TRANSFORMER CLINIC

WEB EVENT

How to Maximize Transformer Reliability and In-Market Availability

MISTRAS

Hydro Québec Institut de recherche

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Meet the Experts

How to Maximize Transformer Reliability and In-Market Availability

Michel Duval

keynote

FORMERLY OF Hydro Québec Institut de recherche

- Internationally renowned leader in Dissolved Gas Analysis (DGA)
- Creator of the Duval Triangle®

Arturo Núñez

speaker

MISTRAS

- Manager of MISTRAS Group's Substation Reliability COE
- Certified Level III in Acoustic Emission

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Dissolved Gas Analysis (DGA)

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Transformer Failures

How to Maximize Transformer Reliability and In-Market Availability

Duke Energy, 2009

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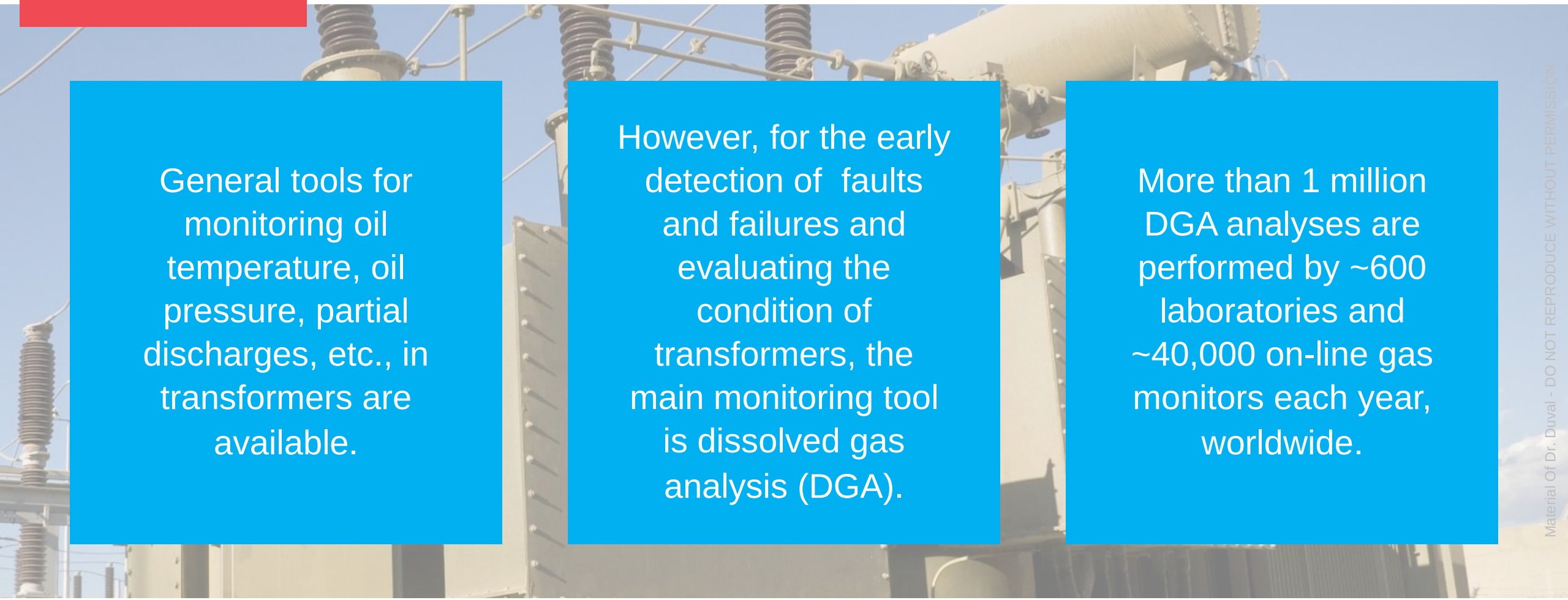
Monitoring Tools

How to Maximize Transformer Reliability and In-Market Availability



General tools for monitoring oil temperature, oil pressure, partial discharges, etc., in transformers are available.

However, for the early detection of faults and failures and evaluating the condition of transformers, the main monitoring tool is dissolved gas analysis (DGA).

More than 1 million DGA analyses are performed by ~600 laboratories and ~40,000 on-line gas monitors each year, worldwide.

DGA Diagnosis Methods Use Hydrocarbon Gases

1. **One gas at a time**
   Key Gas Method
2. **Two gases at a time**
   Rogers, IEC Ratio Methods
3. **Three gases at a time**
   Duval Triangles 1, 4, 5
4. **Four gases at a time**
   Korea
5. More recently...
   Five gases at a time
   Duval Pentagons 1, 2

Carbon oxides and furans are then used to confirm the diagnosis provided by hydrocarbon gases as to whether paper is involved or not in faults.

The 6 Basic Types of Faults Detectable by DGA

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PD

Partial discharges of the corona-type

D1

Low-energy discharges, including partial discharges of the sparking-type.

D2

High-energy discharges

T1

Thermal faults of low temperature T < 300ºC

T2

Thermal faults of 300 <T< 700ºC

T3

Thermal faults of high temperature T >700ºC

These faults are detectable with the Rogers, Triangle 1 and Pentagon 1 methods.

The Additional Sub-Types of Thermal Faults Detectable by DGA

S

Stray gassing of oil at T <200ºC, because of the chemical instability of oil

O

Overheating of oil or paper at T <250ºC

T3/T2 in oil only (T3-H):

At T >700/ 300ºC

These 3 sub-types of thermal faults and corona PDs are of minor concern in transformers because they are in oil or do not result into carbonization of paper.

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T3/T2 in oil only (T3-H):

At T >700/ 300ºC

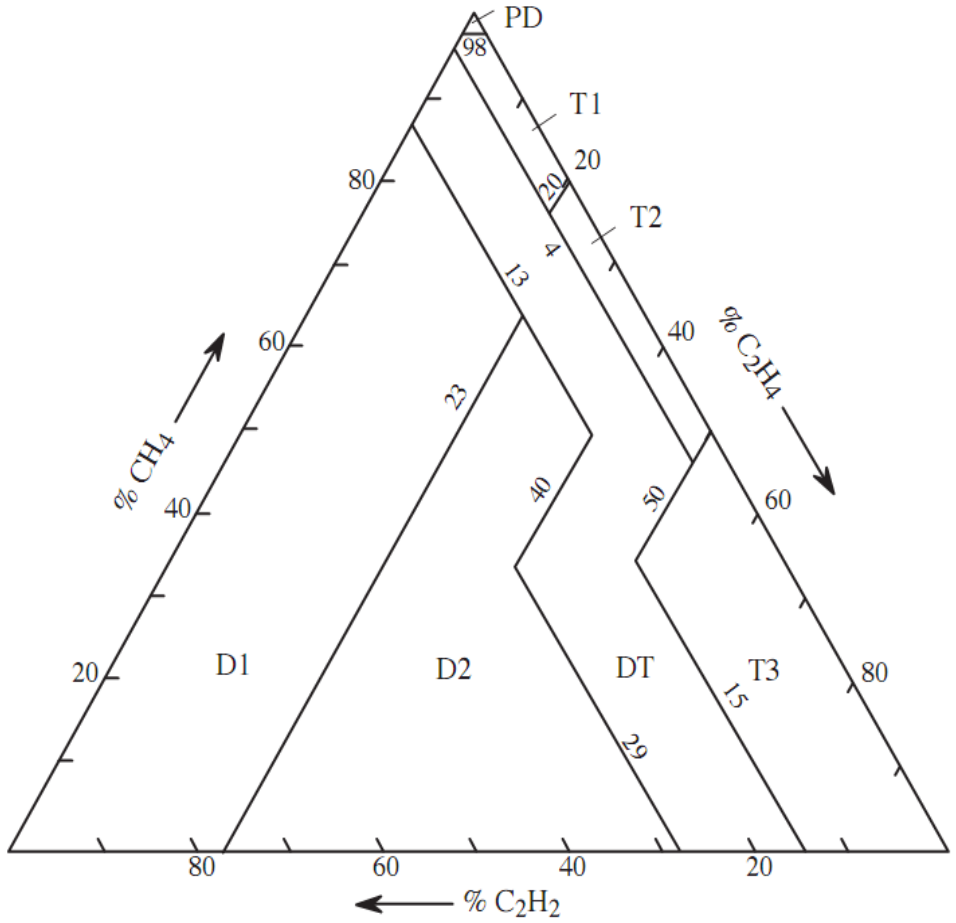
C

Carbonization of paper at T >300ºC, potentially more dangerous because of the loss of insulating properties of paper

These 4 additional sub-types of thermal faults and corona PD are detectable with Triangles 4, 5 and Pentagon 2.

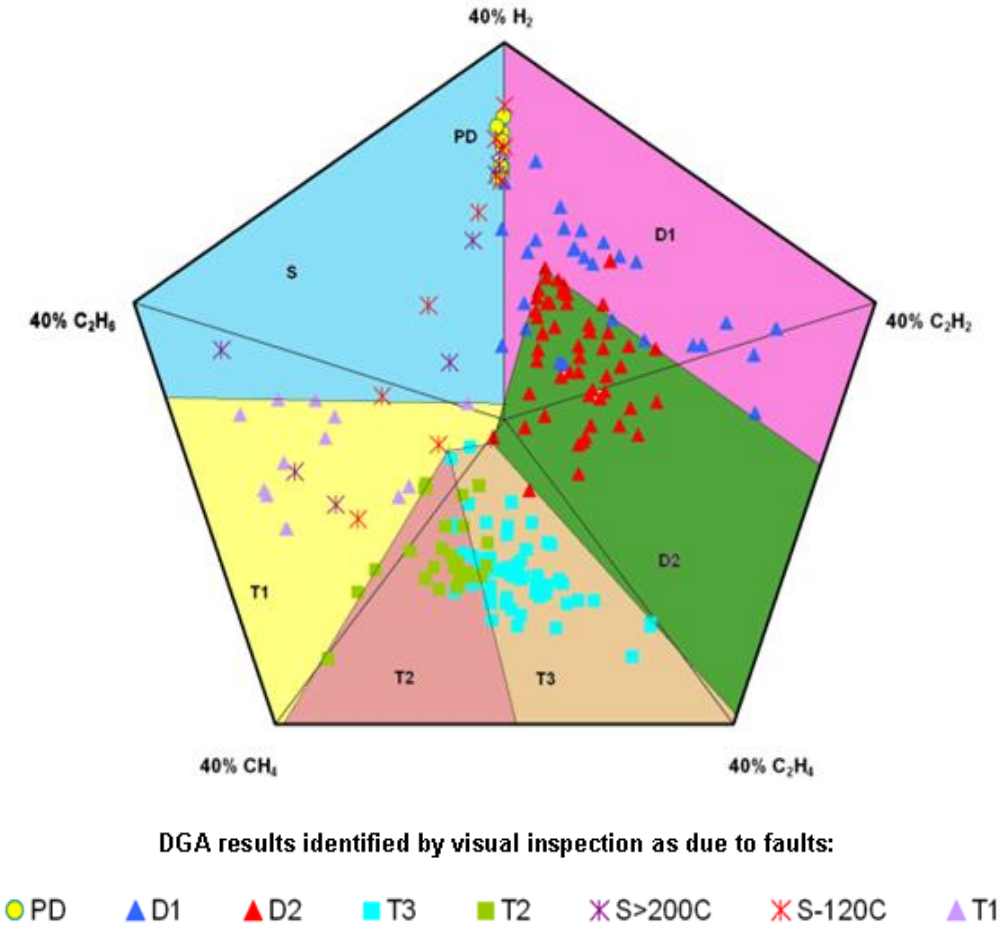
Duval Triangle 1 (updated 2002)

Triangle 1 is applicable to transformers, reactors, bushings and cables filled with mineral oils and for understanding materials degradation in general.
Any significant gas formation is an indication of a fault.



Duval Pentagon 1 (2011-2014)

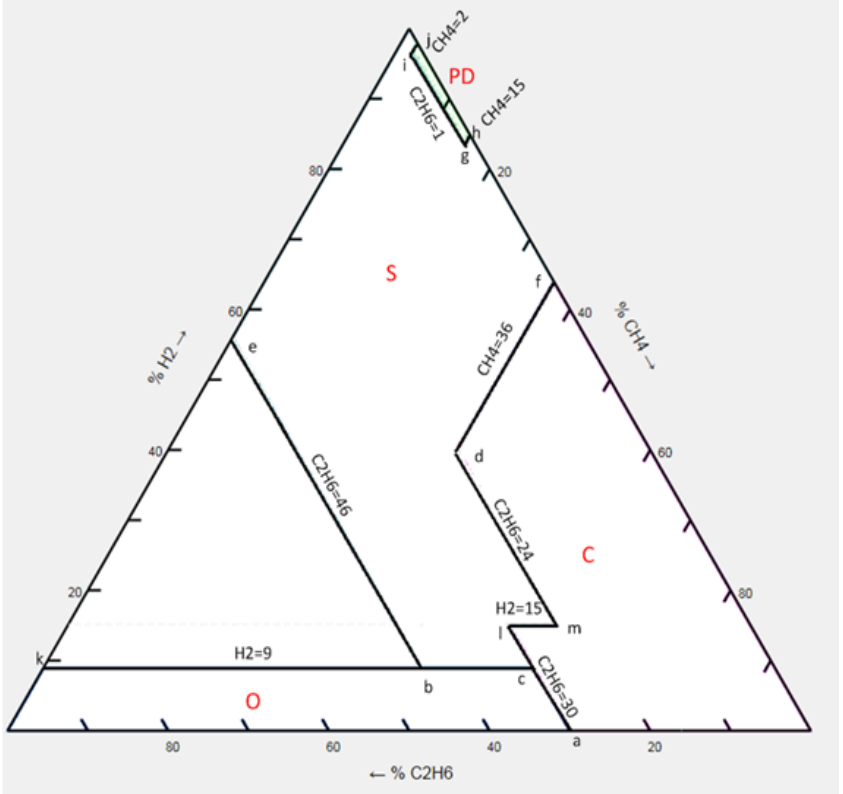
The order of gases at the 5 summits of the pentagon corresponds to the increasing energy required to produce these gases, i.e., from H2 to C2H2 counter-clockwise.



Duval Triangle 4 (updated 2012)

Zones:

- **S** Stray gassing of oil (T<200°C).
- **O** Overheating, T<250°C.
- **C** Possibility (not 100% certainty) of carbonization of paper.
- **PD** Corona partial discharges (close to zone S, verify with stray gassing tests in the lab).



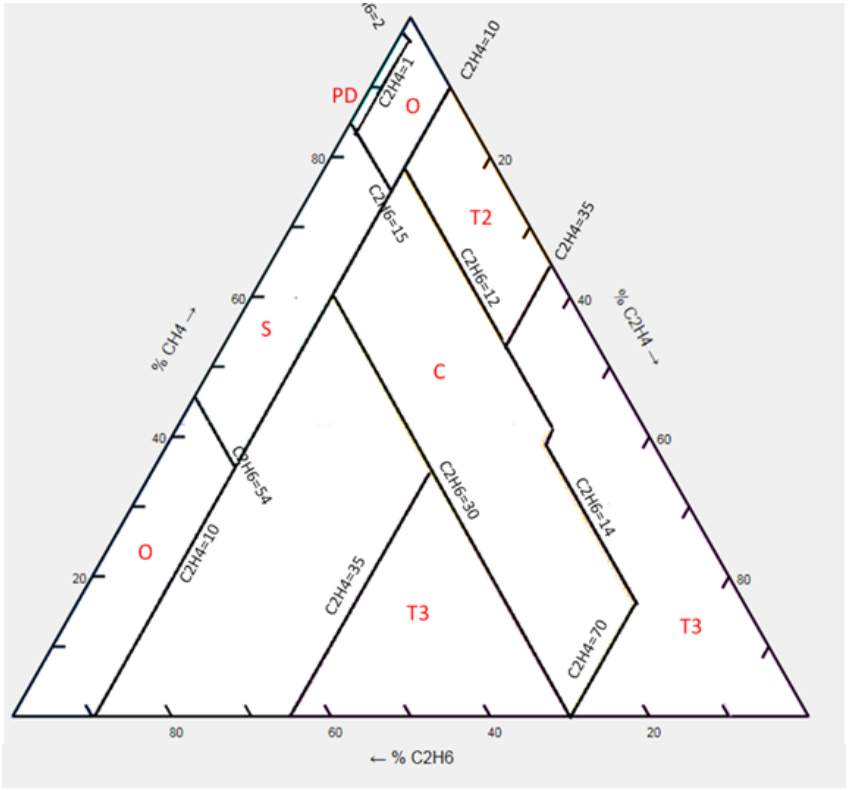
Graph courtesy: Serveron

Duval Triangle 5 (updated 2012)

Zones:

T3/T2 (T3-H) Hot spots <u>in oil only</u> (T>700°C and >300°C)

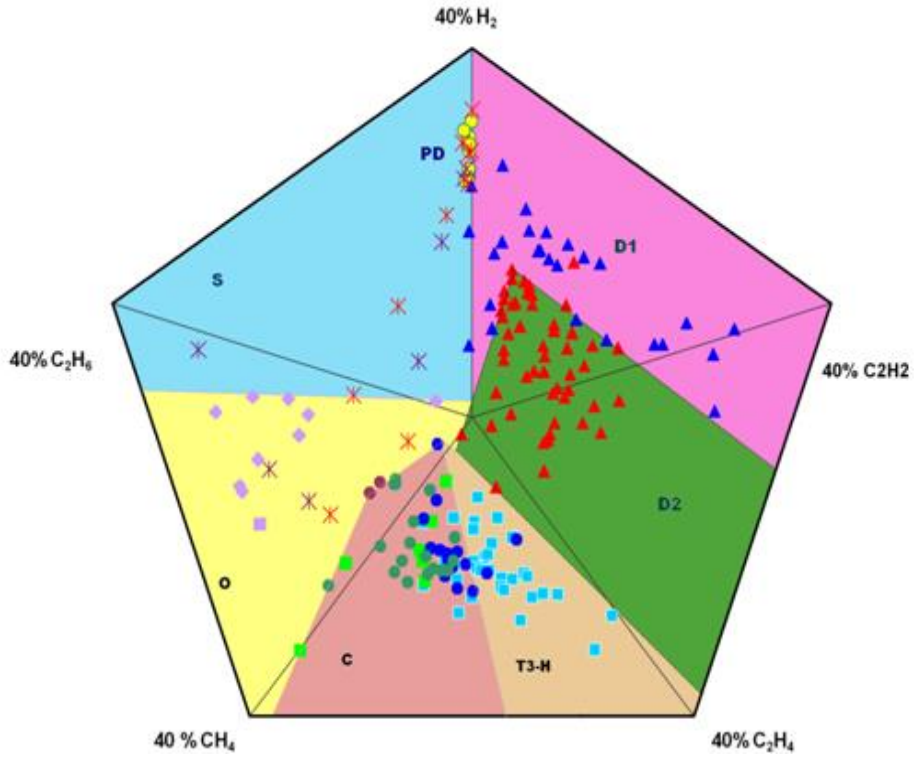
C Possibility (not 100% certainty) of carbonization of paper



Graph courtesy: Serveron

Duval Pentagon 2

Free algorithms for Triangles 1 to 7 and Pentagons 1 and 2 are available from duvalm@ireq.ca



DGA results identified by visual inspection as due to faults:

PD D1 D2 S>200C S-120C T3-H
T2-H T1-H T3-C T2-C T1-C T1-O

The Occurrence of Faults in Transformers (CIGRE WG47)

Triangle Used	Fault	% of DGA Cases
1	T3	30
	T2	22
	T1	20
	D1	1
	D2	4
5	T3-H	28
	C	12
4	S	20
	O	9
	PD	1

Complementary Acoustic Emission Tests

When DGA indicates high-temperature faults T3, T2, T3-H, C or sparking discharges D1, complementary acoustic tests may be useful to:

- Find the location of the fault (provided it is outside of windings or core)

- Confirm whether or not the fault is:
  - In oil only (T3-H), and not too much of a concern,
  - or may involve carbonization of paper (C), or sparking D1, and is potentially dangerous for the transformer

Acoustic Emission Transformer Monitoring

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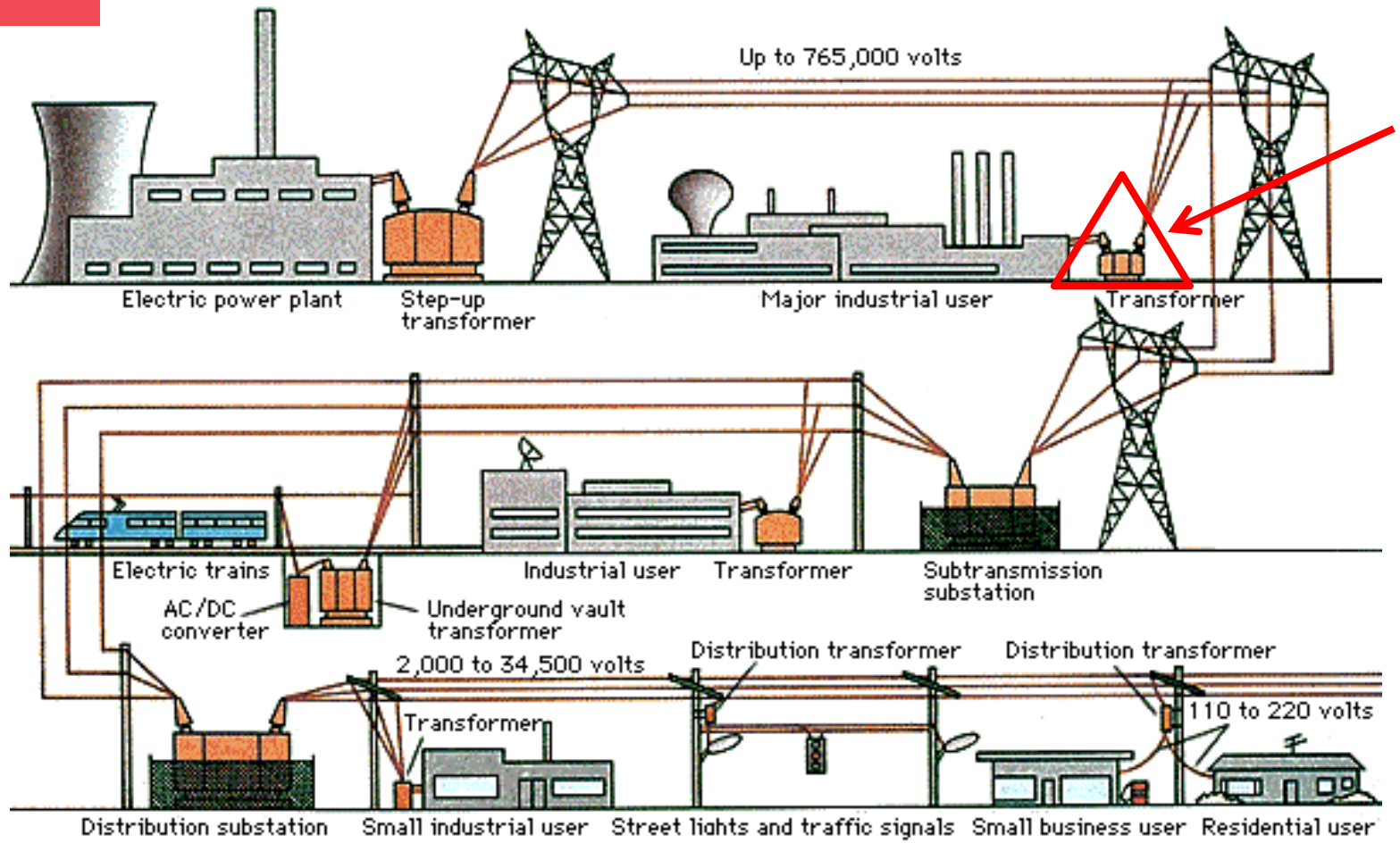
Transformers & Substations are an integral part of overall performance!

