Acoustic/Vibration-Based Condition Monitoring System for Tapchangers

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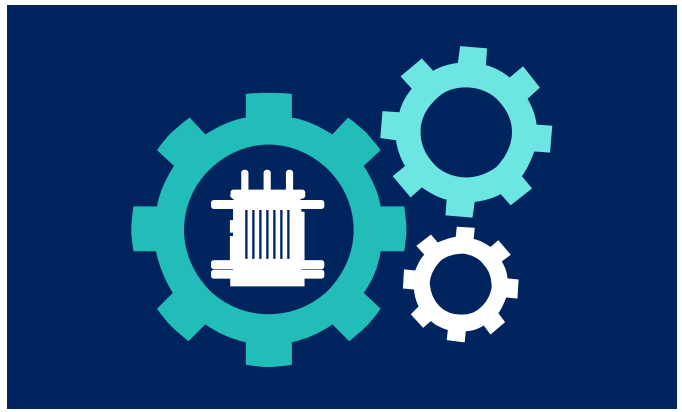
Agenda

Introduction

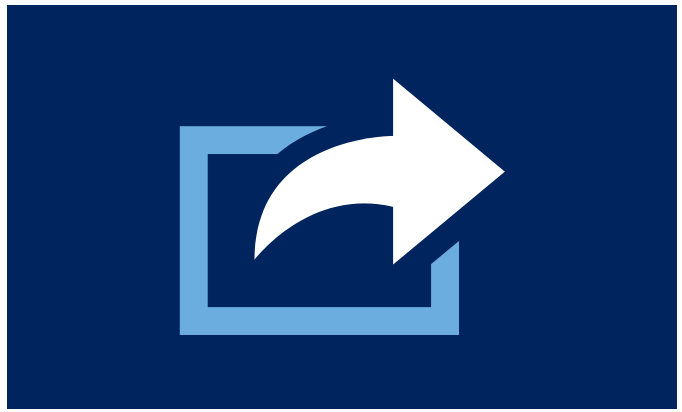
Background

Previous research



Weaponisation

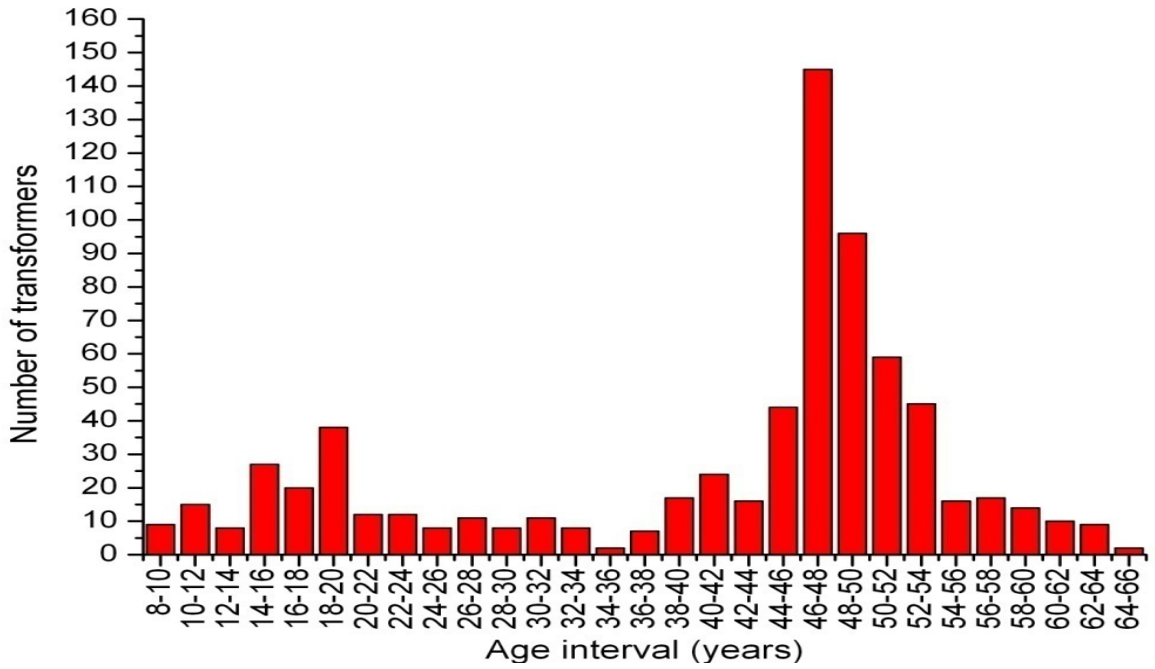
Results so far



Next steps

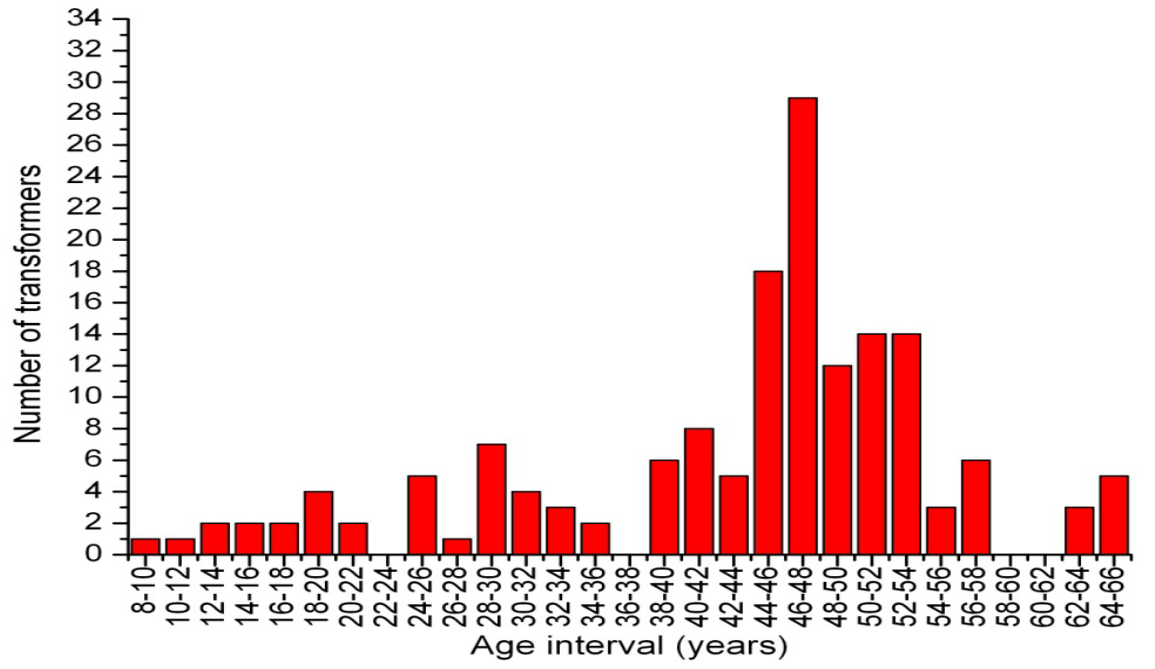
Transformer and tapchanger fleet

33 kV Tapchangers



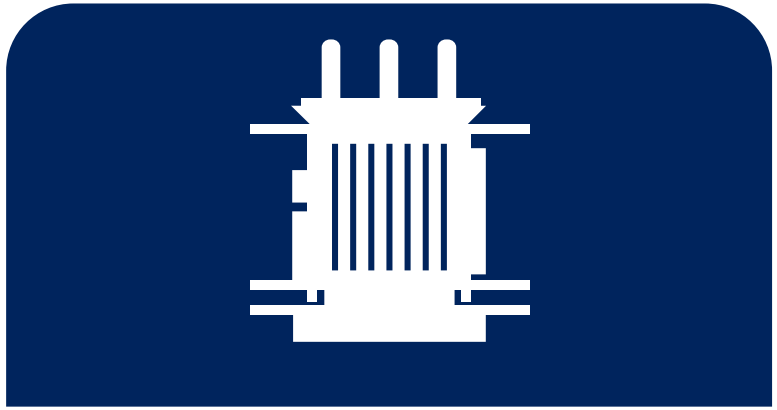
720 units
345 predicted end of life by 2023

