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Safeguarding renewable energy generation

Camlin Energy

For more than four decades, we have been innovating to protect and optimize the world's energy infrastructures.

We empower our customers with the insights to make strategic decisions that are crucial for protecting assets and networks, driving a resilient, flexible and sustainable future.

Empowering Your Tomorrow

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Empowering global energy infrastructure…

…locally, with Camlin Energy facilities across 17 countries

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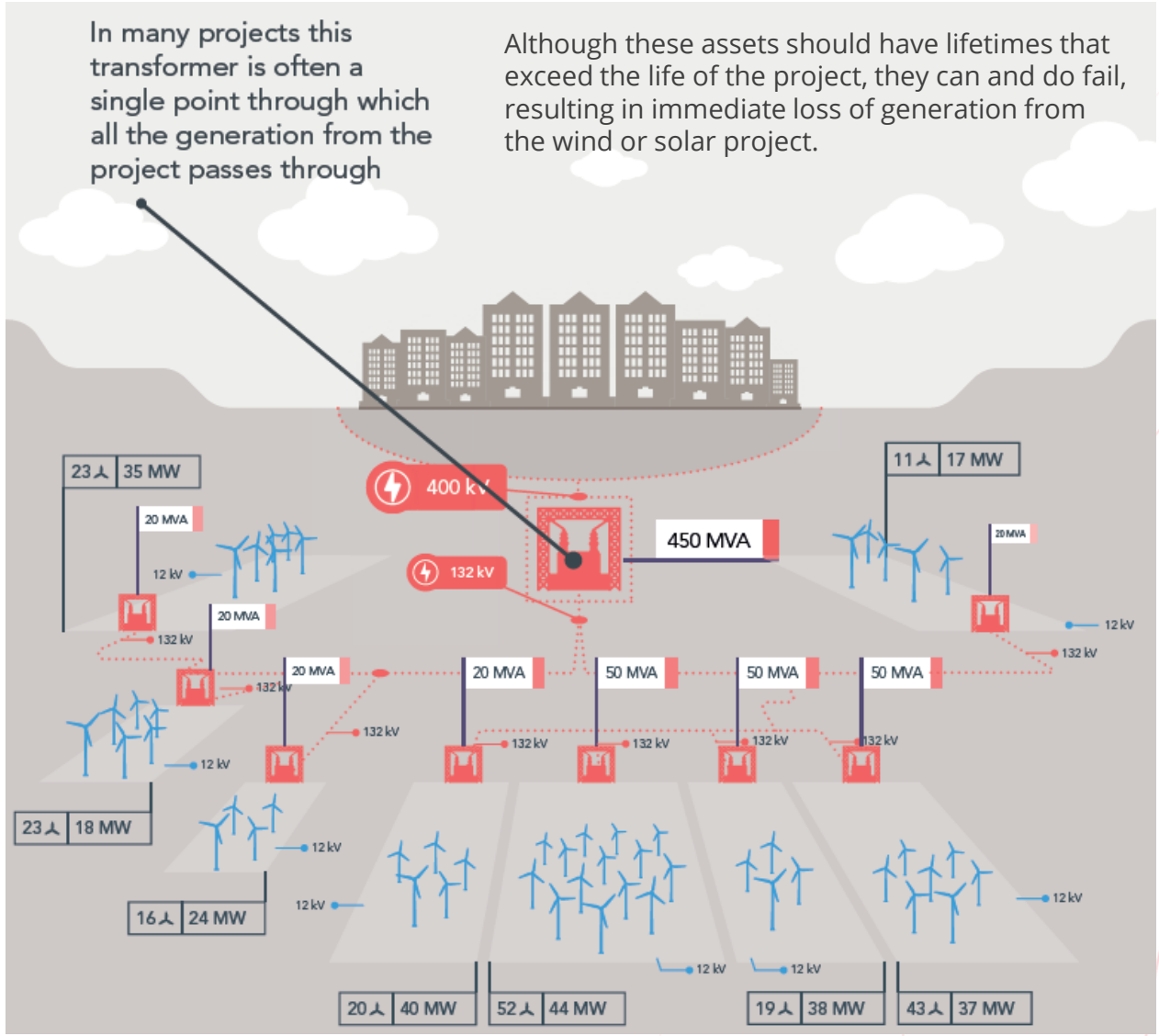
Benefits of Camlin Energy's solutions






	Transformer Monitoring Including EHV and HV Transformer, Bushing & LTC Monitoring	Circuit Breaker Monitoring	Overhead Lines Fault Location & Management, LV & HV Overhead Network Monitoring & Management	Low Voltage Networks Fault Location & Management, LV Network Monitoring & Management	Generator Monitoring	In-Building Power Networks Rising & Lateral Mains Large Commercial and Industrial
Faults, Network resilience, Opex reductions and Safety	✓	✓	✓	✓	✓	✓
Capacity: Capacity & Network Planning	✓		✓	✓		✓
Asset: Asset Health & Investment Support	✓	✓	✓	✓	✓	✓

Why transformer monitoring?



A transformer failure could cost $75m in lost revenues

Example revenue loss if undetected issue leads to catastrophic failure and replacement transformer	
Project size	250 MW
Average loading rate	35%
Electricity price	$50 per MWh
Transformer replacement lead time	24 months
Revenue loss over lead time	**$75.6m**

Other costs and losses can include:

- Contractual penalties for failure to supply
- Cost of repair or replacement of the failed transformer
- Additional insurance costs
- Safety impacts

Benefits of monitoring

Risk Management

- Visibility of developing issues in transformer
- Real-time view of health across fleet

Condition based maintenance

- Transition to condition-based maintenance
- Predictive Insights to support for long term scenario planning –suggested actions!
- Avoid unnecessary interventions and costs

Financial security

- Mitigate financial and operational risks from loss of service
- Insurance cost reduction
- Informed investment decisions

Increase asset availability

- Reduce unplanned outages and downtime
- Increased availability
- Long-term reliability (life extension/repowering)

Protect your People

- Improve safety and protect against loss of life – bushing failures often cause fire or explode
- Minimise time spent on site
- Minimize public exposure and environmental risks

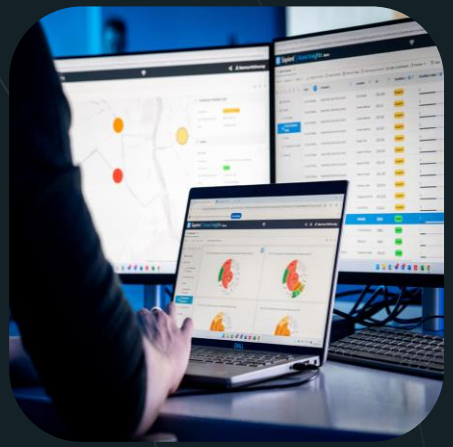
Operational Efficiency

- Reduced & optimized O&M costs
- Reduce need for manual testing
- Independence from OEM
- Manage for loss of expertise and knowledge

Complete transformer monitoring solutions, from install to expert insights

TOTUS
The monitoring system: range of options to choose from to balance budget and risk

Installation & servicing
Install and maintenance of your monitoring system



Asset Insights Software
Delivers predictive analytics and prescriptive actions

Expert support
Specialist transformer experts available to support

Monitoring partnership

Alignment to your transformer asset management strategy

- Our customer success consultants can work closely with your key stakeholders to support the development of your monitoring strategy

Baseline health of your transformer fleet

- Our transformer experts can review the health of transformer fleet from available offline data. With knowledge of the criticality of each transformer, the monitoring program can be defined.

Deployment of TOTUS systems

- TOTUS is a modular monitoring system, configured to maximize monitoring of each transformer within available budget. We, managing delivery and installation of your monitoring project.

Data-drive maintenance actions

- Asset Insights software provides actionable insights using TOTUS and other data to determine condition index, identify failure mode and recommend the maintenance action. Our transformer experts can support with condition assessment reports, and alarms can come directly into our Sapient centre for immediate review.

Review success

- Our customer success consultants can review the implementation of monitoring program, ensuring systems and process are optimized and all stakeholders are receiving expected value from monitoring project.

Project example

Background:

- Customer's asset management strategy was updated to require monitoring following unexpected transformer failure and significant revenue lost.

Customer requirements:

- With limited internal resource, they required a partner who could fully manage and run the monitoring program.

Camlin Energy engaged to:

- Deploy **TOTUS systems** on all critical transformers
- Integrate with Camlin Energy's **Sapient centre** for immediate expert response following any alarms
- Provide transformer and fleet **condition assessment** reports
- Access to live view of transformer health and maintenance actions through asset insights software
- Be available to support with **expert support** as needed
- Review customer systems and processes to ensure monitoring program is a **success**


THANK YOU

Annex 1: TOTUS

TOTUS monitoring capabilities

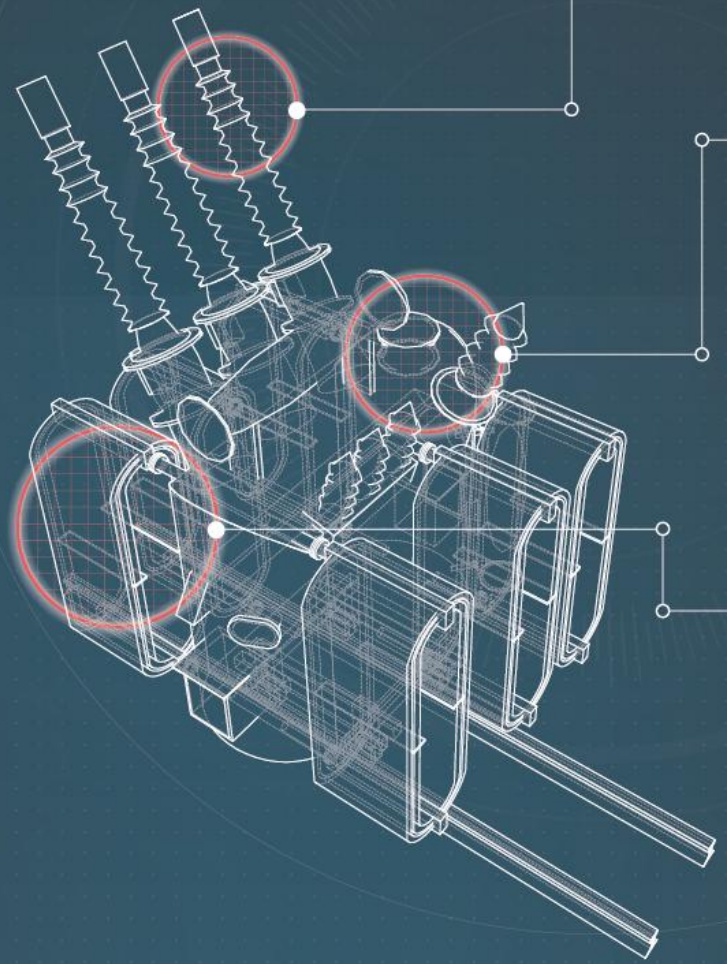
TOTUS Transformer Monitoring

A comprehensive solution designed for the real-time monitoring and management of power transformers.

