



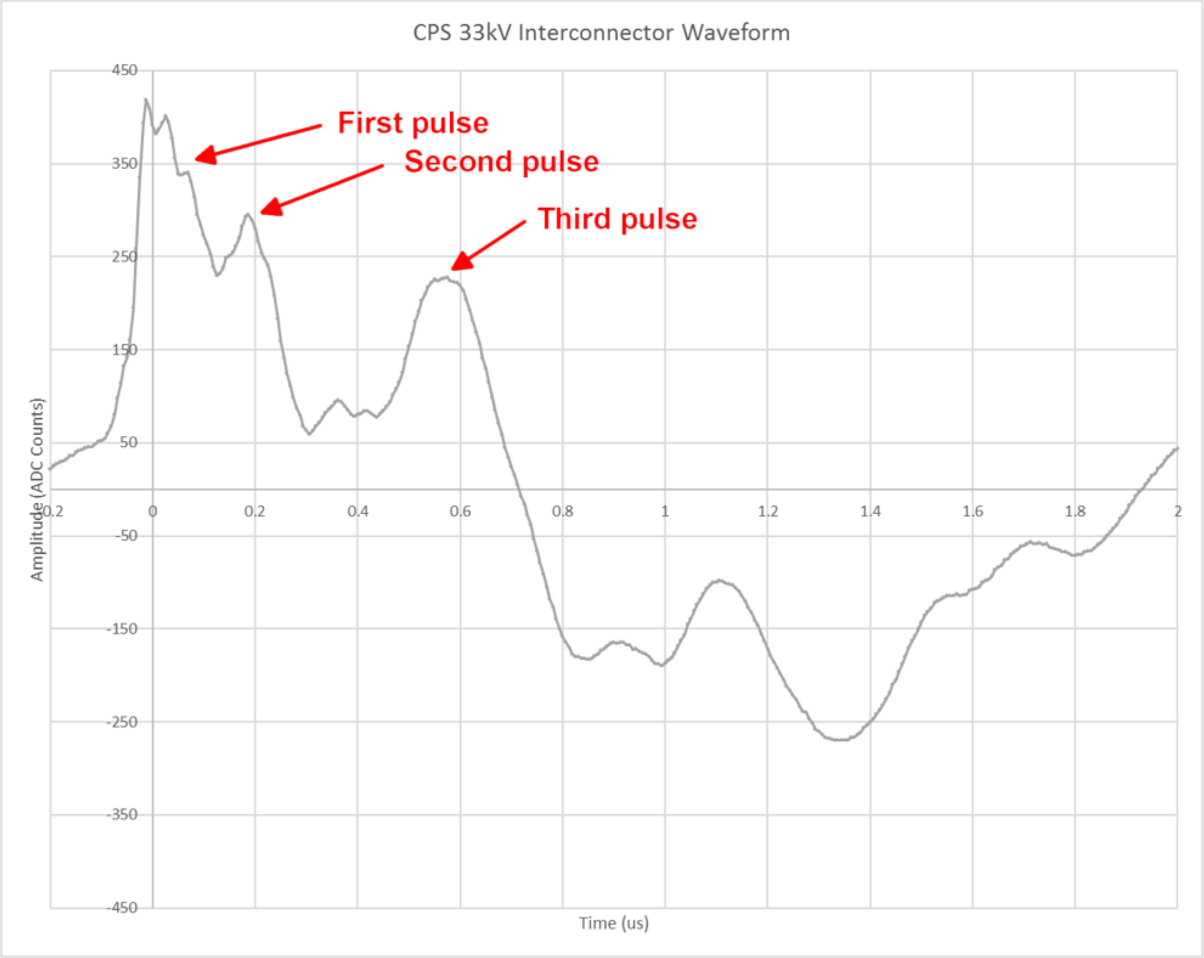
CableData monitor analysis

Phase plot



CableData monitor analysis

Waveform capture

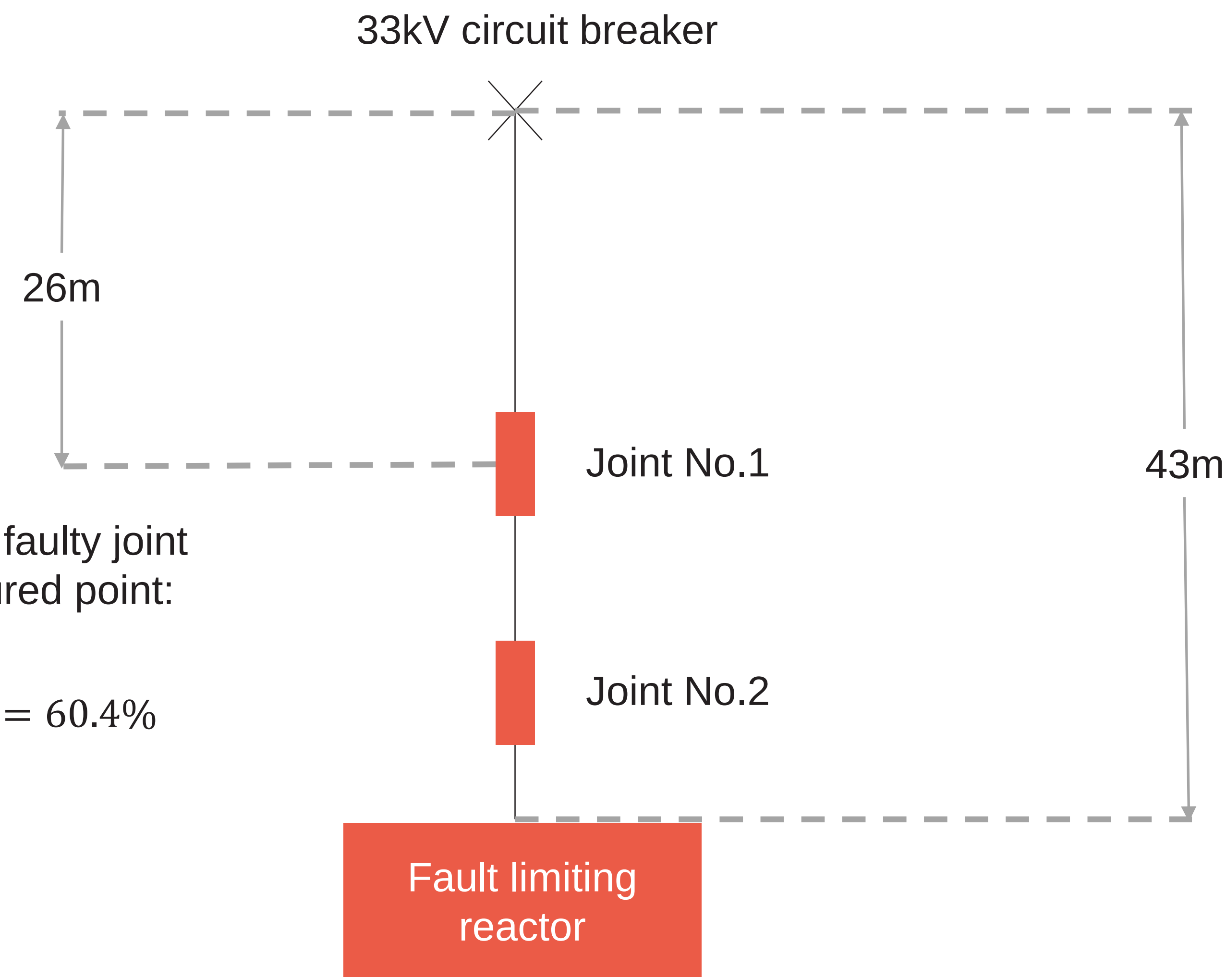


Calculations from the pulse timings also put the source at 60% of the cable length out from the substation

Initial result analysis

- Plant drawings told us that there was only one joint in the cable.
- Initial results placed the Partial Discharge where a joint was not shown.
- Discussions with plant engineers determined an additional joint had been installed approx. 10-20 years ago, drawings not updated.
- With legacy sites, the value of updating documentation was not as valued in the past.
- Digital technology can help us to map these circuits.

Cable layout details



Distance to faulty joint from measured point:

$$\frac{26}{43} \times 100 = 60.4\%$$

Remedial action

- Approval from senior management to excavate suspect joints and replace
- Excavation completed and suspect joint position found to have been installed in a ground water drain

Alternative cable route

Faulty section spiked and cut out, new section of cable installed and jointed.

Cable jointing and termination

Cable jointing and termination

Post repair reduction in partial discharge

Re-energisation of the circuit showed a large reduction in the TEV magnitude present on cable armour

Before (31dB)

After (1dB)

Cost benefit analysis

High value production – 24/7 whole site monitoring

Year		0	1	2	3	4	5
