PARIS SESSION 2024

In-service Circuit Breaker Condition Assessment

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Introduction - Elimpus

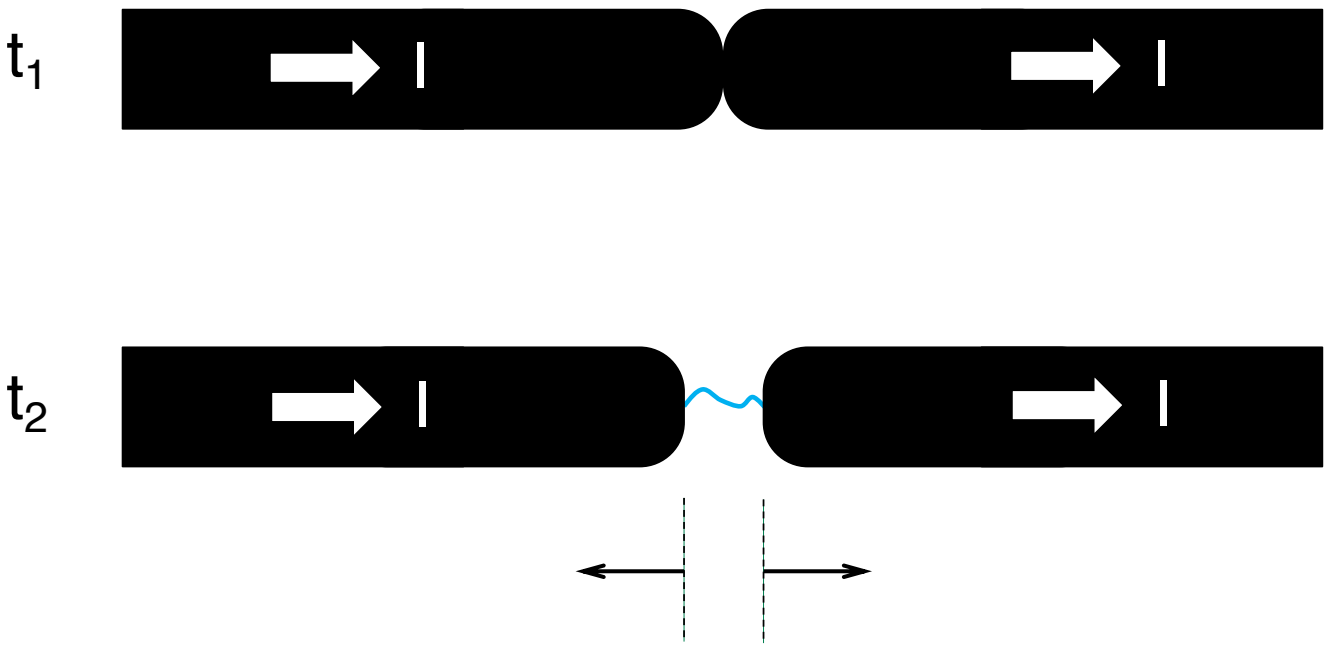
- Elimpus founded in 2007 – spin-out from University of Strathclyde
- Condition monitoring solutions provider
- Manufacturer of radiometric partial discharge (PD) monitoring technology
- Provide site services for PD, transformer dissolved gas monitoring (DGA), SF6 gas density monitoring, circuit breaker monitoring

Introduction – circuit breaker monitoring

- 10 years in development
- In-service measurements using portable equipment
- Most of the results obtained from a 2 year trial on a 400kV system:
  - All CBs switched 200 MVAr shunt reactors
  - CBs were a mixture of manufacturers
  - A mixture of spring and hydraulic mechanisms
  - A mixture of AIS and GIS CBs