TOTUS combines sensor technology and integrated analytics to maximise reliability, and longevity of transformers

80%+

of transformer failures are due to failings in the Bushings, Windings and OLTCs.

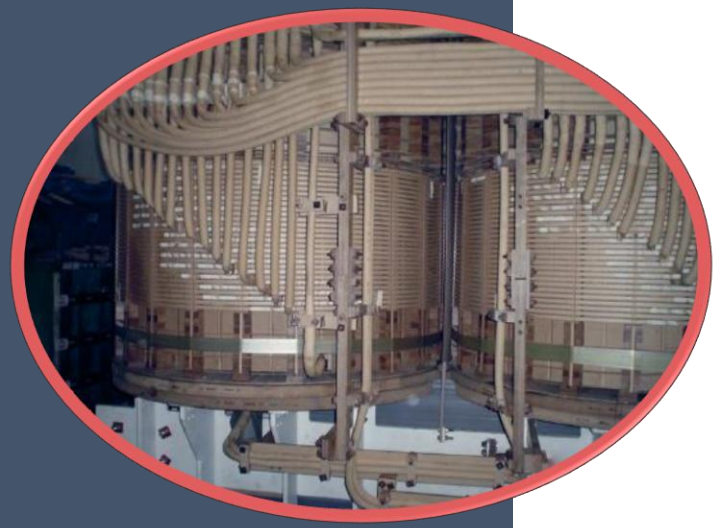


BUSHING MONITORING
+17% Failure Rate

TAP CHANGER
+26% Failure Rate

TRANSFORMER MAIN TANK
+40% Failure Rate

Main Tank



DGA	9 Gas + moisture in oil 5 Gas + moisture in oil Hydrogen + moisture in oil
Partial Discharges	Active PDs Arcing Events
Through Faults	Event Count Cumulative effect
Cooling System	Pump/Fan absorption Cooling Status Temperatures
Models	Hot Spots Ageing / Remaining Life Moisture in paper Bubbling Dynamic Loading Oil Breakdown Voltage
Others	Geomagnetic Induced Currents (GIC) Direct winding temperatures with fiber optics Analog and Digital Inputs Integration of any third party monitor/system

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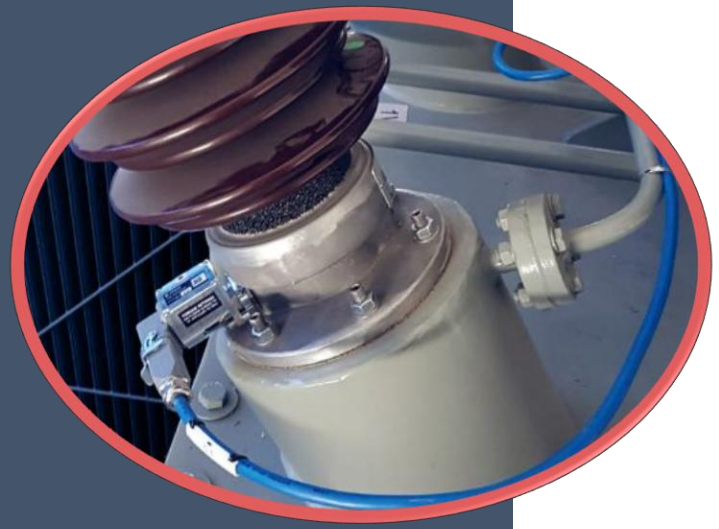
Bushings



Partial Discharges	Active PDs Arcing Events
Leakage currents	Amplitude and phase angle Polar Plot / Sum of current
Capacitance/Tandelta (PF)	Tandelta/PF variations C1 variations C2 variations
Others	Temperature Load Humidity

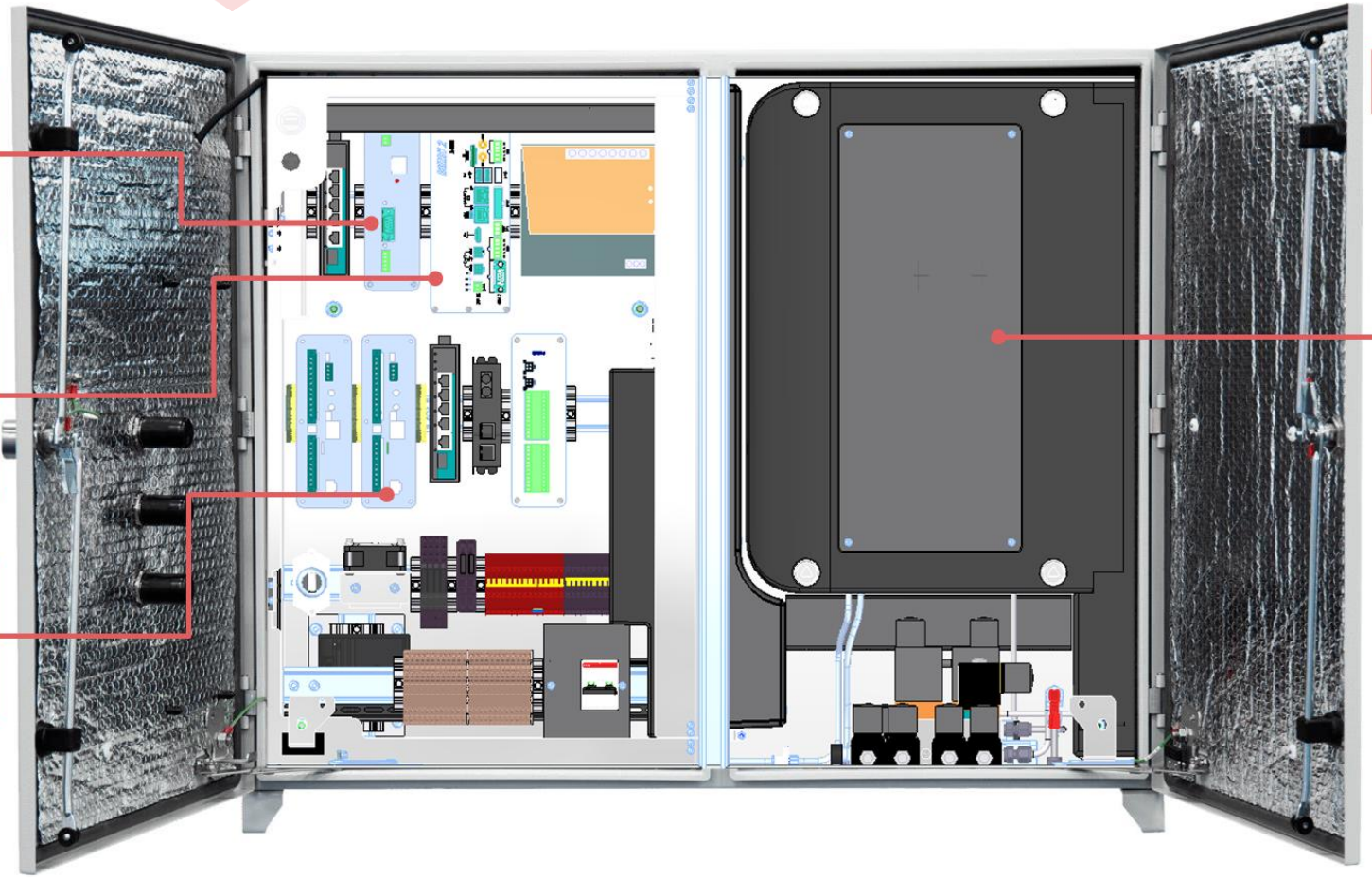
TOTUS Transformer Total Monitoring System

Example system (9-gas with partial discharge and bushing monitoring)