132 kV Tapchangers



180 units
45 predicted end of life by 2023

Transformer strategy – our focus today



Objective £40 – 50 million savings

Use CBRM to reliably manage the fleet

85% reduction in unit cost v replacement

Improve unit reliability

25%
Bushings and connections

5%
Tank and radiator

~15%
Tap changer

~55%
Insulation

Acoustic monitoring of TC with Liverpool University

Fibre mounted
under flashing tape

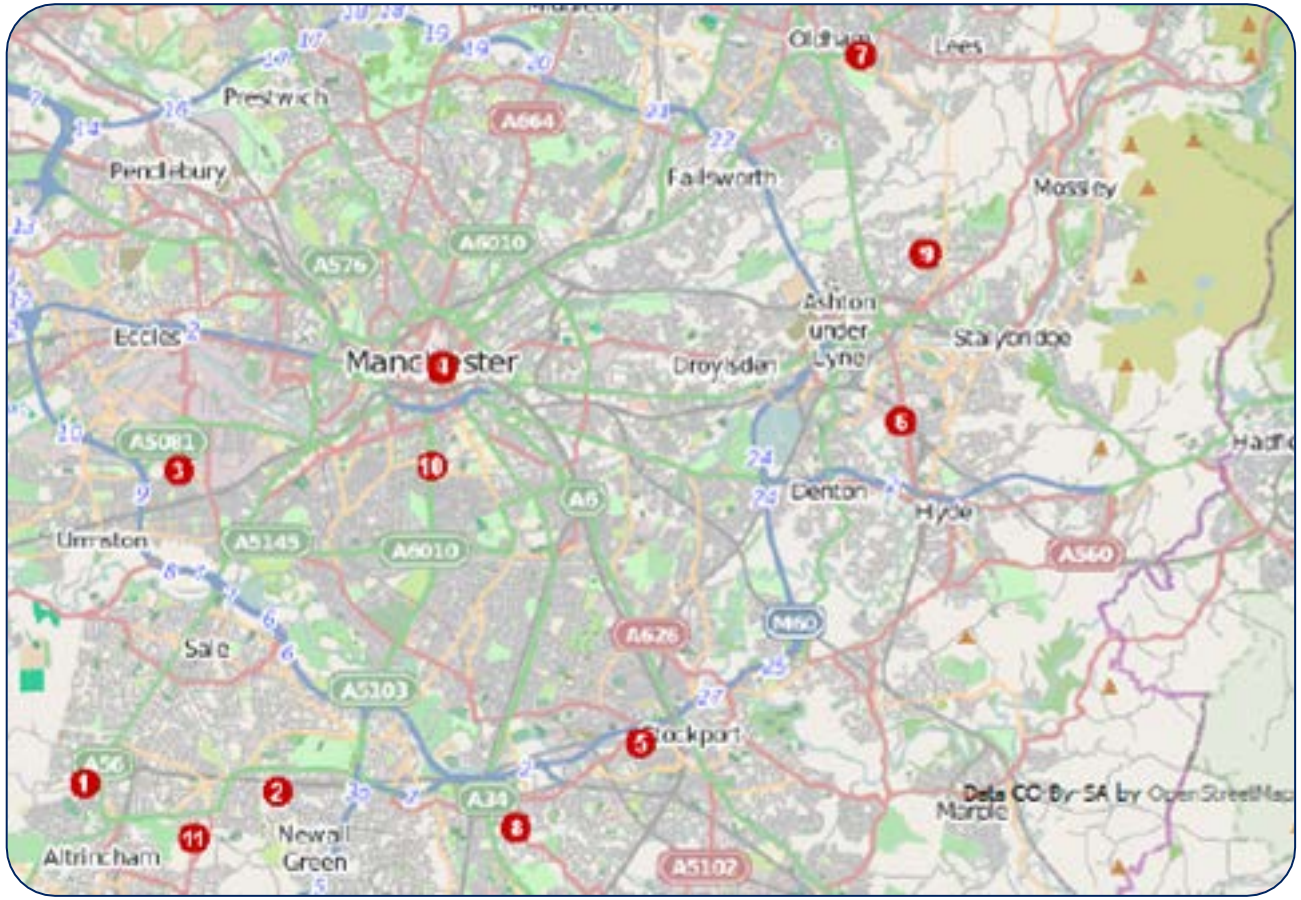
11 sites trialled across Electricity North West

Three types of acoustic signals arise from the tap changer unit

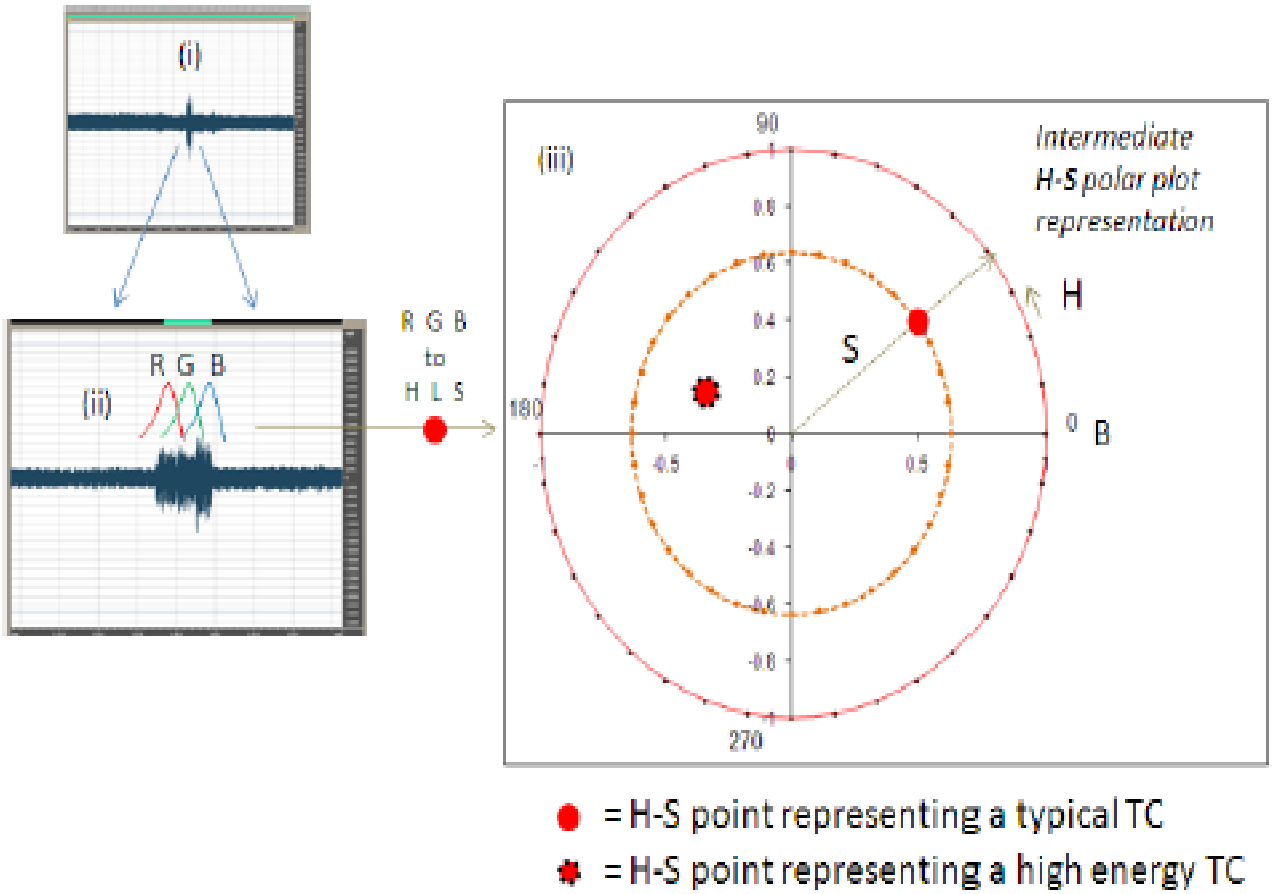
Continuous and variable background transformer humming

Acoustic events produced by the operation of the tap changer unit (TC signals)