How to Maximize Transformer Reliability and In-Market Availability



Impact if this unit went offline! $$$

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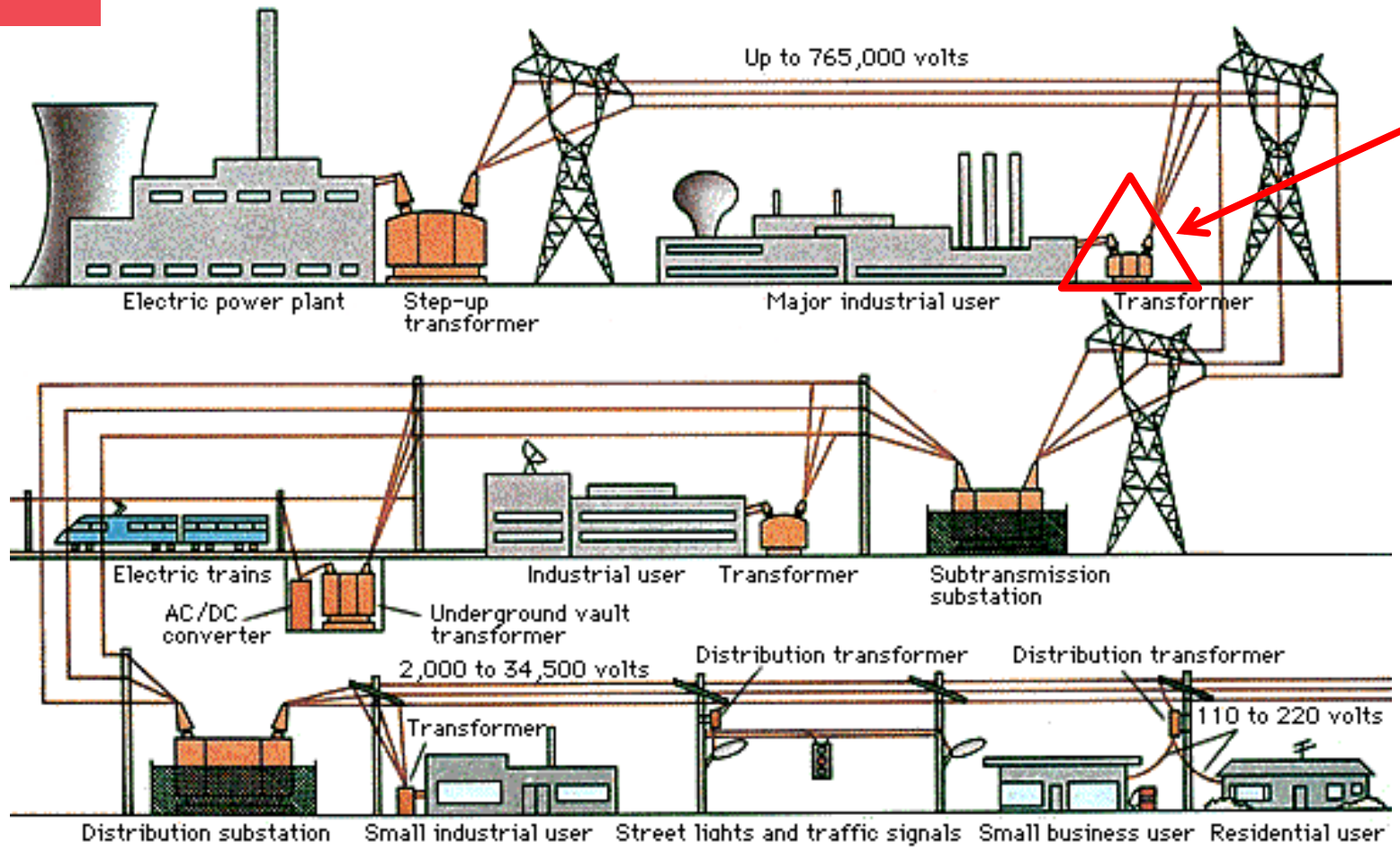

Impact if this unit went offline! $$$

SAMPLE SCREEN OBSERVE MONITOR

Commercial Impact

Transformer Type:

Generator Step Up (GSU)
(Generation Side)

Operational Impacts:

- Plant shut down
- No on-site spare unit
- Delivery of new or repaired unit up to 3 yrs.
- Capital cost $Millions
- Load adjustment required of 30-35% of max when problem discovered
- Loss of revenue
- Profit impact
- EPA fugitive emissions issue due to oil leaking

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What is Acoustic Emission?

- A Non-Destructive Testing Method
- Used for evaluation of mechanical structures since the 1950's
- Applied for transformer testing since 1970s

DEFINITION: "Acoustic Emissions are transient elastic waves generated by the rapid release of energy from localized sources within a material" (ASTM E610-82)

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Acoustic Emissions

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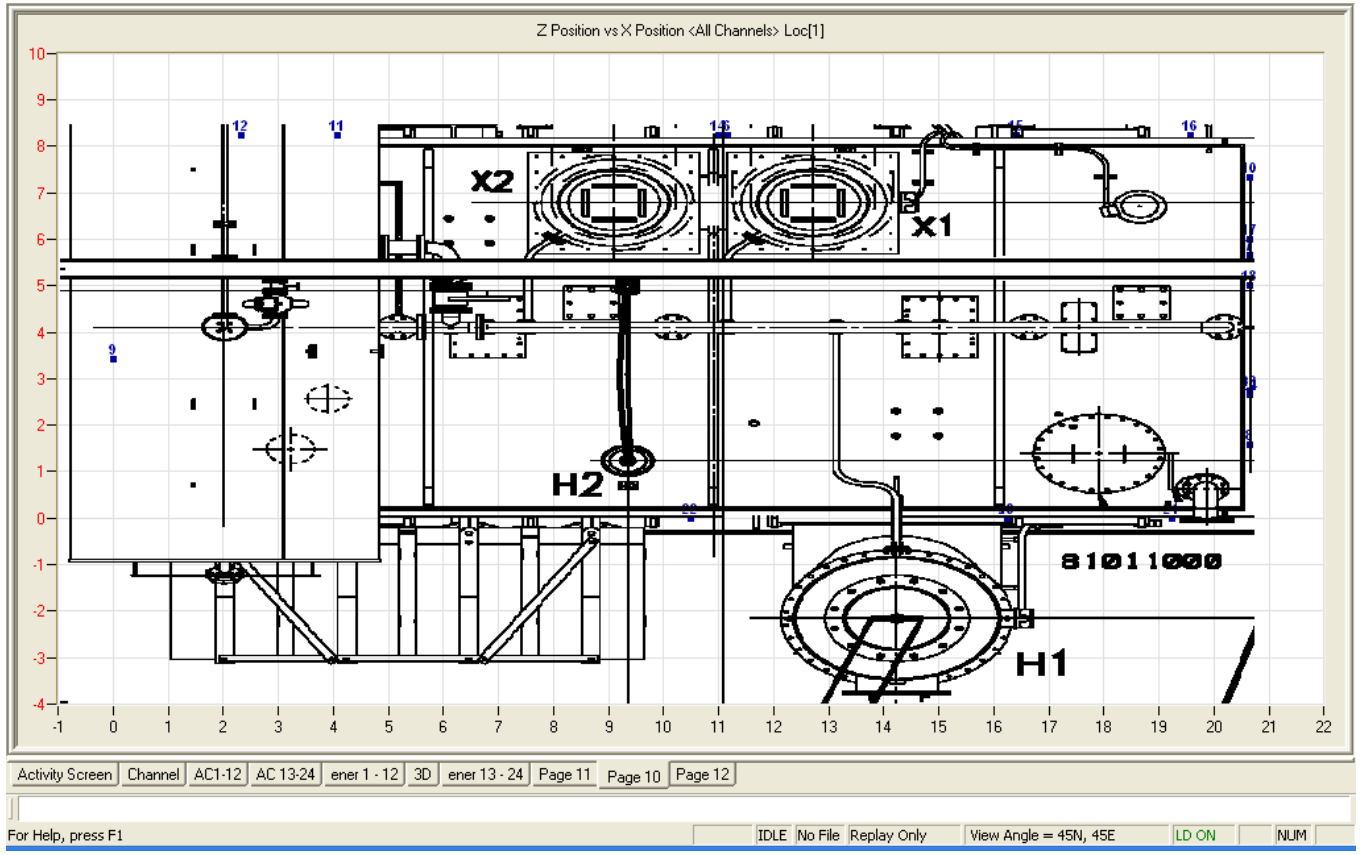

SAMPLE | SCREEN | OBSERVE | MONITOR

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Acoustic Emissions

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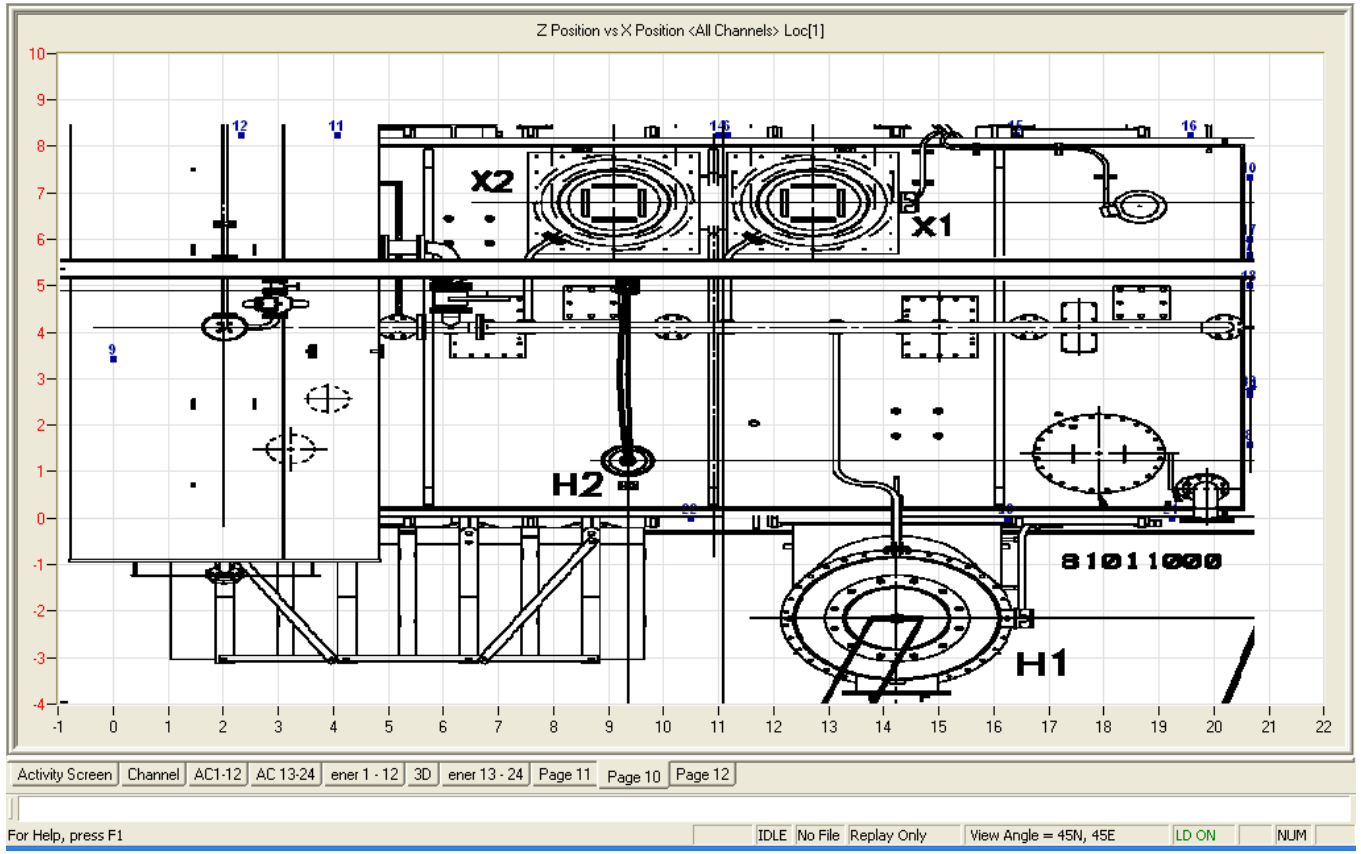

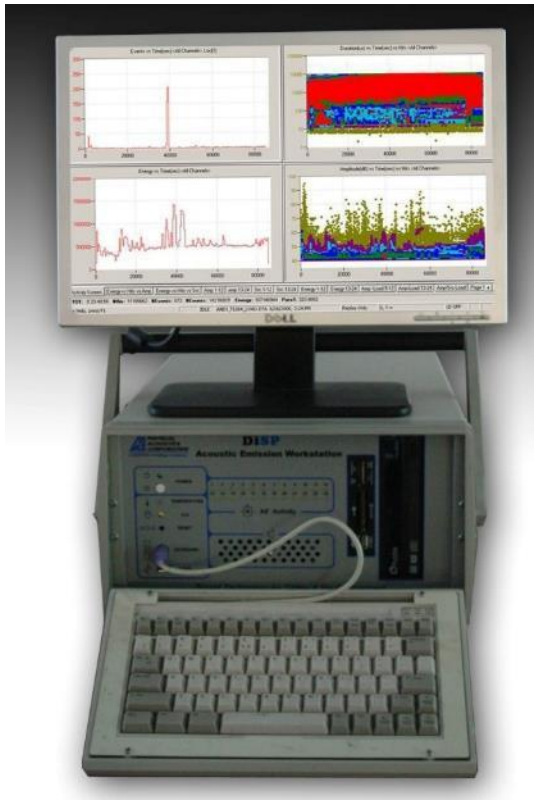

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Acoustic Emissions

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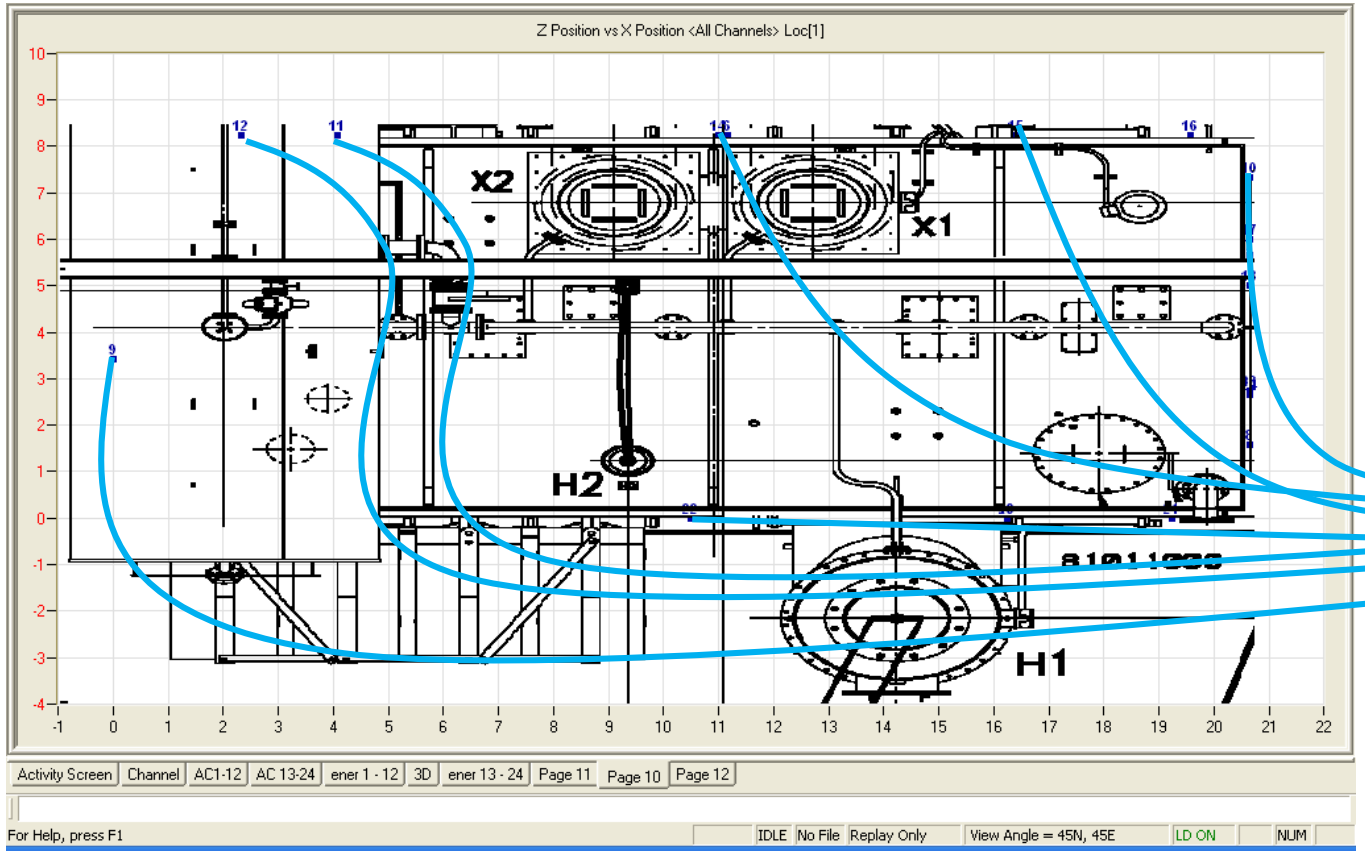

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Acoustic Emissions

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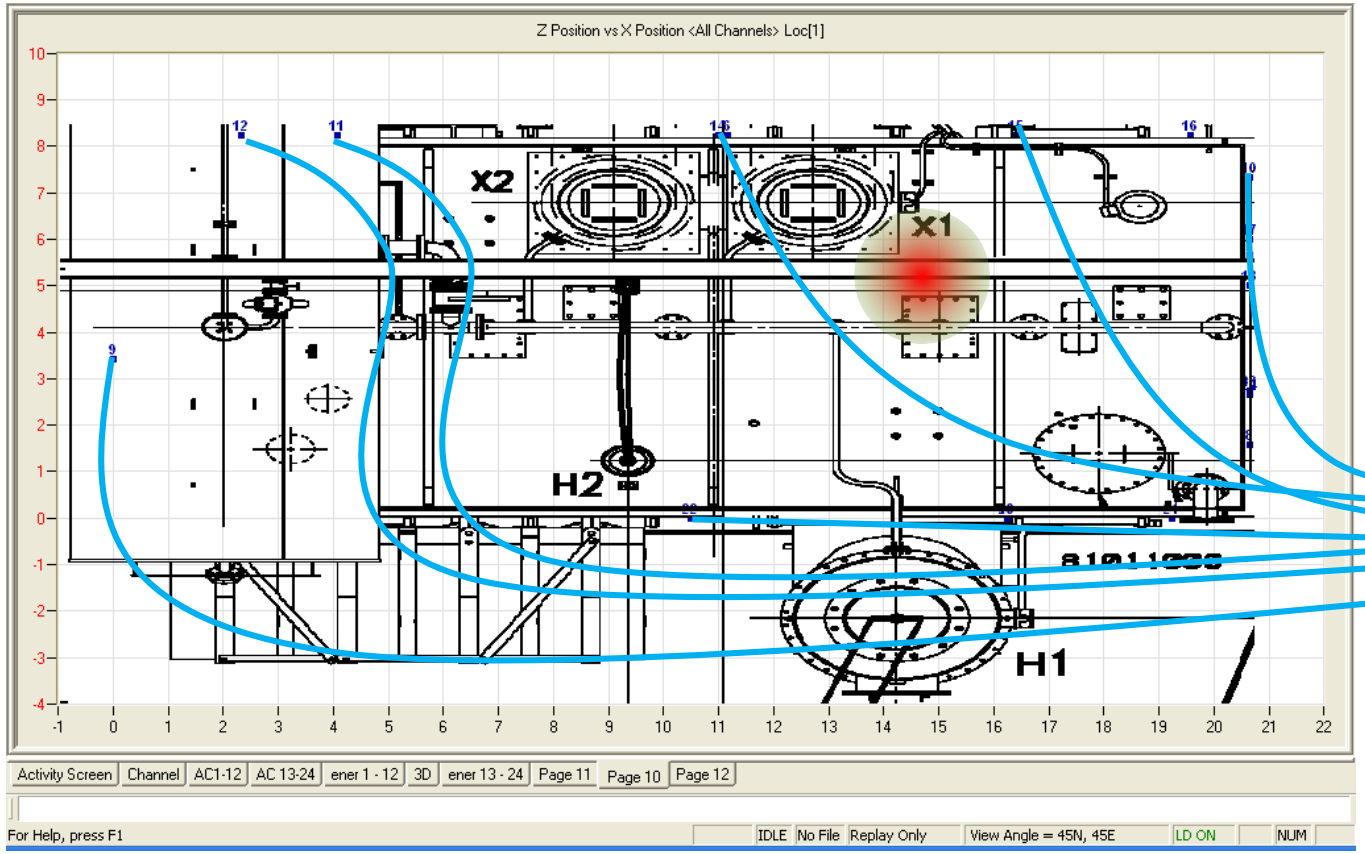

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Acoustic Emissions

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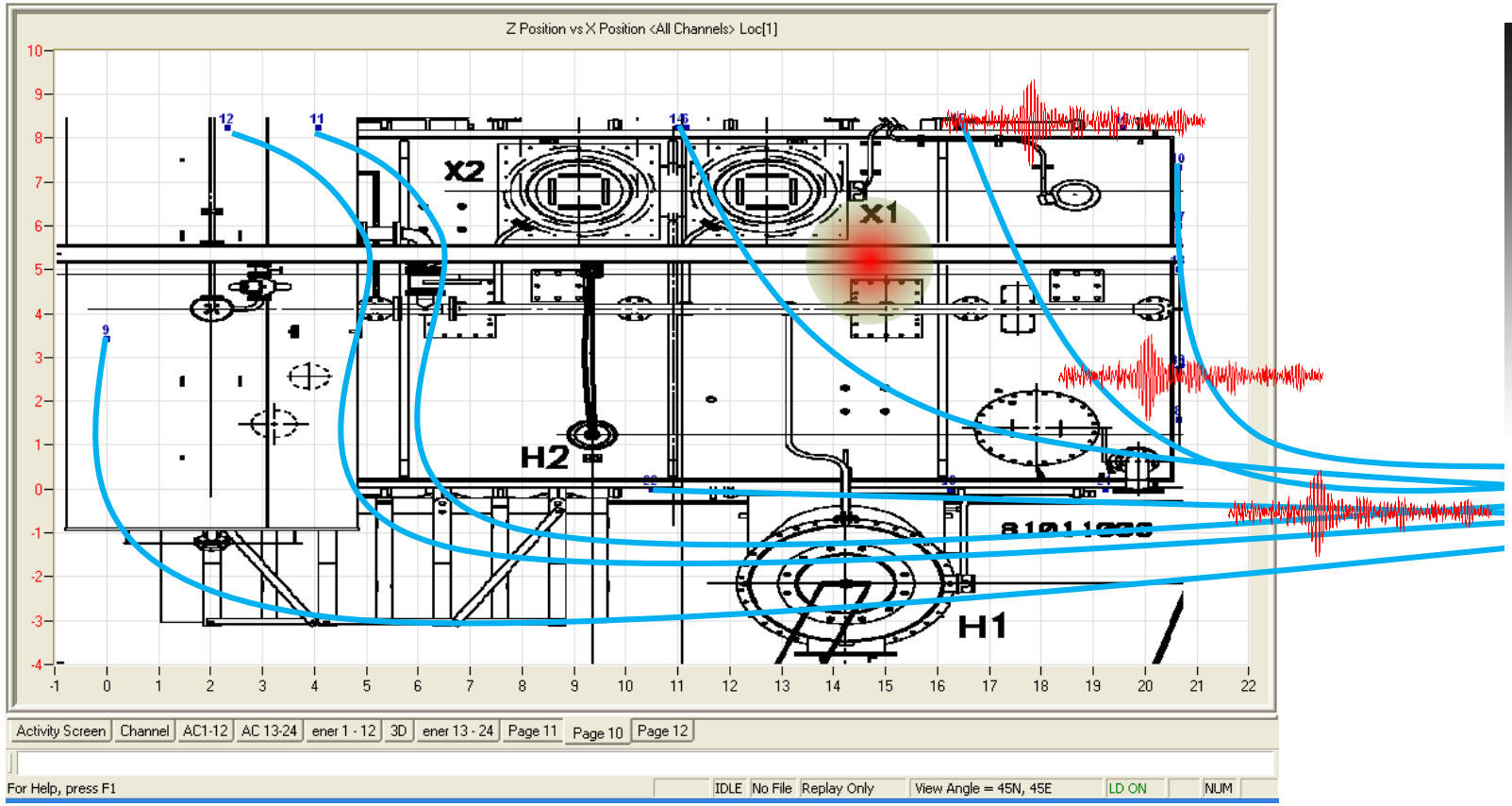

SAMPLE | SCREEN | OBSERVE | MONITOR

Is this standardized?