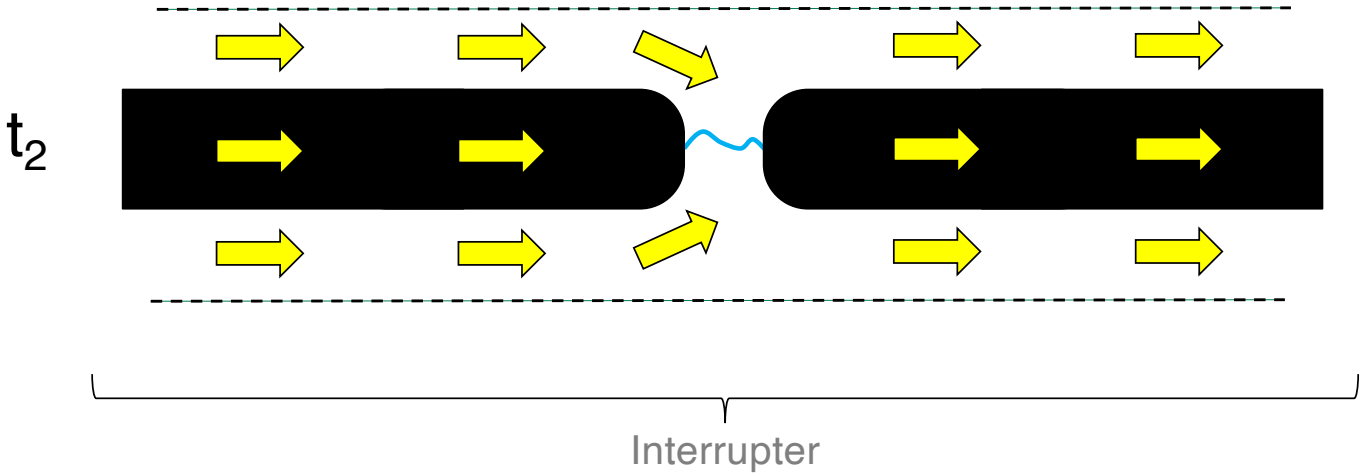
Circuit breaker theory

Arcing contacts – start of arc



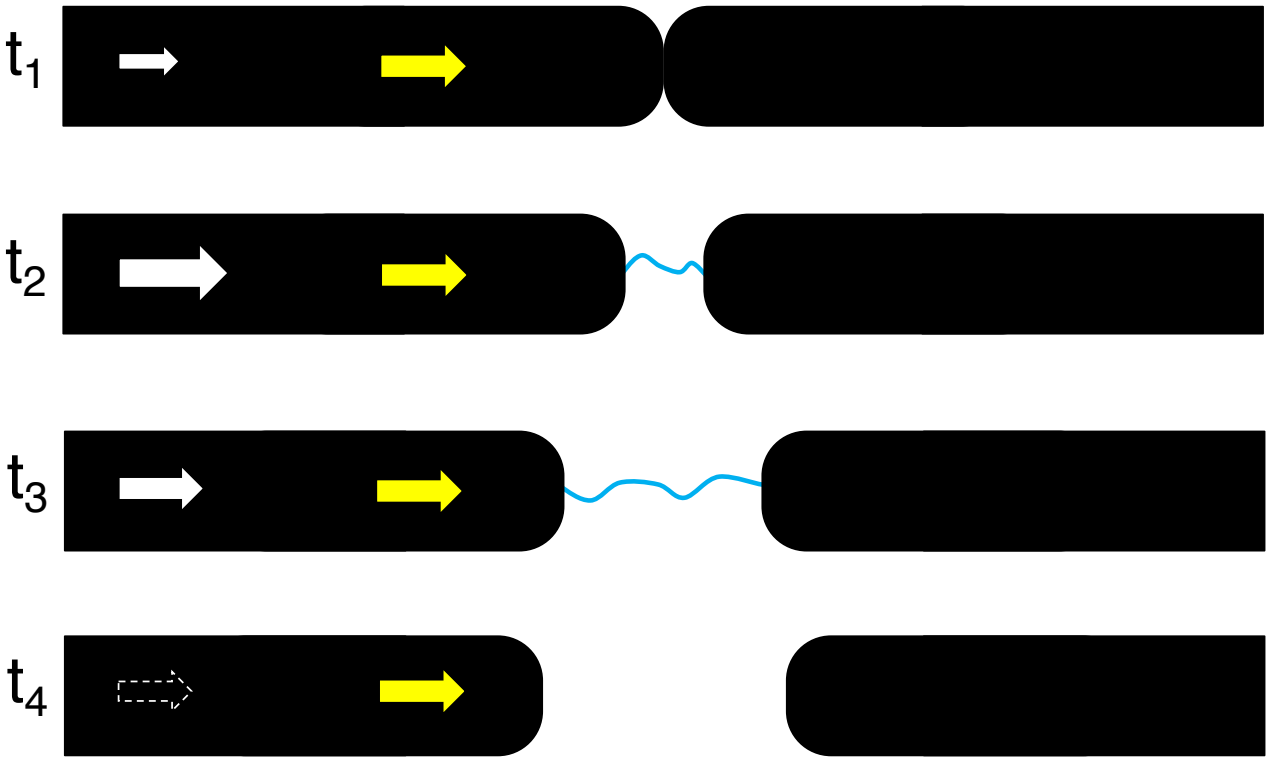
Contacts move apart

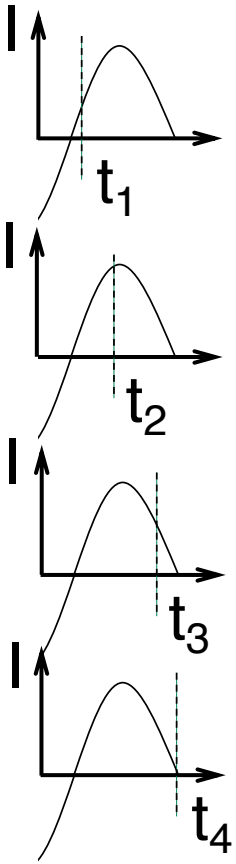
Arcing contacts – control of arc with gas flow



Gas flow, e.g. SF6, compressed air

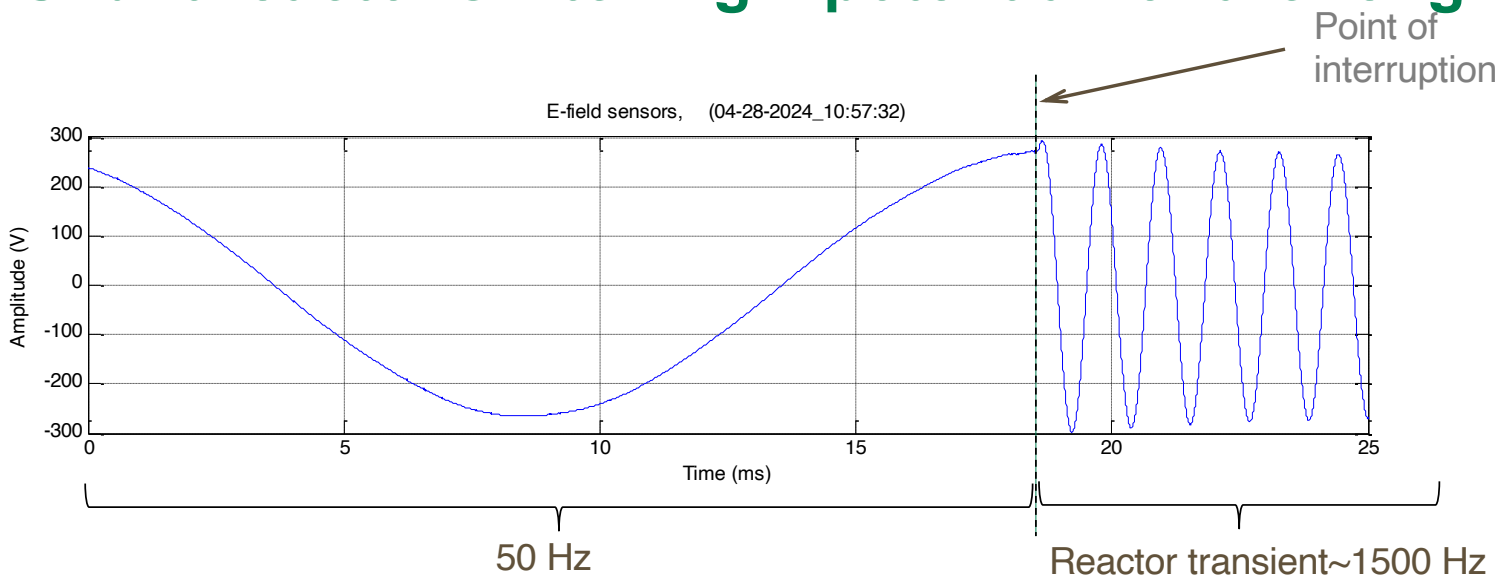
Arcing contacts – extinction of arc

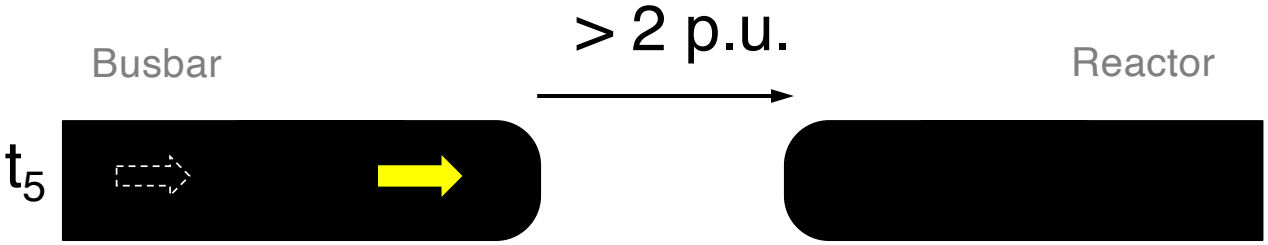




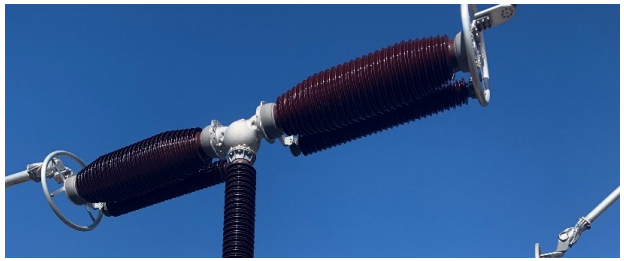
Arc extinguished at current zero crossing.
'Ideal' scenario – requires Controlled Switching Relay (CSR)

Shunt reactor switching – potential for arc re-igniting



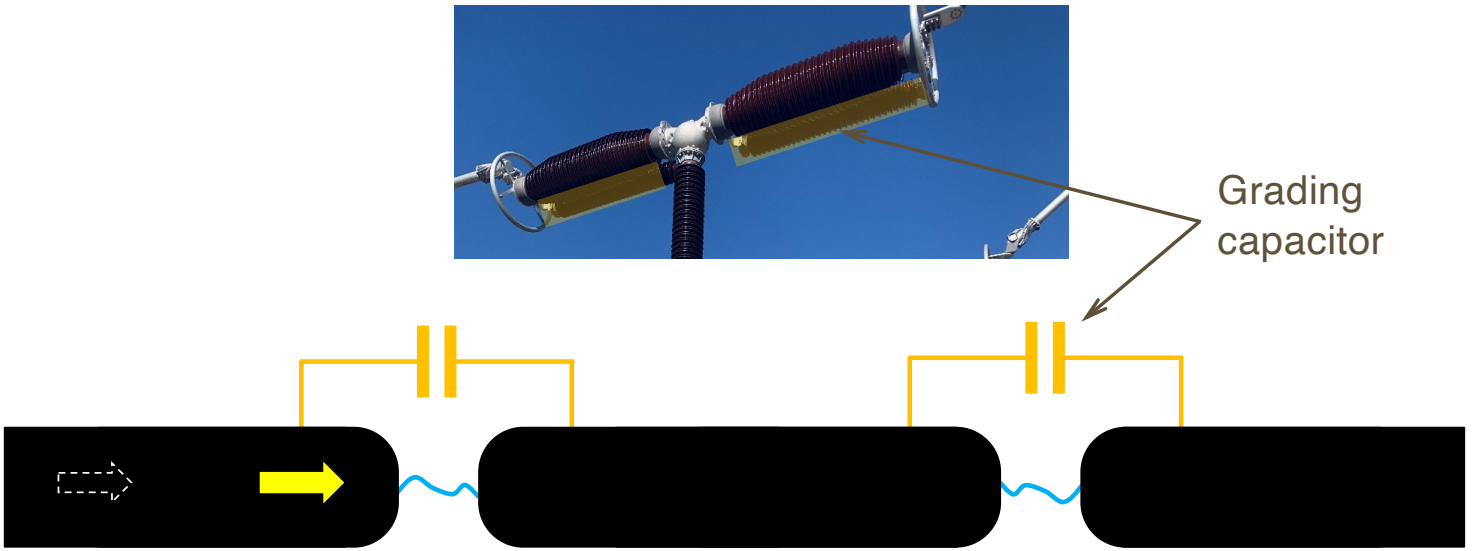


Coping with high recovery voltages – two breaks per phase



1. Two breaks per phase allows for a higher recovery voltage
2. Grading capacitors equalises the recovery voltage across the two interrupters