- Input/output
- Temperature
- Models

- Embedded Server
- Embedded Modem

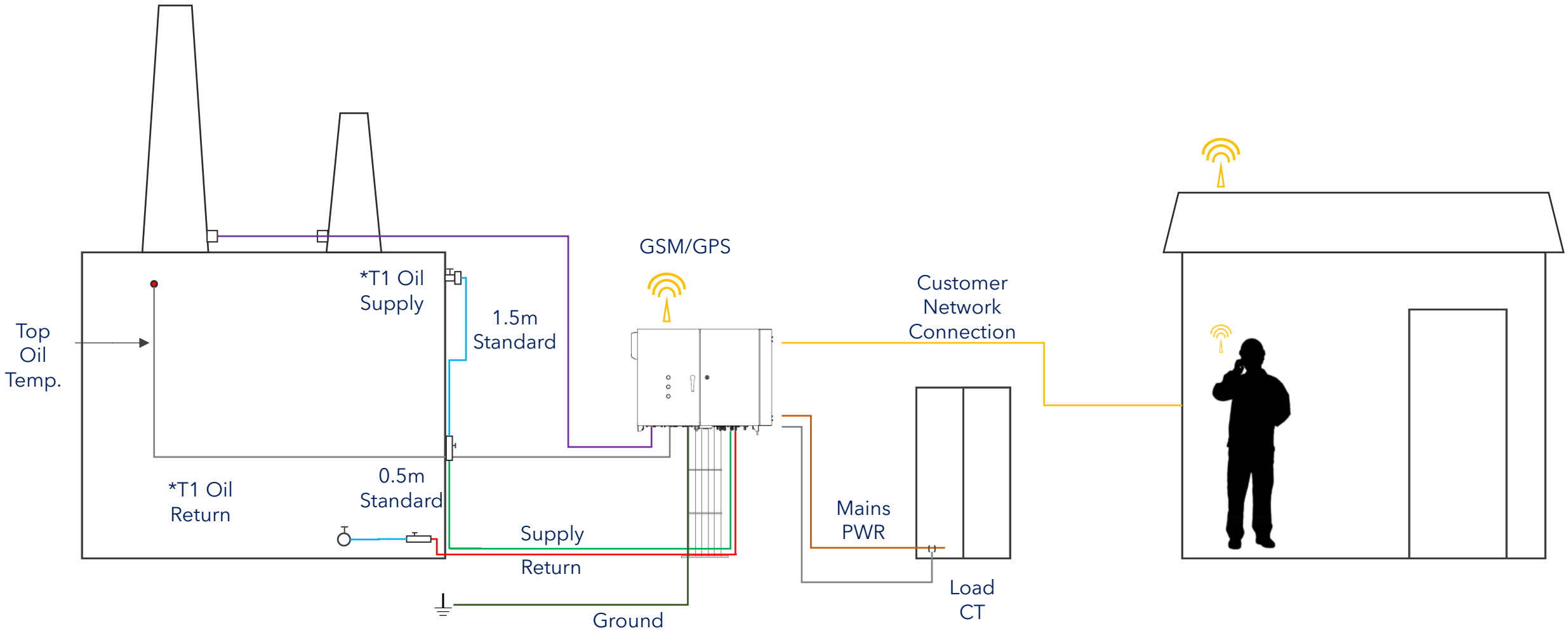
- PD
- Bushing
- TFC



9 gas DGA

IEC61850
MODBUS
DNP3
HTTPS
RELAYS

Example installation layout




CAMLIN
TOTUS

DGA

PhotoAcoustic

No consumables

Oxygen included

Accurate

Field Proven

Ester Oil compatible

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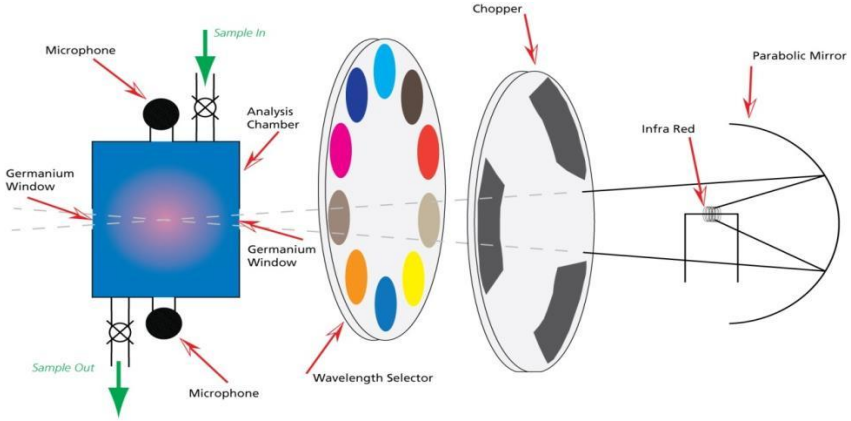
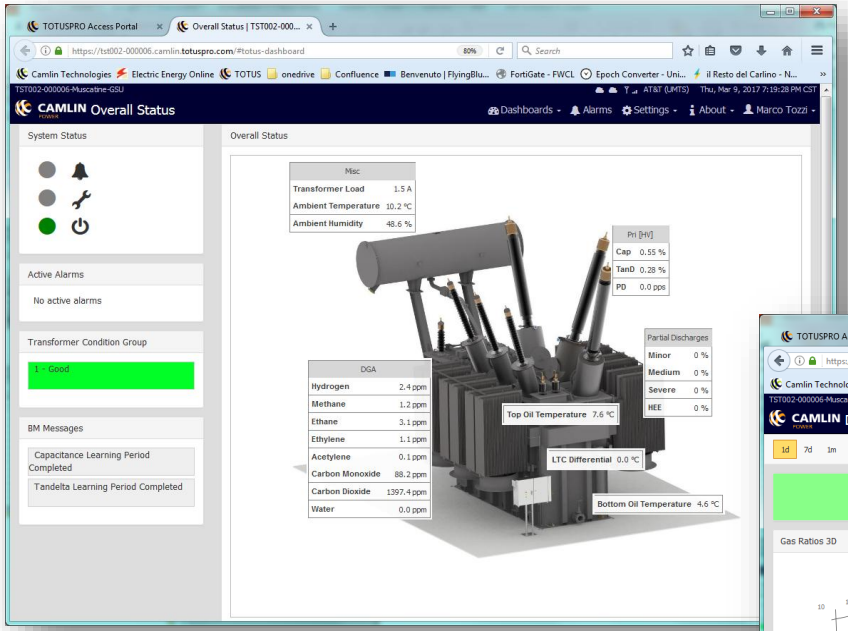
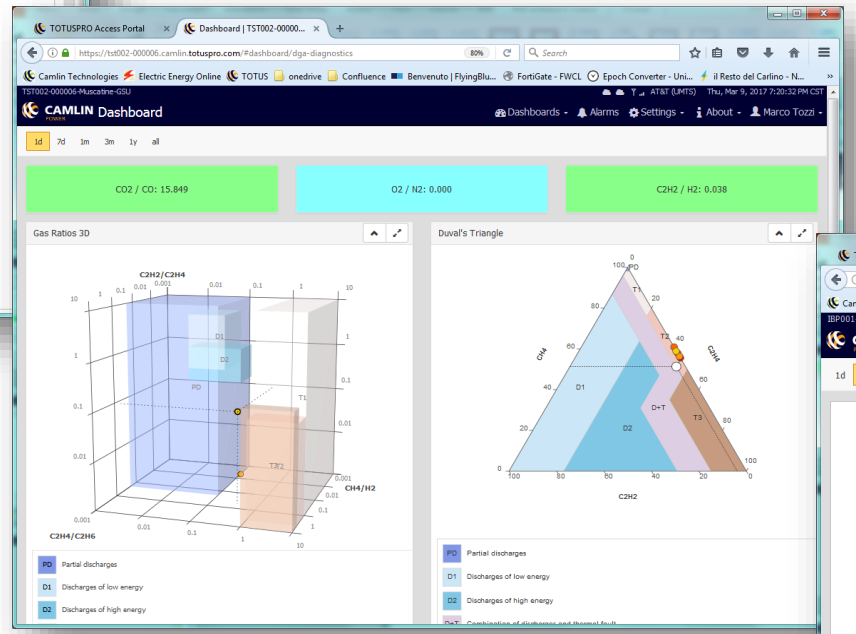
Technology	PAS
Gases	H2, CO, CH4, C2H2, C2H4, C2H6, O2, N2 ,CO2
Moisture in oil	YES
No consumables	YES

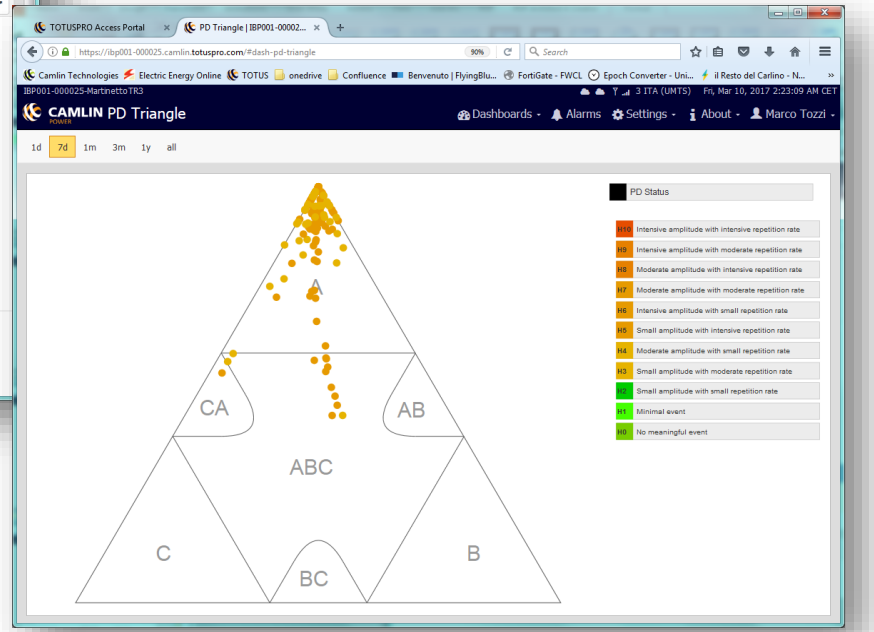


Analysis Tool/Parameters	IEEE C57.104 2018	IEC 60599	TOTUS
TCG (Total Combustible Gas)	✓		✓
TDCG (Total Dissolved Combustible gas)	✓		✓
Key Gas Method	✓		✓
Doenenburg Ratios	✓		✓
Roger Ratios	✓		✓
Basic Gas Ratios		✓	✓
Duval Triangle	✓ NEW	✓	✓
Duval Pentagon	✓ NEW		✓
CO2/CO Ratio	✓ NEW	✓	✓
O2/N2 Ratio		✓	✓
C2H2/H2 ratio		✓	✓
NEI index	✓ NEW		✓

Web Based


CAMLIN Overall Status
System Status
Active Alarms
No active alarms
Transformer Condition Group
1 - Good
BM Messages
Capacitance Learning Period Completed
Tandelta Learning Period Completed
Overall Status
Misc
Transformer Load 1.5 A
Ambient Temperature 10.2 °C
Ambient Humidity 48.6 %
Pri [HV]
Cap 0.55 %
TanD 0.28 %
PD 0.0 pps
Partial Discharges
Minor 0 %
Medium 0 %
Severe 0 %
HEE 0 %
DGA
Hydrogen 2.4 ppm
Methane 1.2 ppm
Ethane 3.1 ppm
Ethylene 1.1 ppm
Acetylene 0.1 ppm
Carbon Monoxide 88.2 ppm
Carbon Dioxide 1397.4 ppm
Water 0.0 ppm
Top Oil Temperature 7.6 °C
LTC Differential 0.0 °C
Bottom Oil Temperature 4.6 °C


CAMLIN Dashboard
CO2 / CO: 15.849
O2 / N2: 0.000
C2H2 / H2: 0.038
Gas Ratios 3D
Duval's Triangle
C2H2/C2H4
CH4/H2
C2H4/C2H6
C2H2
Partial discharges
Discharges of low energy
Discharges of high energy


CAMLIN PD Triangle
PD Status
CA
AB
ABC
C
BC
B

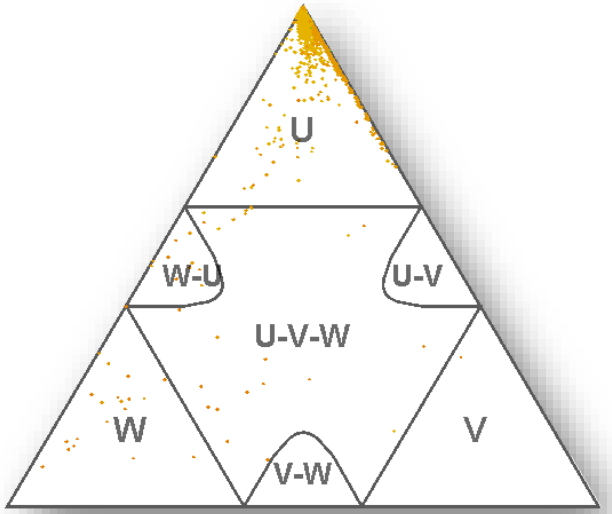
PD

HW Reliable

No false Alarms

Identifies Arcing

Easy Embedded Interpretation



PD Triangle identifies the Winding and Phase

H10	Intensive amplitude with intensive repetition rate
H9	Intensive amplitude with moderate repetition rate
H8	Moderate amplitude with intensive repetition rate
H7	Moderate amplitude with moderate repetition rate
H6	Intensive amplitude with small repetition rate
H5	Small amplitude with intensive repetition rate
H4	Moderate amplitude with small repetition rate
H3	Small amplitude with moderate repetition rate
H2	Small amplitude with small repetition rate
H1	Minimal event
H0	No meaningful event