- ASTM Standards – Definitions, instrumentation, applications
  - E1316
  - E650
  - E750
  - E1106, etcetera
- IEEE Std. C57.127-2007 (ACTIVE WG)

  IEEE Guide for the Detection and Location of Acoustic Emissions from Partial Discharges in Oil-Immersed Power Transformers and Reactors

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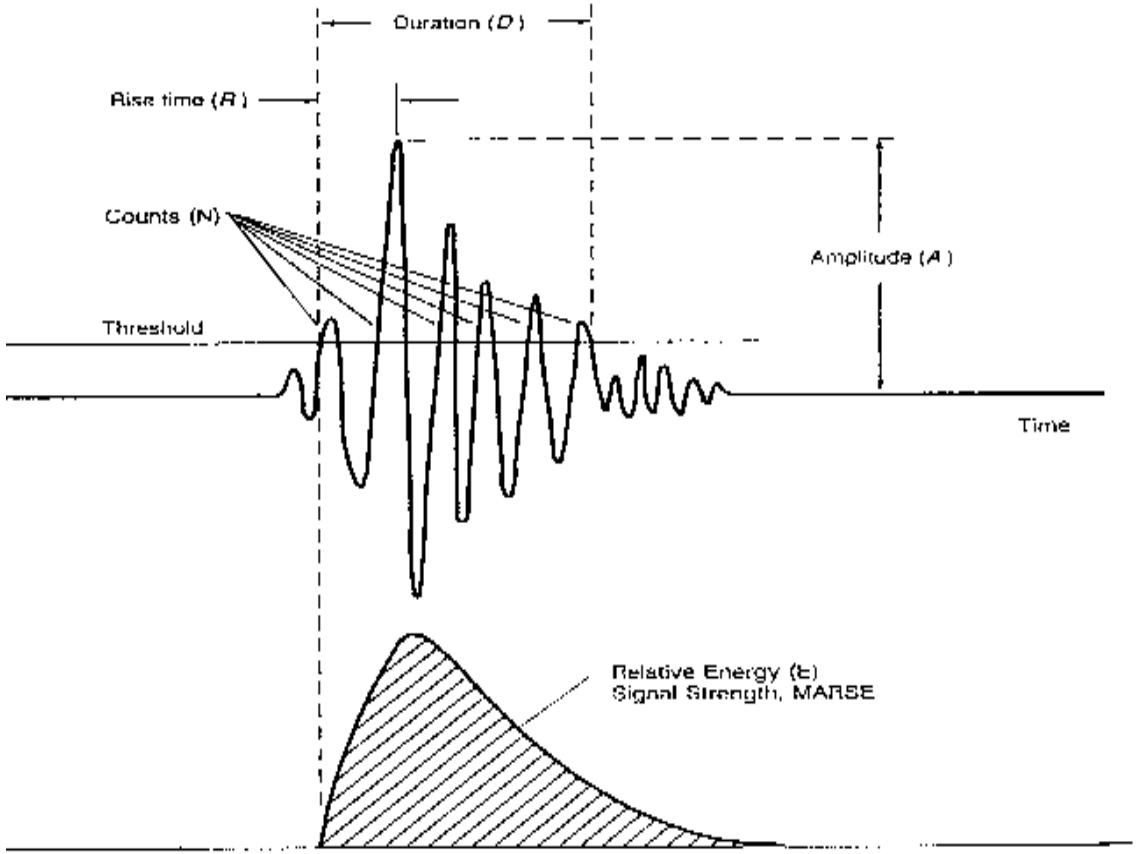

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Transformer Asset Protection Solutions

How to Maximize Transformer Reliability and In-Market Availability

Screening Testing

Transformers < 10 MVA
- **Multiple units per day**

Diagnostic Testing

Power Transformers (GSU's, Transmission)
- **24 HOUR TEST**
  - **Acoustic Emission**
  - **Dissolved Gas Analysis**
  - **Infrared Inspection**
  - **Vibration**
  - **Oil Quality**
  - **Electrical PD (HFCT)**

On Line Monitoring

Power Transformers
- **24/7 Monitoring**
- **Short term or permanent**

SAMPLE | SCREEN | OBSERVE | MONITOR

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Screening Tests

How to Maximize Transformer Reliability and In-Market Availability

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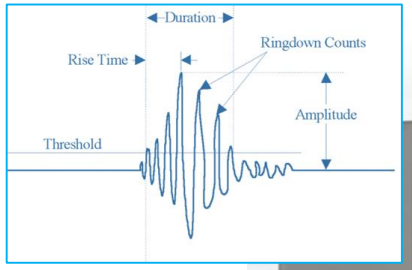
Acoustic Emission



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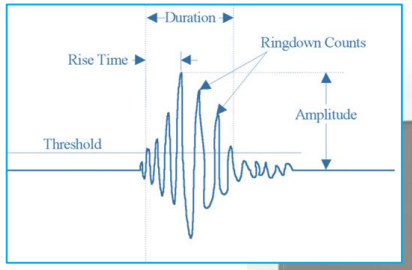

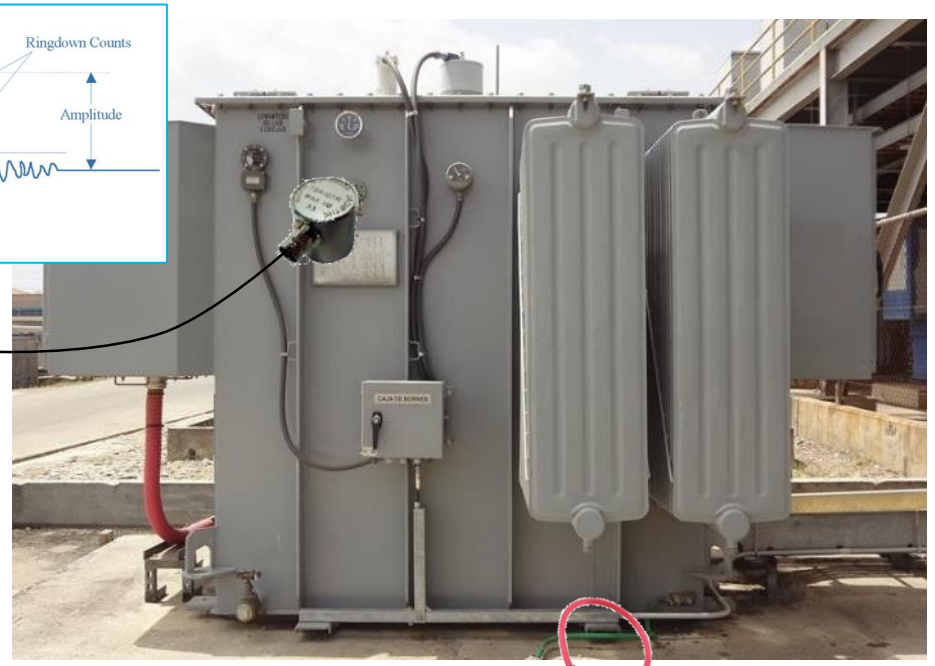

Acoustic Emission

PD detection using High Frequency Current Transducer (HFCT)

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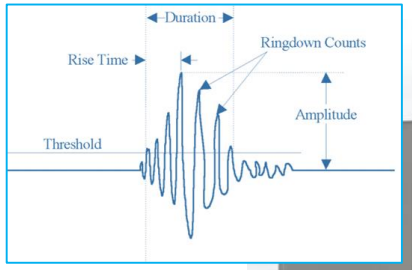
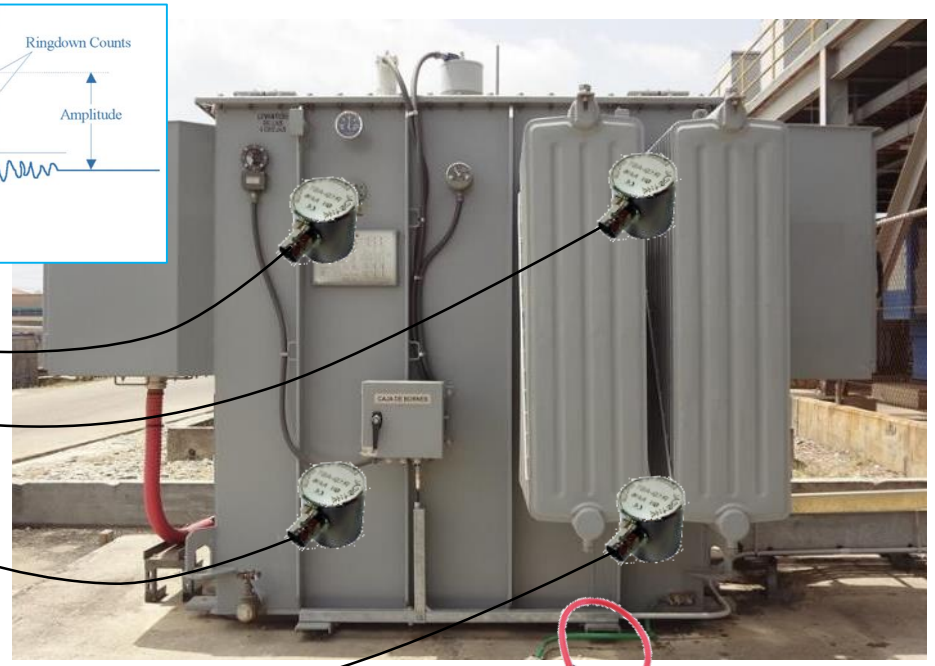
Screening Tests

How to Maximize Transformer Reliability and In-Market Availability





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Screening Tests

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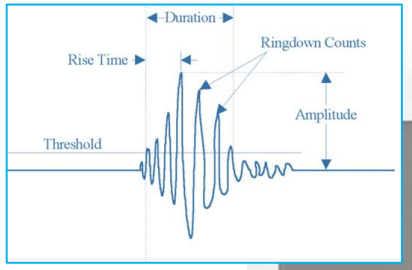

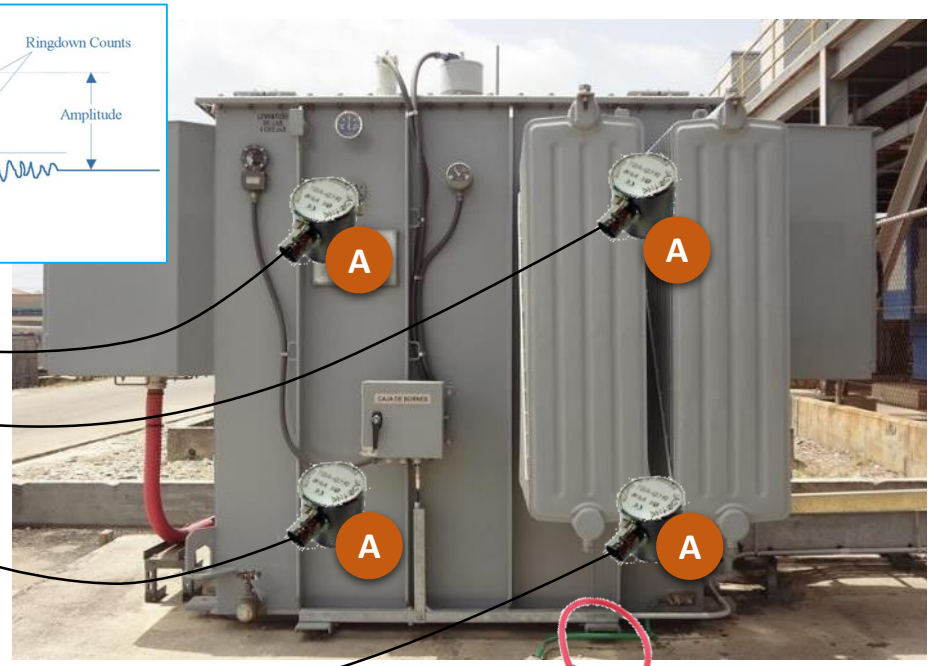

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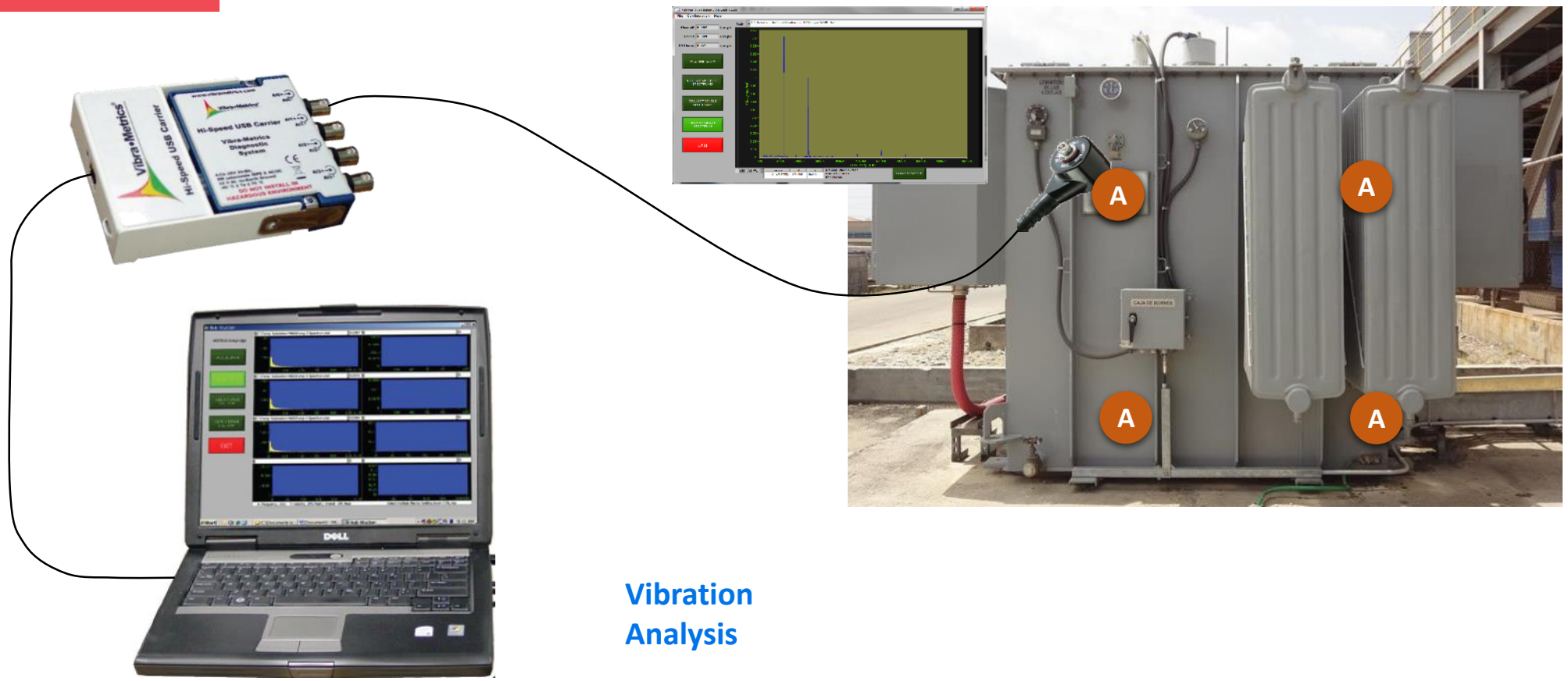
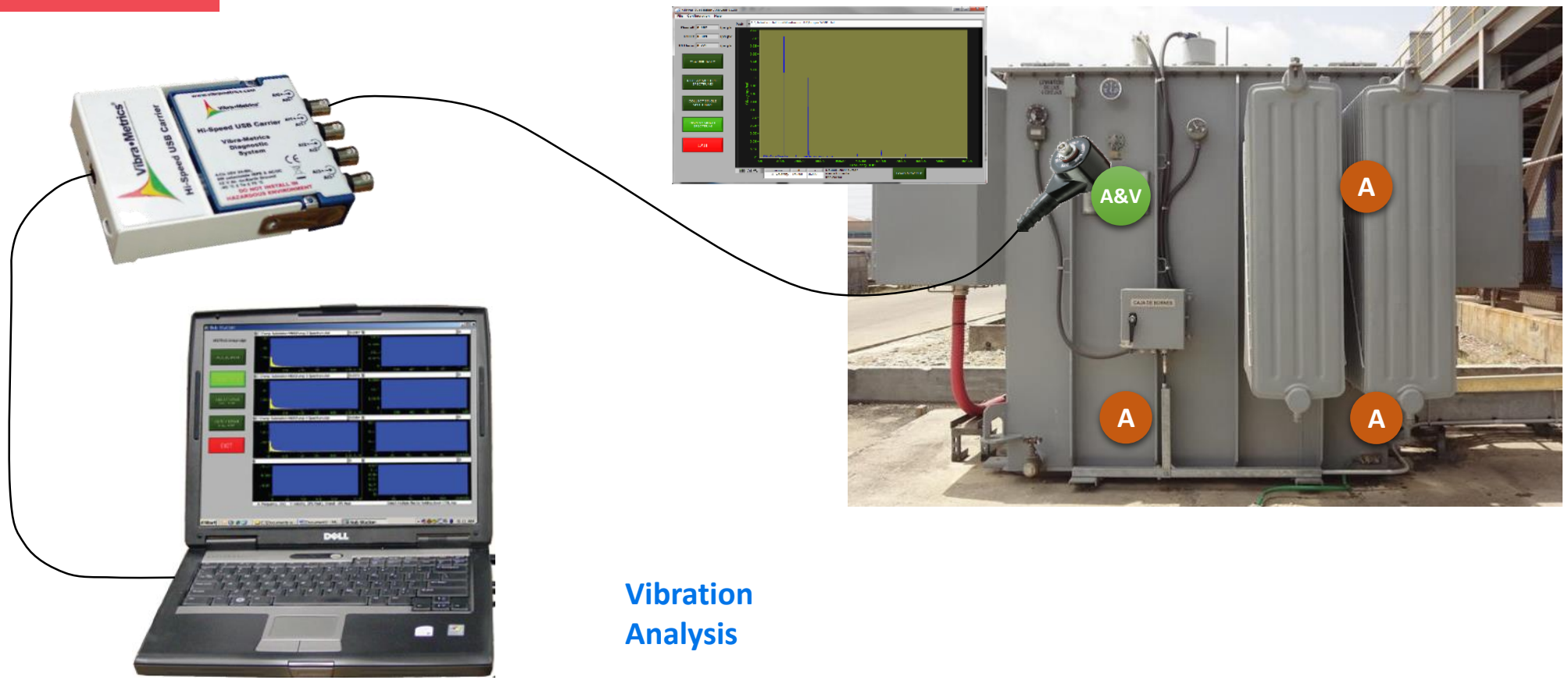


Vibration Analysis

Screening Tests



Vibration Analysis

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Screening Tests

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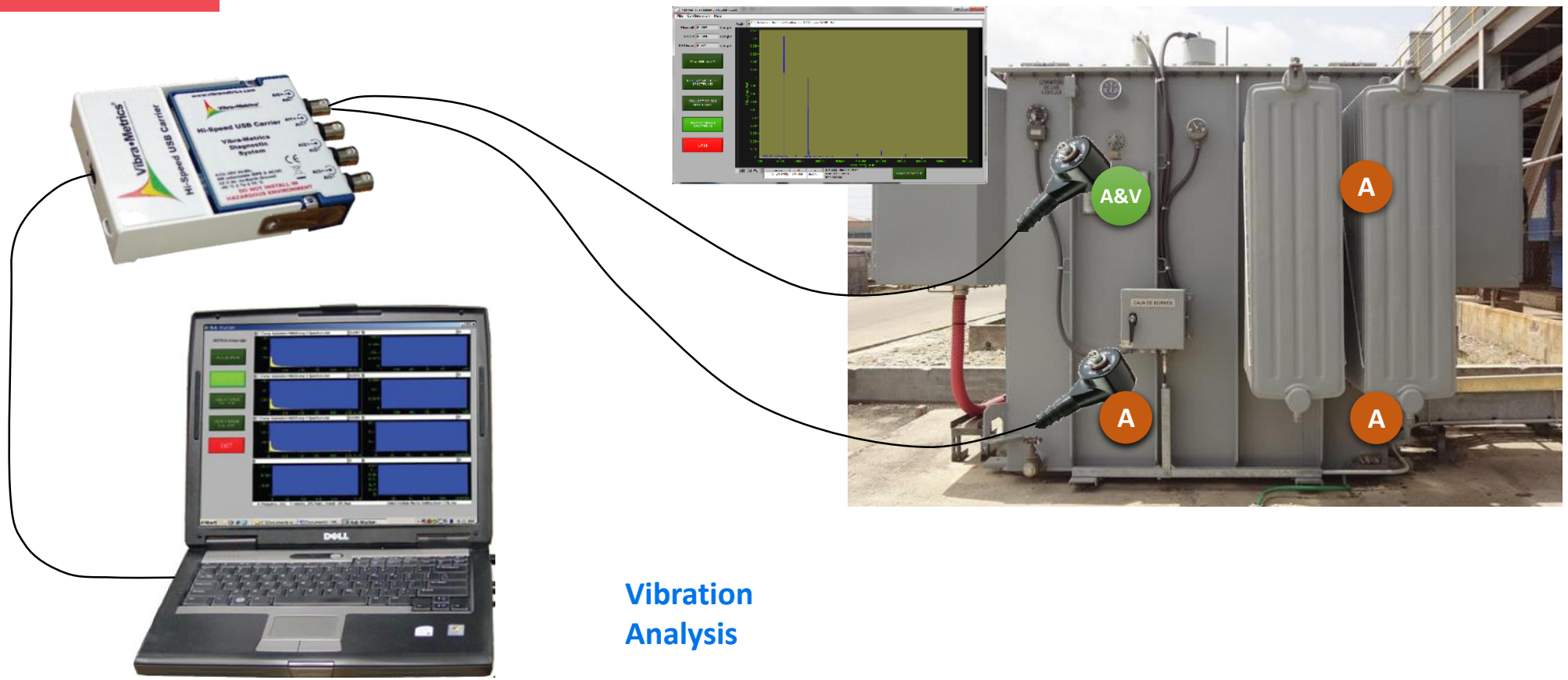