‘Other’ events, which are produced either by the transformer itself



Primary chromatic processing of TC events

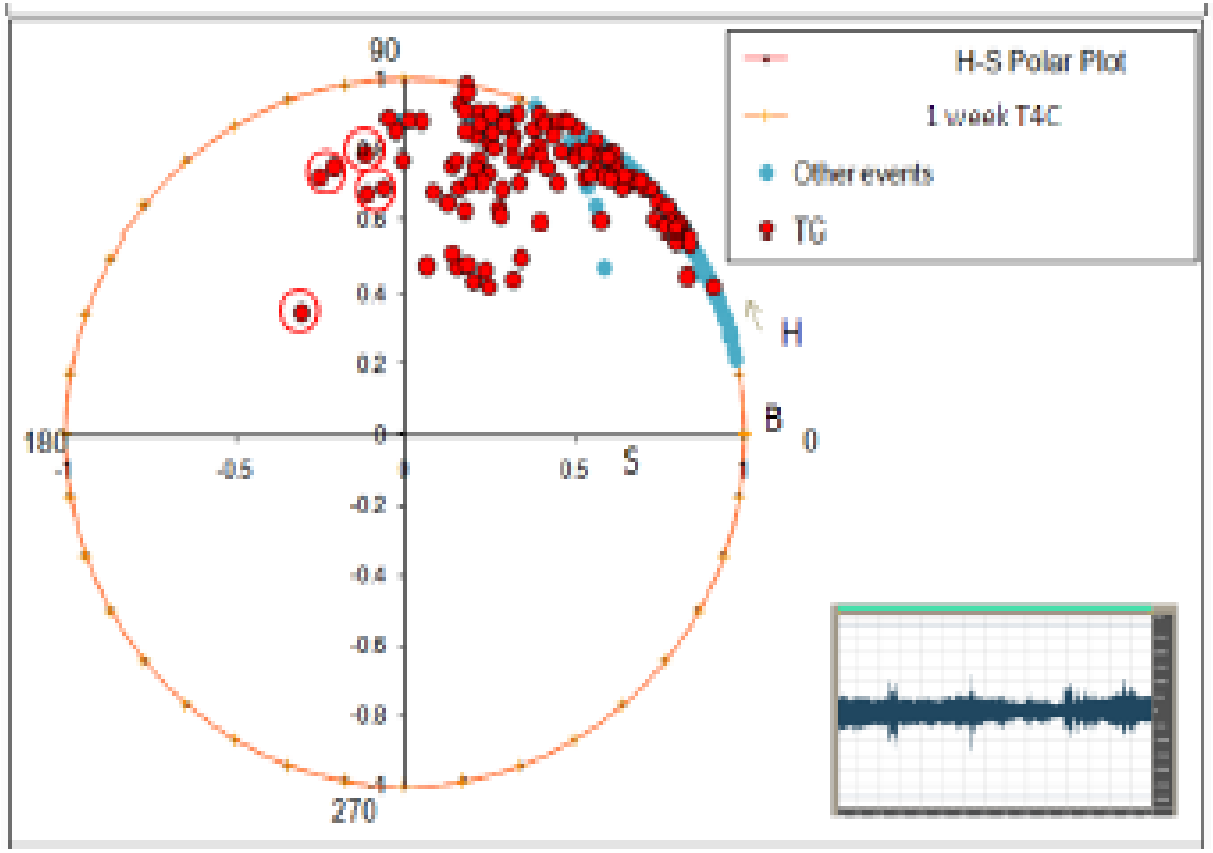


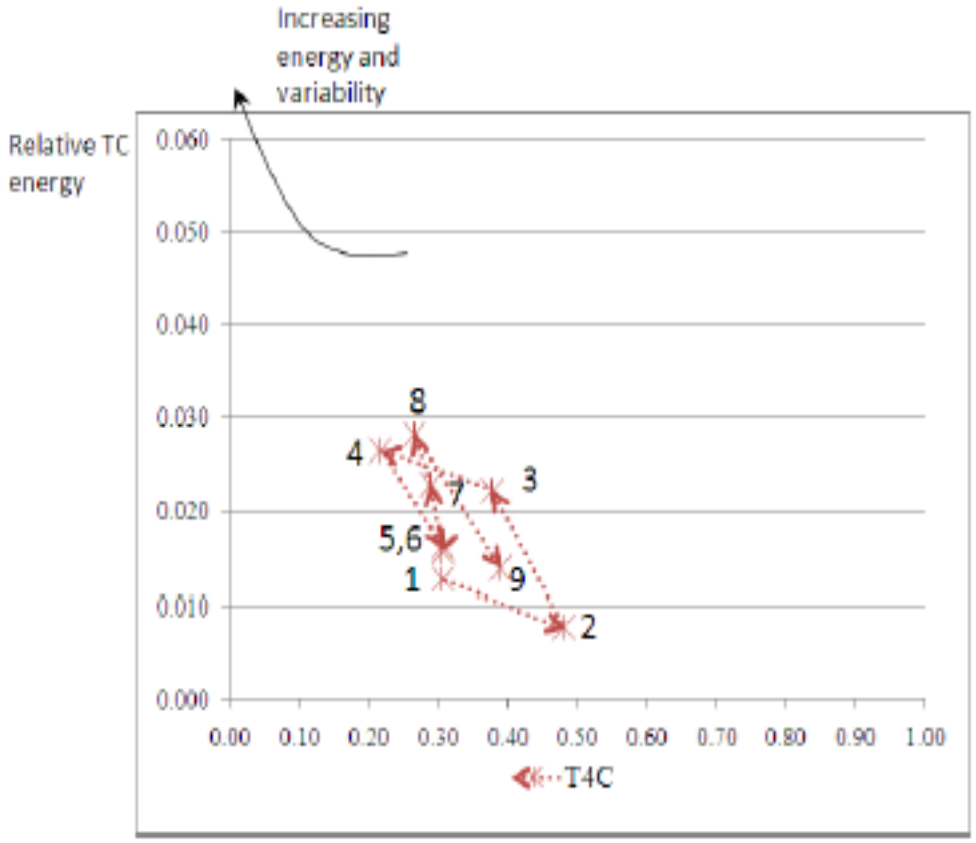
Demonstrates chromatic processing of the acoustic signals

Chromatic algorithms are then used to translate the three R, G, B event parameters into a parameter space known as the Hue (H), Lightness (L) and Saturation (S) system

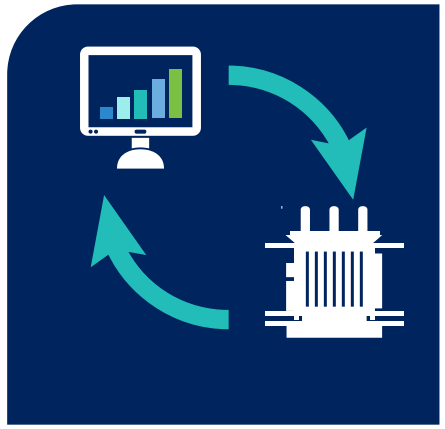
The H and S parameters for the TC event are then plotted on an intermediate H-S polar plot representation