Coping with high recovery voltages – two breaks per phase



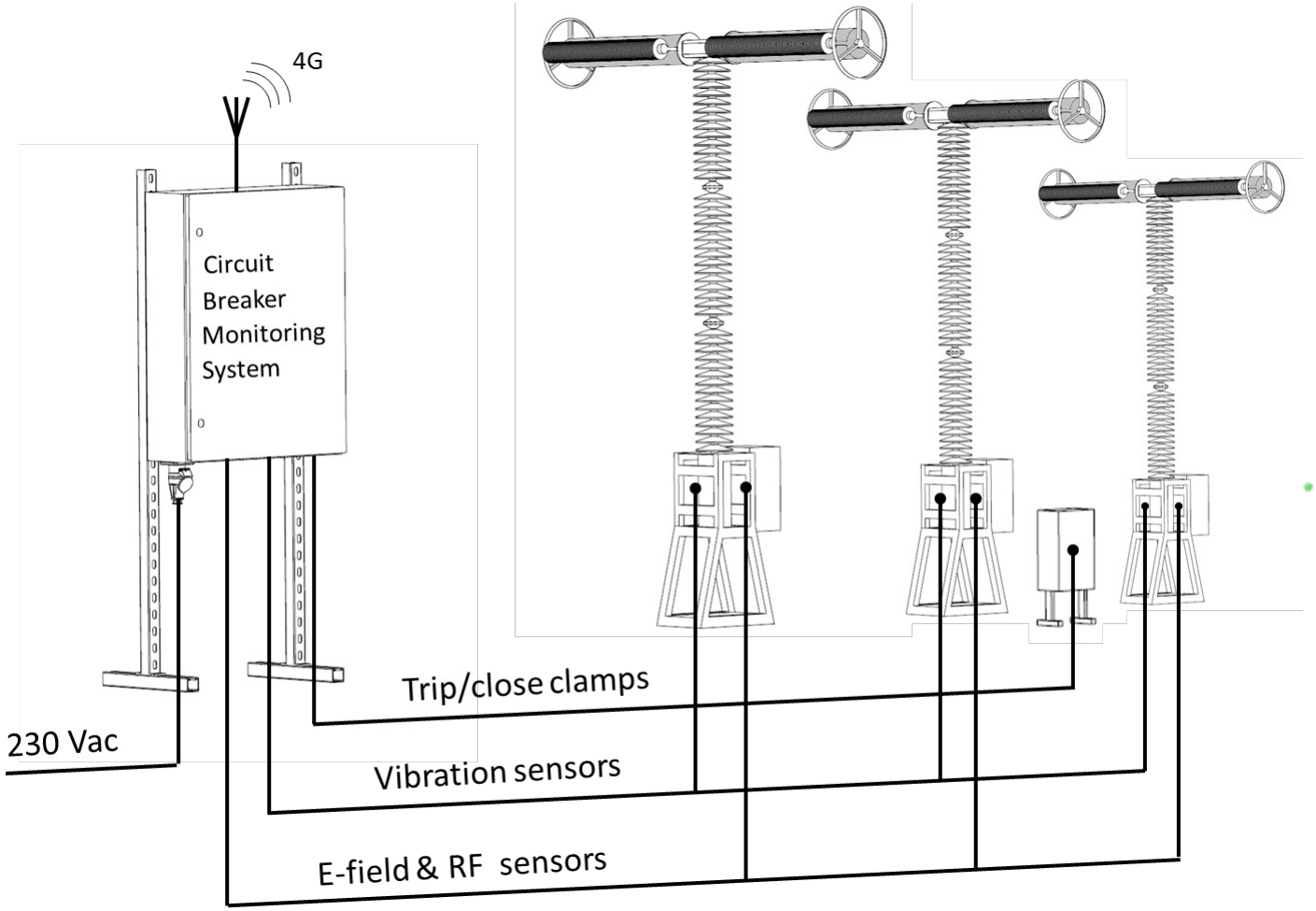
1. Two breaks per phase allows for a higher recovery voltage
2. Grading capacitors equalises the recovery voltage across the two interrupters

CB summary

- Current interrupted by natural zero crossing
- Interrupter creates an arc which allows the contacts to separate before the zero crossing
- Arc should be controlled by the gas flow and contact separation
- Interrupting the arc is ‘easy’; preventing re-ignitions is not
- Re-ignitions should, ideally, not occur
- Grading capacitors used to equalise system voltage across the two contacts
- Controlled switching relays used to eliminate re-ignitions

CB monitoring system

Overview of monitoring system

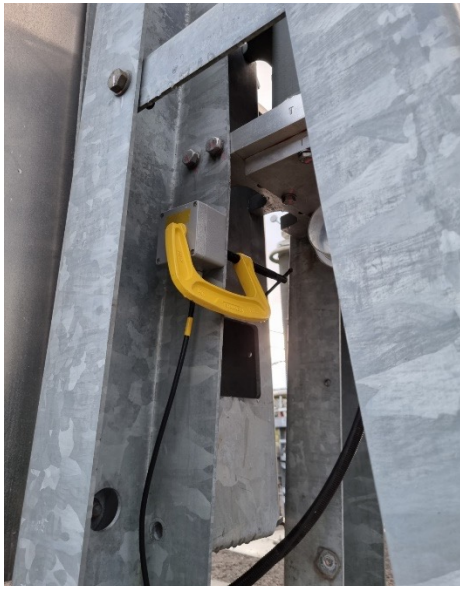


Sensors

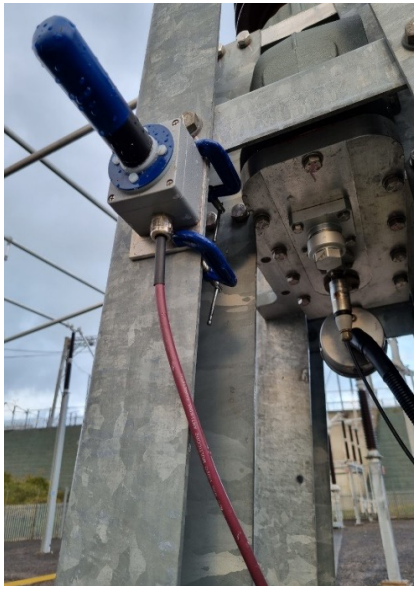
Measurements on each phase:

- Vibration – measures progress of the mechanism/drive train movement
- Radio frequency emissions – determines performance of the interrupters and grading capacitors
- 50 Hz electric field – acts as a voltage transformer for the reactor terminals, determines current extinction and re-ignitions
- Trip (or close) coil current – for mechanism timing
- Line current – timing, current extinction (optional for shunt reactor switching)