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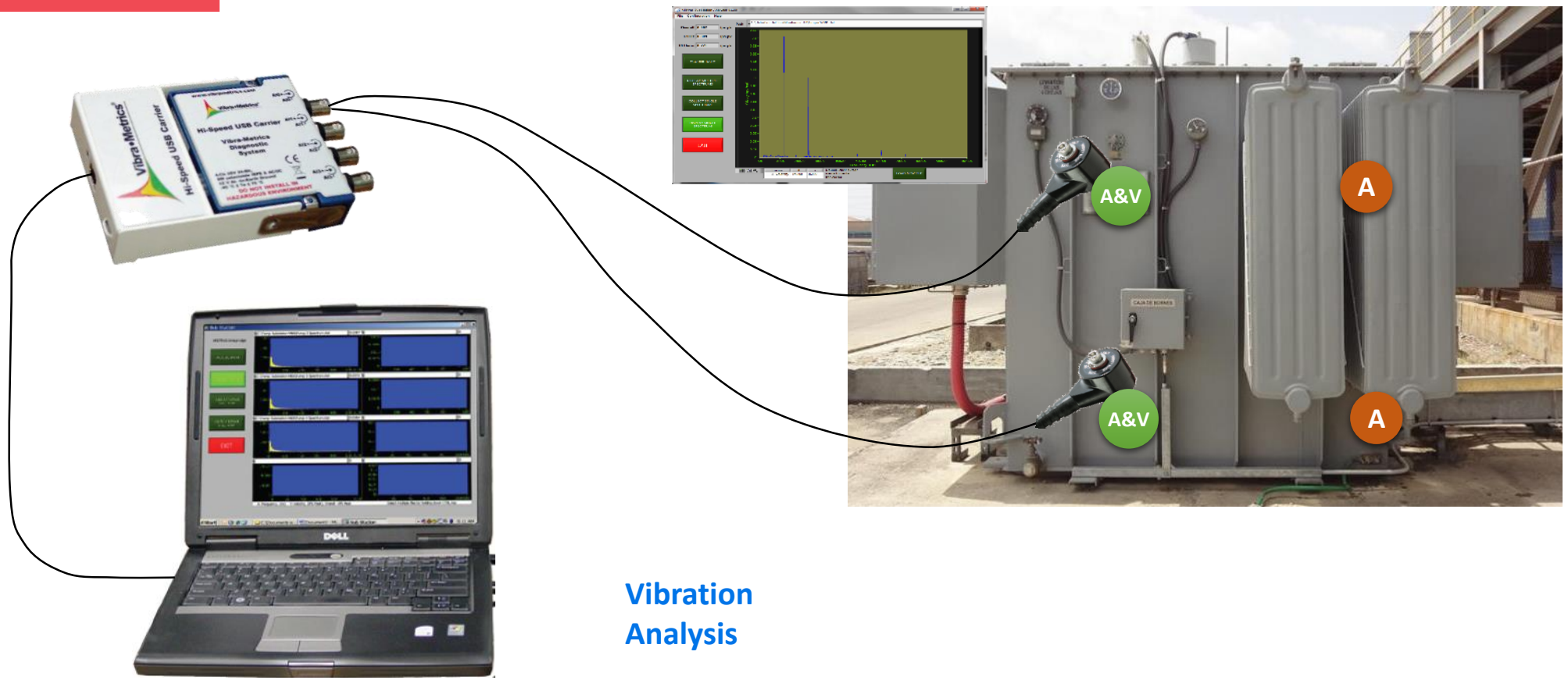

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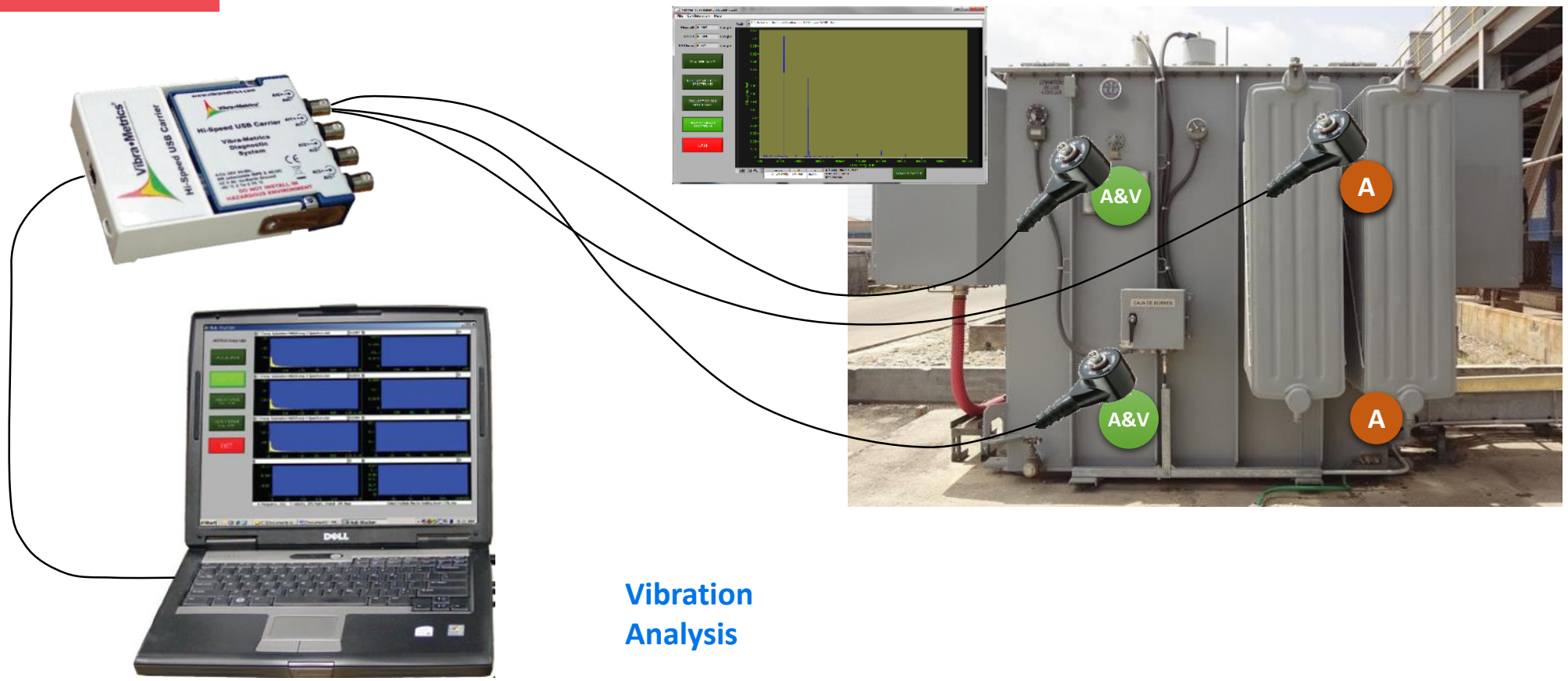

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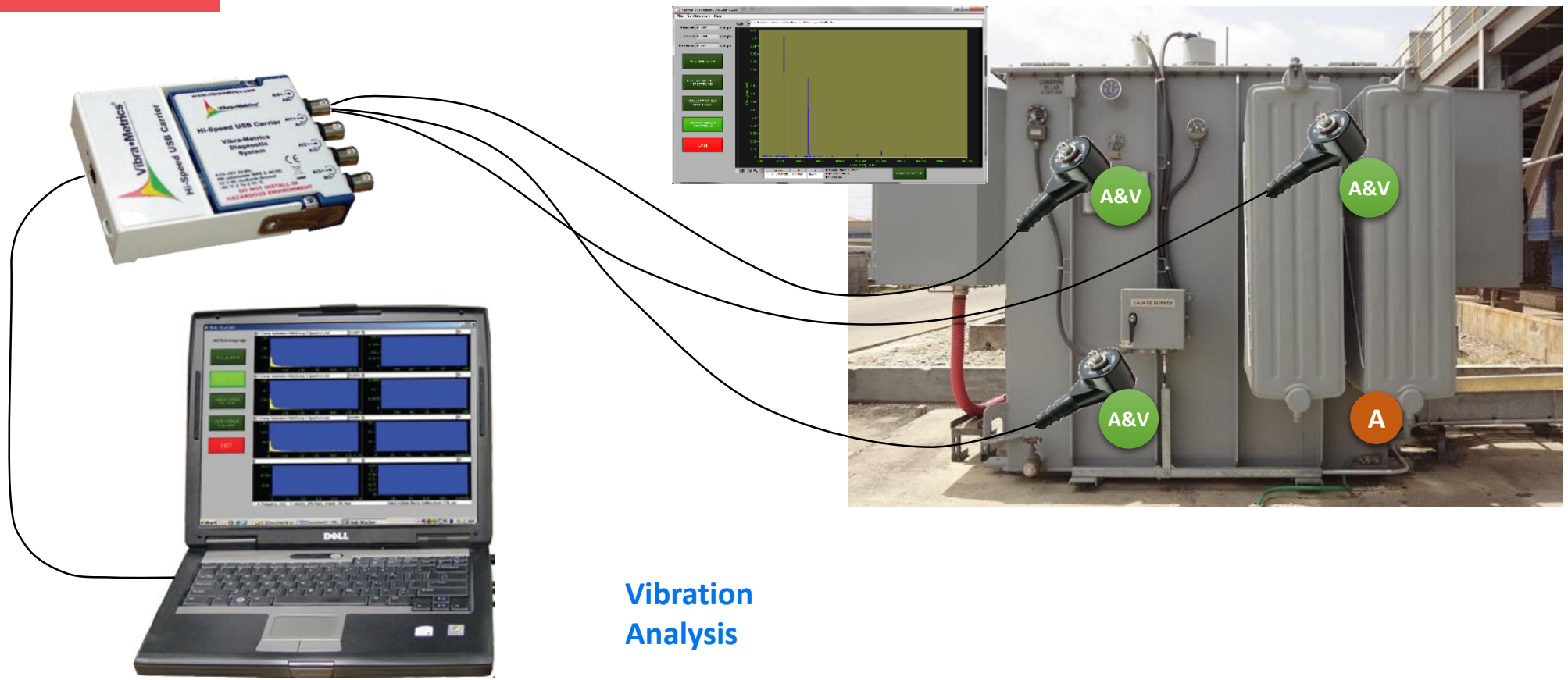

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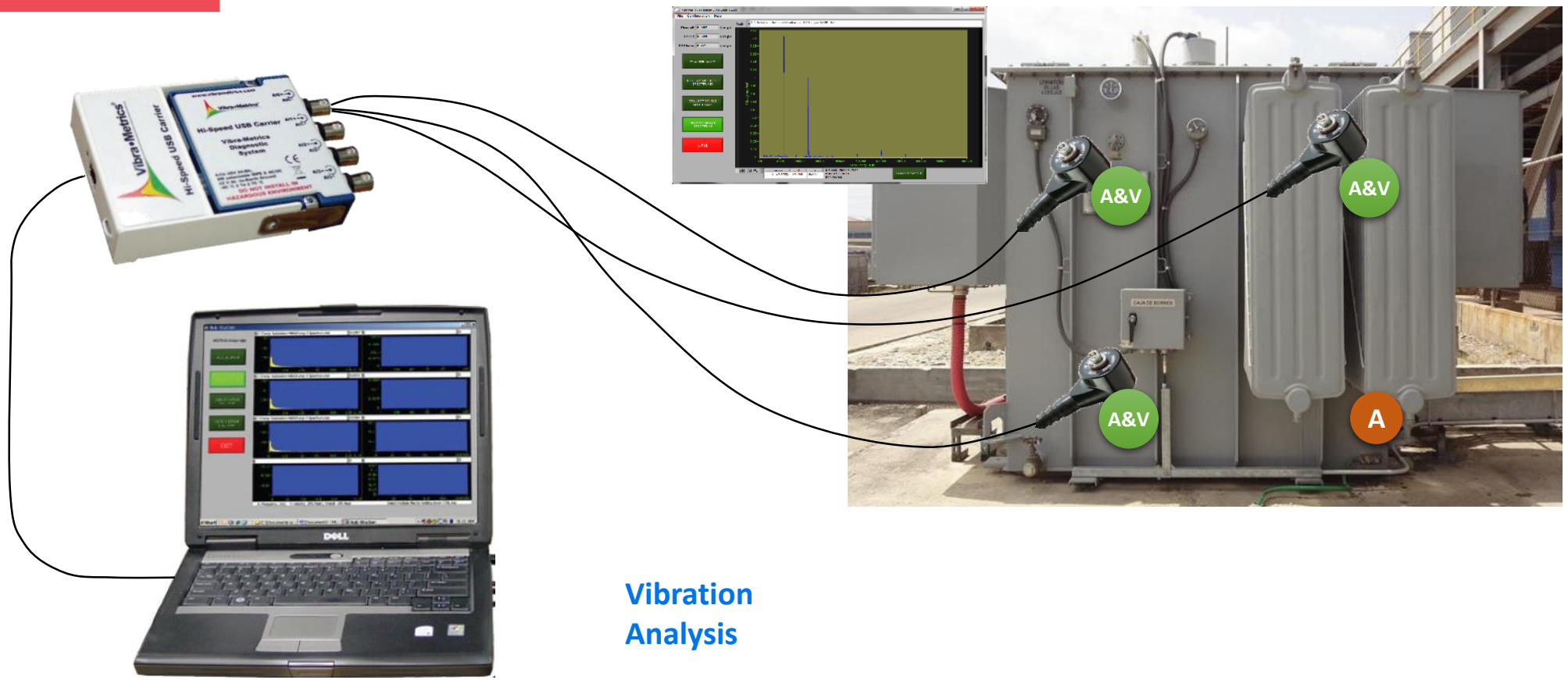

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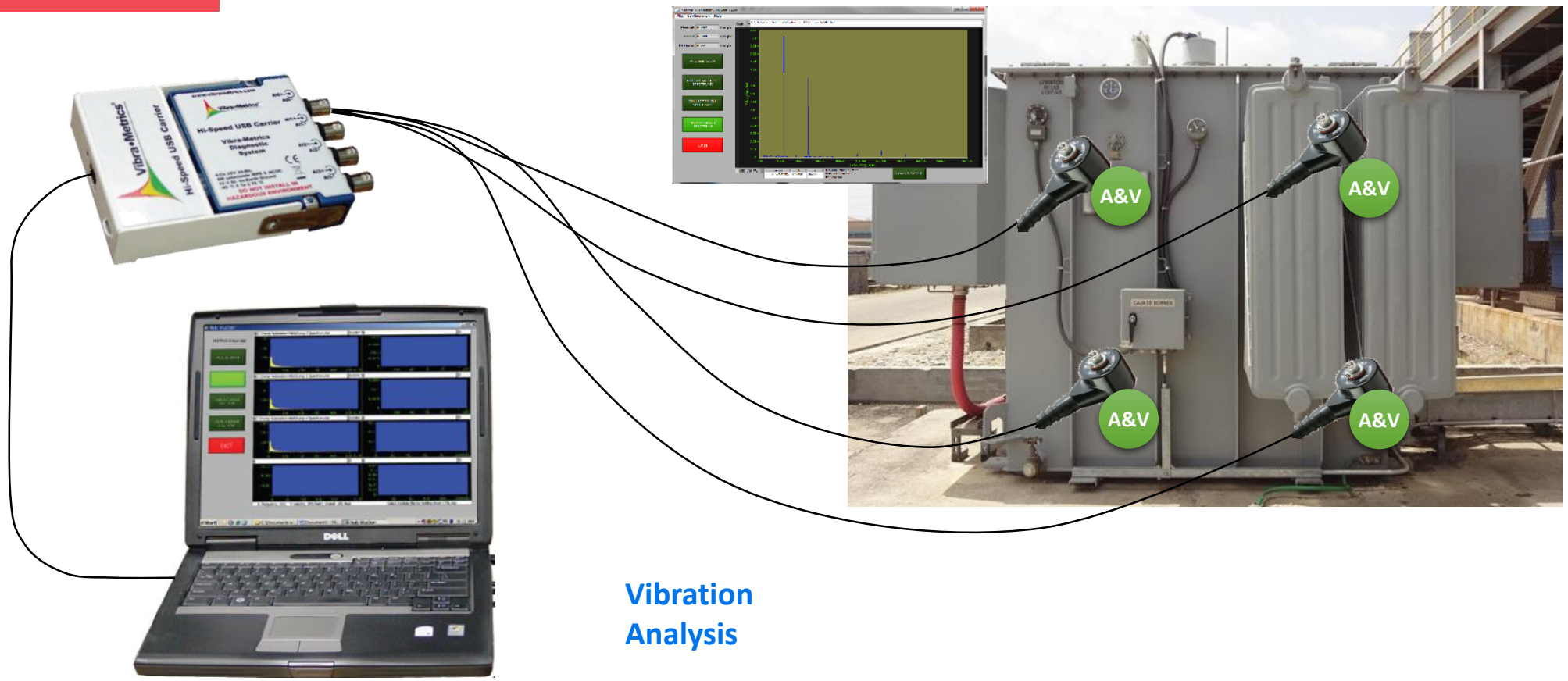

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Screening Tests

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Screening Tests

How to Maximize Transformer Reliability and In-Market Availability

Infrared Inspection

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How to Maximize Transformer Reliability and In-Market Availability

Audible Sound Measurements

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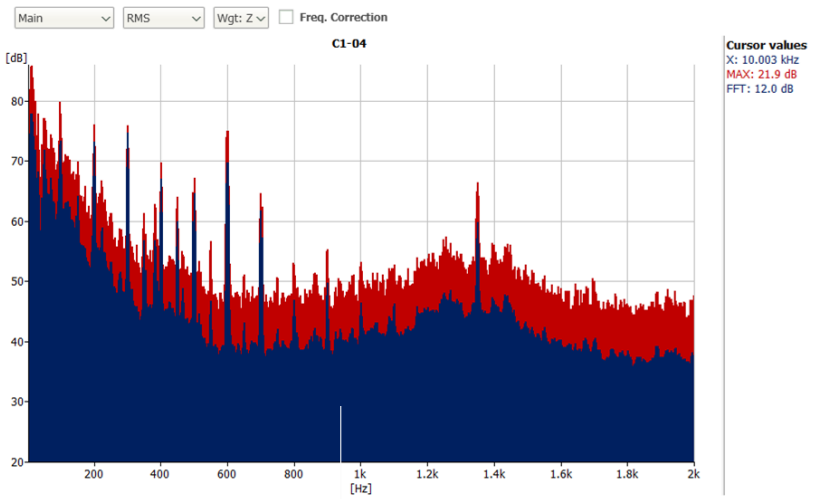

Audible Sound Measurements

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Oil Sampling

How to Maximize Transformer Reliability and In-Market Availability

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Oil Sampling

How to Maximize Transformer Reliability and In-Market Availability

Dissolved Gas Analysis (DGA)

SAMPLE | SCREEN | OBSERVE | MONITOR

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Oil Sampling

How to Maximize Transformer Reliability and In-Market Availability

Dissolved Gas Analysis (DGA)

Oil Quality

SAMPLE | SCREEN | OBSERVE | MONITOR

Installation Tests and Monitoring

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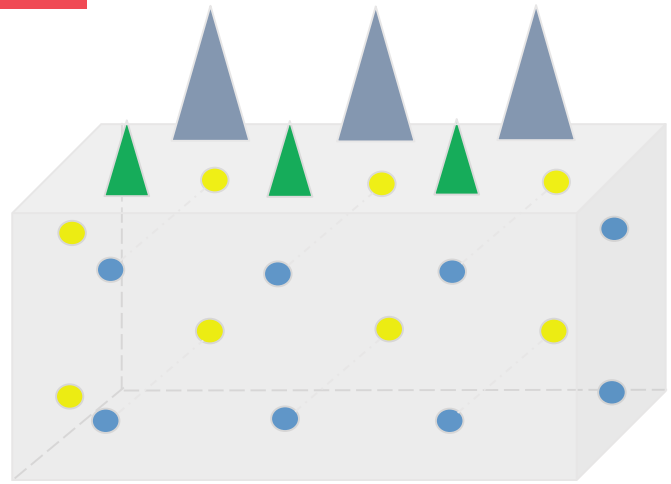
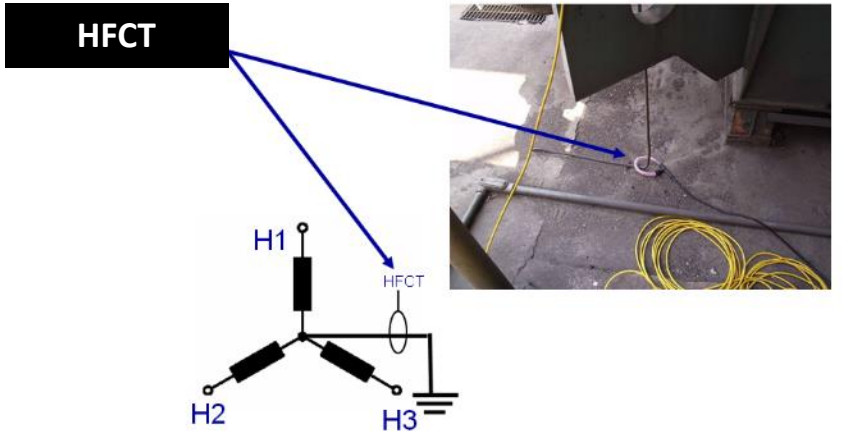
How to Maximize Transformer Reliability and In-Market Availability

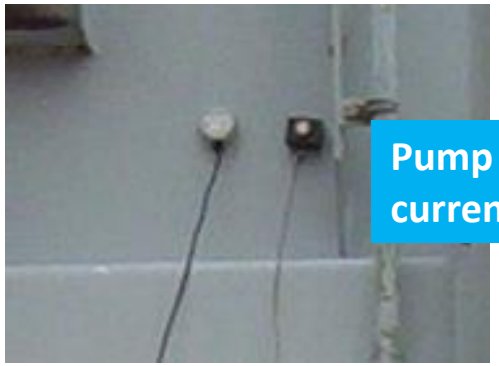


HFCT

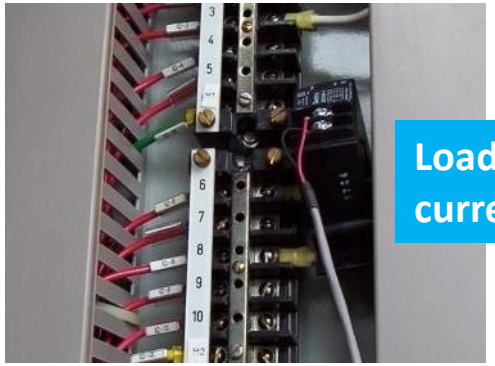


Other info:

DGA Winding Temp.