Modelling of results





Opportunities



Proved their was an opportunity to collect data in TPs

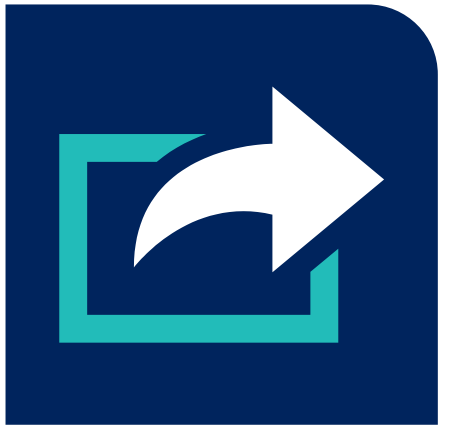
Data not easy to interpret

eg PD

Requires additional inputs to be more usable

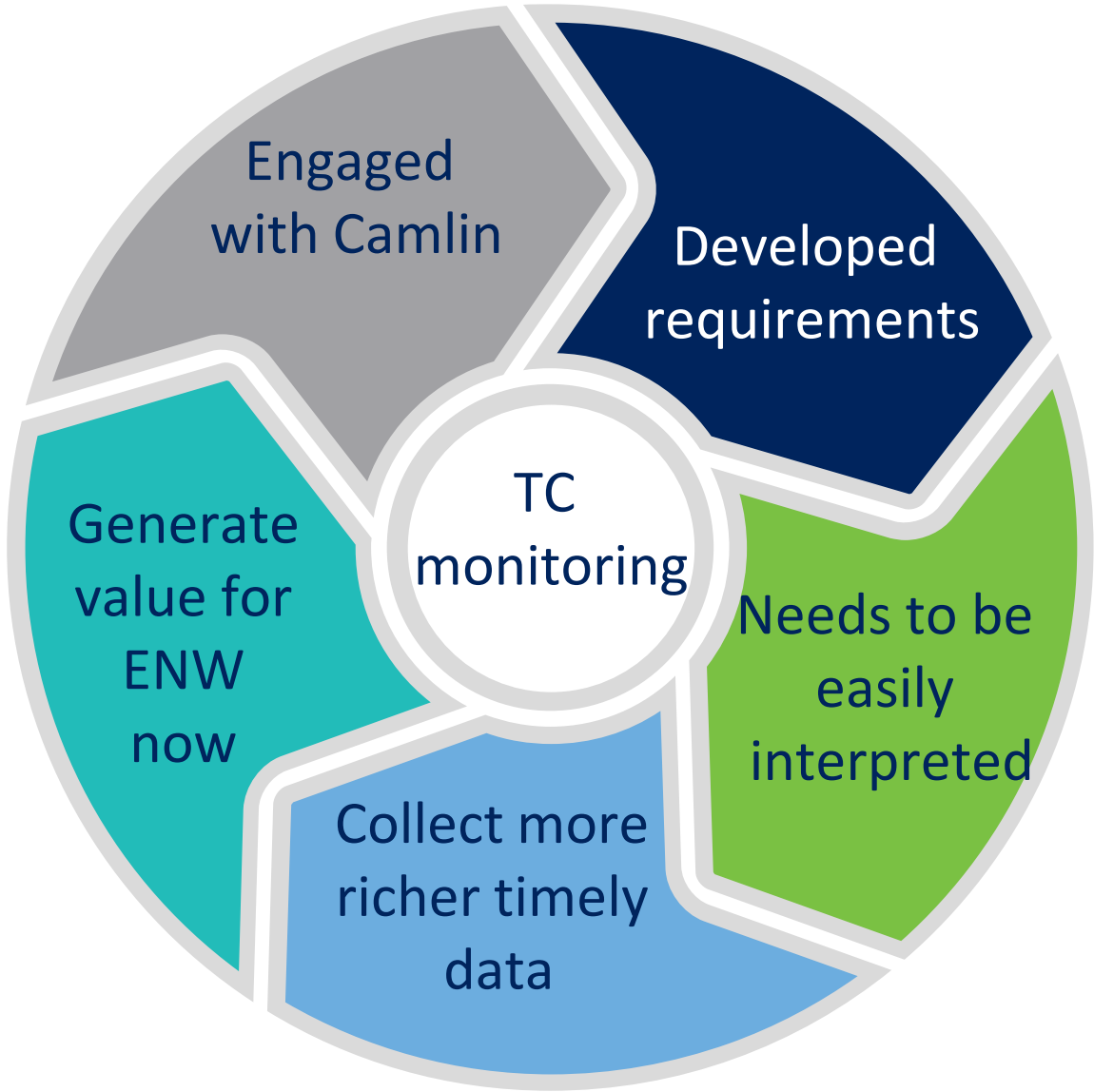
Used on the CLASS project to show wear on TC

Now BAU



Needs further innovation to be able to weaponise

Our strategy



Background

NIA funded project to test feasibility of detecting problems

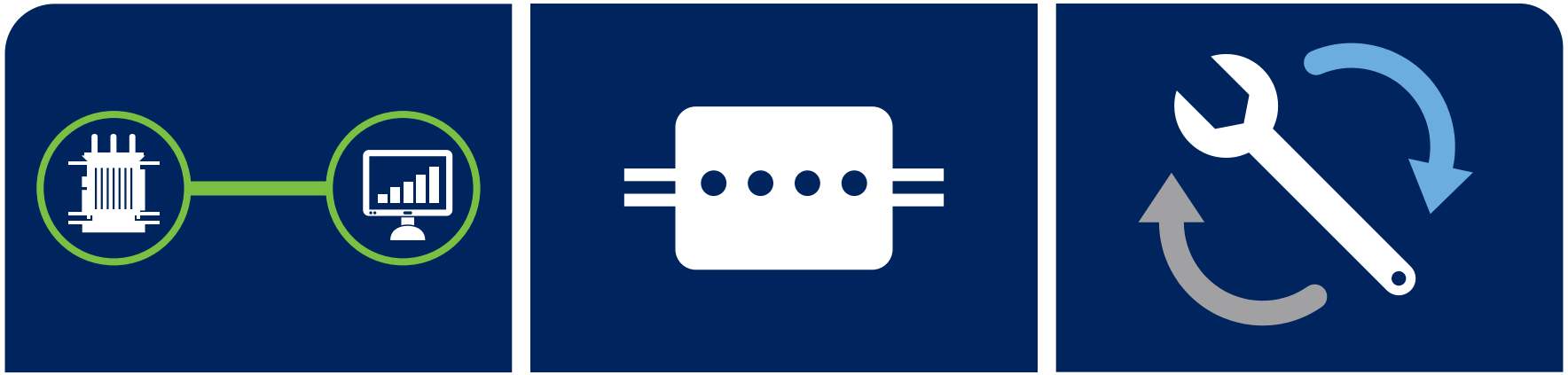
Acoustic/ vibration acquisition system

Record information during each tap change switching event for a period of two years

Goal: to process recorded data with tools looking for trends referable to ageing of tapchanger

Will lead to improved asset management of tap changers

Prototype installations



Three units developed and installed to learn what we can or need to collect

Wide bandwidth sensors initially used to collect data to fine tune bandwidth of sensors

Proved that motor current is related to the torque it applies from friction, stiction etc

Alpha prototype installations

Three alpha prototypes installed and commissioned in July 2017

Winifred Road Primary
Altrincham Grid
Baguley Primary

Complete waveform from Accelerometer and CTs @ 192kHz

Temperatures

Tap position for each switching event

All data sent to remote server

Introduction of specific lossless compression reduced data size by 50%

Installed system generate on average 3/4 events per day each around 15/25MB

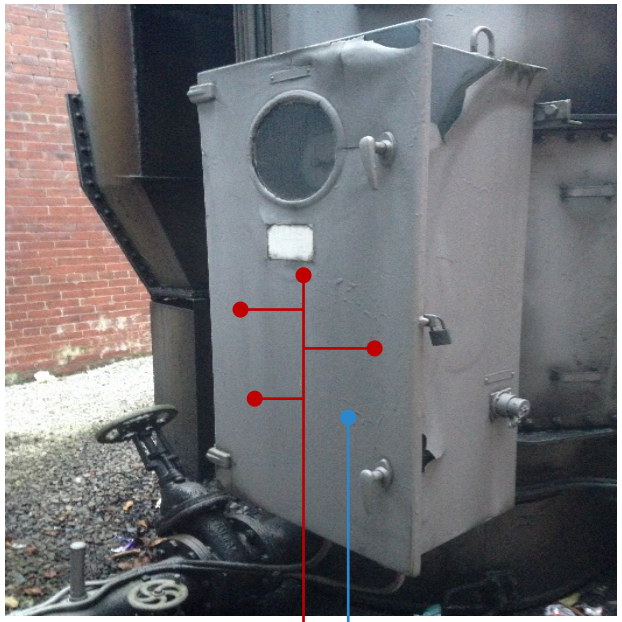
Each system should generate about 2/3 GB per month

Down sampling of CT's waveform should be implemented to reduce data of about 30%

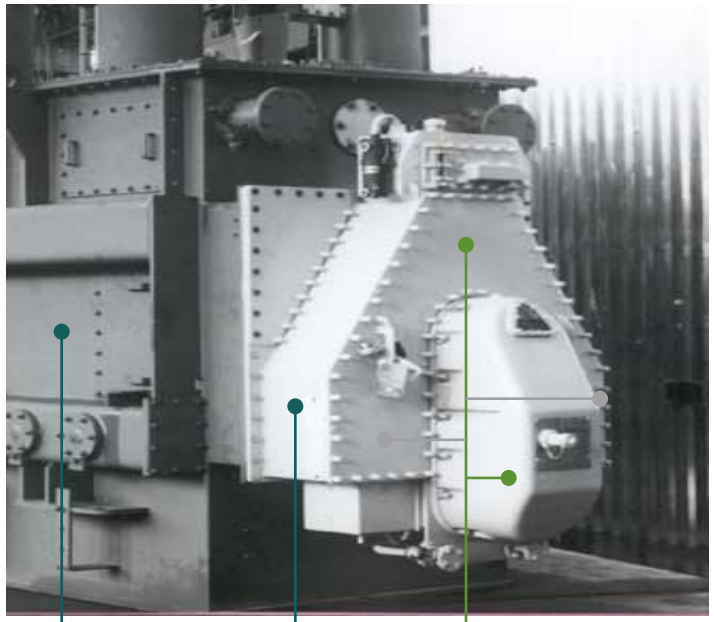
Preliminary 'hand-crafted' data analysis has identified issues on two of three monitored tap changers