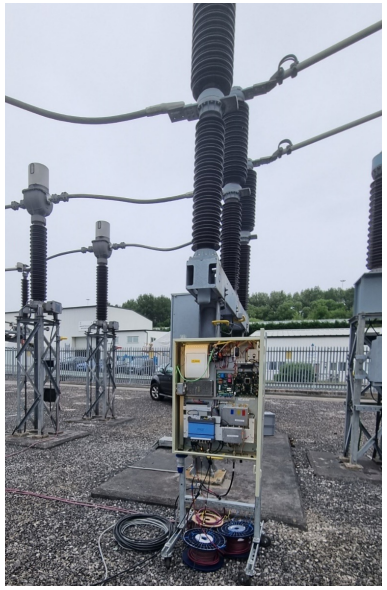
Typical setup



Vibration sensor

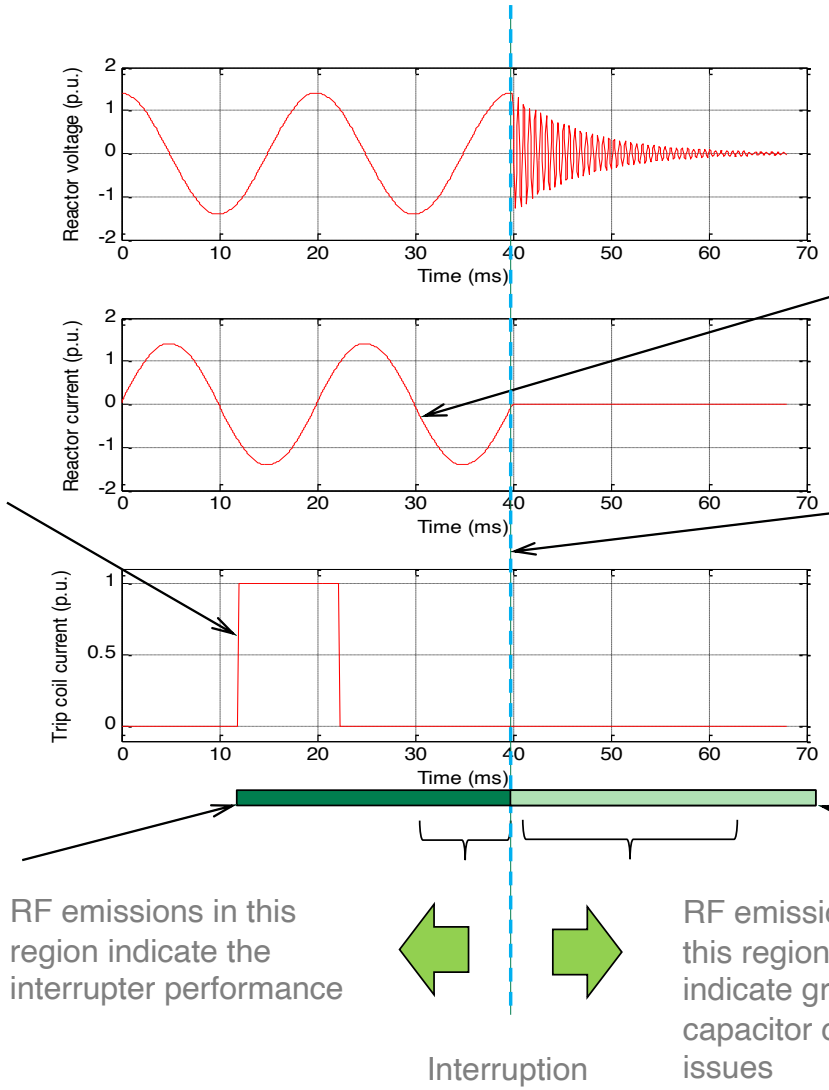


RF and E-field sensor



Recording unit in-situ

Measurement overview – shunt reactor



The contacts open and the arcing starts

Start command for the open operation

Current has been successfully interrupted

Vibration signals show progress of mechanism

Vibration signals in this region can indicate damping issues

RF emissions in this region indicate the interrupter performance

RF emissions in this region can indicate grading capacitor or PD issues

Interruption

Typical signals measured

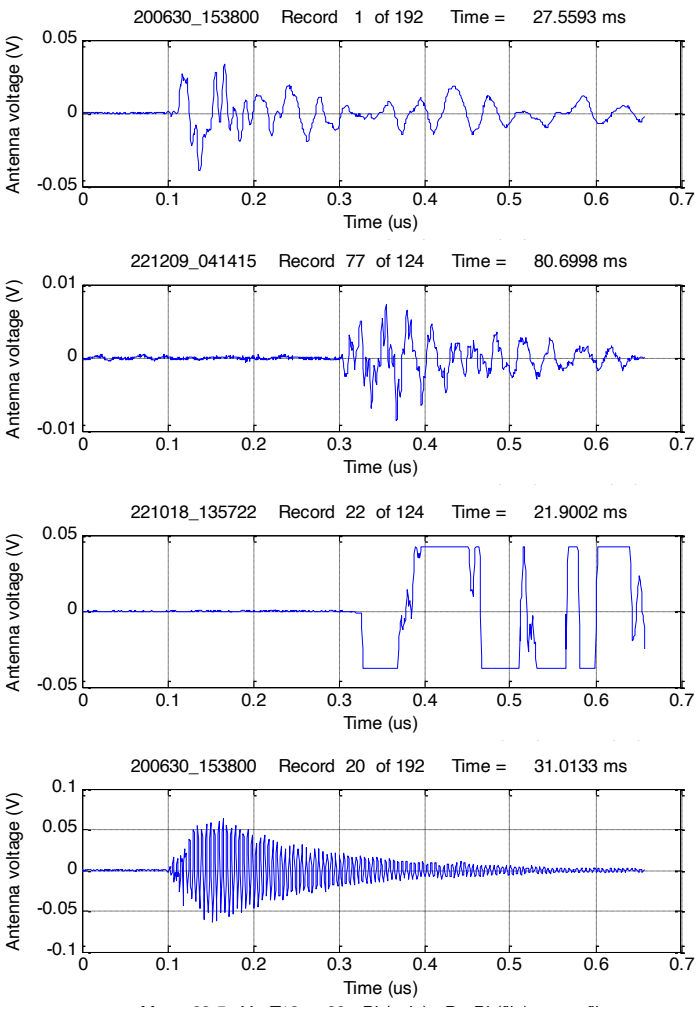
Typical RF emissions

Arc instability emissions

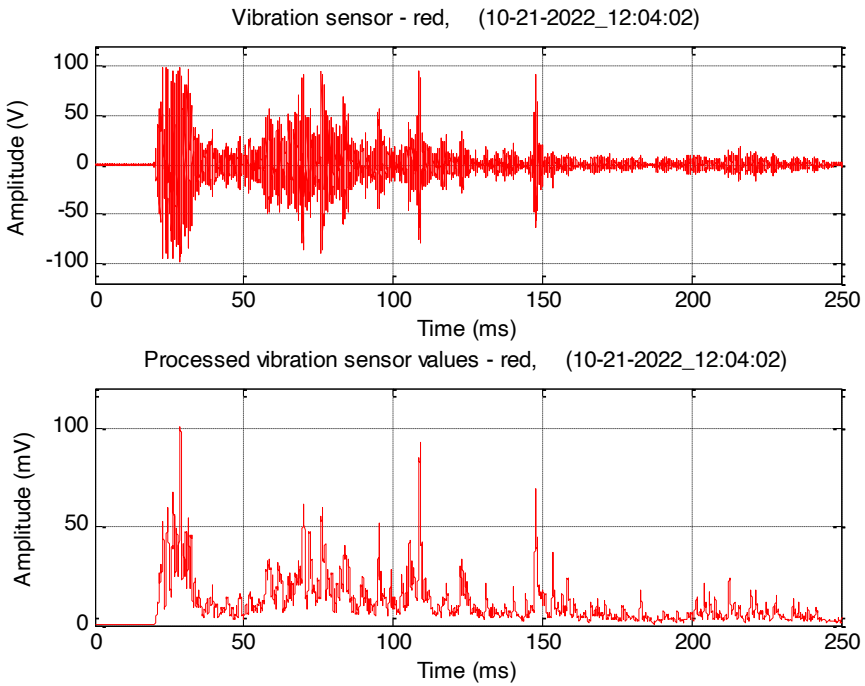
Grading capacitor partial discharge (PD) emissions

Re-ignition emissions – extremely high amplitude

Other partial discharge (PD) emissions, e.g. particles in interrupter chambers agitated by mechanical movement