Pump current



Load current

Main tank and LTC compartment temperature

LTC motor current

SAMPLE | SCREEN | OBSERVE | MONITOR

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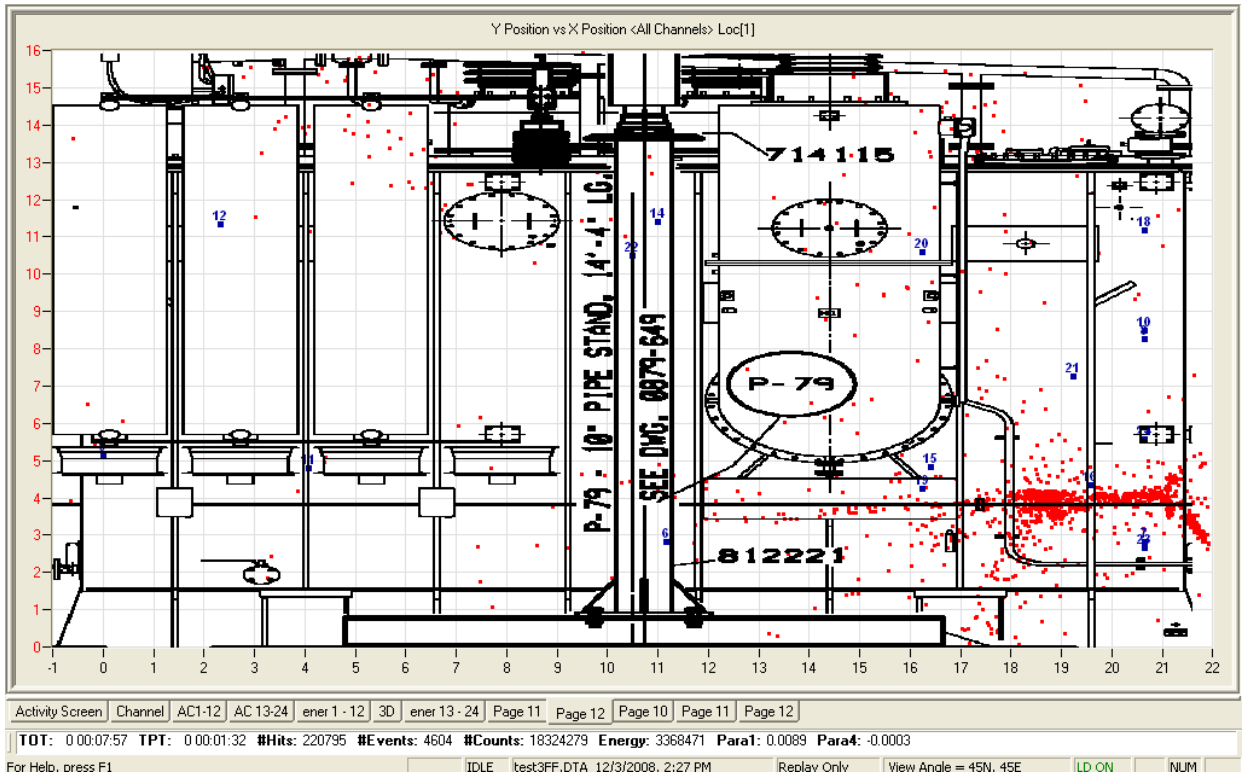
Source Location

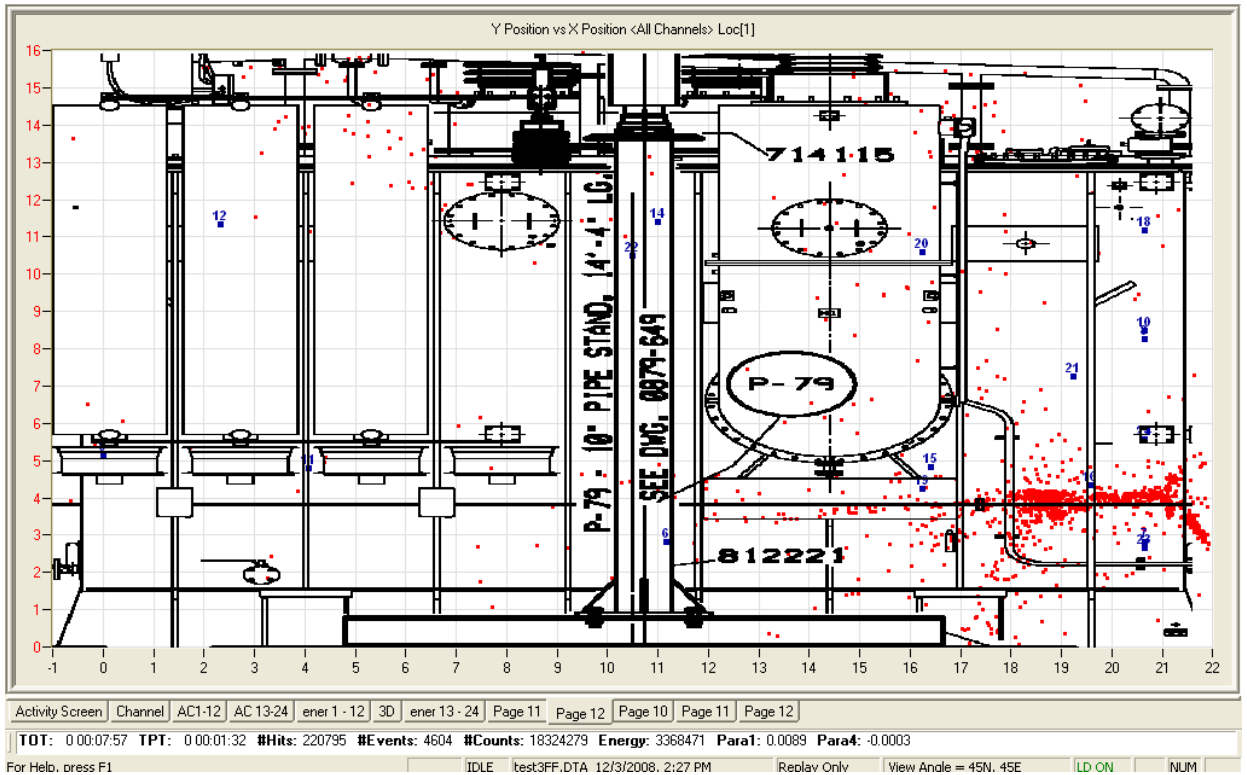
How to Maximize Transformer Reliability and In-Market Availability

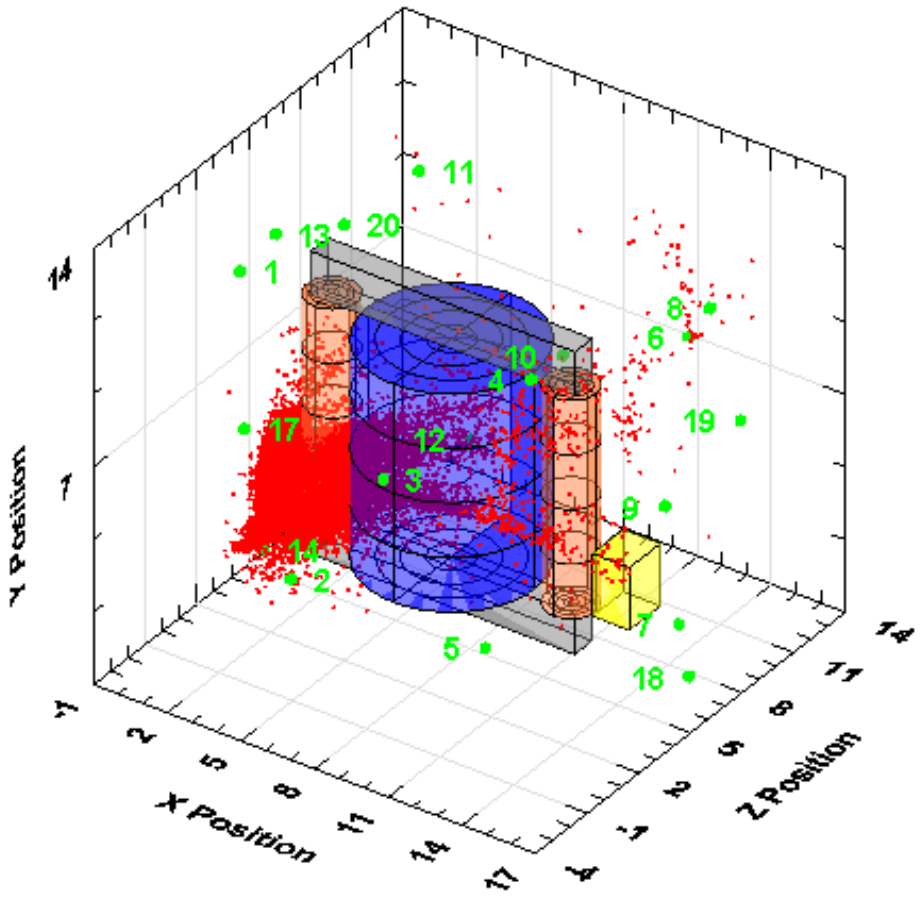


TRANSFORMER CLINIC

Source Location

How to Maximize Transformer Reliability and In-Market Availability





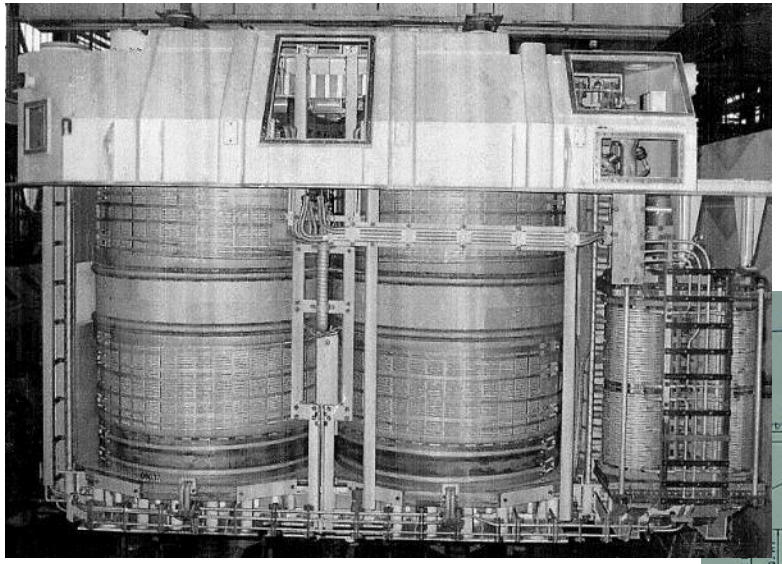
TRANSFORMER CLINIC

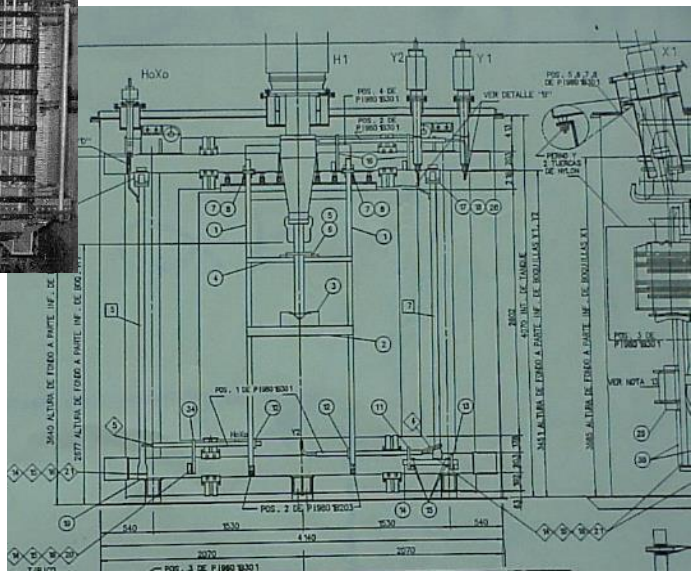
Data Analysis

How to Maximize Transformer Reliability and In-Market Availability

Processes Involved

- Remove environmental noise
- Remove normal operating noise
- Obtain fault information
- Correlation with operating parameters
- Correlate with internal components
- Prepare report
- Update Database (>1500 units worldwide)

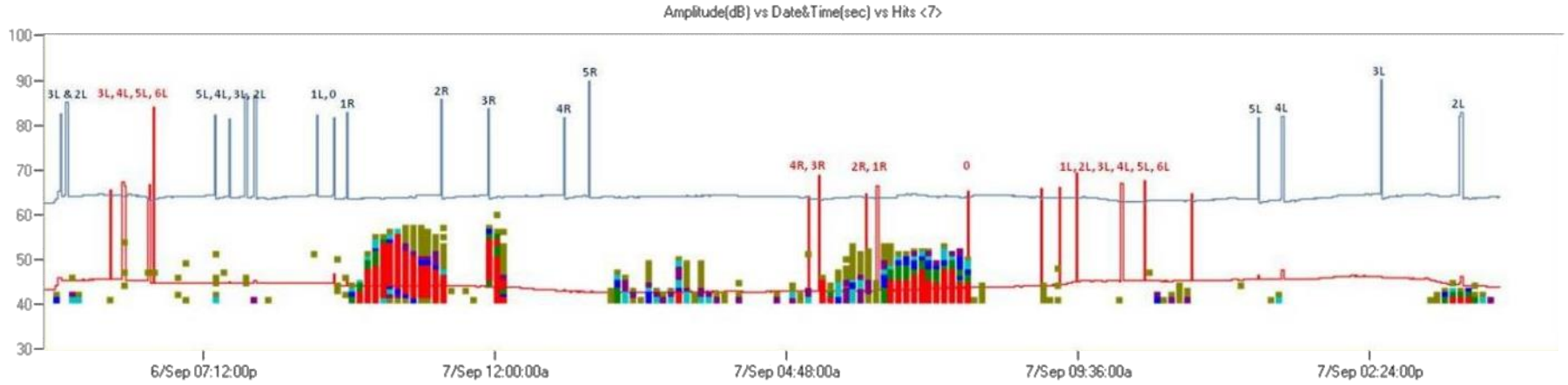


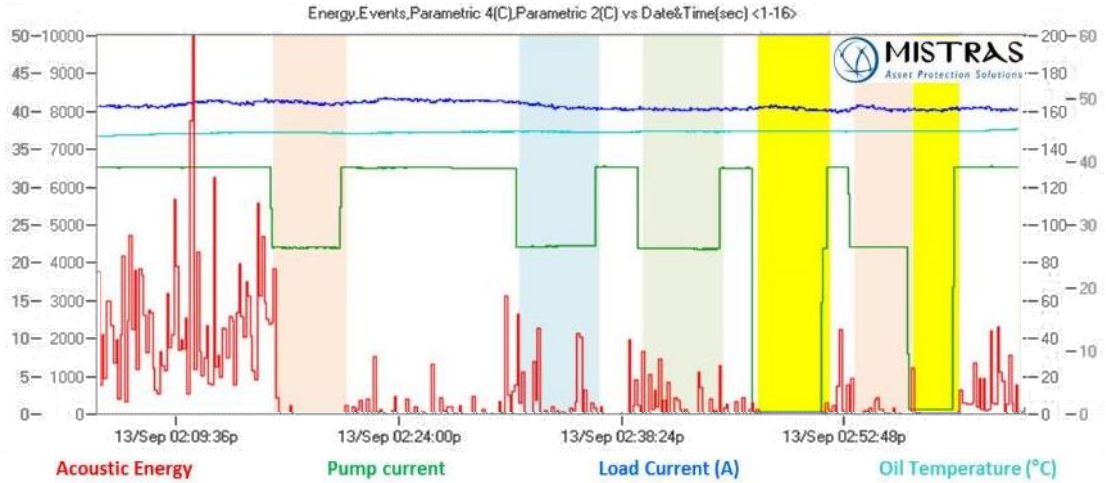


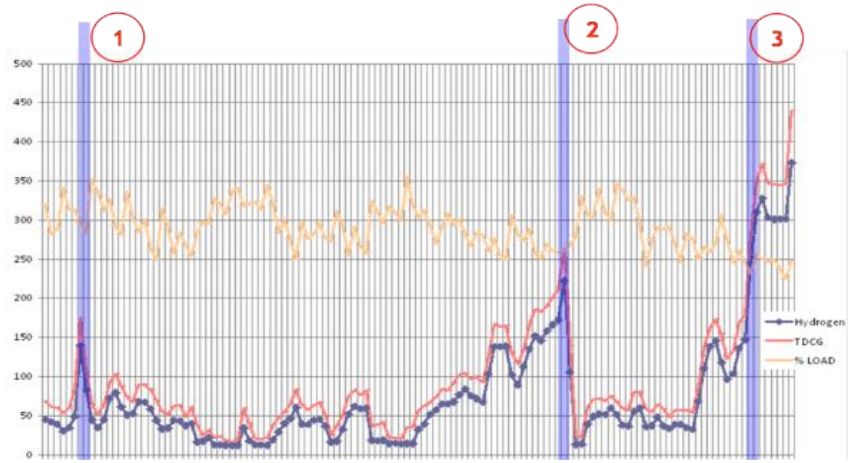
TRANSFORMER CLINIC

Correlation with Operating Parameters

How to Maximize Transformer Reliability and In-Market Availability







Recent Developments

- 1970s-1990s AE only used for detection of electrical sources
- Not only electrical problems were detected
- 2001 Electric Power Research Institute (EPRI) TC project started, some results:
  - Field and laboratory testing demonstrated that (with proper instrumentation and test procedures) **Thermal and Mechanical Faults** (not only PD) can be detected acoustically.
  - Correlation with operating parameters has been established.
  - Correlation of DGA (individual gases and AE obtained)
  - A database and a Combined grading system (DGA + AE) were created

A & B – Normal Operation **C – Incipient Fault** **D – Active Fault**

Acoustic On-line Monitoring System: Sensor Highway III™

- NEMA Cabinet
- Up to 16 AE channels available
- Accepts up to 16 additional signals (4-20 mA or 0-10 VDC)
- Stores data on hard drive
- Data uploaded automatically to a FTP site multiple times a day
- Can communicate through, cell phone modem, wireless network or Ethernet cable

www.mgiolm.mistrasgroup.com

On-line Monitoring System Data Access

OLM Webpage

Remote Access

Utility's Data Center:
OPC or MODBUS

Case Studies

TRANSFORMER CLINIC

Case Study 1

How to Maximize Transformer Reliability and In-Market Availability

- Three phase Transformer
- Core form
- 144/13.8 Kv
- ONAN/ONAF/OFAF
- 90/120/160 MVA
- Built in 1996

A slight increase in combustible gases was observed on this unit since February 2010.

An acoustic emission test was performed on June 2010 to try detect and locate the gassing source.