PD Intensity evaluated every hour

Reliable connection to the bushing >> 2000 installations

Technical details

- 24/7 continuous monitoring
- Hourly PRPD Pattern
- Simultaneous acquisitions
- Automatic denoising
- Automatic cross coupling rejection
- 30 Vpp scale with 2 mV resolution
- IEC60270 compliant

ADAPTORS

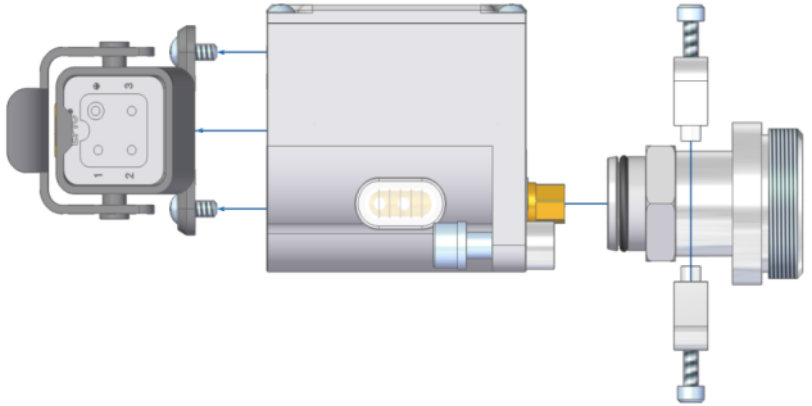
2000+ installations

Stress life test in extreme conditions

Reliable and safe

Allows offline test without complete removal

Manufactured in Camlin



Technical details

- IP 67
- No plastic exposed to sunlight
- No need to remove the head to do offline test
- Visual check of good connection

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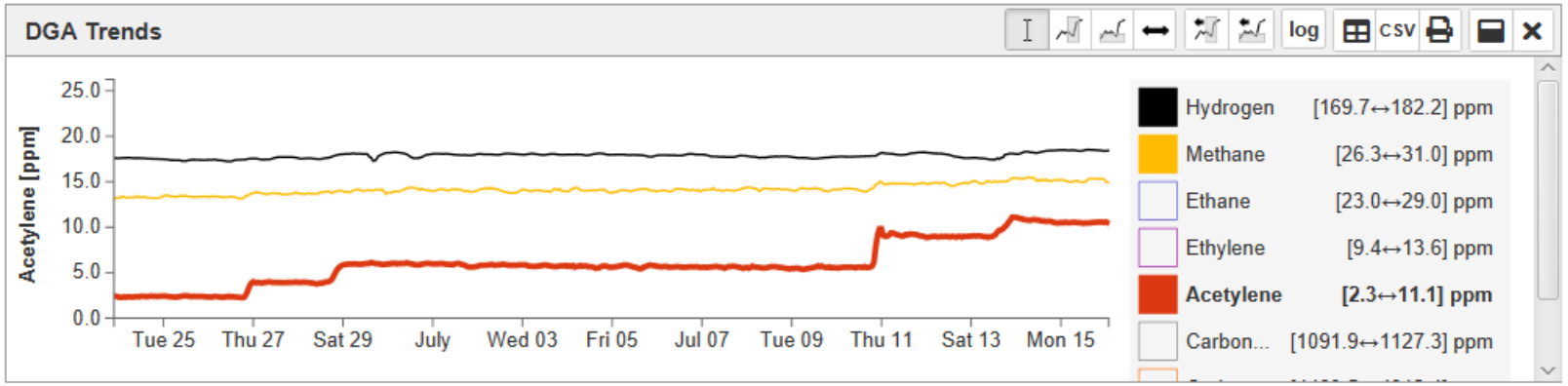
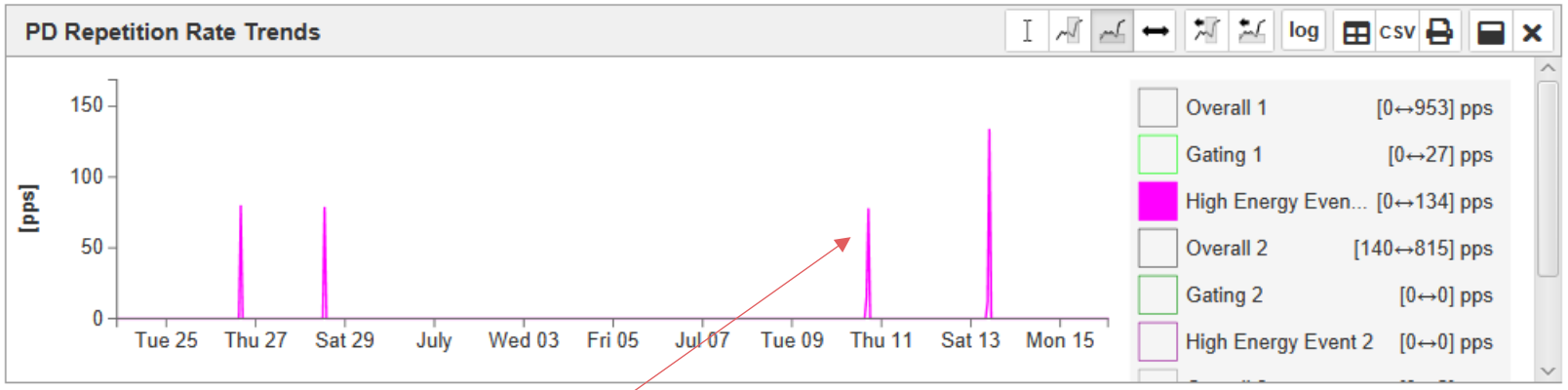
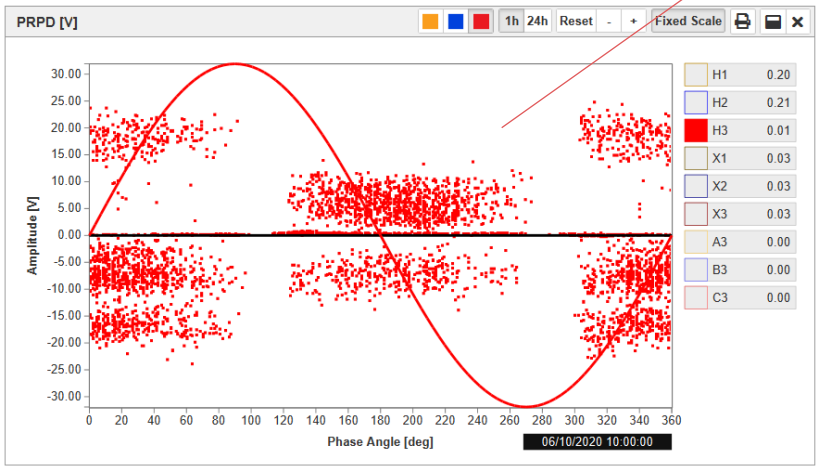
ARCING

It identifies

- The winding
- The phase
- The exact moment of the event
- The arcing nature/cause







Technical details

- 24/7 continuous monitoring
- Hourly PRPD Pattern
- Simultaneous acquisitions
- Automatic denoising
- Automatic cross coupling rejection
- 30 Vpp scale with 2 mV resolution

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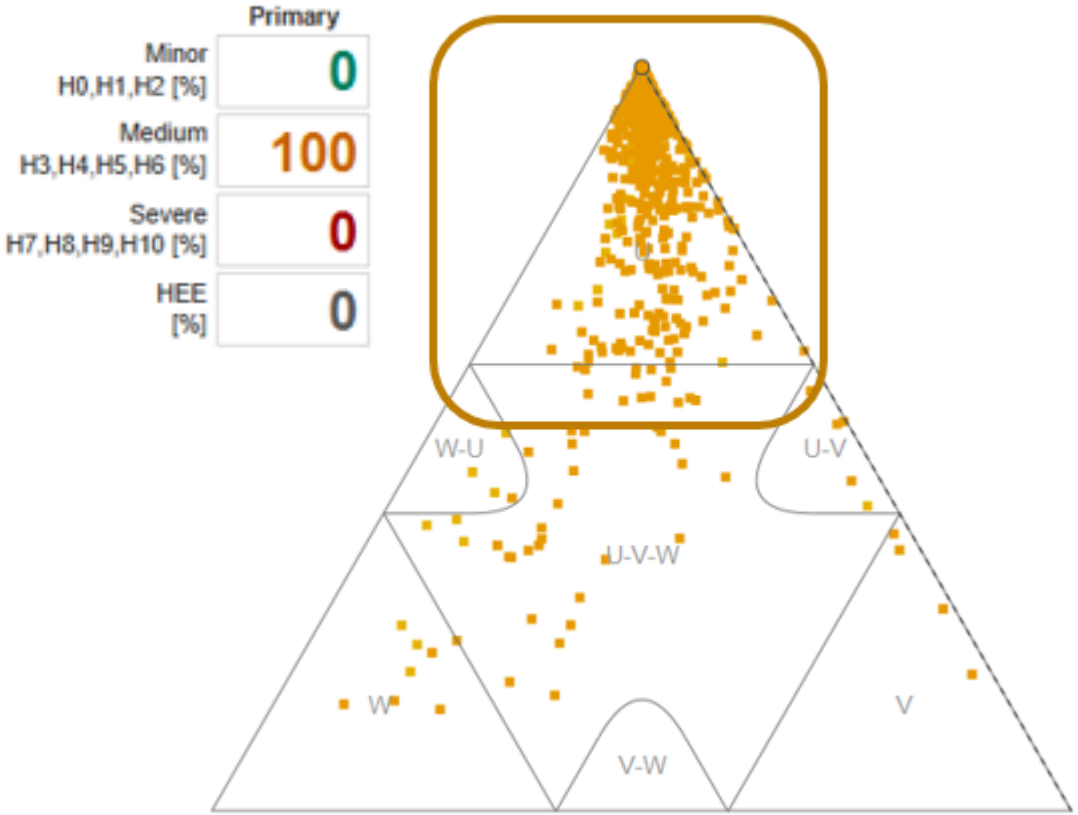
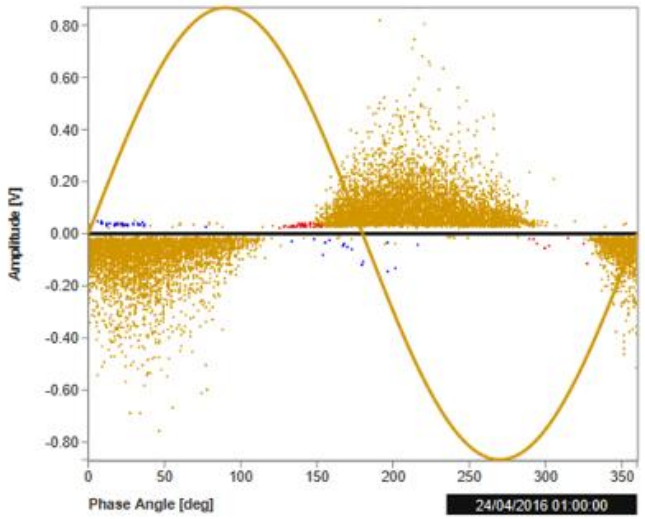
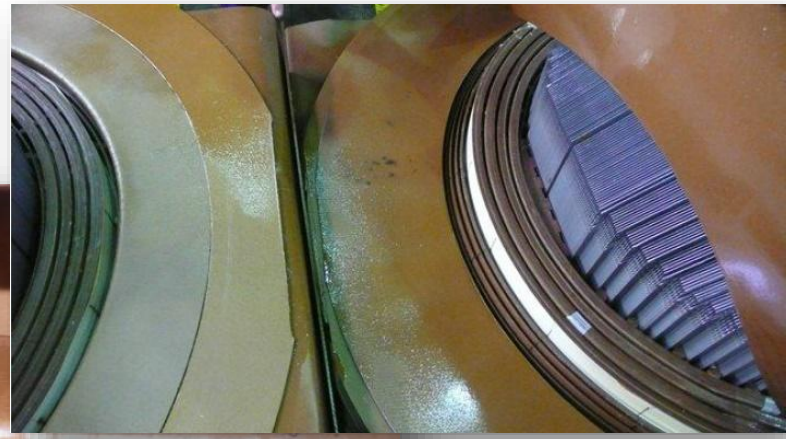
PD in winding stress ring in 63 MVA transformer