Latest system overview

Transformer control kiosk



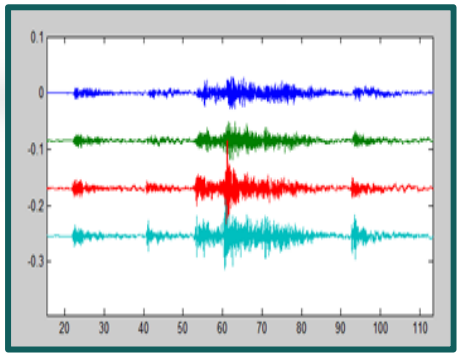
Tap changer



Tap changer monitoring system

2G/3G link

SFTP server collects vibration and current waveform generated by each switchover



Ambient Temperature probe

2x temperature probes (1x tap changer tank temp, 1x transformer tank temp.)

4x accelerometers or AE sensor

Tap position

4x CTs (1x transformer current, 3x tap changer motor current)

Mains power input

Acquisition module

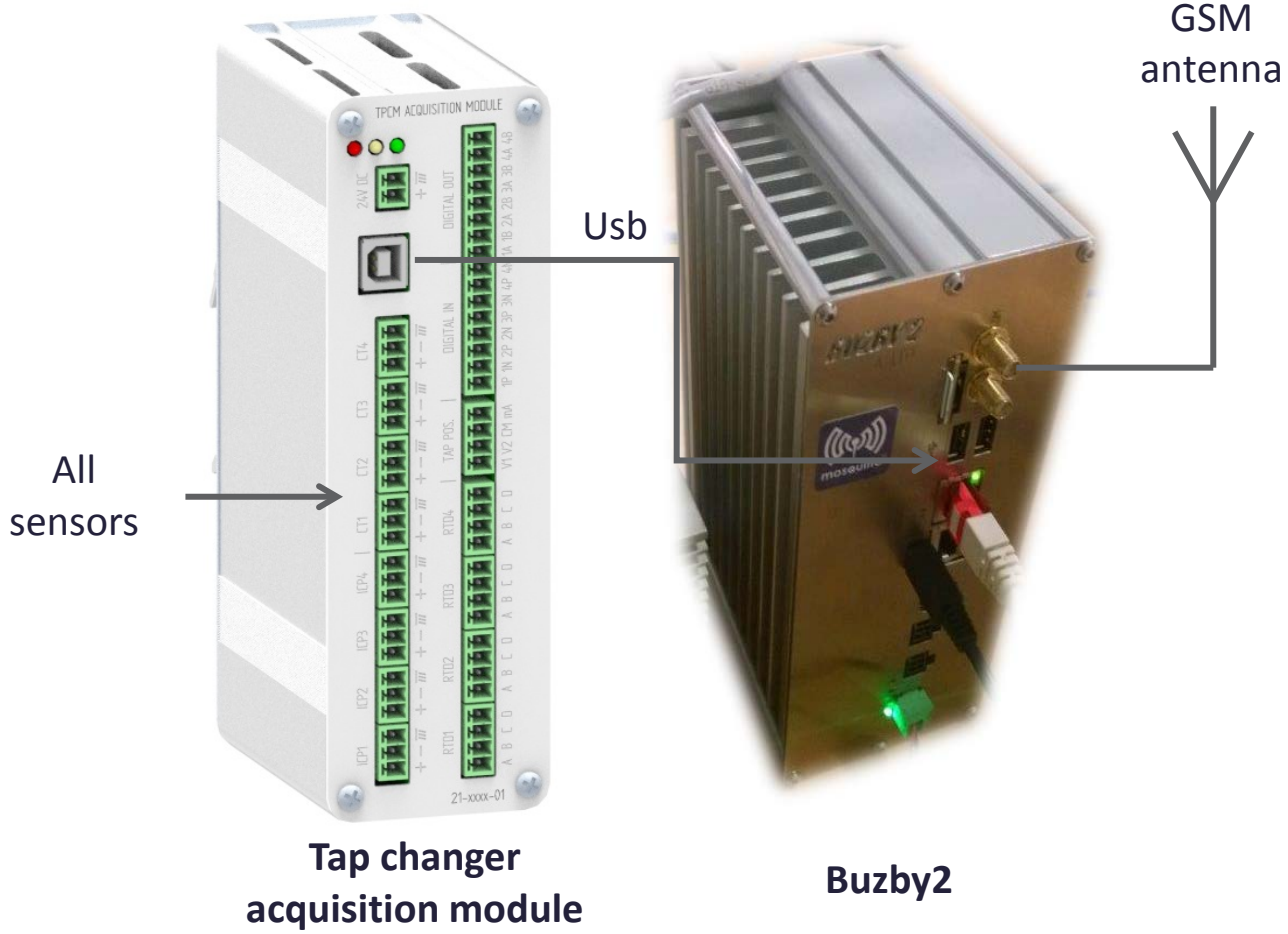
High and not scalable cost

Relatively low sampling frequency (50kHz)

Proprietary and high cost development tools (LabView)

Limited amount of data means **high failure risk of statistical analysis approach**

Acquisition model



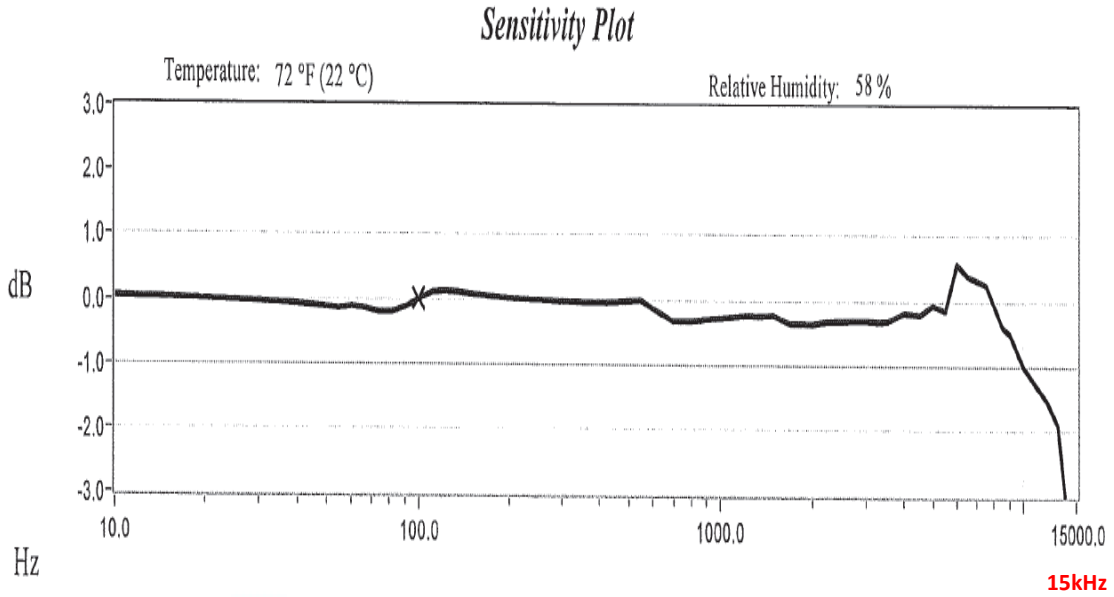
- Complete custom USB acquisition module designed
- Flexible 8 channel 24bit 192kHz differential input
- Auxiliary isolated analogue input
- Auxiliary isolated digital I/O
- 4 input for RTD temperature sensor
- USB interface compatible with any Linux PC using standard drivers
- Acquisition module designed and tested in about 6 months
- Cost effective and quantity scalable solution

Vibration and acoustic sensors

Analysis of mechanical vibration produced by gear and switch

Require sensor capable of vibration detection with phase coherence across spectrum up to 10kHz