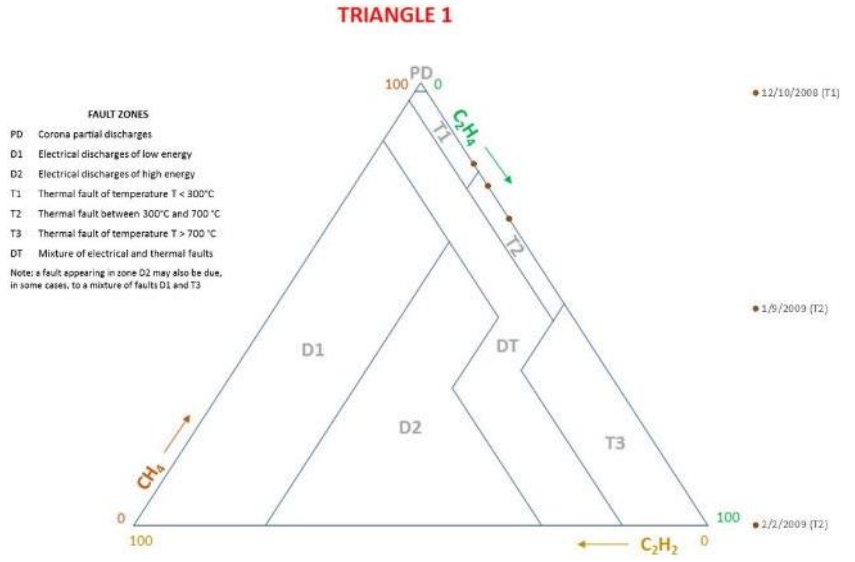
TRANSFORMER CLINIC

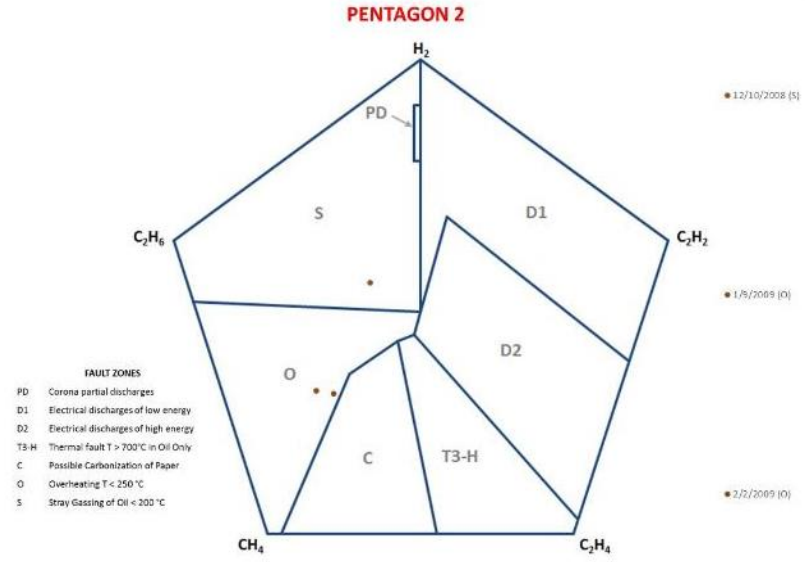
Dissolved Gas Analysis

How to Maximize Transformer Reliability and In-Market Availability

Data prior to AE test

DATE	H_2	CO	CO_2	CH_4	C_2H_6	C_2H_4	C_2H_2	TDCG
Feb 02 2010	19	166	2861	211	155	94	0	645
Jan 09 2009	13	151	1472	174	129	53	0	520
Dec 10 2008	326	82	811	209	135	47	0	799



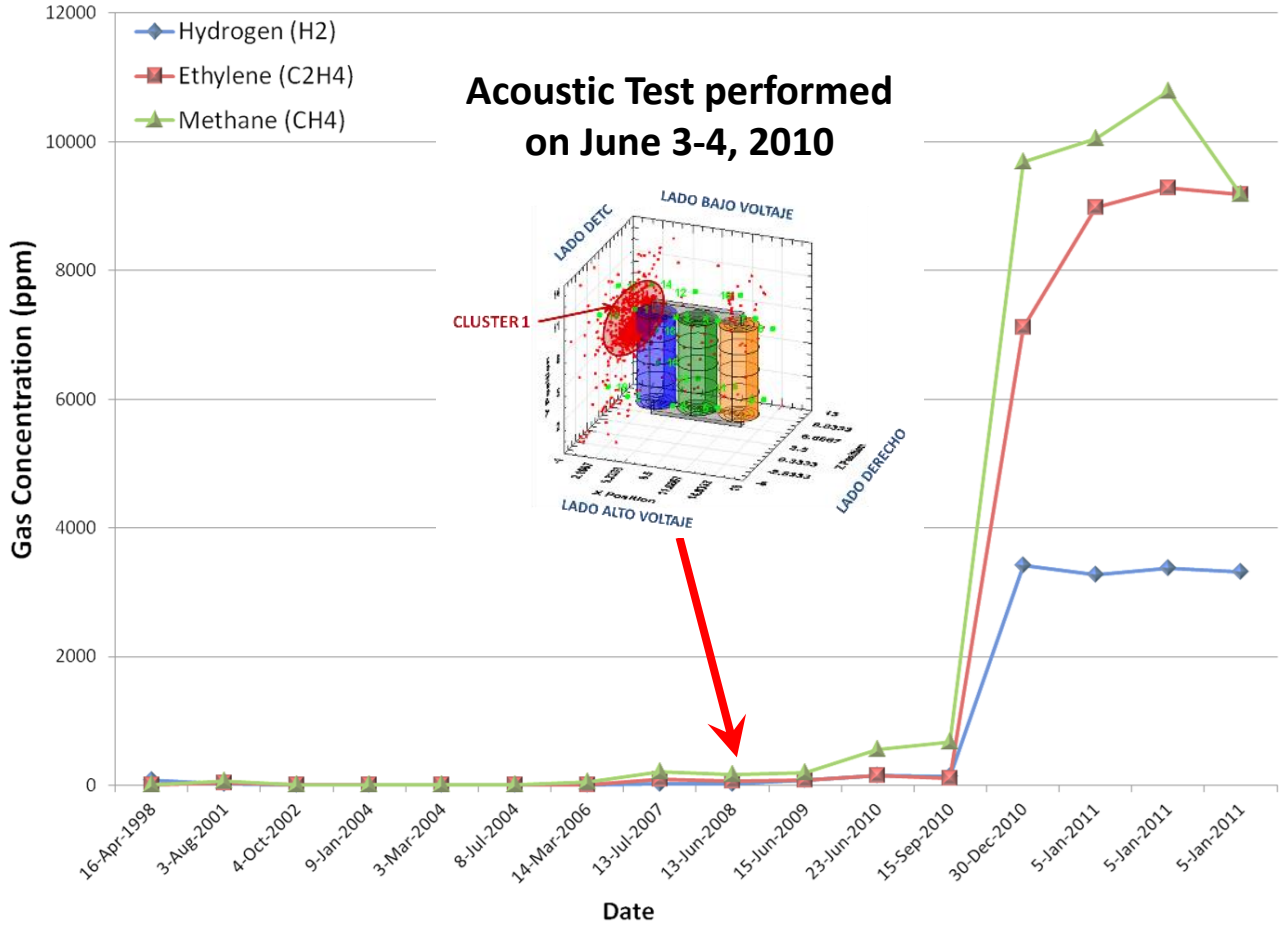


TRANSFORMER CLINIC

Dissolved Gas Analysis

How to Maximize Transformer Reliability and In-Market Availability

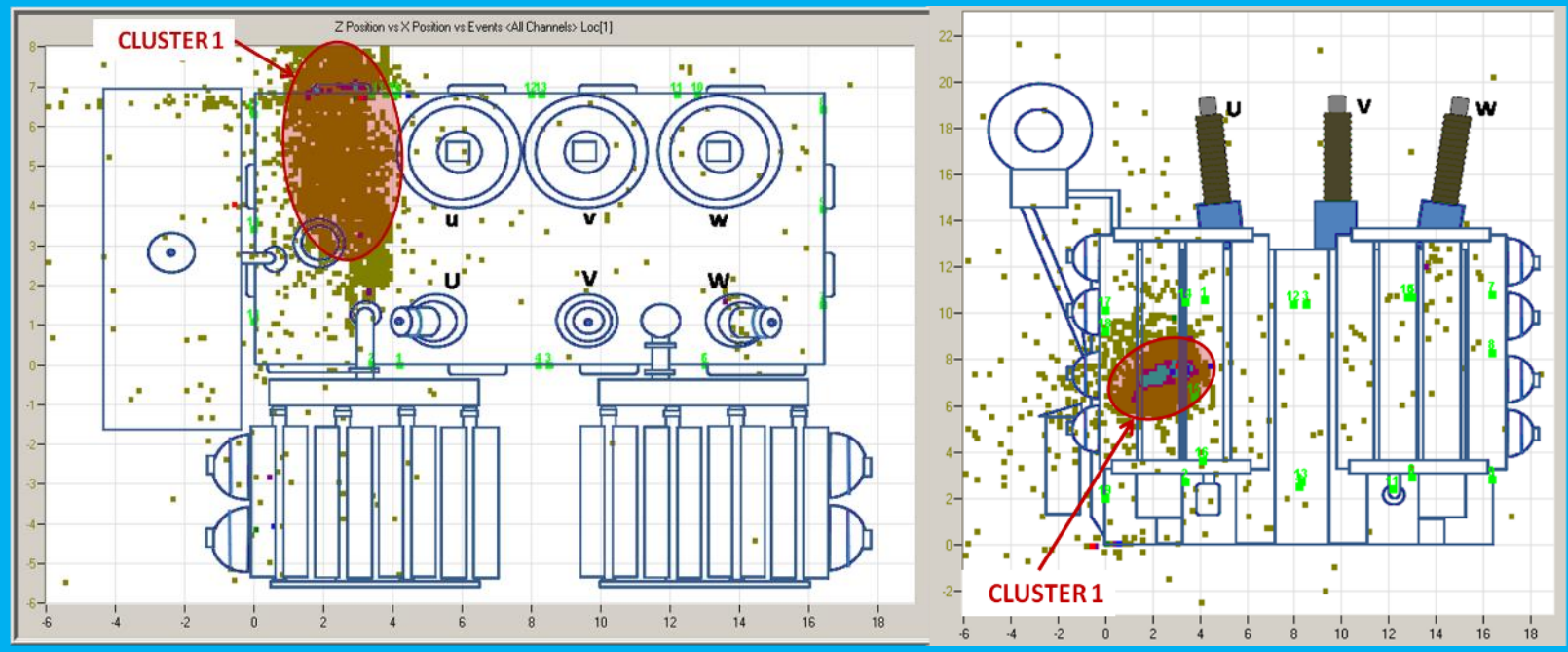
A sudden increase in the gas concentration was observed on December 2010 (few months after the acoustic test).



TRANSFORMER CLINIC

Fault Location

A sudden increase in the gas concentration was observed on December 2010 (few months after the acoustic test).



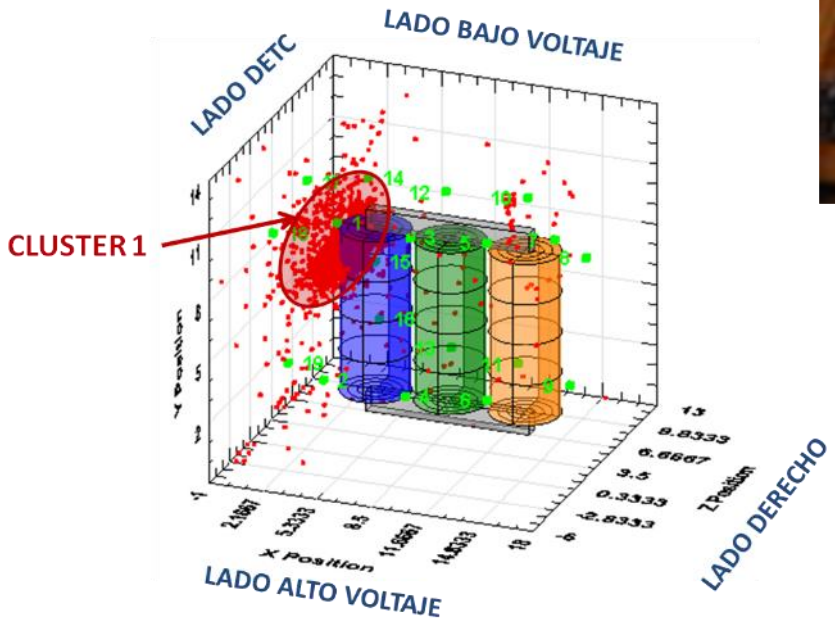
Internal Inspection

How to Maximize Transformer Reliability and In-Market Availability

The oil for this transformer tested positive for **Corrosive Sulfur**.

The unit was inspected in January 2011.

On the area where the acoustic activity was located, severe damaged was found on the conductor of **Phase U**, on the upper part of the coil.



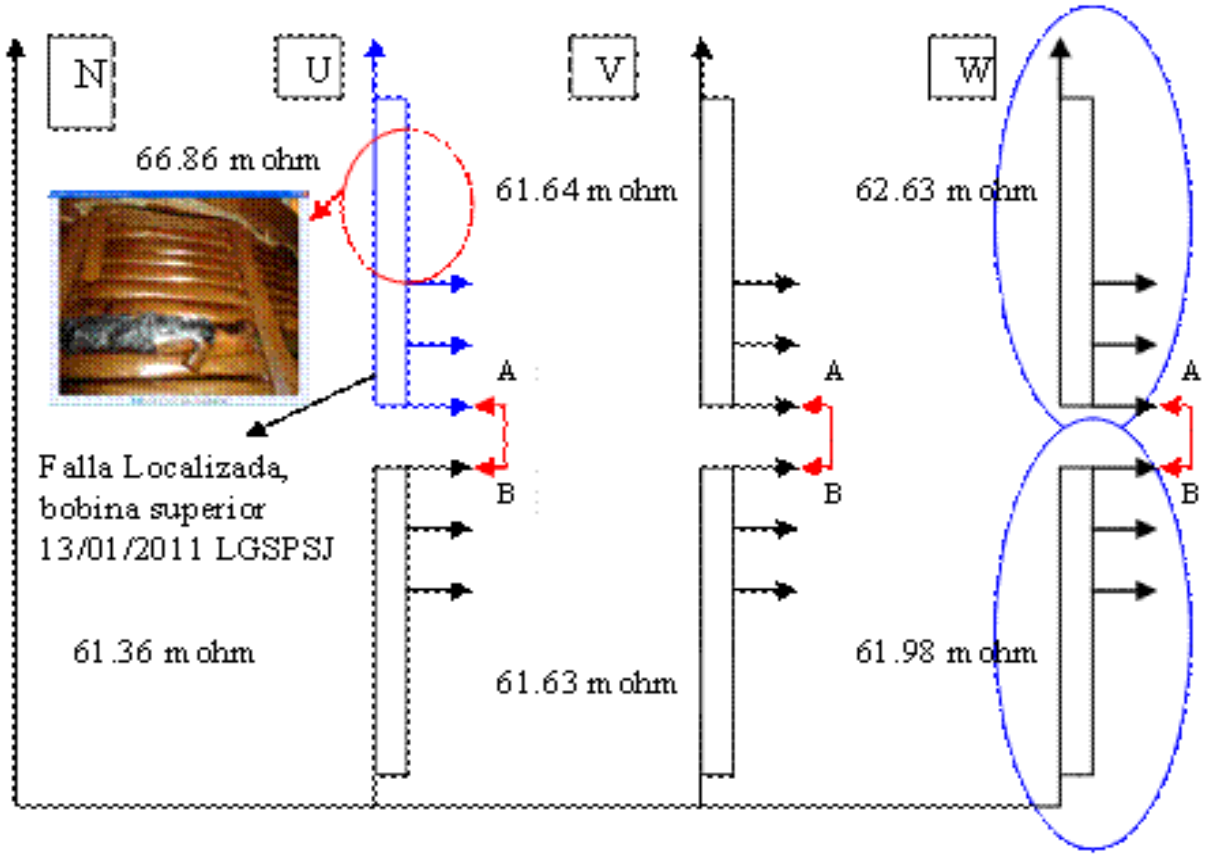
SAMPLE | SCREEN | OBSERVE | MONITOR

Provide Early Fault Detection

TRANSFORMER CLINIC

Internal Inspection

How to Maximize Transformer Reliability and In-Market Availability



TOP COIL

TAP 3

BOTTOM COIL

TRANSFORMER CLINIC

Benefits for End Users

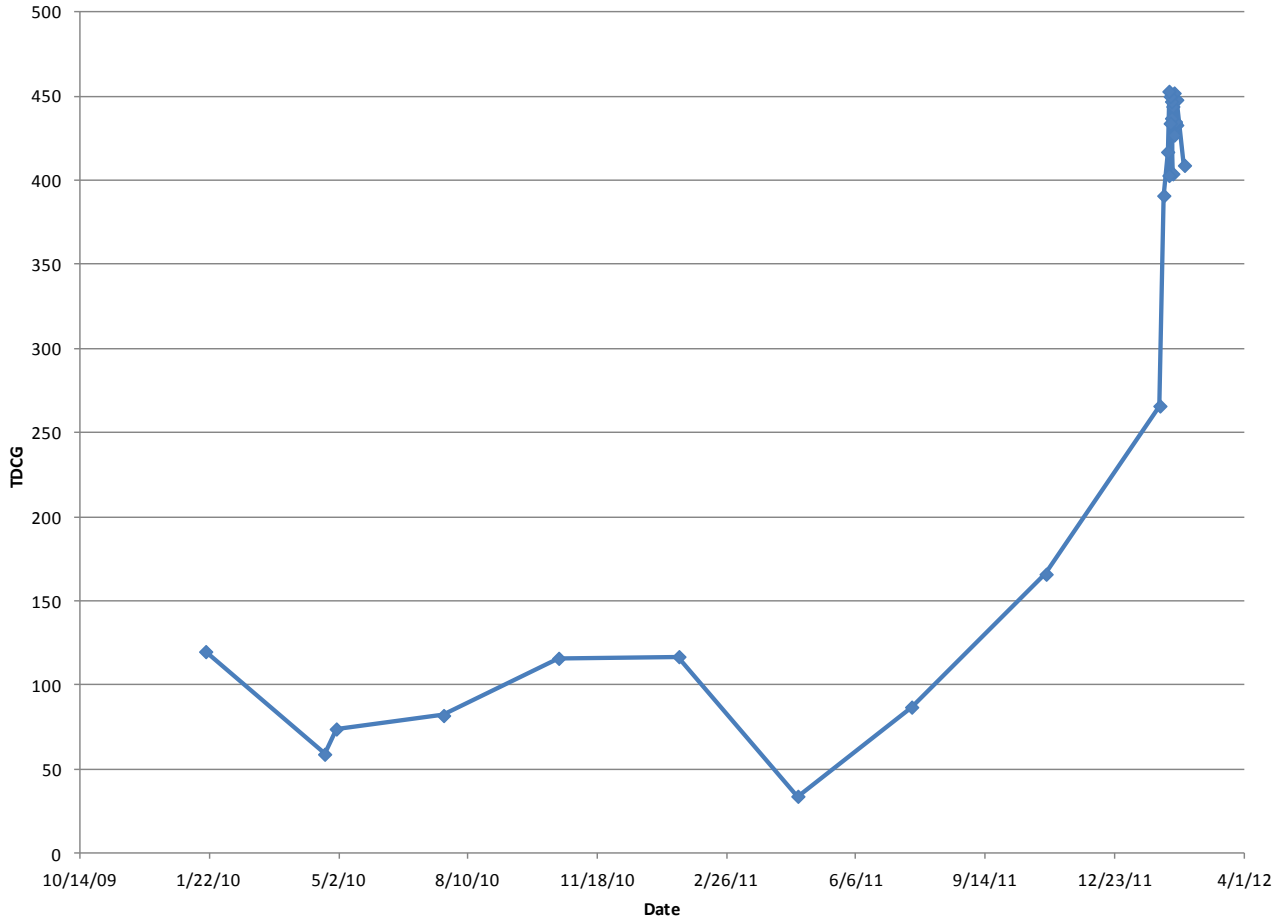
How to Maximize Transformer Reliability and In-Market Availability

Case Study 1

Added Value of a Comprehensive Reliability Program

☑ Provide Early Fault Detection	☑ Lower Operating Risk	☑ Alert Operating Teams of Potential Issues
☐ Prevent Negative Profit Impact	☐ Prevent Loss of Revenue	☐ Maximize In-Market Availability
☐ Extend Asset Lifecycle	☐ Avoid Legal Actions	☐ Avoid EPA Fines

Case Study 2 – Nuclear plant GSU – DGA trend 2009-2012



TRANSFORMER CLINIC

DGA Diagnosis

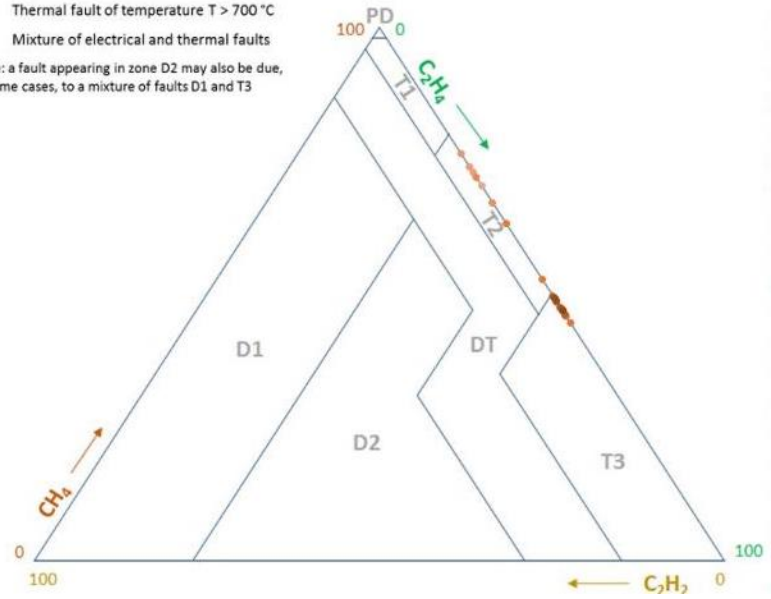
How to Maximize Transformer Reliability and In-Market Availability

TRIANGLE 1

FAULT ZONES

PD	Corona partial discharges
D1	Electrical discharges of low energy
D2	Electrical discharges of high energy
T1	Thermal fault of temperature T < 300°C
T2	Thermal fault between 300°C and 700 °C
T3	Thermal fault of temperature T > 700 °C
DT	Mixture of electrical and thermal faults

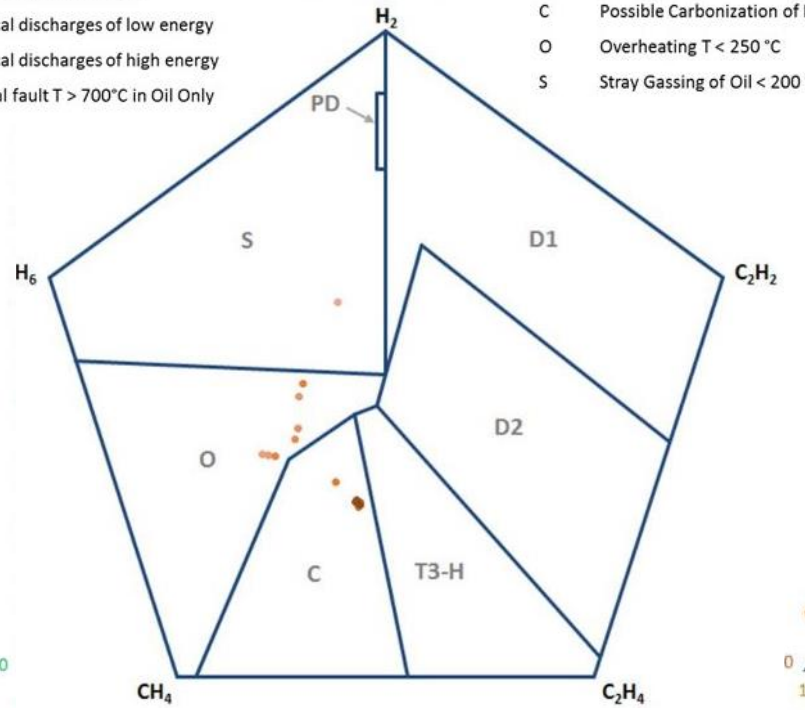
Note: a fault appearing in zone D2 may also be due, in some cases, to a mixture of faults D1 and T3



PENTAGON 2

FAULT ZONES

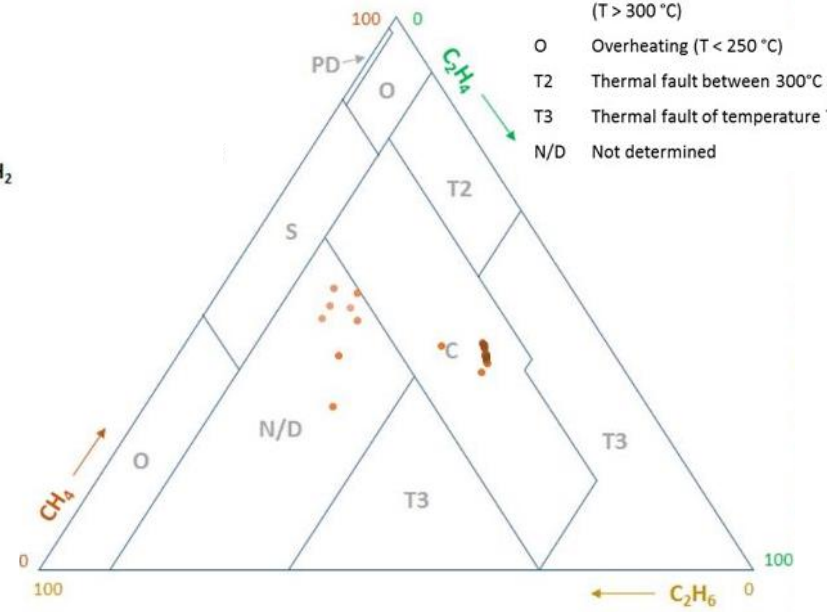
PD	Corona partial discharges
D1	Electrical discharges of low energy
D2	Electrical discharges of high energy
T3-H	Thermal fault T > 700°C in Oil Only
C	Possible Carbonization of Paper
O	Overheating T < 250 °C
S	Stray Gassing of Oil < 200 °C