Benefits		£0	£1,000,000	£1,000,000	£1,000,000	£1,000,000	£1,000,000
Cumulative Benefits		£0	£1,000,000	£2,000,000	£3,000,000	£4,000,000	£5,000,000
Estimated Costs							
	Upfront	£360,000	£0	£0	£0	£0	£0
	Ongoing	£50,000	£50,000	£50,000	£50,000	£50,000	£50,000
Total Costs		£410,000	£50,000	£50,000	£50,000	£50,000	£50,000
Net Cumulative Cost/Benefit		-£410,000	£540,000	£1,490,000	£2,440,000	£3,390,000	£4,340,000

- Based upon a high value production environment, where a 33kV fault can cause disruption to the operating processes.
- Applicable to high value industries such as chemical manufacturing, heavy engineering, oil & gas, public services etc.

Conclusions

- Partial Discharge monitoring was successfully applied to detect a developing fault on a 33kV circuit
- Digital “on-line” technology is enabling this to be done “none intrusively”
- A location for the discharge was identified through the use of analysis software
- This coincided with a joint position – a known point of weakness within a high voltage circuit
- The defective joint was replaced in a planned and controlled manner before it failed catastrophically – avoiding costly disruption to production
- Further work required to implement a comprehensive suite of fault detection equipment across site
- This would yield huge benefits to the business, reducing the number of disruptive faults impacting operations

Thank you

EA Technology Limited
Capenhurst Technology Park
Capenhurst, Chester CH1 6ES

www.eatechnology.com