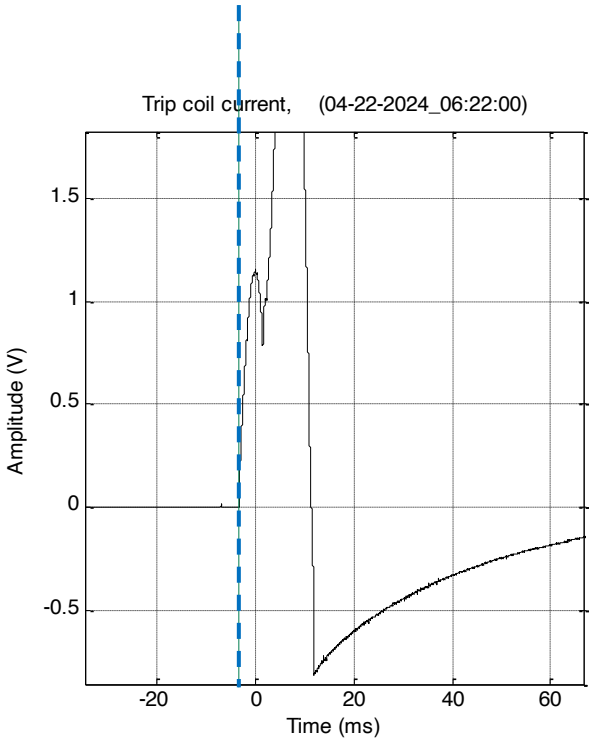
Vibration signals

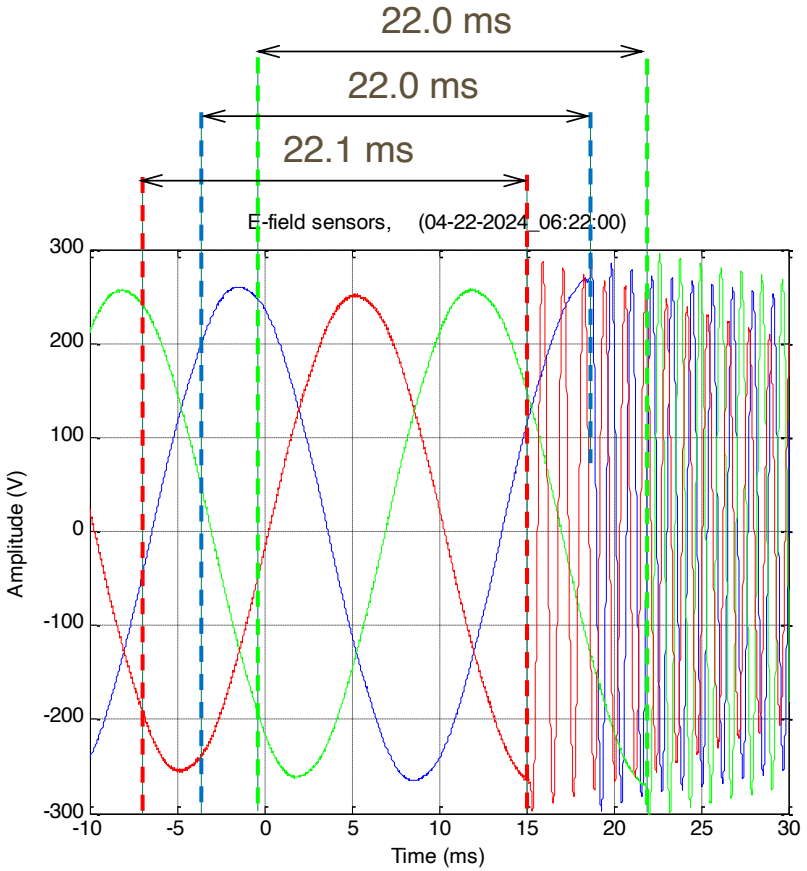


a) Raw data

b) After envelop detection

In-service CB timing

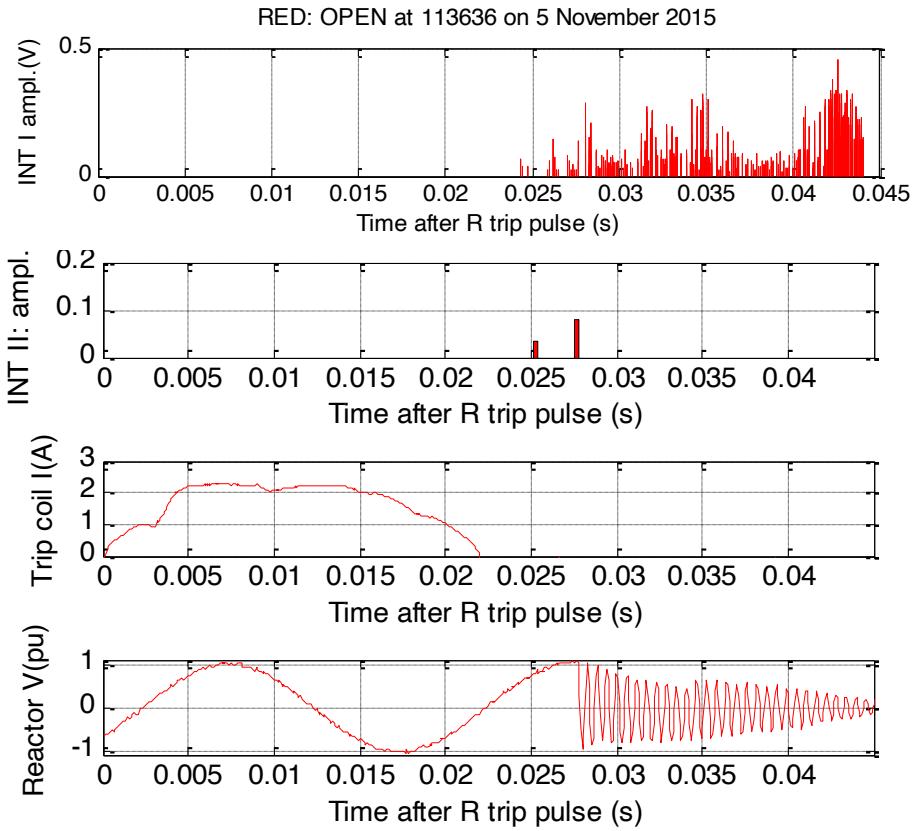




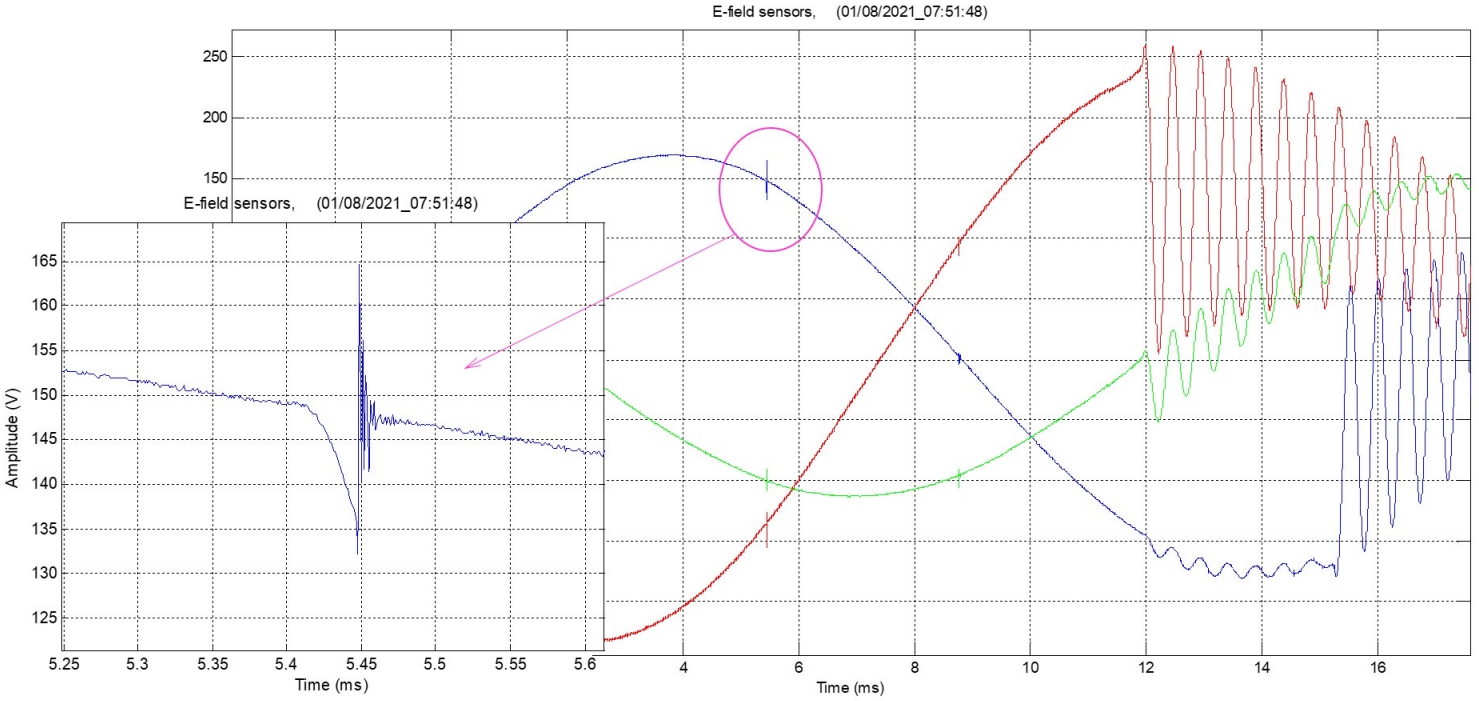
1. Current interruption determined from busbar voltages
2. Origin of graphs relates to start of vibration, not trip pulse