TRIANGLE 5

FAULT ZONES

PD	Corona partial discharges
S	Stray gassing of mineral oil (T < 200 °C)
C	Hot spots with carbonization of paper (T > 300 °C)
O	Overheating (T < 250 °C)
T2	Thermal fault between 300°C and 700 °C
T3	Thermal fault of temperature T > 700 °C
N/D	Not determined



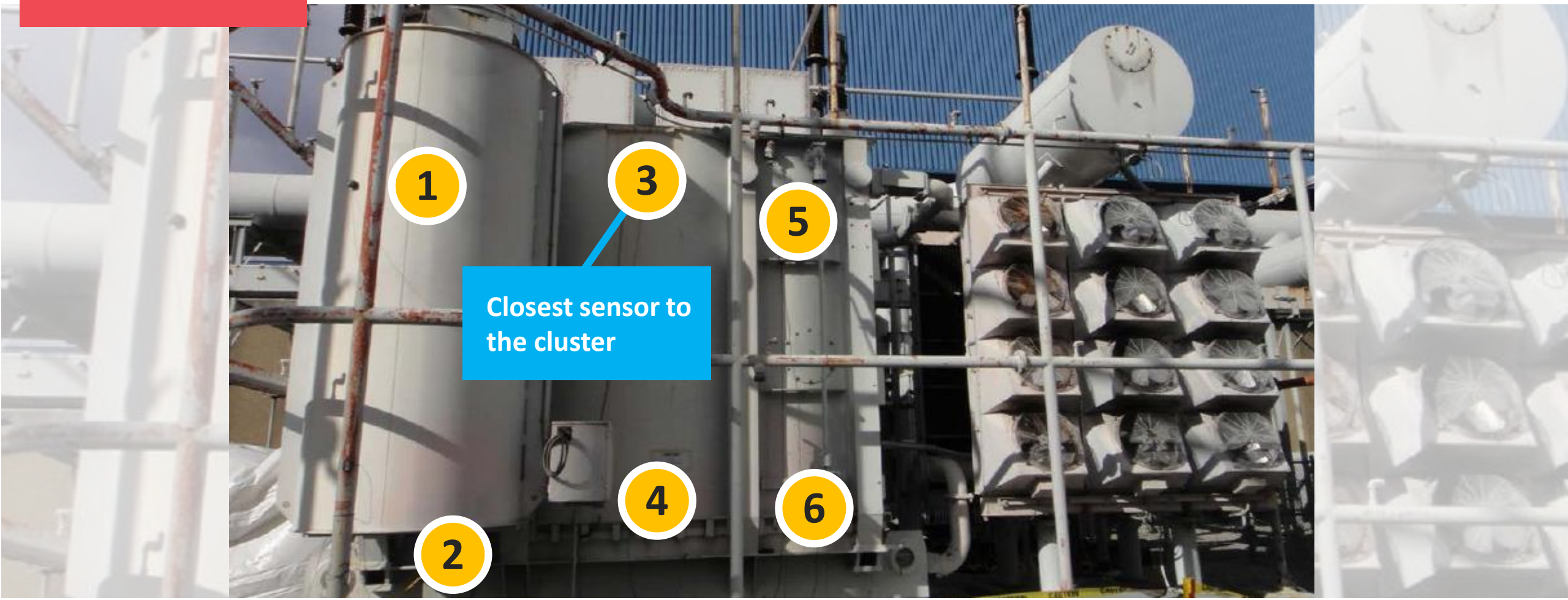
SAMPLE | SCREEN | OBSERVE | MONITOR

Alert Operating Teams of Potential Issues

TRANSFORMER CLINIC

View of The HV Side of the Transformer

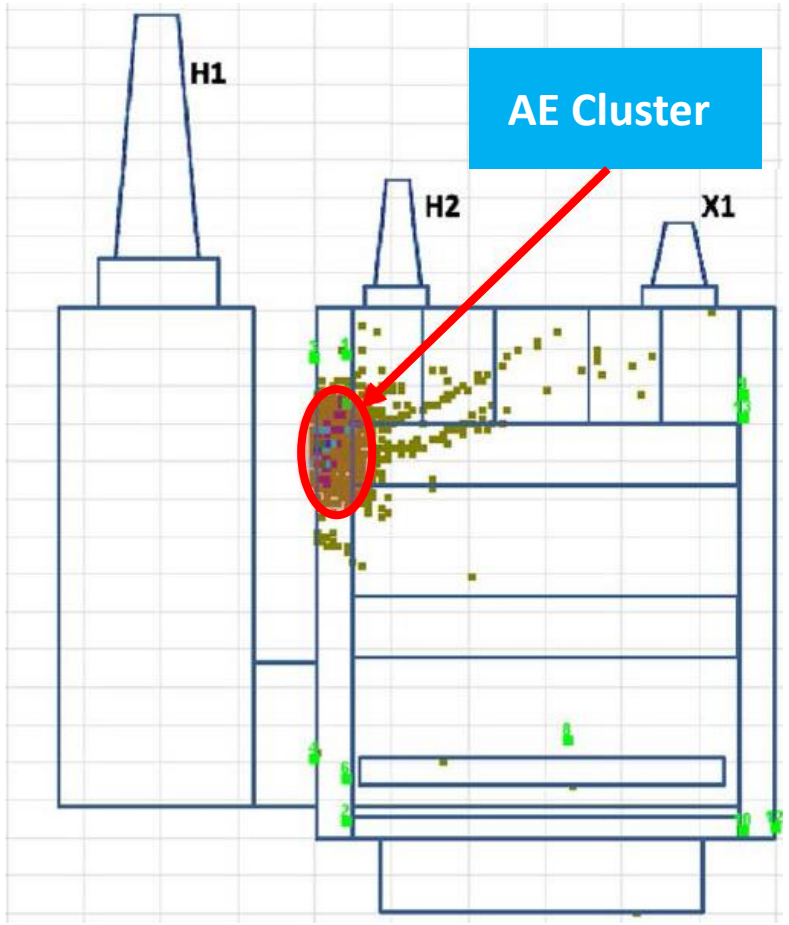
How to Maximize Transformer Reliability and In-Market Availability

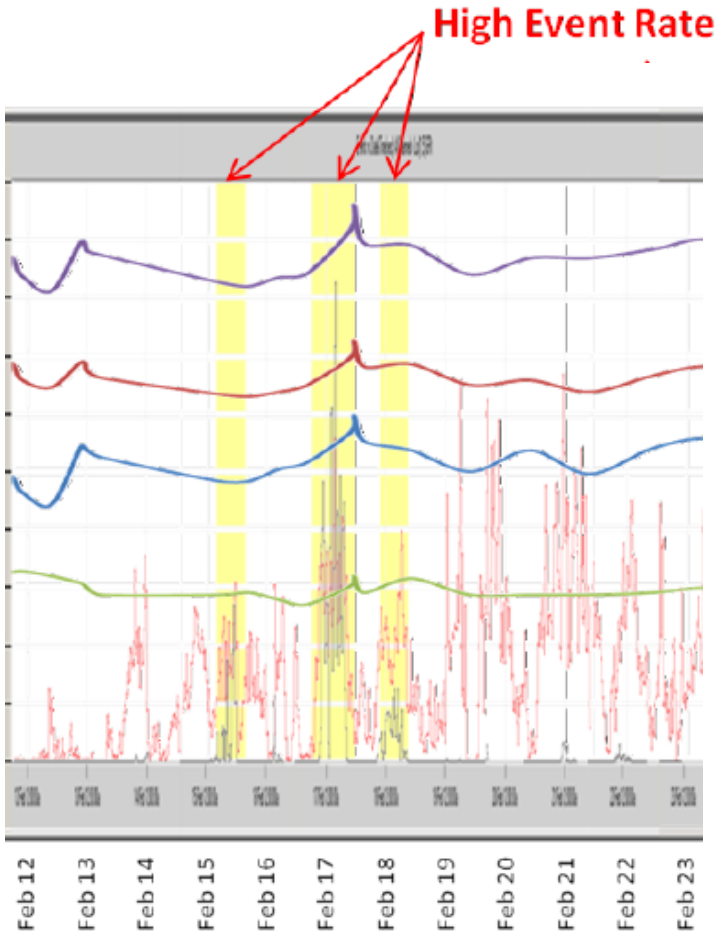


SAMPLE | SCREEN | OBSERVE | MONITOR

Provide Early Fault Detection

Location of AE signals and corresponding correlation with DGA





(TDCG)

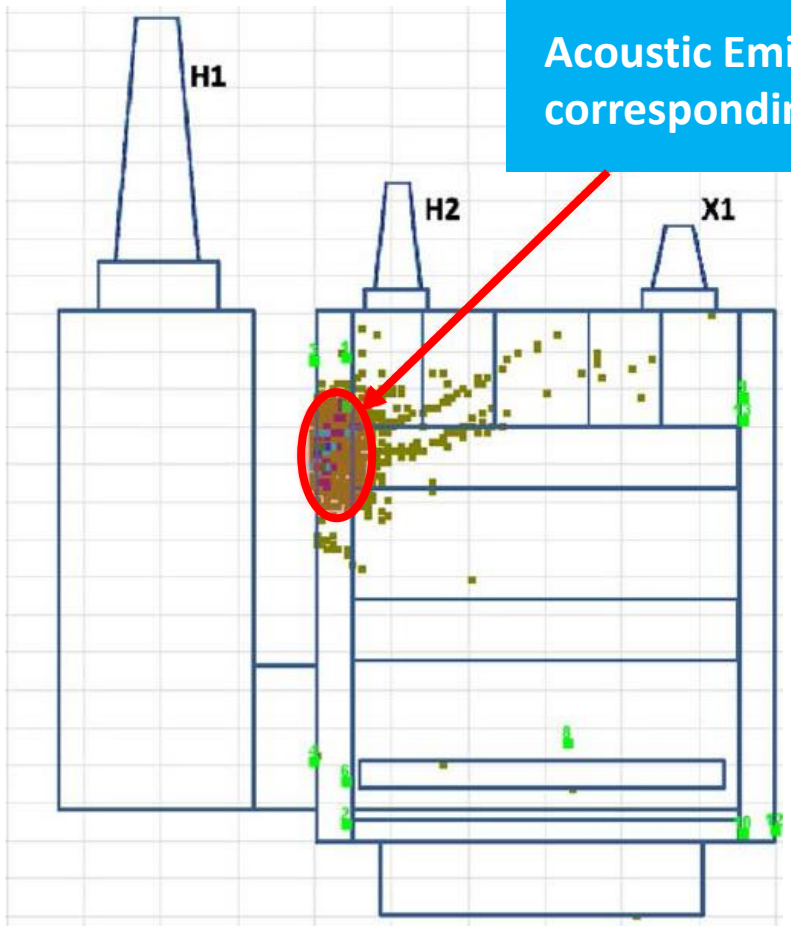
Ethylene (C2H4)

Methane (CH4)

Ethane (C2H6)

TRANSFORMER CLINIC

Location of AE signals and Corresponding Overheating Inside Transformer



Acoustic Emission cluster and the corresponding flux shield overheating

TRANSFORMER CLINIC

Remedial Action: Added Insulation to Flux Shields

How to Maximize Transformer Reliability and In-Market Availability

SAMPLE | SCREEN | OBSERVE | MONITOR

Prevent Negative Profit Impact

TRANSFORMER CLINIC

Benefits for End Users

How to Maximize Transformer Reliability and In-Market Availability

Case Study 2

Added Value of a Comprehensive Reliability Program

☑ Provide Early Fault Detection	☑ Lower Operating Risk	☑ Alert Operating Teams of Potential Issues
☑ Prevent Negative Profit Impact	☑ Prevent Loss of Revenue	☑ Maximize In-Market Availability
☐ Extend Asset Lifecycle	☐ Avoid Legal Actions	☐ Avoid EPA Fines

Case Study 3 – GSU TRANSFORMER

EPRI Substation Equipment Diagnostics Conference Paper, 2004

TRANSFORMER CLINIC

Case Study 3 – GSU TRANSFORMER

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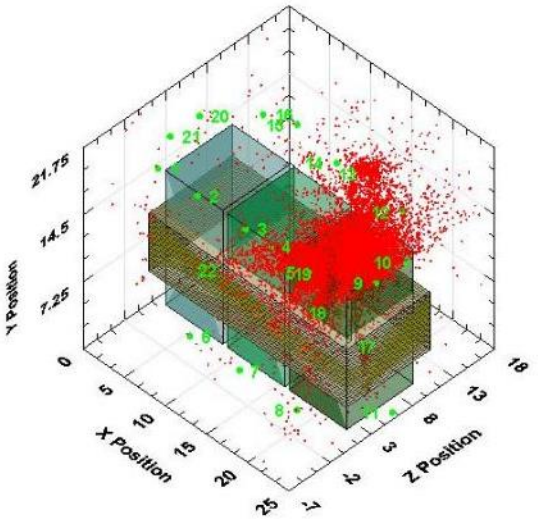
How to Maximize Transformer Reliability and In-Market Availability



SAMPLE | SCREEN | OBSERVE | MONITOR

TRANSFORMER CLINIC

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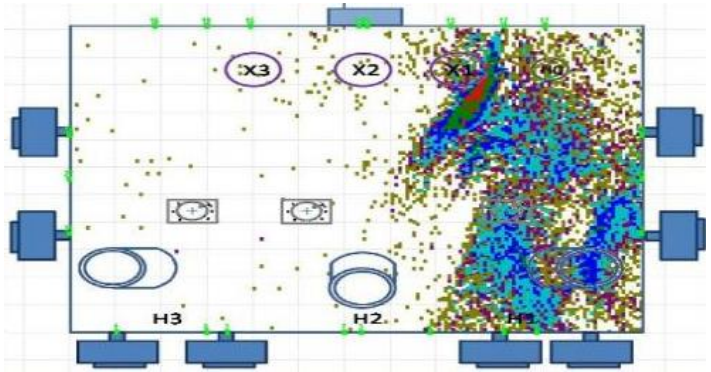

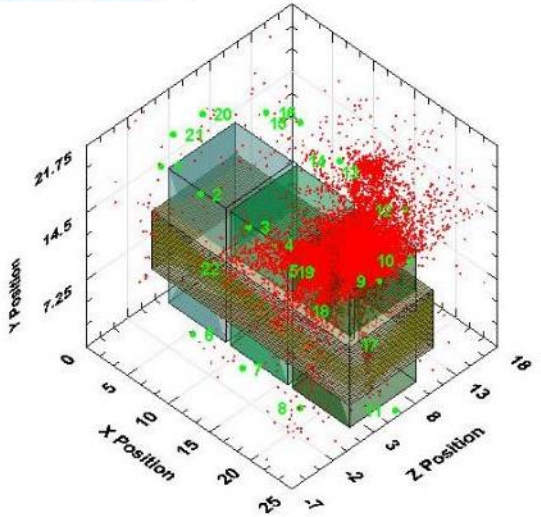

TRANSFORMER CLINIC

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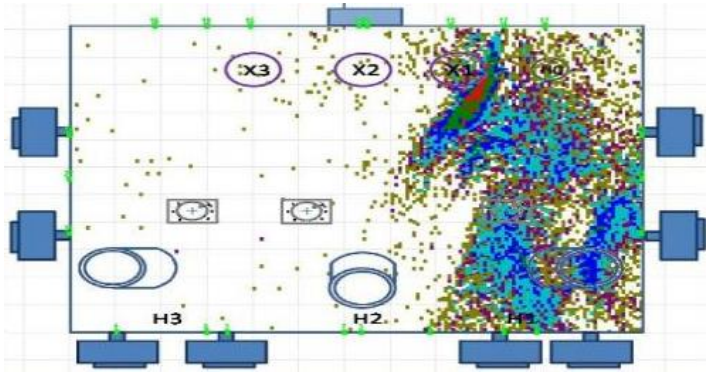

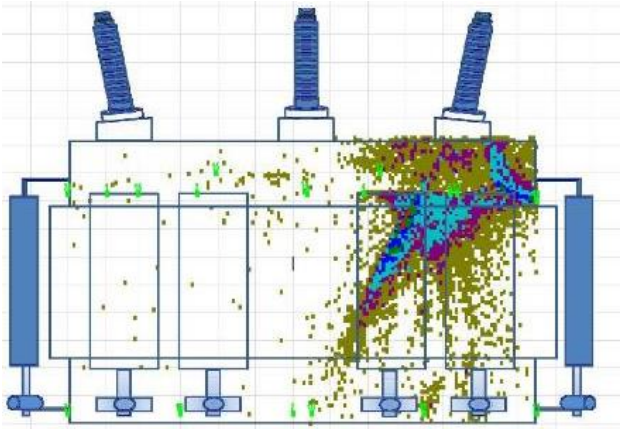

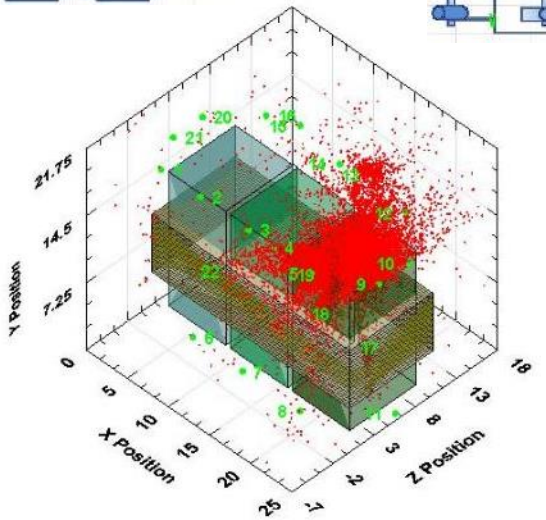

SAMPLE | SCREEN | OBSERVE | MONITOR

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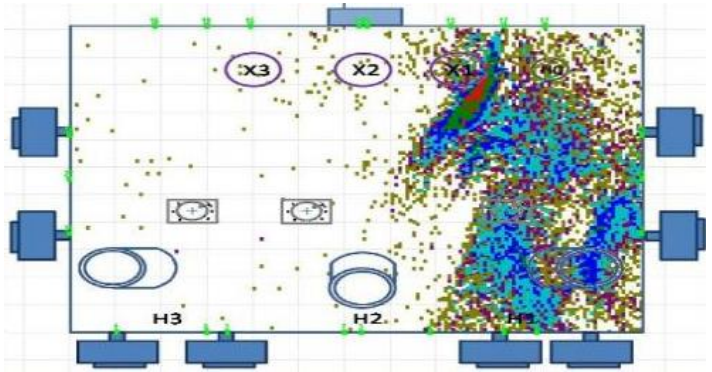

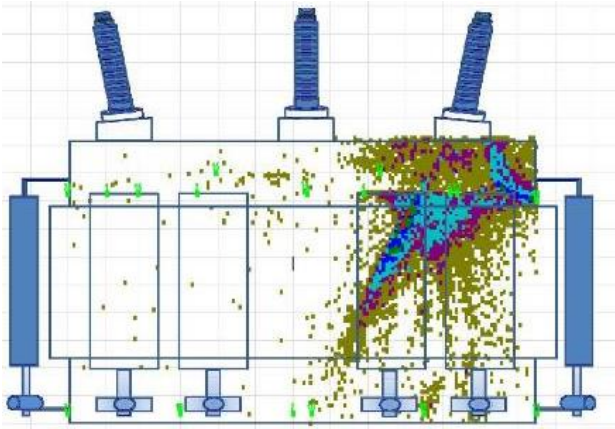

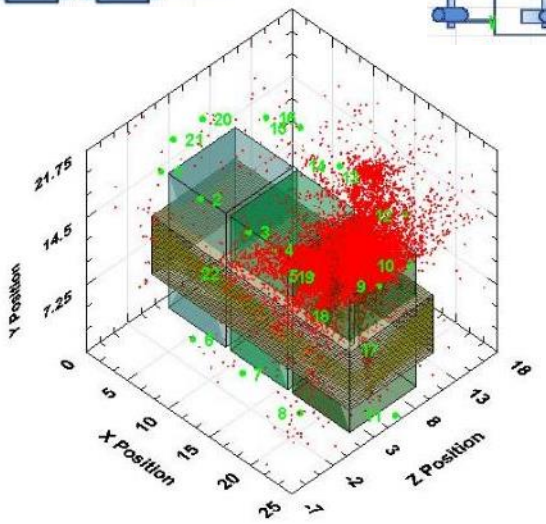

SAMPLE | SCREEN | OBSERVE | MONITOR

TRANSFORMER CLINIC

DGA Diagnosis

How to Maximize Transformer Reliability and In-Market Availability

TRIANGLE 1

FAULT ZONES

PD	Corona partial discharges
D1	Electrical discharges of low energy
D2	Electrical discharges of high energy
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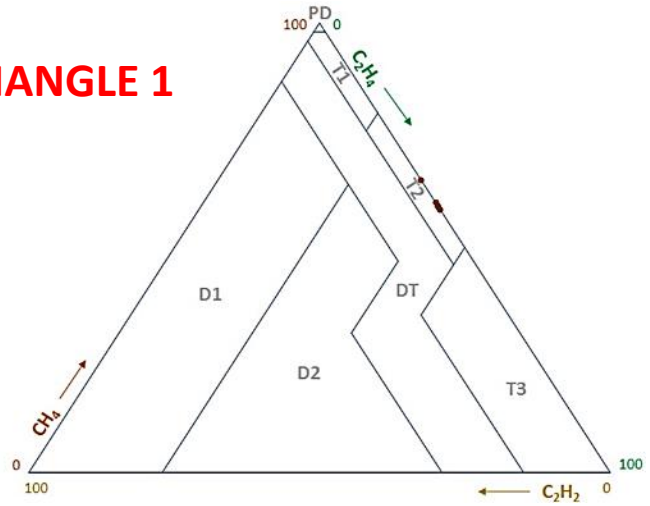
T2	Thermal fault between 300°C and 700 °C
T3	Thermal fault of temperature T > 700 °C
DT	Mixture of electrical and thermal faults

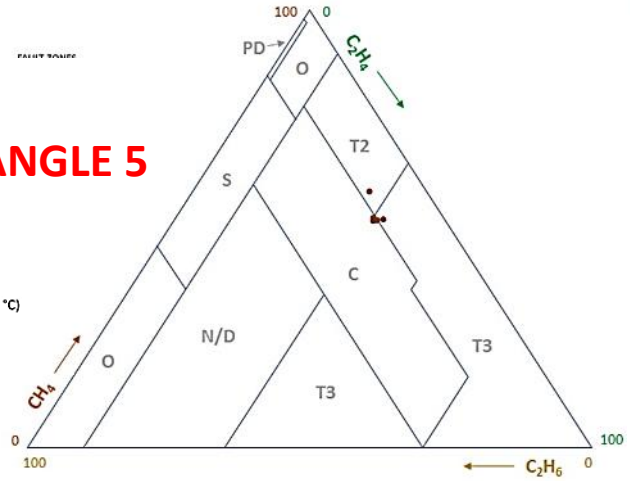
Note: a fault appearing in zone D2 may also be due, in some cases, to a mixture of faults D1 and T3