ICP Industrial accelerometer used *(0.5 to 10-15kHz)*

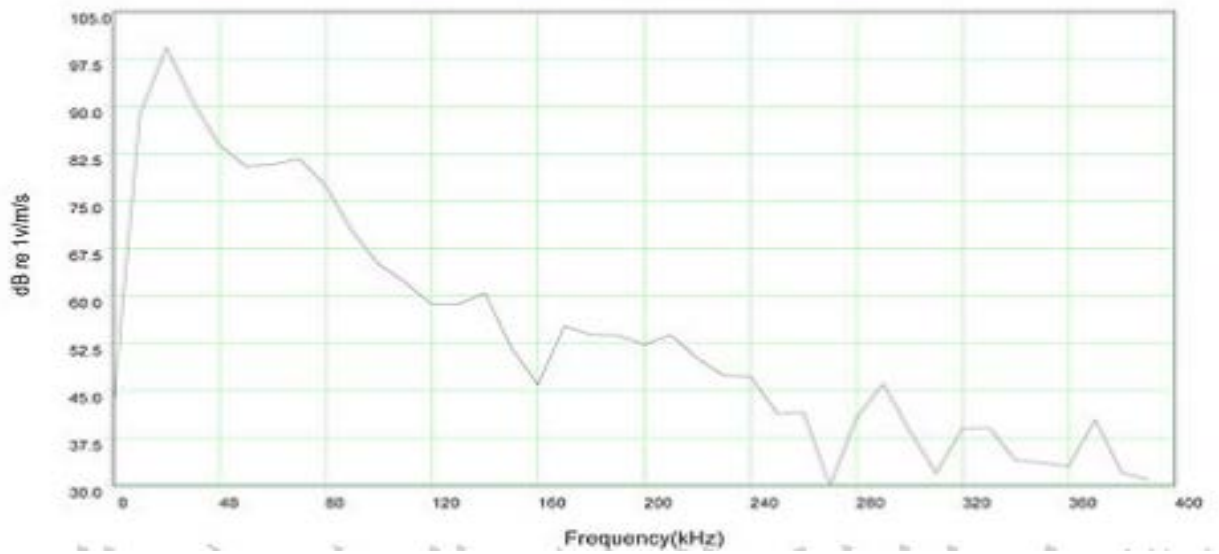


Vibration and acoustic sensors

Detection of noise produced by arcing and PD during switching

Require sensor capable of detect high frequency acoustic energy (> 50kHz, where mechanical noise roll off)

Acoustic emission resonating sensor used *(15 to 150kHz)*

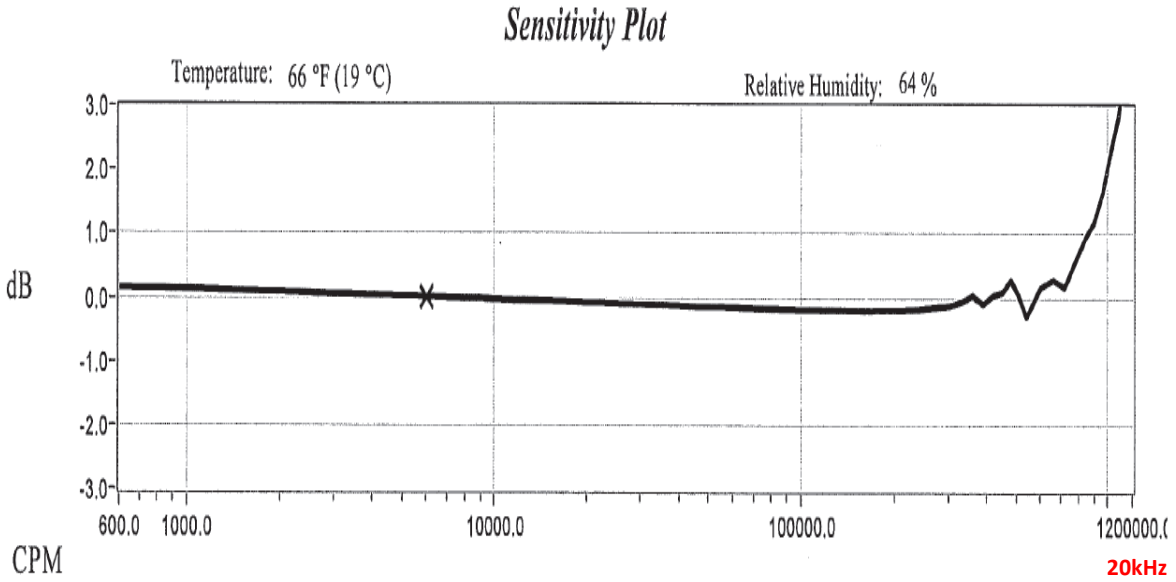


150kHz

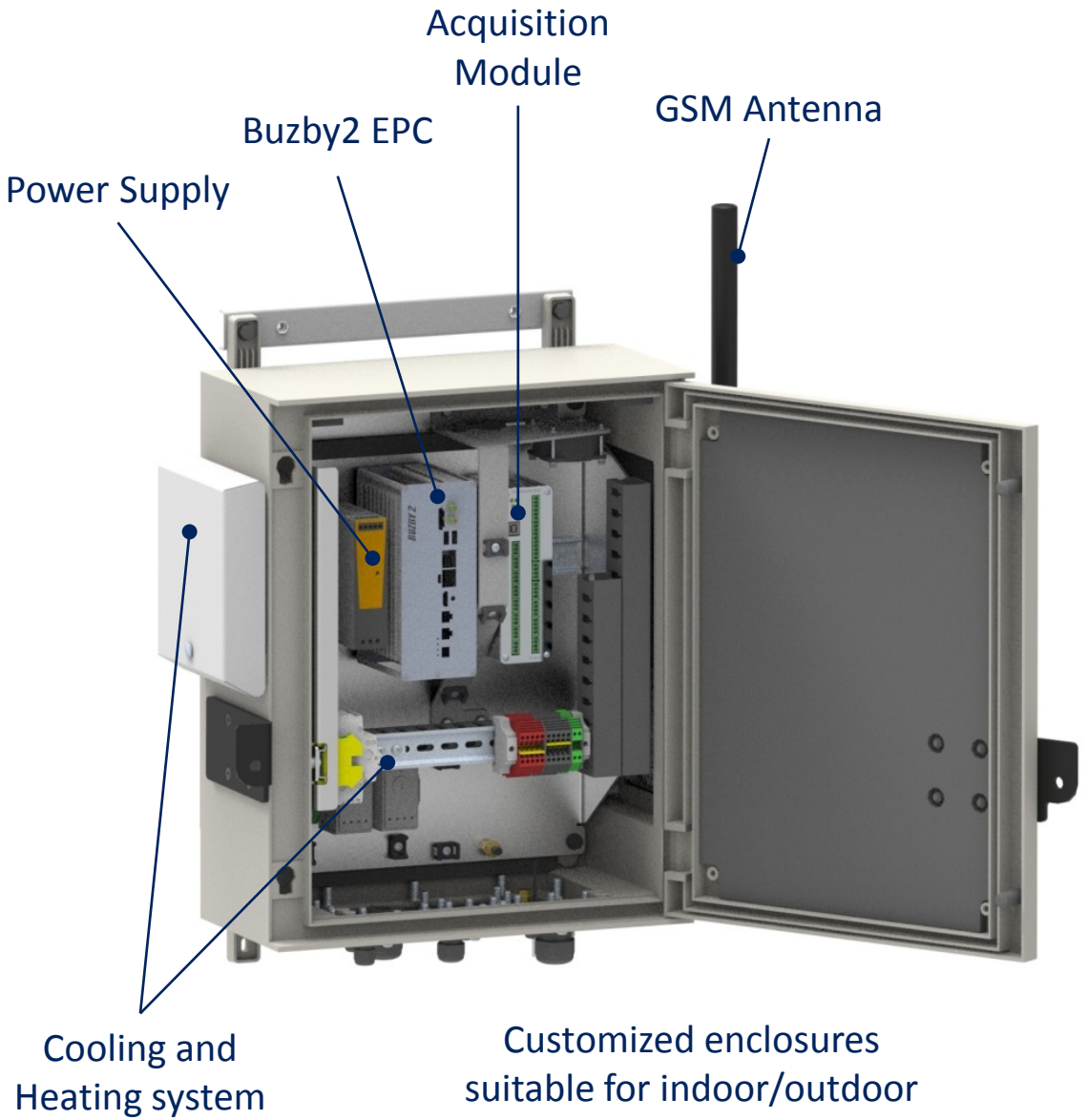
Vibration and acoustic sensors

Acquisition module can sample up to 192kHz so can be used with all kind of sensor (AE requires specific preamp)

Hi quality industrial accelerometer is similar cost to AE sensor and seems capable to detect energy up to 100kHz.