- PD Pattern provided without noise and cross-coupling, automatically every hour



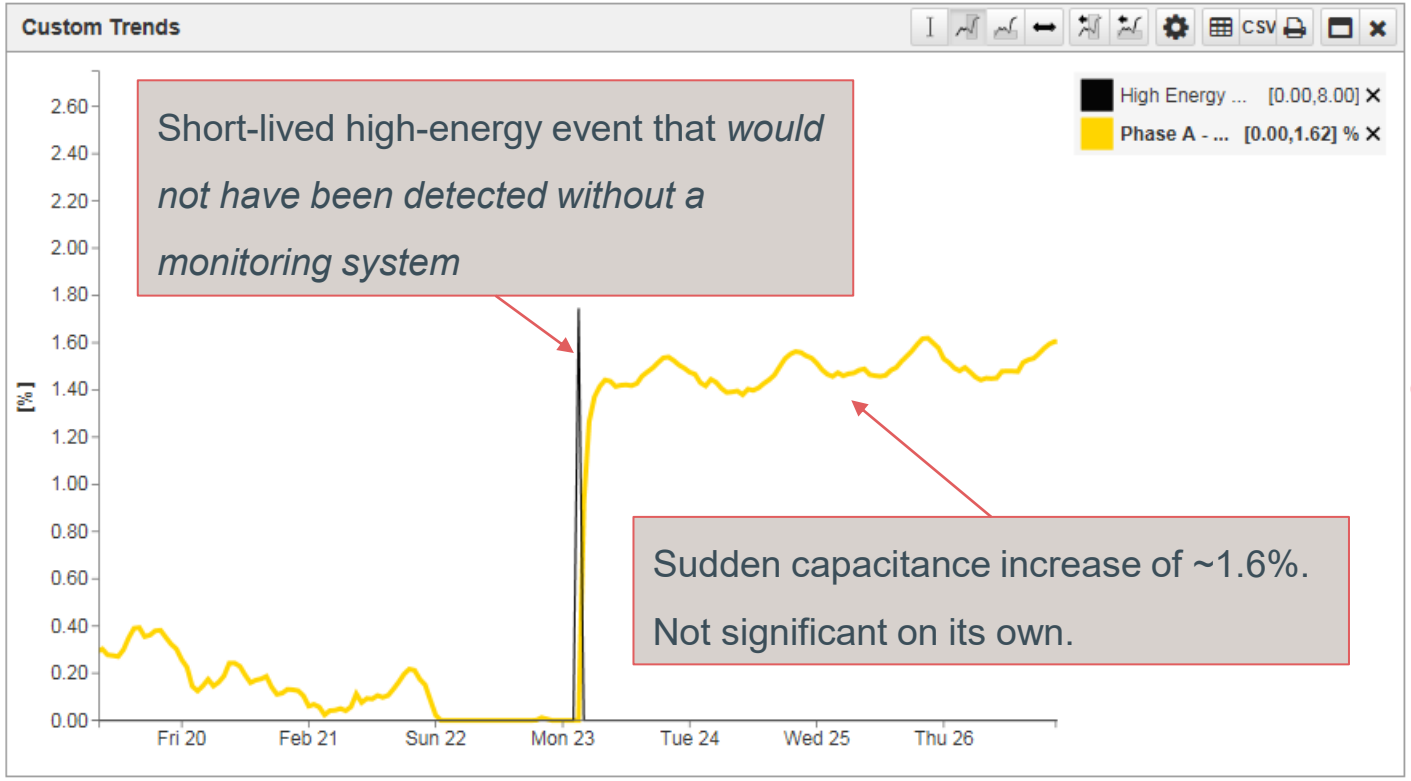
- TOTUS indicates 100% presence of Medium PD
- PD Triangle identifies phase U as the source

DETECTED BY COMBINATION OF PD AND DGA, CONFIRMED BY VISUAL INSPECTION

Case study example: OIP Bushing

Transformer saved as Camlin's online bushing monitoring system detected the developing fault before it led to catastrophic failure

Data charts from monitoring solution:



Details:

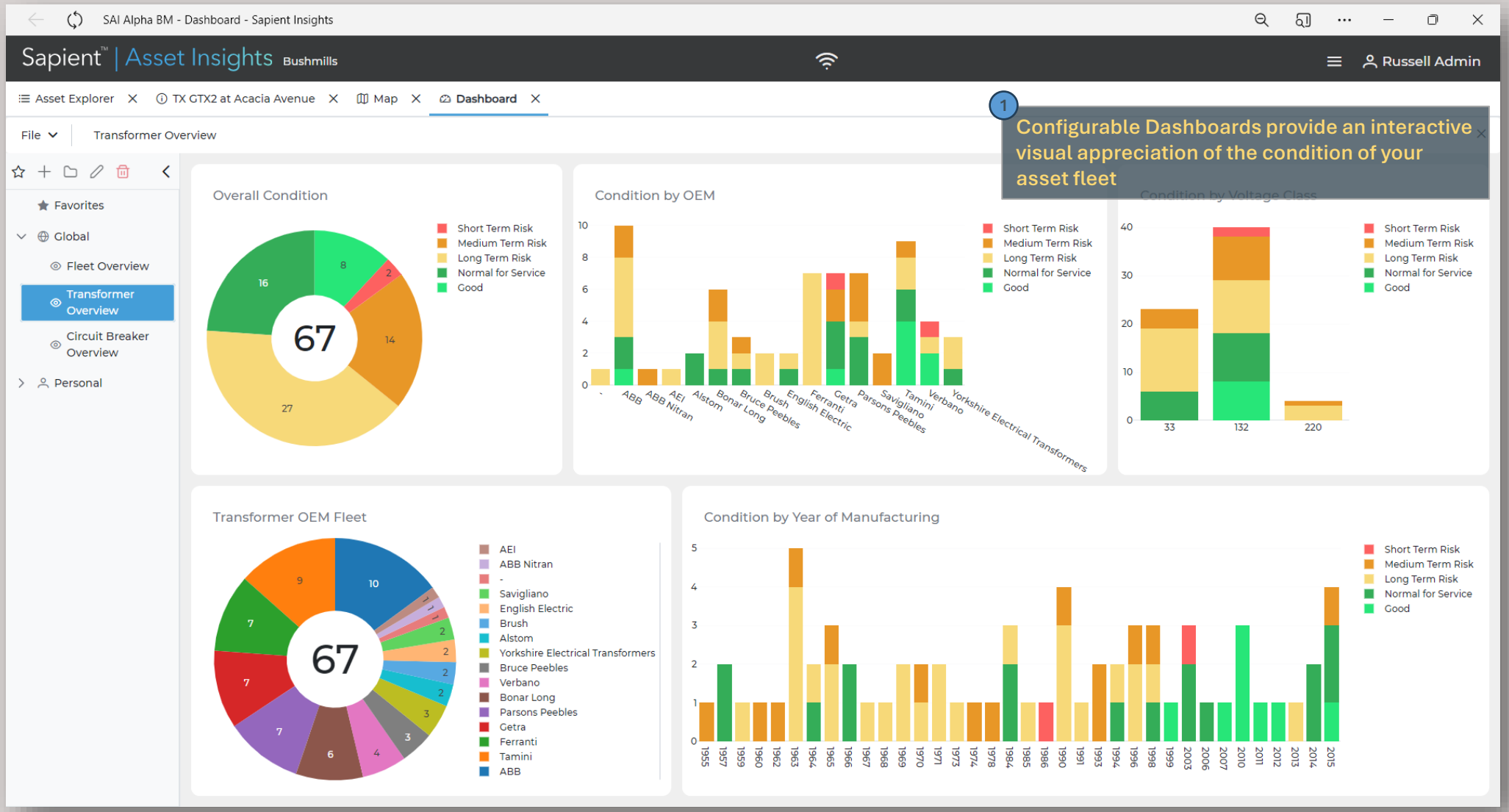
- Bushing type: Oil Impregnated Paper
- Bushing age: installed 1990

Camlin solution identified that this could be due to arcing between layers. This was verified through testing and bushing immediately replaced. The data driven insights were key - the small capacitance increase would normally be dismissed as unimportant. However, this fault would have become catastrophic.