Defects detected

Grading capacitor defect

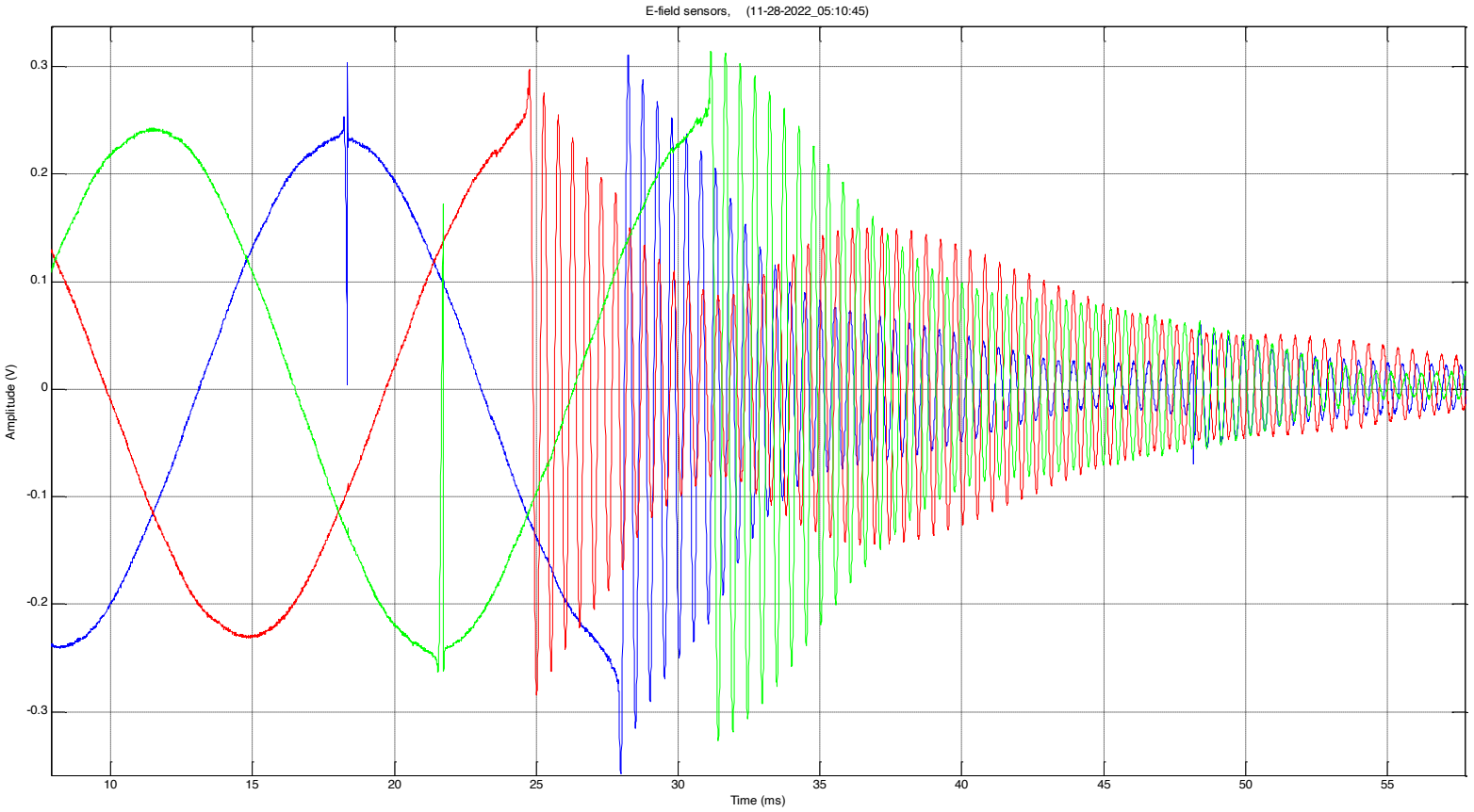


Re-ignition – CSR error

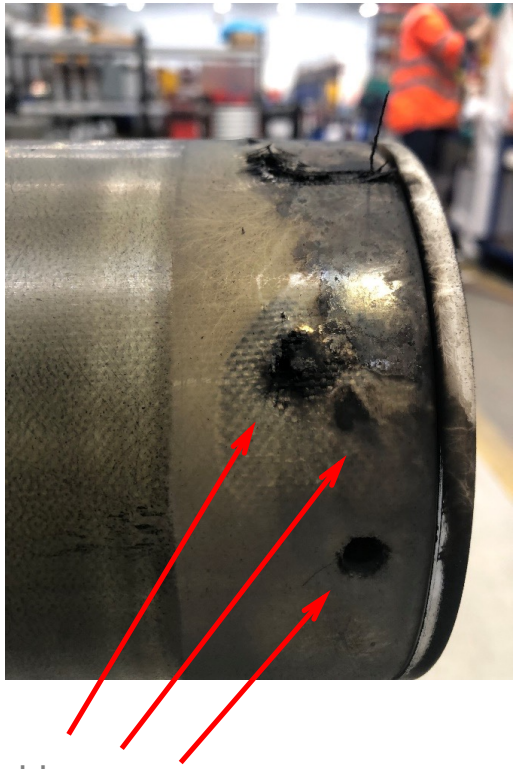


This issue was resolved by replacing/recommissioning the controlled switching relay