Electro-mechanical system



Project status

Electromechanical fully designed (Lisburn)

Acquisition module fully designed and tested (Parma)

Linux software designed and tested (Glasgow)

Three alpha prototypes installed and commissioned

Basic statistic implemented on server (Parma)

Site inspections carried out to plan installation

40 systems installation scheduled

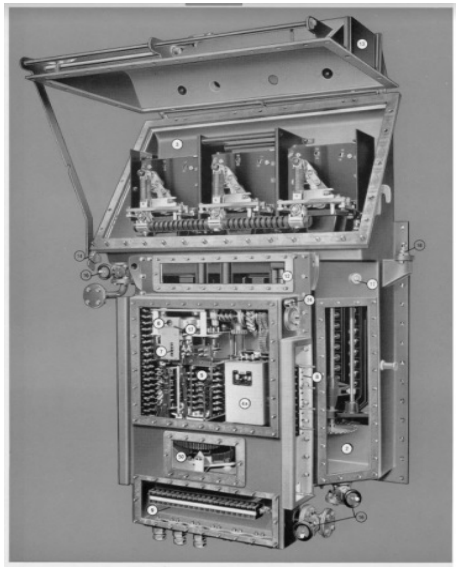
Statistical analysis of incoming data and algorithm development to determinate ‘system condition’

Alpha prototype installation: Winifred Rd

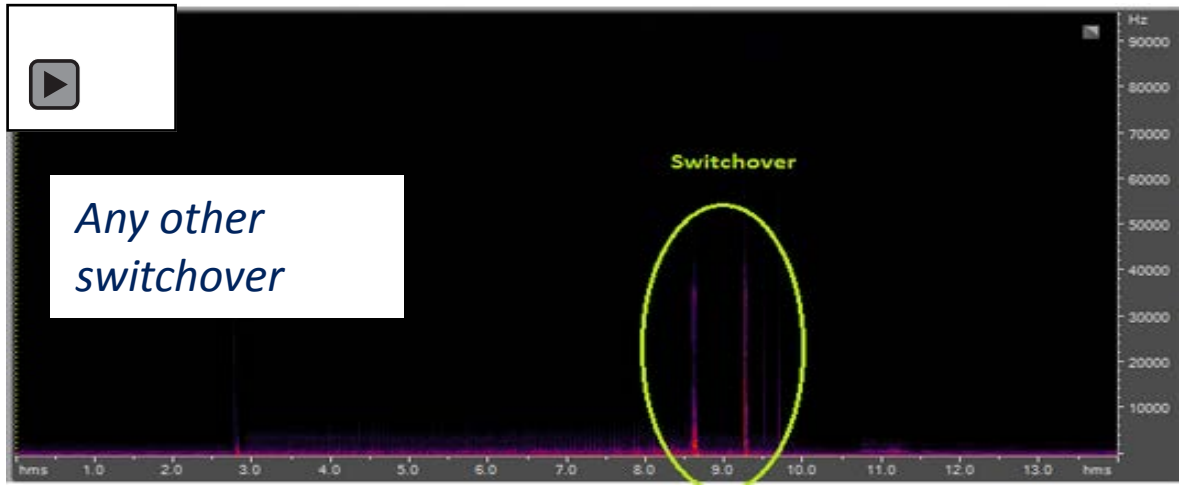
Site: **Winifred Road Primary**

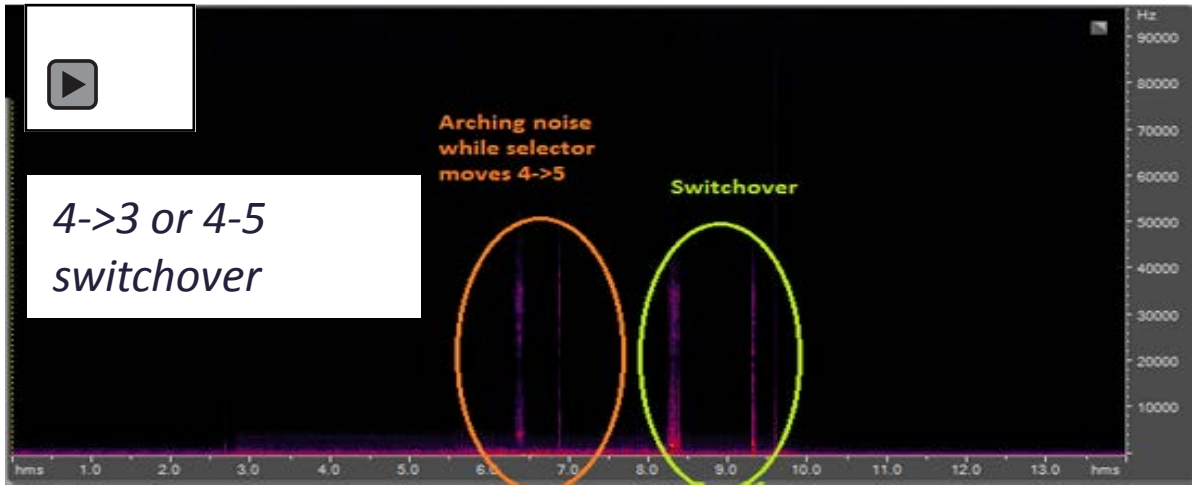
Tap changer type: **Ferranti DC3**

During the selector movement phase of last step of switching sequence 5->4->3 or 3->4->5 arcing noise presence can be clearly heard.



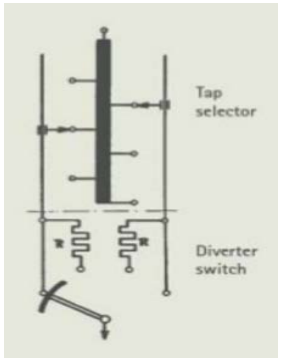
Event_ID	BS_TapPos[#]	AS_TapPos[#]
20170717T052222	3	4
20170717T055305	4	5
20170717T055808	5	4
20170717T080014	4	5
20170717T081220	5	4
20170717T091245	4	3
20170717T091806	3	4
20170717T162033	4	3
20170717T163919	3	4
20170717T172635	4	5
20170717T173504	5	4
20170717T191248	4	3
20170717T192946	3	4
20170717T193015	4	5
20170717T194042	5	4
20170717T204802	4	5
20170717T213717	5	4
20170717T234952	4	3