Annex 2: Asset Insights

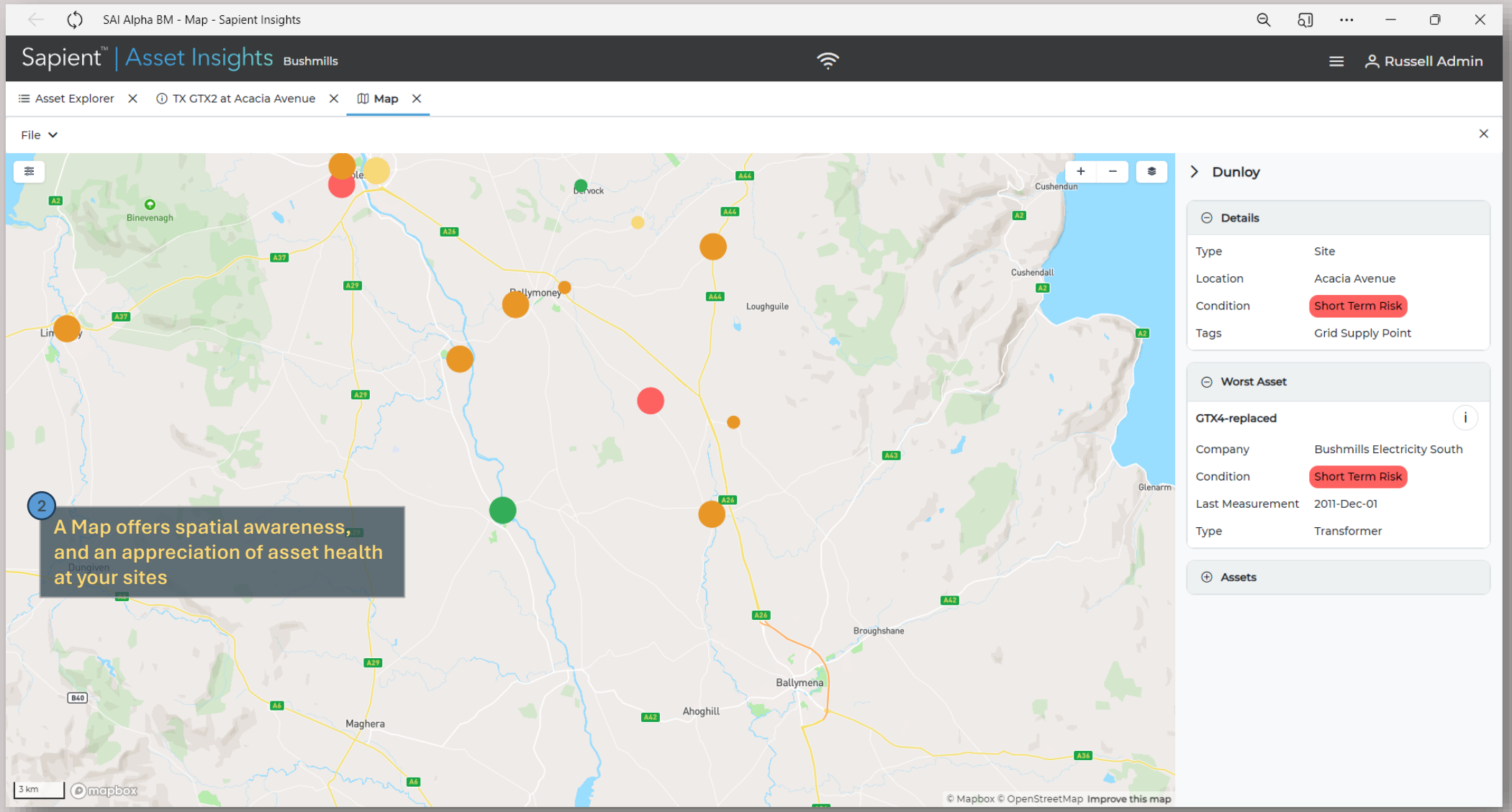
Sapient™ | Asset Insights

Dashboard



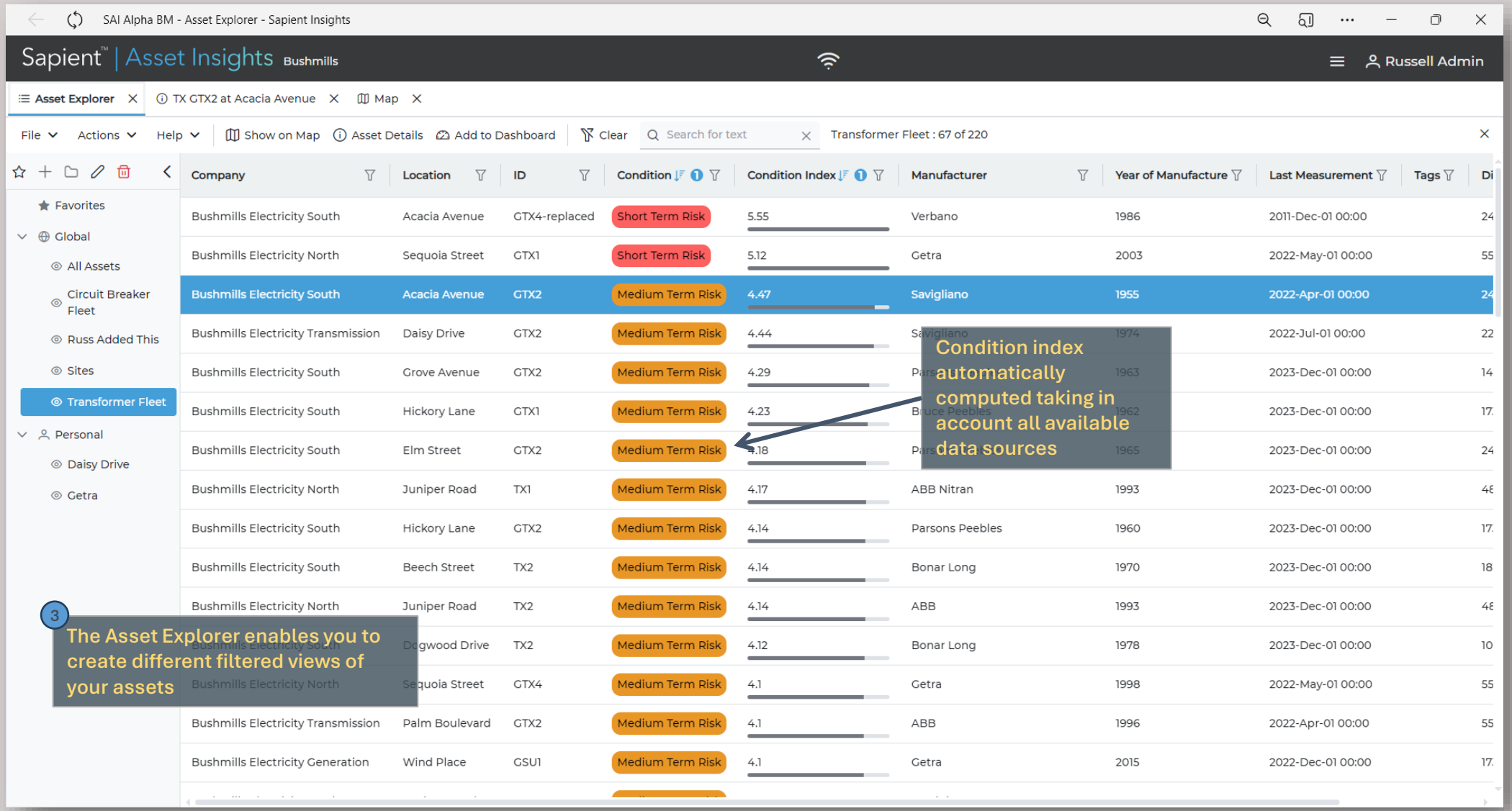
Sapient™ | Asset Insights

GIS View



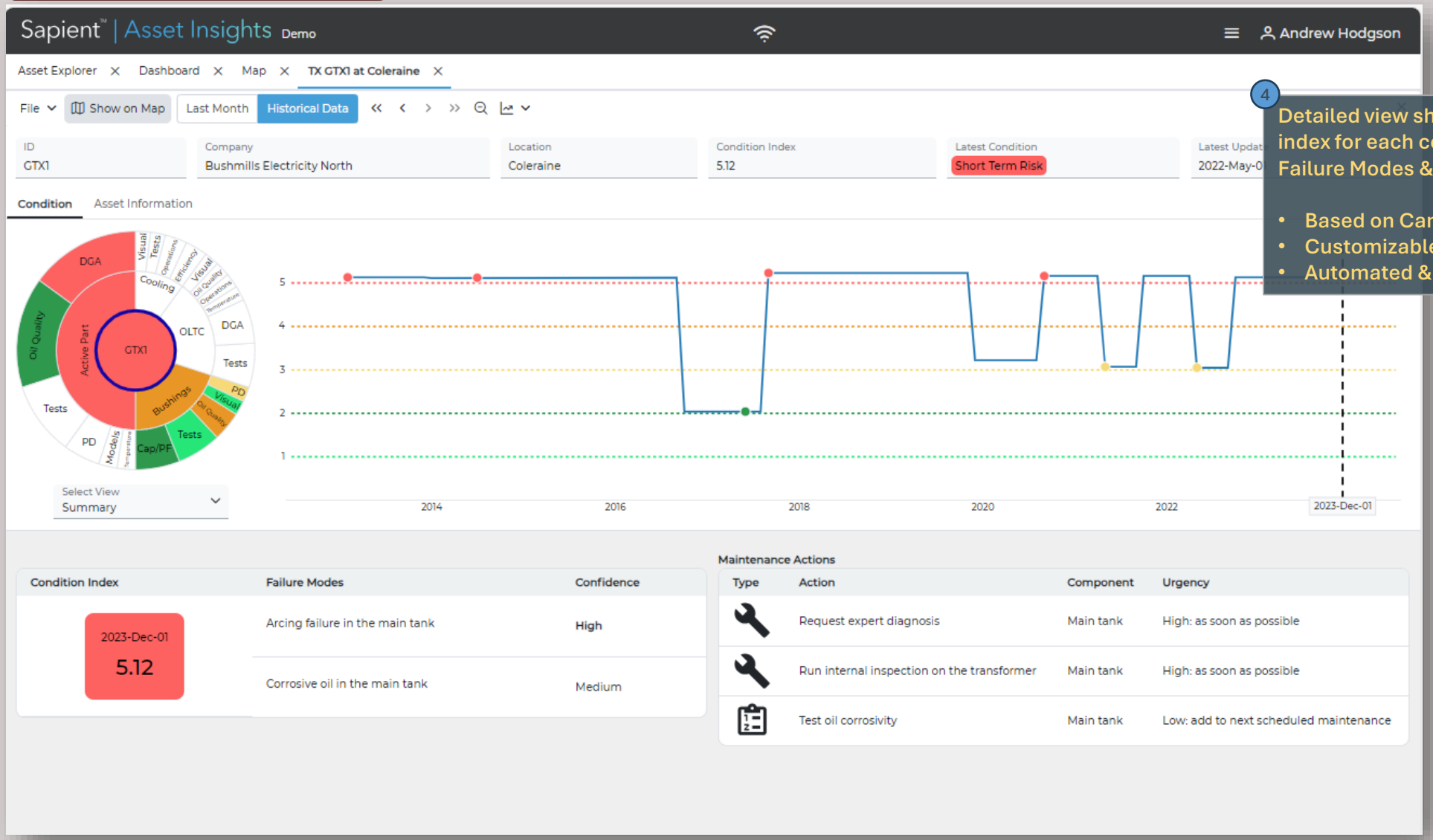
Sapient™ | Asset Insights

Asset Explorer



Sapient™ | Asset Insights

Transformer Details



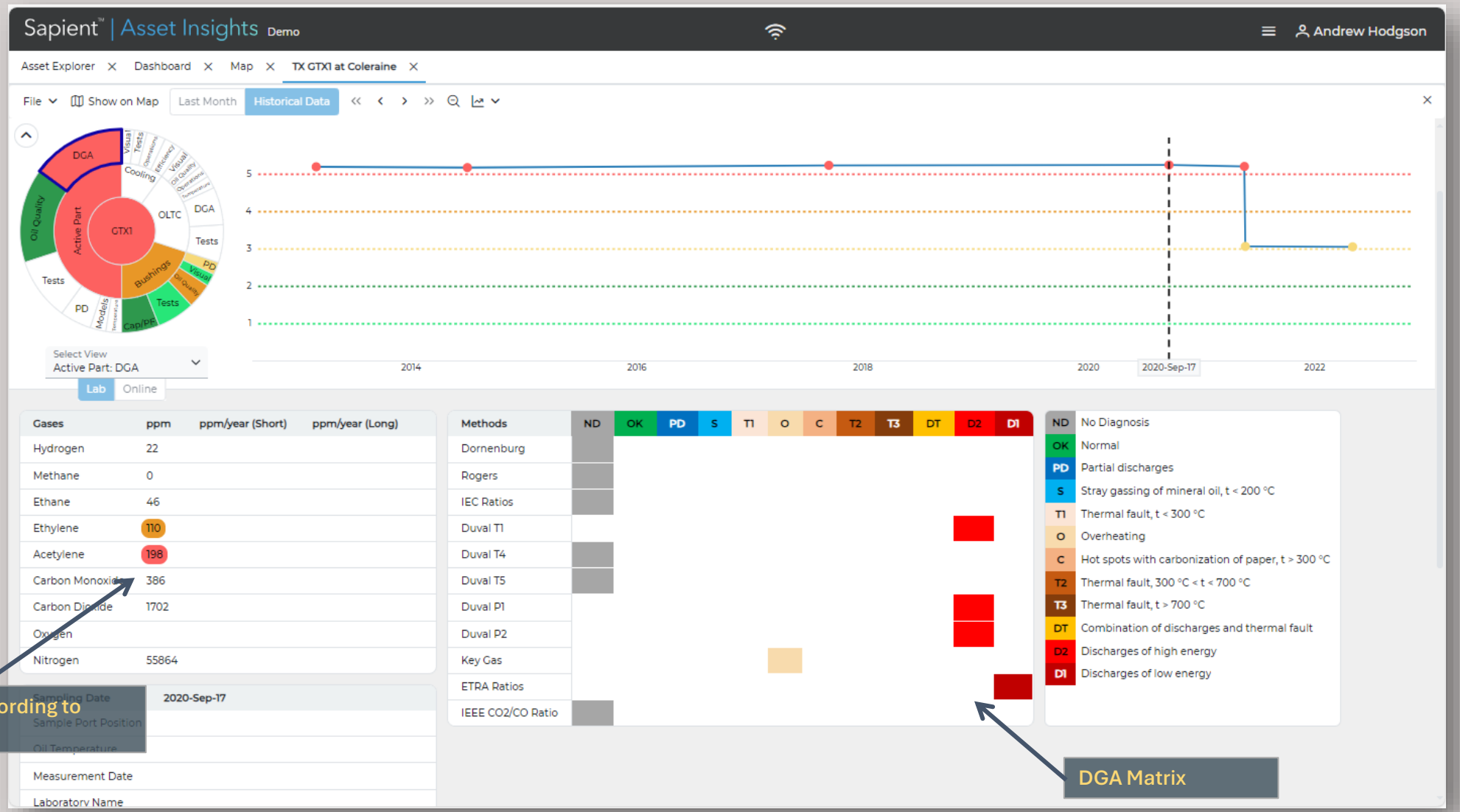
4

Detailed view showing condition index for each component
Failure Modes & Prescriptive Actions

- Based on Camlin expertise
- Customizable insights
- Automated & data driven

Sapient™ | Asset Insights

Transformer DGA

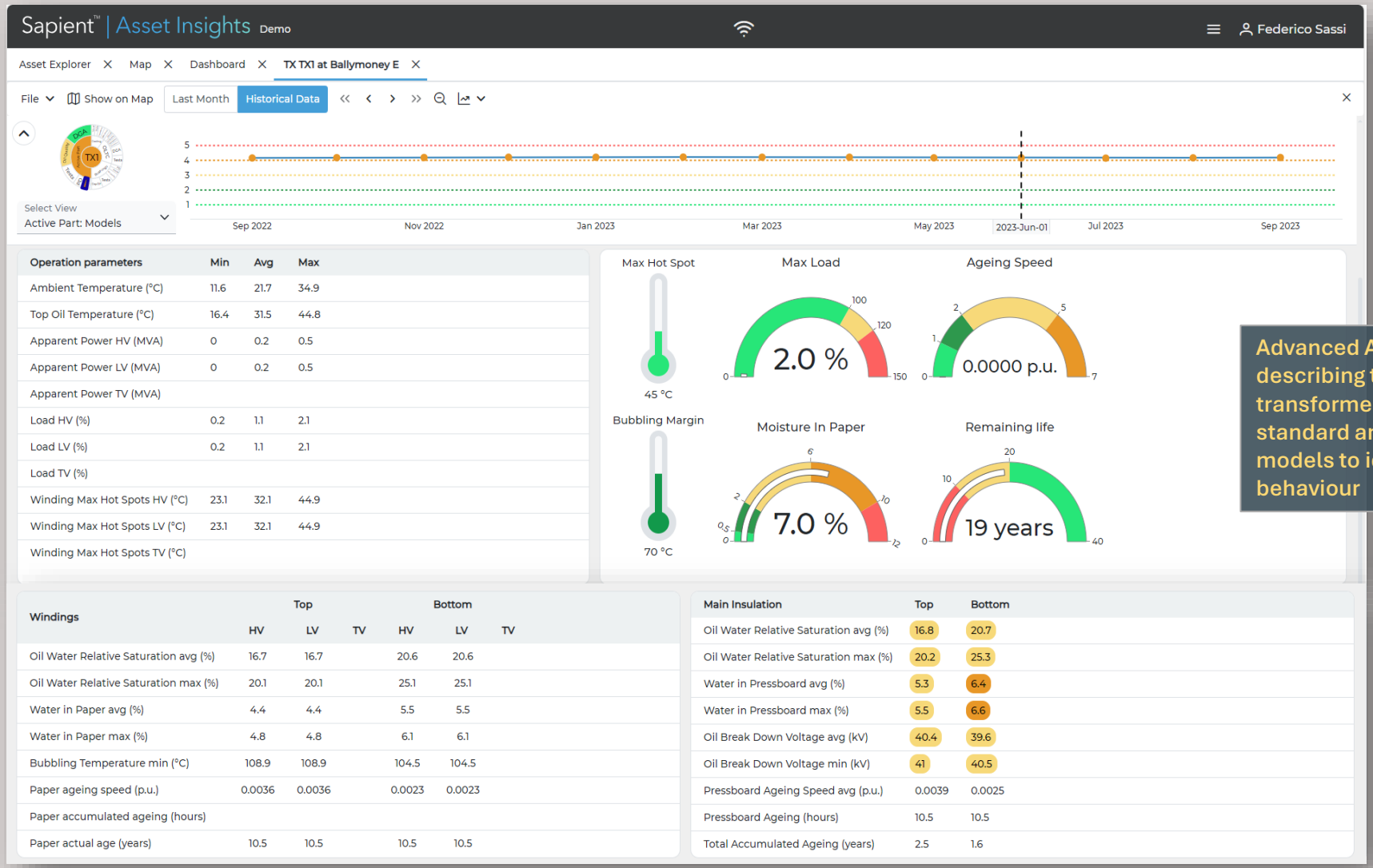


Cell coloured according to condition index

DGA Matrix

Sapient™ | Asset Insights

Transformer Models



Operation parameters	Min	Avg	Max
Ambient Temperature (°C)	11.6	21.7	34.9
Top Oil Temperature (°C)	16.4	31.5	44.8
Apparent Power HV (MVA)	0	0.2	0.5
Apparent Power LV (MVA)	0	0.2	0.5
Apparent Power TV (MVA)			
Load HV (%)	0.2	1.1	2.1
Load LV (%)	0.2	1.1	2.1
Load TV (%)			
Winding Max Hot Spots HV (°C)	23.1	32.1	44.9
Winding Max Hot Spots LV (°C)	23.1	32.1	44.9
Winding Max Hot Spots TV (°C)			

Windings	Top			Bottom		
	HV	LV	TV	HV	LV	TV
Oil Water Relative Saturation avg (%)	16.7	16.7		20.6	20.6	
Oil Water Relative Saturation max (%)	20.1	20.1		25.1	25.1	
Water in Paper avg (%)	4.4	4.4		5.5	5.5	
Water in Paper max (%)	4.8	4.8		6.1	6.1	
Bubbling Temperature min (°C)	108.9	108.9		104.5	104.5	
Paper ageing speed (p.u.)	0.0036	0.0036		0.0023	0.0023	