Re-ignition – after interruption

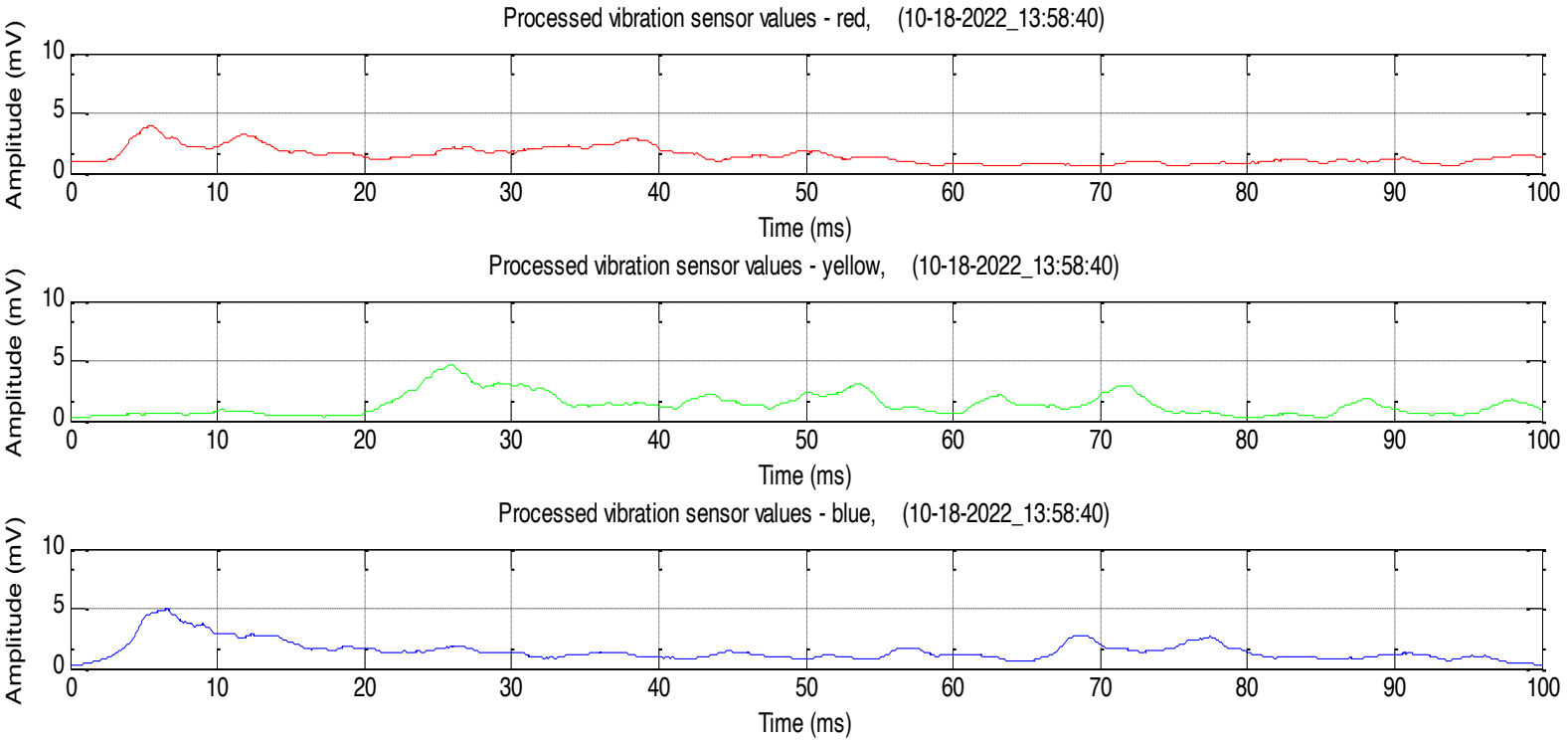


Interrupter damage – puncture holes

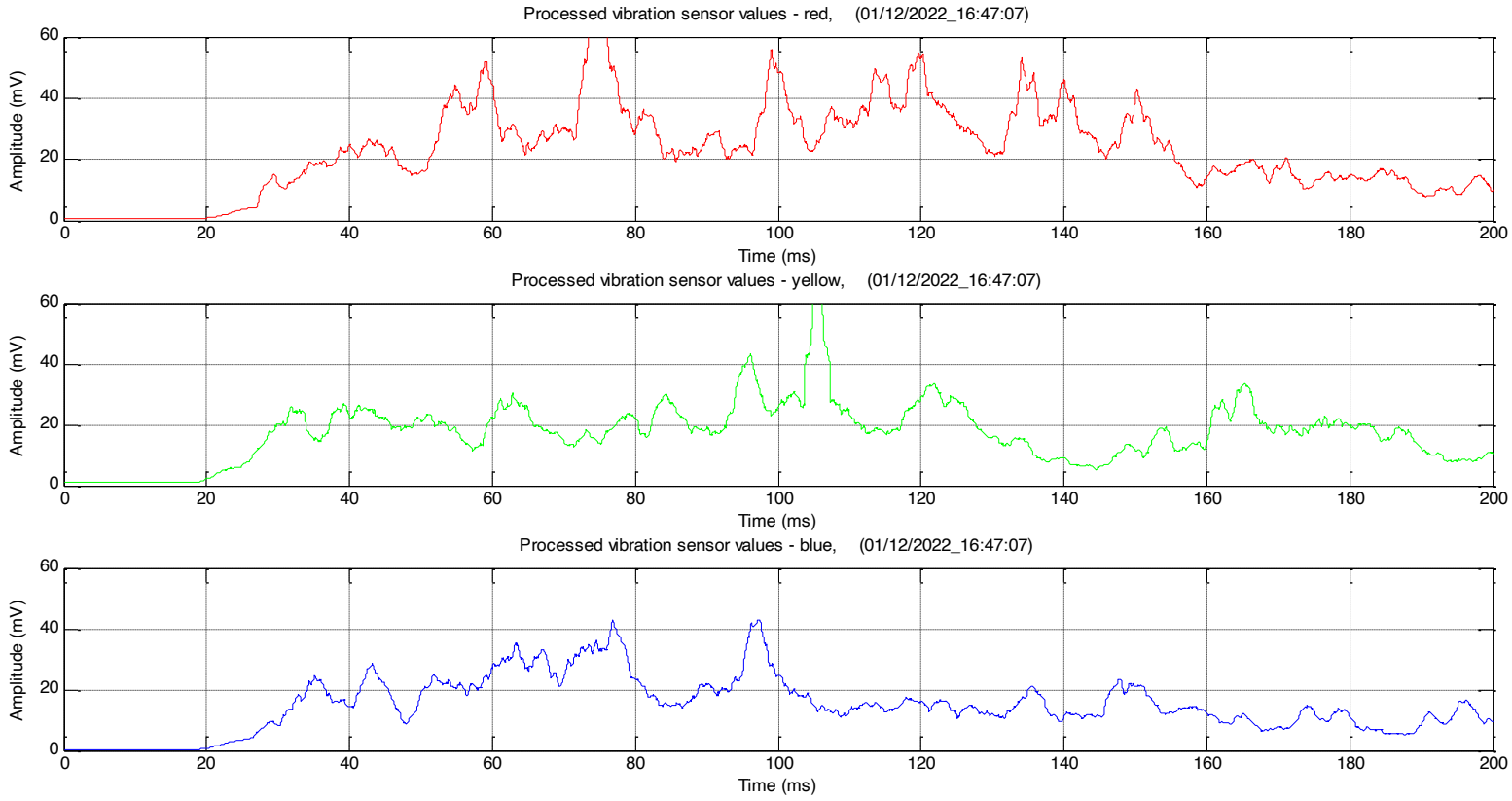


Puncture holes in interrupter tube caused by arc reigniting in incorrect position