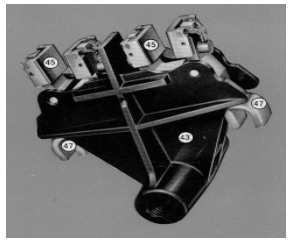


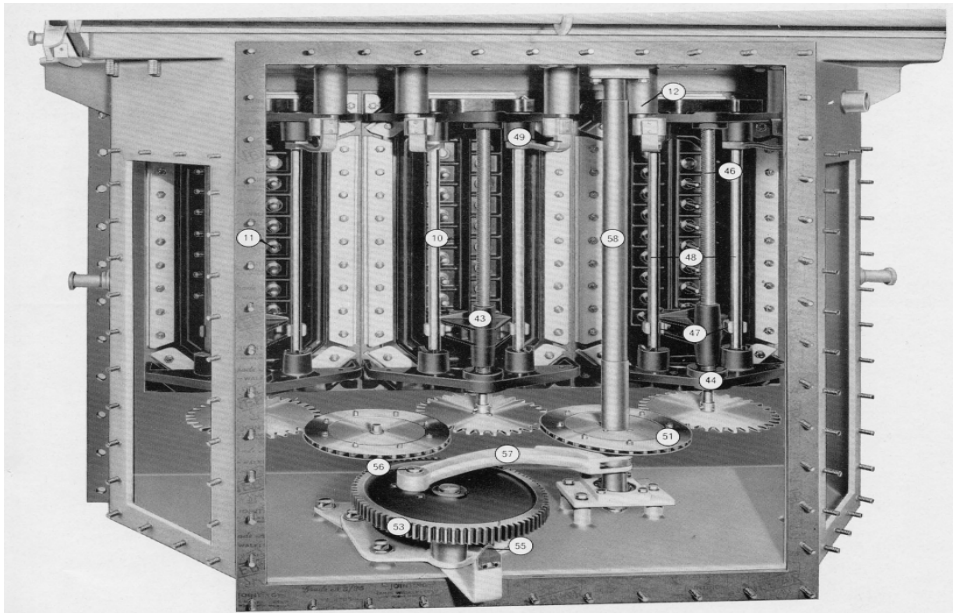


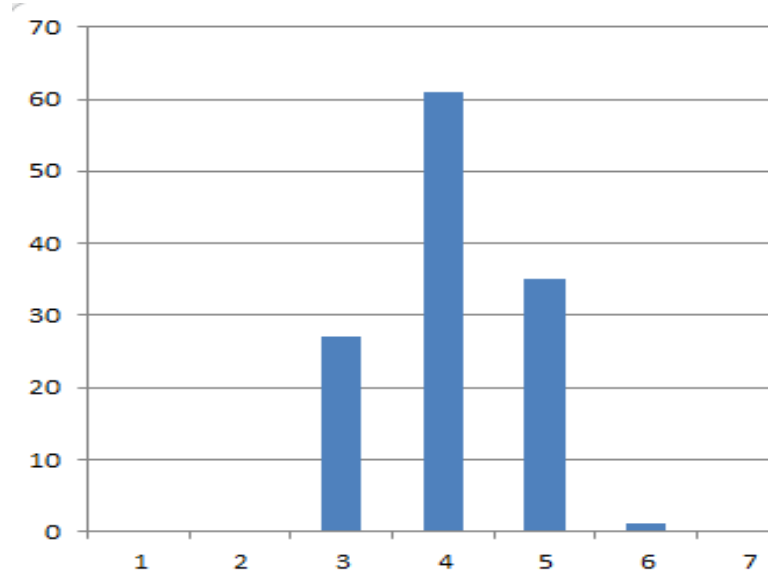
Alpha prototype installation: Winifred Rd

The arcing noise indicates that tap 4 contact of one of the three selectors is excessively worn









Observing tap usage statistics shows that tap 4 is the most used tap position

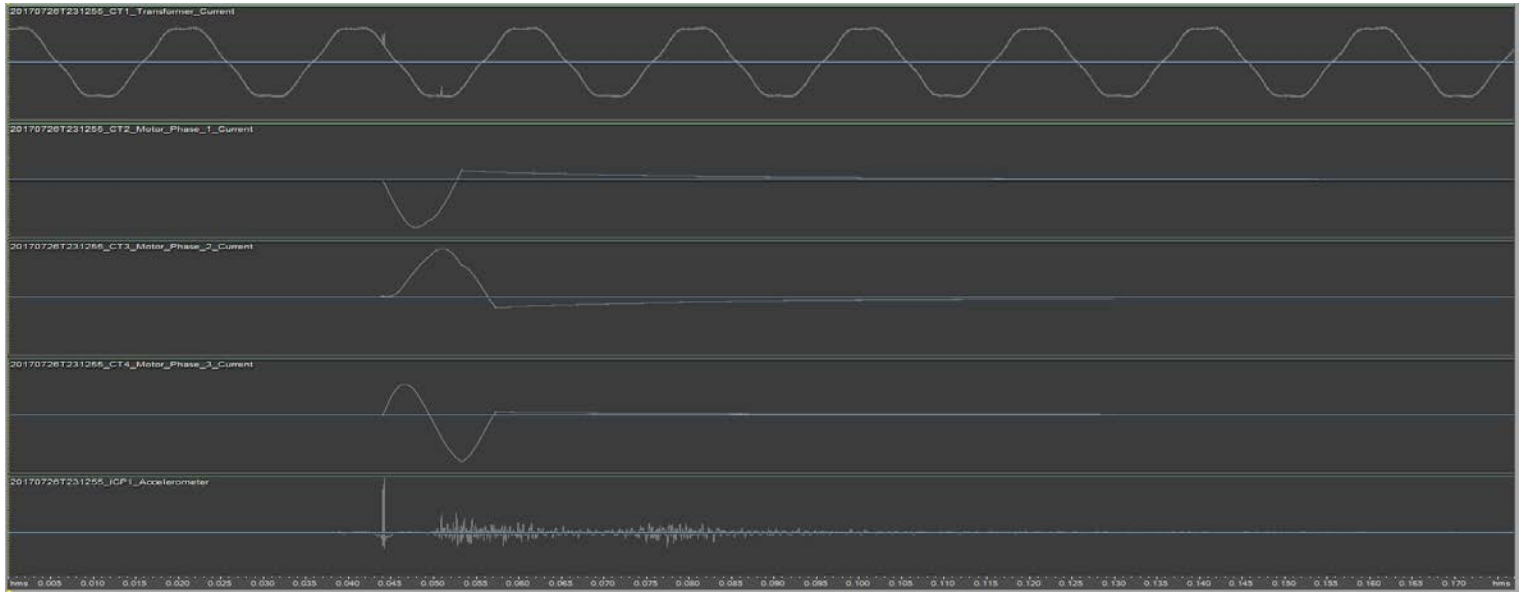
Currently the tap changer is on fixed tap awaiting inspection

Alpha prototype installation: Altrincham

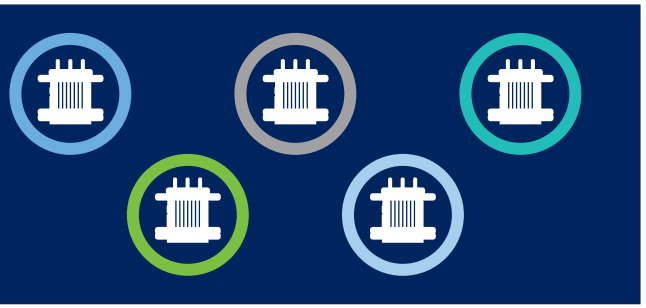
Site: **Altrincham Grid**

Tap changer type: **Fuller HS319** ● Recorded anomalous events ● 2/3 time per week always involving tap 8 ● Currently under investigation

Event_ID	BS_Timestamp	Event_Time[s]	BS_TapPos[#]	AS_TapPos[#]
20170726T140949	26/07/2017 14:09	5	7	8
20170726T231255	26/07/2017 23:12	3	8	8
20170726T231433	26/07/2017 23:14	5	8	9
20170727T061730	27/07/2017 06:17	5	9	8
20170728T234721	28/07/2017 23:47	5	8	9
20170729T063347	29/07/2017 06:33	5	9	8
20170729T101106	29/07/2017 10:11	3	8	8
20170730T014838	30/07/2017 01:48	5	8	9
20170730T043726	30/07/2017 04:37	5	9	10
20170802T153206	02/08/2017 15:32	6	8	7
20170802T210651	02/08/2017 21:06	6	7	8
20170802T232039	02/08/2017 23:20	3	8	8
20170802T232254	02/08/2017 23:22	5	8	9
20170803T055703	03/08/2017 05:56	6	9	8
20170812T065819	12/08/2017 06:58	5	10	9
20170812T081414	12/08/2017 08:14	5	9	8
20170813T004753	13/08/2017 00:47	3	8	8
20170813T005010	13/08/2017 00:50	3	8	8
20170813T005236	13/08/2017 00:52	5	8	9
20170813T065700	13/08/2017 06:56	5	9	10
20170813T081430	13/08/2017 08:14	5	10	9



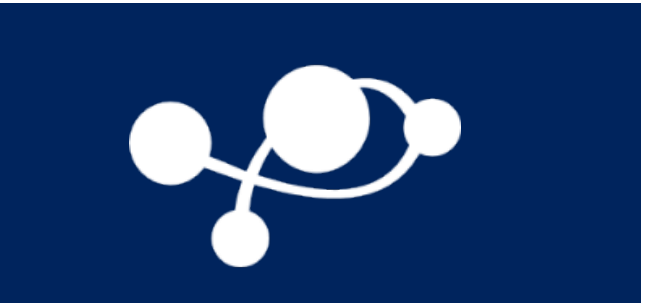
Next steps



40 sites are being installed now

Data collection ongoing for next two years

Examine the key questions on TC



Develop a TC signature for various TC models

Use machine learning and data mining to create a signature envelope

Move from time based to condition based interventions

For more information

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