Paper accumulated ageing (hours)						
Paper actual age (years)	10.5	10.5		10.5	10.5	

Main Insulation	Top	Bottom
Oil Water Relative Saturation avg (%)	16.8	20.7
Oil Water Relative Saturation max (%)	20.2	25.3
Water in Pressboard avg (%)	5.3	6.4
Water in Pressboard max (%)	5.5	6.6
Oil Break Down Voltage avg (kV)	40.4	39.6
Oil Break Down Voltage min (kV)	41	40.5
Pressboard Ageing Speed avg (p.u.)	0.0039	0.0025
Pressboard Ageing (hours)	10.5	10.5
Total Accumulated Ageing (years)	2.5	1.6

Advanced Analytics models describing the status of the transformer, applying industry-standard and Camlin proprietary models to identify transformer behaviour

Annex 3: Expert Services

Transformer Supervision Package

Transformer Supervision Package (with Annual assessment)		
CA-2	Annual Condition Assessment w/ alarm review	•
CA-6	Emergency report within 24 hour (if required)	•
CA-5	Event Analysis (if required)	•
	Other support as required	•

Summary:
The initial diagnostic assessment benchmarks the health of the transformer at the time of installing the monitoring system. It is included with the monitoring system.

Following this, the DGA alarm thresholds are optimized (annually) and a detailed annual condition assessment performed.

Should there be a transformer alarm or trip, our team will support with a rapid emergency report and a deeper analysis into the cause of the event. Other expert support as required is included.

These services are described in more detail on the following pages.