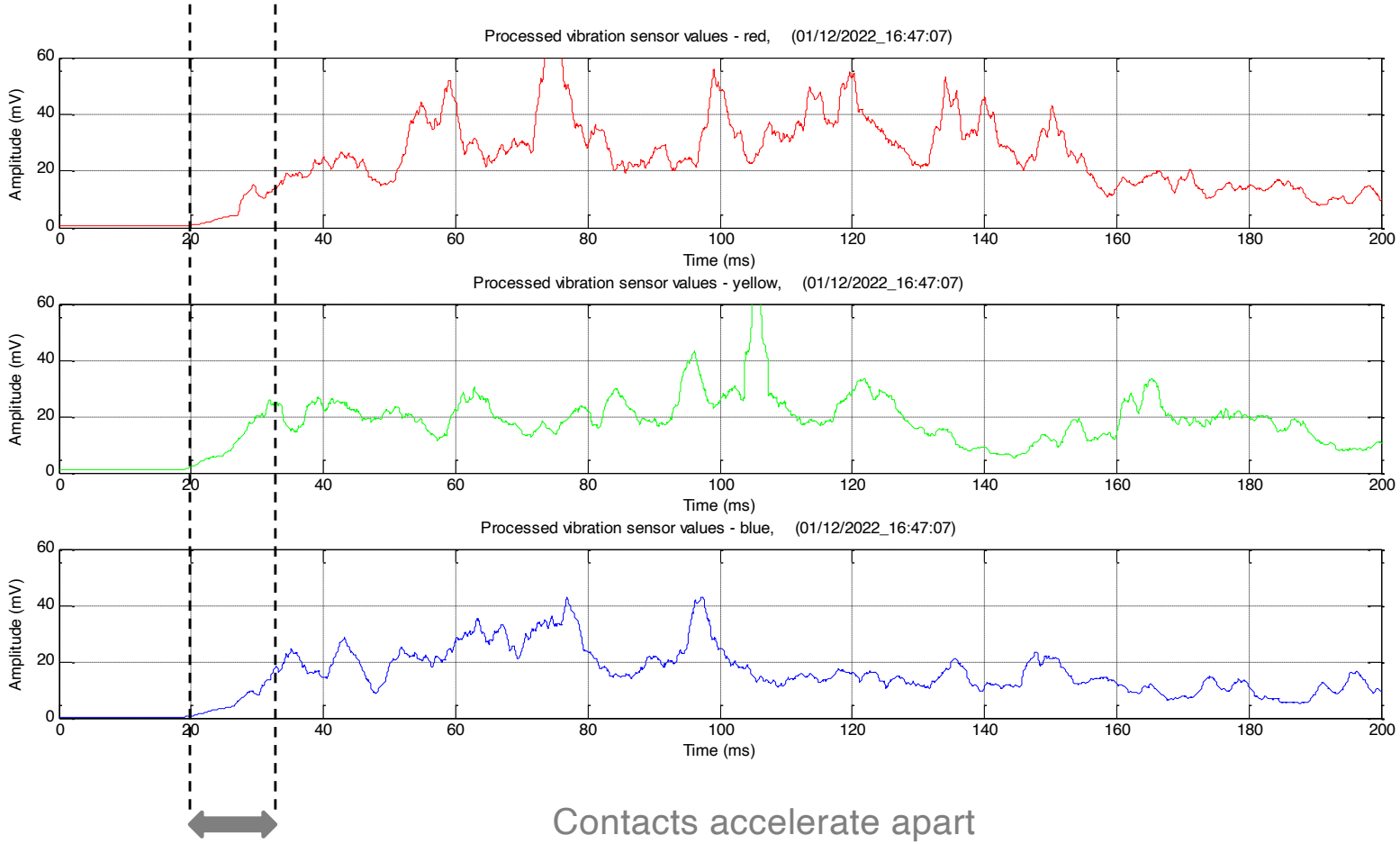
‘Sticking’ mechanism - close



Damping defect - open

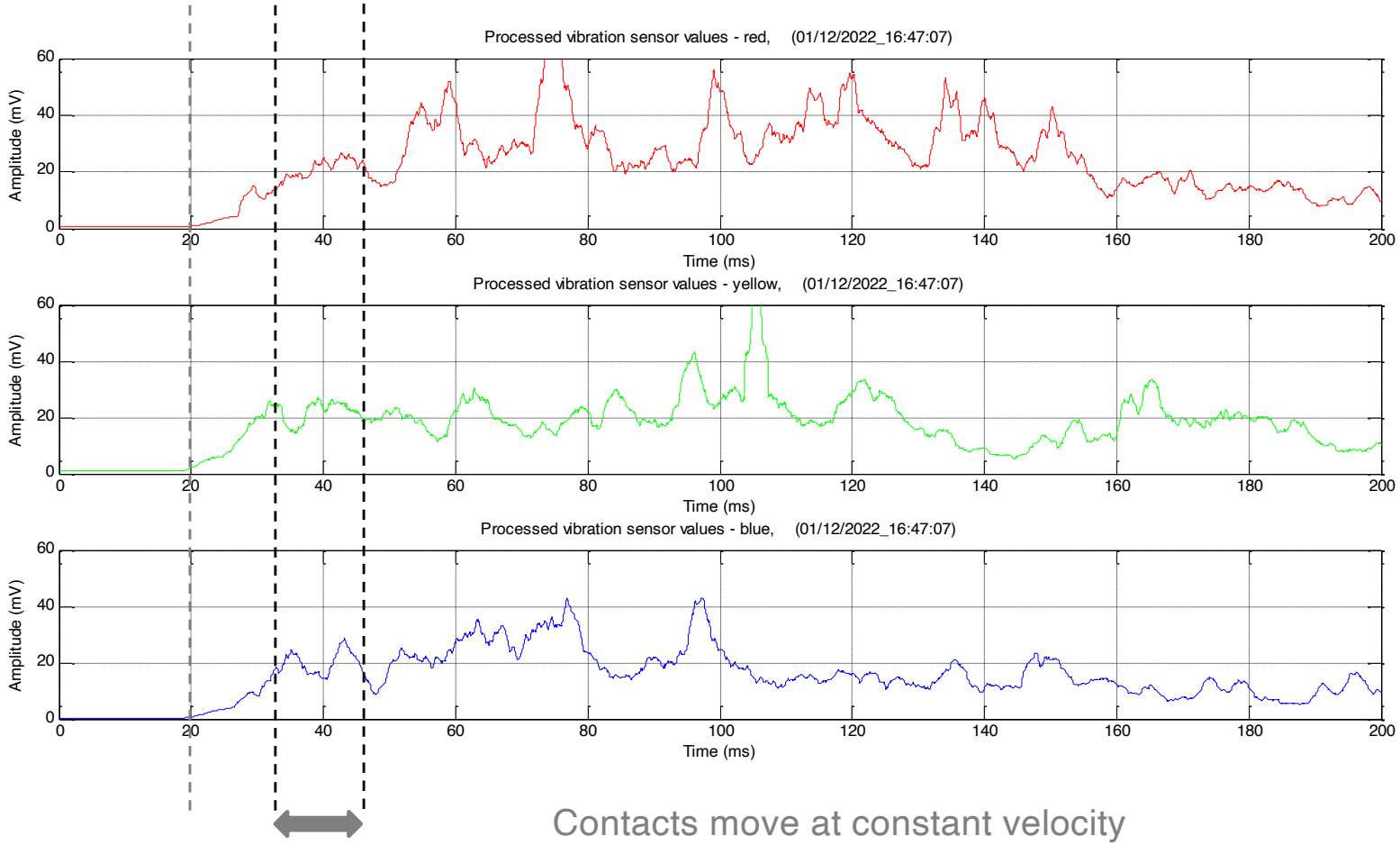


Damping defect - open



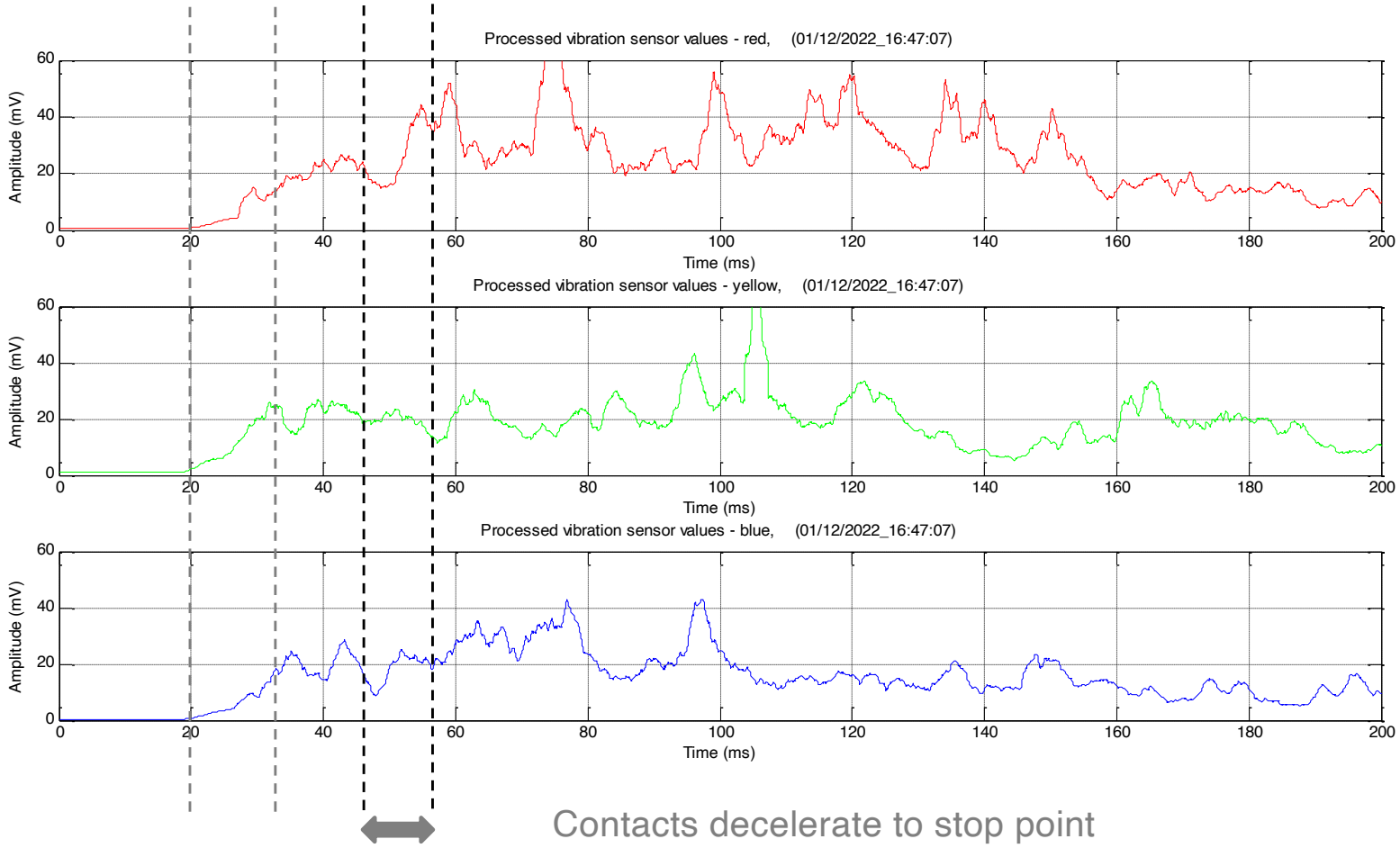
Contacts accelerate apart

Damping defect - open



Contacts move at constant velocity

Damping defect - open



Contacts decelerate to stop point

Conclusions

- Benefits of the circuit breaker monitoring system include:
  - Proven track record in detecting common CB faults
  - Non-invasive technology; requires no outage to install
  - Agnostic to CB type or manufacturer
  - Ideally suited to short duration monitoring campaigns

- This leads to utility benefits including:
  - Increased CB availability and reliability
  - Reduced requirement to conduct routine maintenance
  - Operational savings; better deployment of resources