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CA-2
Annual Diagnosis

Data Required:

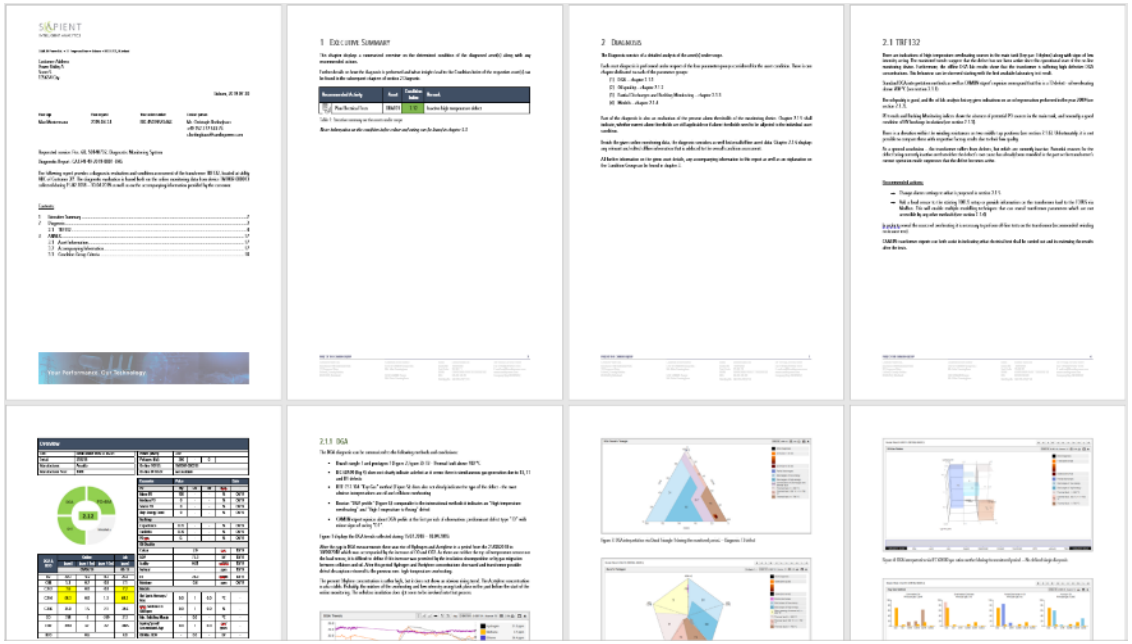
Mandatory
- CA-1 report
- Recent DGA
- Recent Oil quality

Recommended
- Online data
- Any other recent report available

PURPOSE Periodic assessment carried out every year, after the initial report (CA-1) is issued. It will update the initial calculated condition by adding recent DGA, oil quality and online monitors (if any) data. If electrical test and maintenance is necessary during the year a new CA-1 report will be needed.

RESULT Diagnostic Report in English Language, in pdf format (Translation to be quoted separately for Option 1).

DELIVERY 2 working weeks after the submittal of the mandatory data set per each transformer



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CA-6
Emergency Report

Data Required:

Mandatory
- Nameplate
- Online data
- Event description

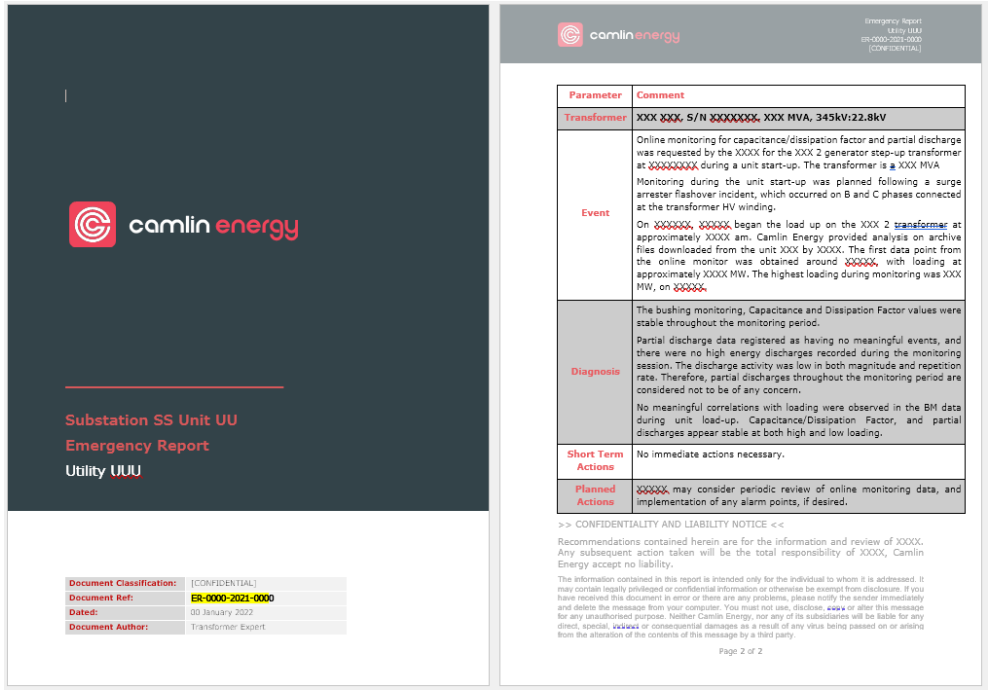
Recommended

- Historical DGA
- Historical Oil quality
- Historical electrical test results
- Any other available report

PURPOSE Identification of potential transformer issues upon alarm notification or customer concerns. Historical condition index is not included.

RESULT Diagnostic Report in English Language, in pdf format. It includes diagnostic assessment and recommended actions.

LEAD TIME 24 hours from order receipt and submittal of mandatory data (only for reports in English)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Substation SS Unit UU
Emergency Report
Utility UUU

Document Classification:	[CONFIDENTIAL]
Document Ref:	ER-0000-2021-0000
Dated:	00 January 2022
Document Author:	Transformer Expert

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Parameter	Comment
Transformer	XXX XXX, S/N XXXXXXX, XXX MVA, 345kV:22.8kV
Event	Online monitoring for capacitance/dissipation factor and partial discharge was requested by the XXXX for the XXX 2 generator step-up transformer at XXXXXXXX during a unit start-up. The transformer is a XXX MVA Monitoring during the unit start-up was planned following a surge arrester flashover incident, which occurred on B and C phases connected at the transformer HV winding. On XXXXXX, XXXXX began the load up on the XXX 2 transformer at approximately XXXX am. Camlin Energy provided analysis on archive files downloaded from the unit XXX by XXXX. The first data point from the online monitor was obtained around XXXXX, with loading at approximately XXXX MW. The highest loading during monitoring was XXX MW, on XXXXX.
Diagnosis	The bushing monitoring, Capacitance and Dissipation Factor values were stable throughout the monitoring period. Partial discharge data registered as having no meaningful events, and there were no high energy discharges recorded during the monitoring session. The discharge activity was low in both magnitude and repetition rate. Therefore, partial discharges throughout the monitoring period are considered not to be of any concern. No meaningful correlations with loading were observed in the BM data during unit load-up. Capacitance/Dissipation Factor, and partial discharges appear stable at both high and low loading.
Short Term Actions	No immediate actions necessary.
Planned Actions	XXXXX may consider periodic review of online monitoring data, and implementation of any alarm points, if desired.

>> CONFIDENTIALITY AND LIABILITY NOTICE <<

Recommendations contained herein are for the information and review of XXXX. Any subsequent action taken will be the total responsibility of XXXX, Camlin Energy accept no liability.

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CA-5
Event Analysis

Data Required:

Mandatory
- Nameplate
- Historical DGA
- Historical Oil quality
- Online data
- Event description

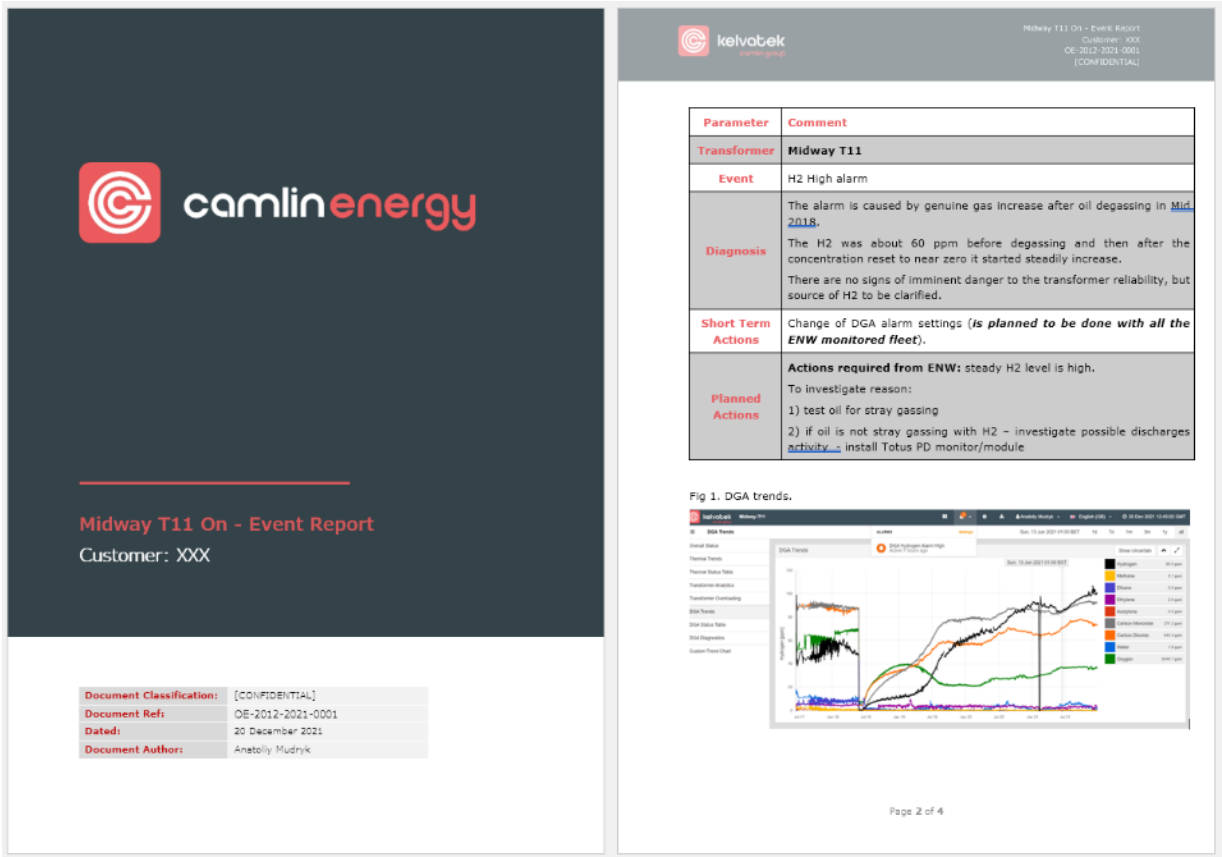
Recommended

- Historical electrical test results
- Historical maintenance reports

PURPOSE Identification of potential transformer issues upon alarm notification or customer concerns.

RESULT Diagnostic Report in English Language, in pdf format (Translation to be quoted separately for Option 1).

LEAD TIME 2 weeks from order receipt and submittal of mandatory data.

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