TRIANGLE 5

FAULT ZONES

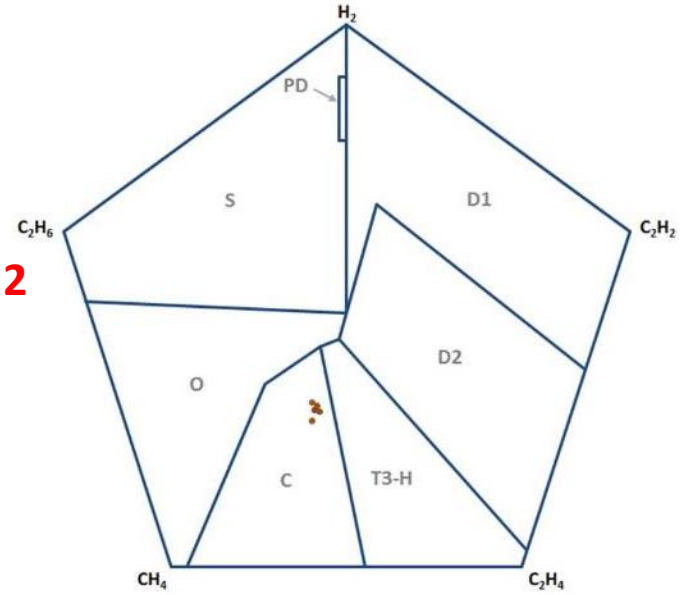
PD	Corona partial discharges
S	Stray gassing of mineral oil (T < 200 °C)
C	Hot spots with carbonization of paper (T > 300 °C)
O	Overheating (T < 250 °C)
T2	Thermal fault between 300°C and 700 °C
T3	Thermal fault of temperature T > 700 °C
N/D	Not determined



PENTAGON 2

FAULT ZONES

PD	Corona partial discharges
D1	Electrical discharges of low energy
D2	Electrical discharges of high energy
T3-H	Thermal fault T > 700°C in Oil Only
C	Possible Carbonization of Paper
O	Overheating T < 250 °C
S	Stray Gassing of Oil < 200 °C



TRANSFORMER CLINIC

Benefits for End Users

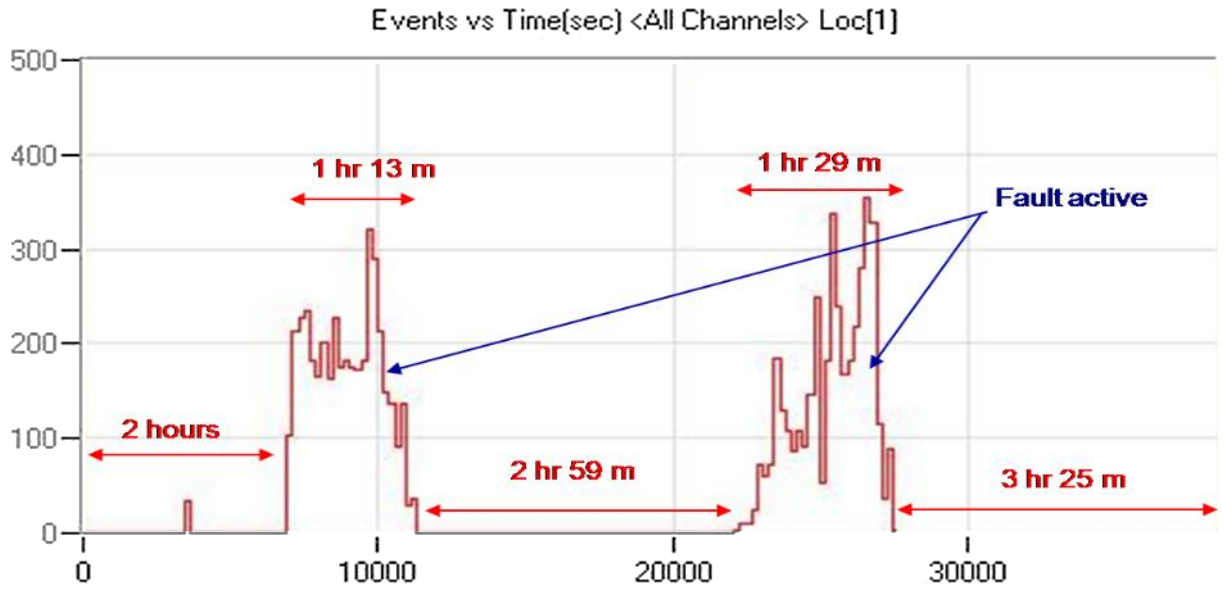
How to Maximize Transformer Reliability and In-Market Availability

Case Study 3

Added Value of a Comprehensive Reliability Program

☑ Provide Early Fault Detection	☑ Lower Operating Risk	☑ Alert Operating Teams of Potential Issues
☑ **Prevent Negative Profit Impact**	☑ **Prevent Loss of Revenue**	☑ **Maximize In-Market Availability**
☐ Extend Asset Lifecycle	☑ **Avoid Legal Actions**	☑ **Avoid EPA Fines**

Date	H^2	CO	CO^2	CH^4	C^2H^6	C^2H^4	C^2H^2	TDCG
May 31, 2005	192	187	728	17	5	3	0	404



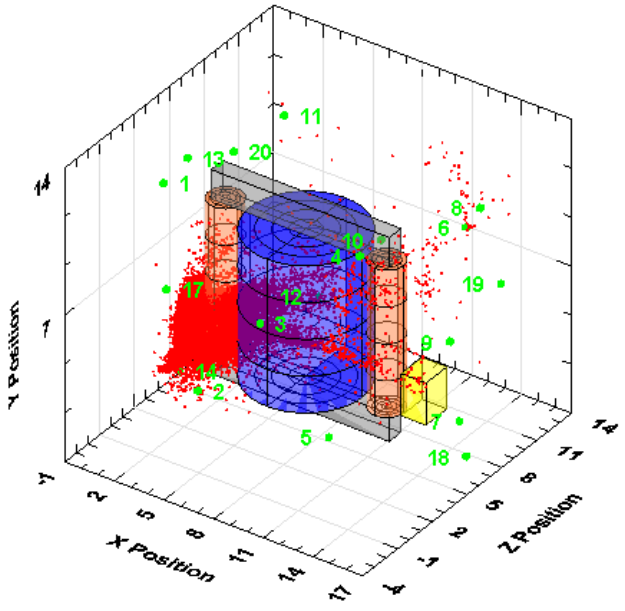
TRANSFORMER CLINIC

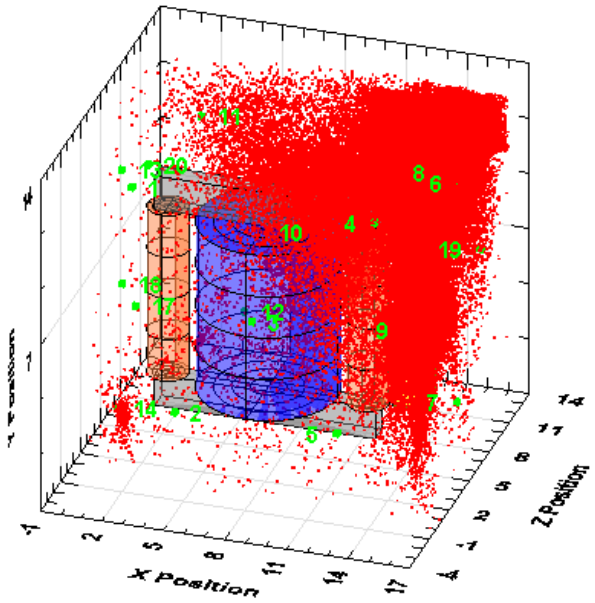
Case Study 4

Case 6 On IEEE STD. C57.127, 2007

How to Maximize Transformer Reliability and In-Market Availability

Date	H^2	CO	CO^2	CH^4	C^2H^6	C^2H^4	C^2H^2	TDCG
May 31, 2005	192	187	728	17	5	3	0	404





SAMPLE | SCREEN | OBSERVE | MONITOR

Provide Early Fault Detection

Case Study 4

Case 6 On IEEE STD. C57.127, 2007

Date	H^2	CO	CO^2	CH^4	C^2H^6	C^2H^4	C^2H^2	TDCG
May 31, 2005	192	187	728	17	5	3	0	404

TRANSFORMER CLINIC

Benefits for End Users

How to Maximize Transformer Reliability and In-Market Availability

Case Study 3

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Case Study 5

EPRI Substation Equipment ,Maintenance Optimization and Diagnostic Conference Paper, 2009

- Ethylene gasser transformer
- No spare available
- Next to a River (risk of mineral oil contamination if failed)

Case Study 5

EPRI Substation Equipment ,Maintenance Optimization and Diagnostic Conference Paper, 2009

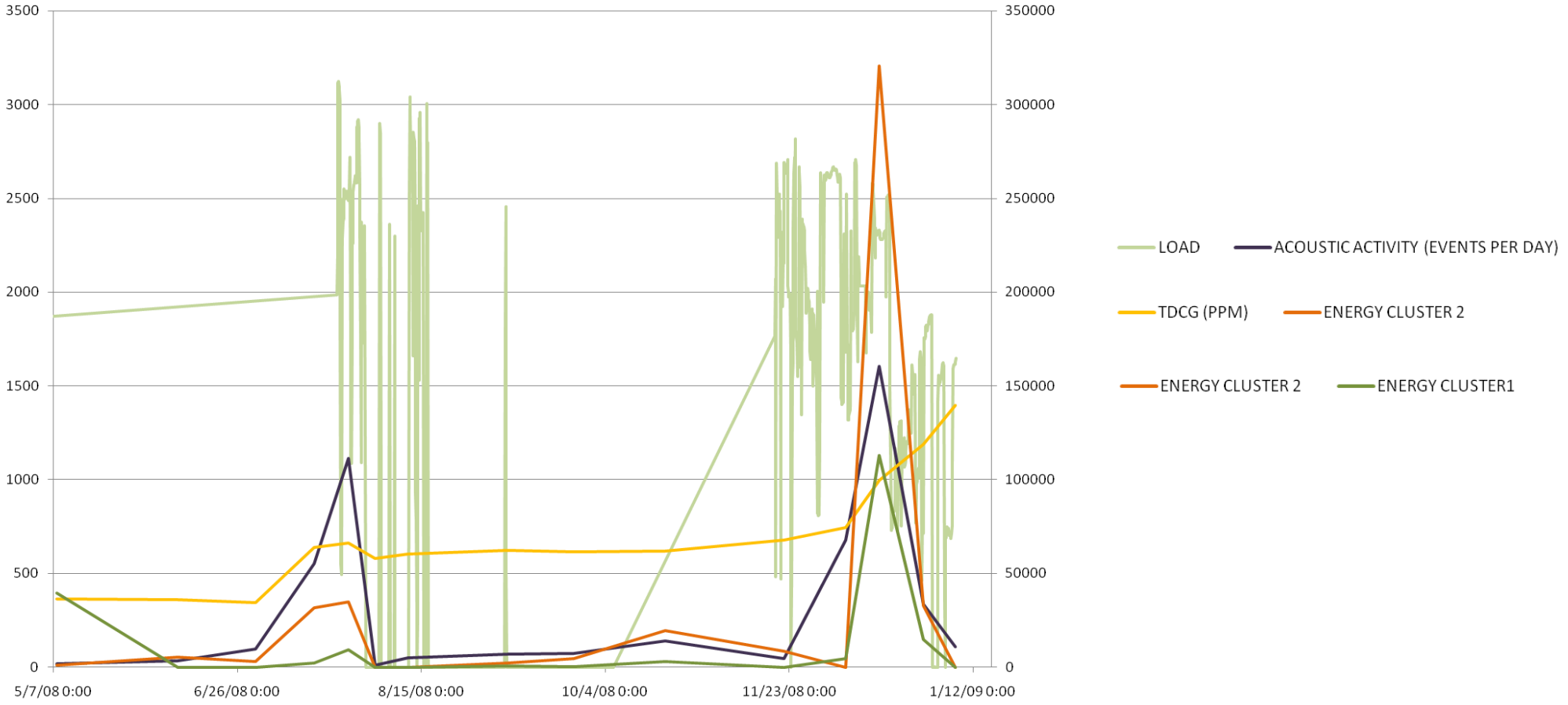
- Ethylene gasser transformer
- No spare available
- Next to a River (risk of mineral oil contamination if failed)
- Monitored acoustically to provide warning if fault increased in severity
- Two areas of activity found at different times

TRANSFORMER CLINIC

Case Study 5

EPRI Substation Equipment ,Maintenance Optimization and Diagnostic Conference Paper, 2009

How to Maximize Transformer Reliability and In-Market Availability



SAMPLE | SCREEN | OBSERVE | MONITOR

Provide Early Fault Detection

TRANSFORMER CLINIC

Case Study 5

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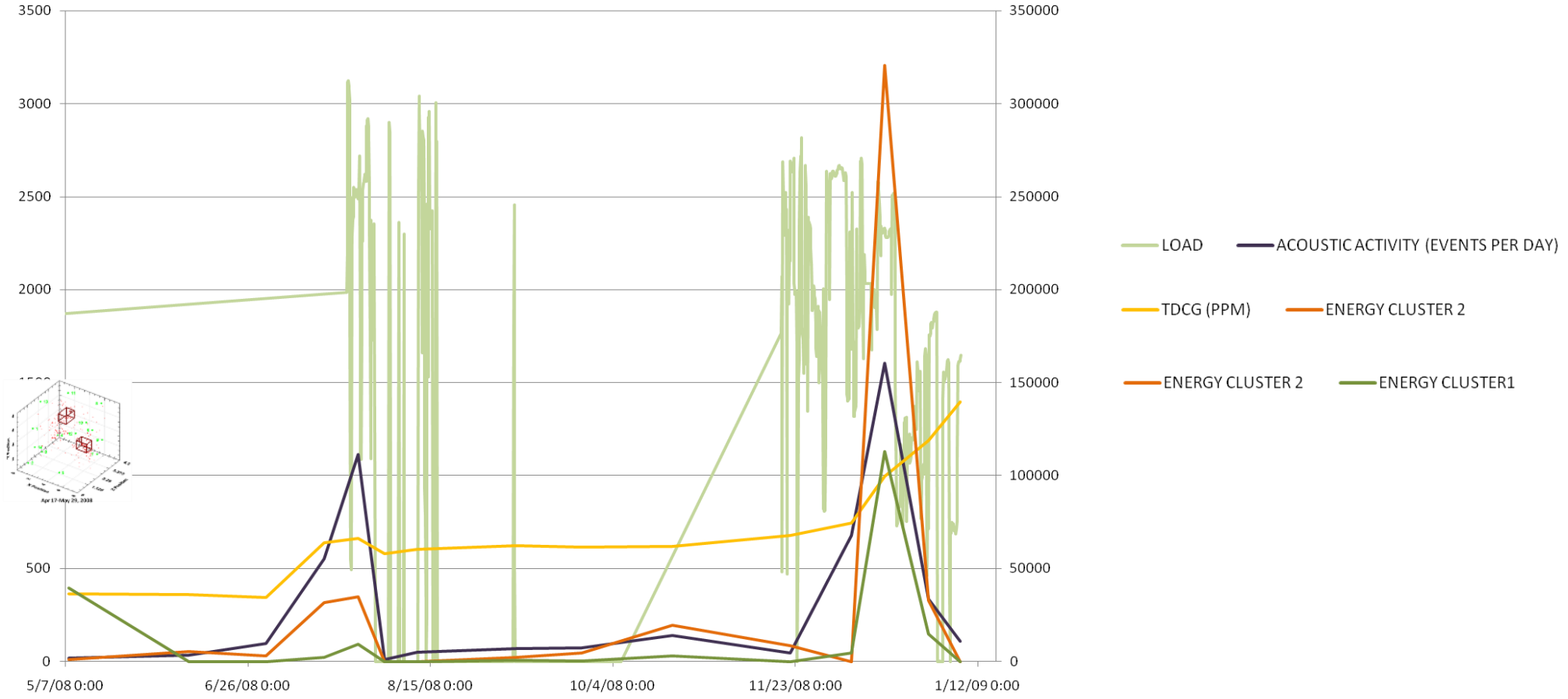

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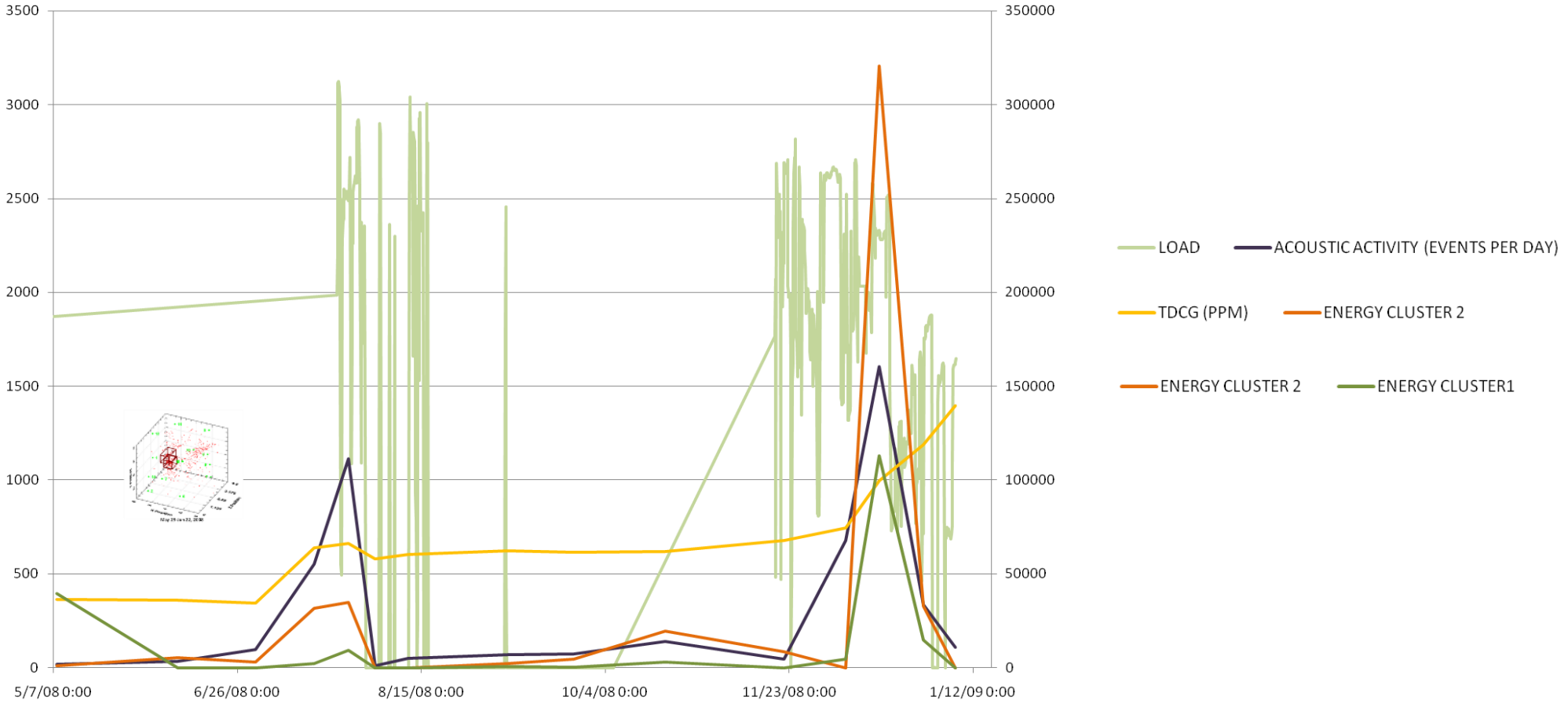

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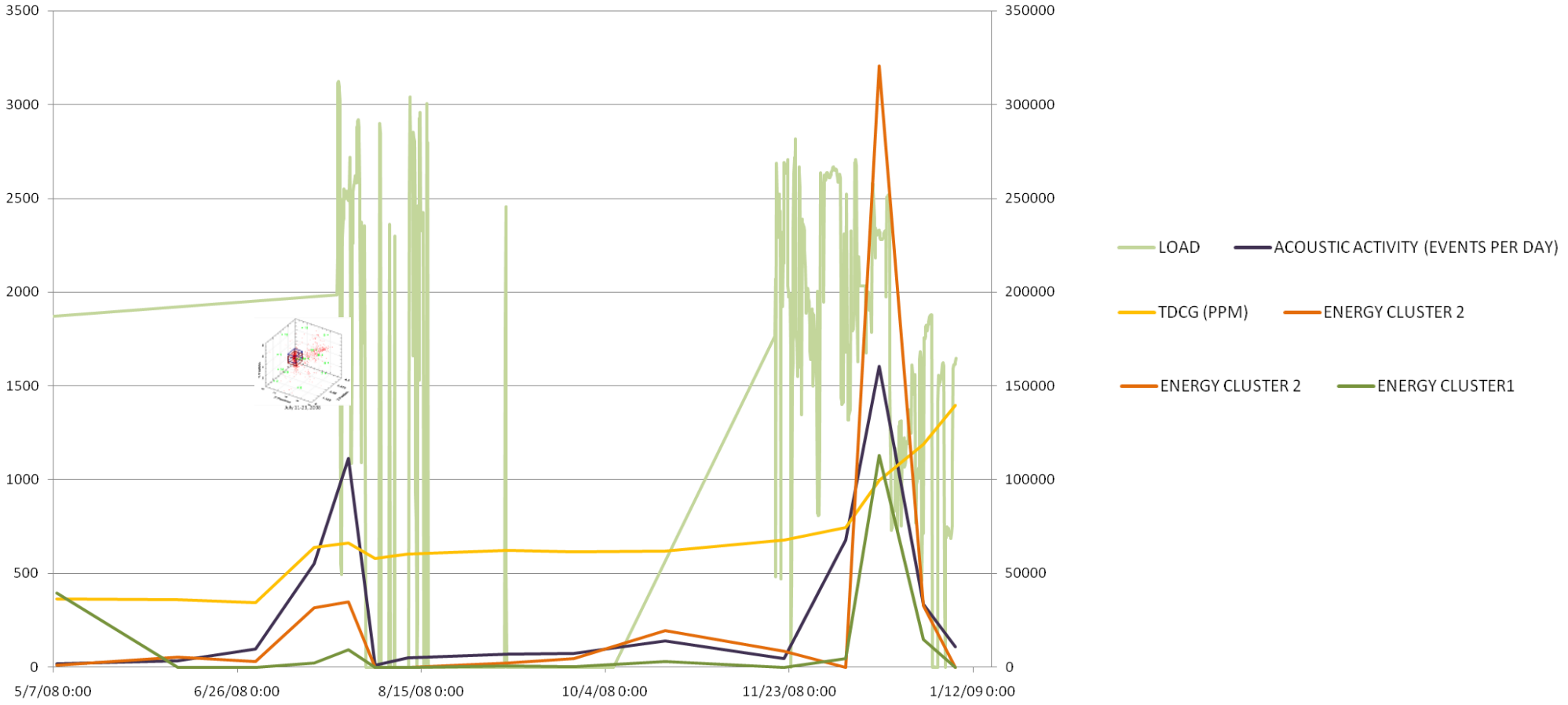

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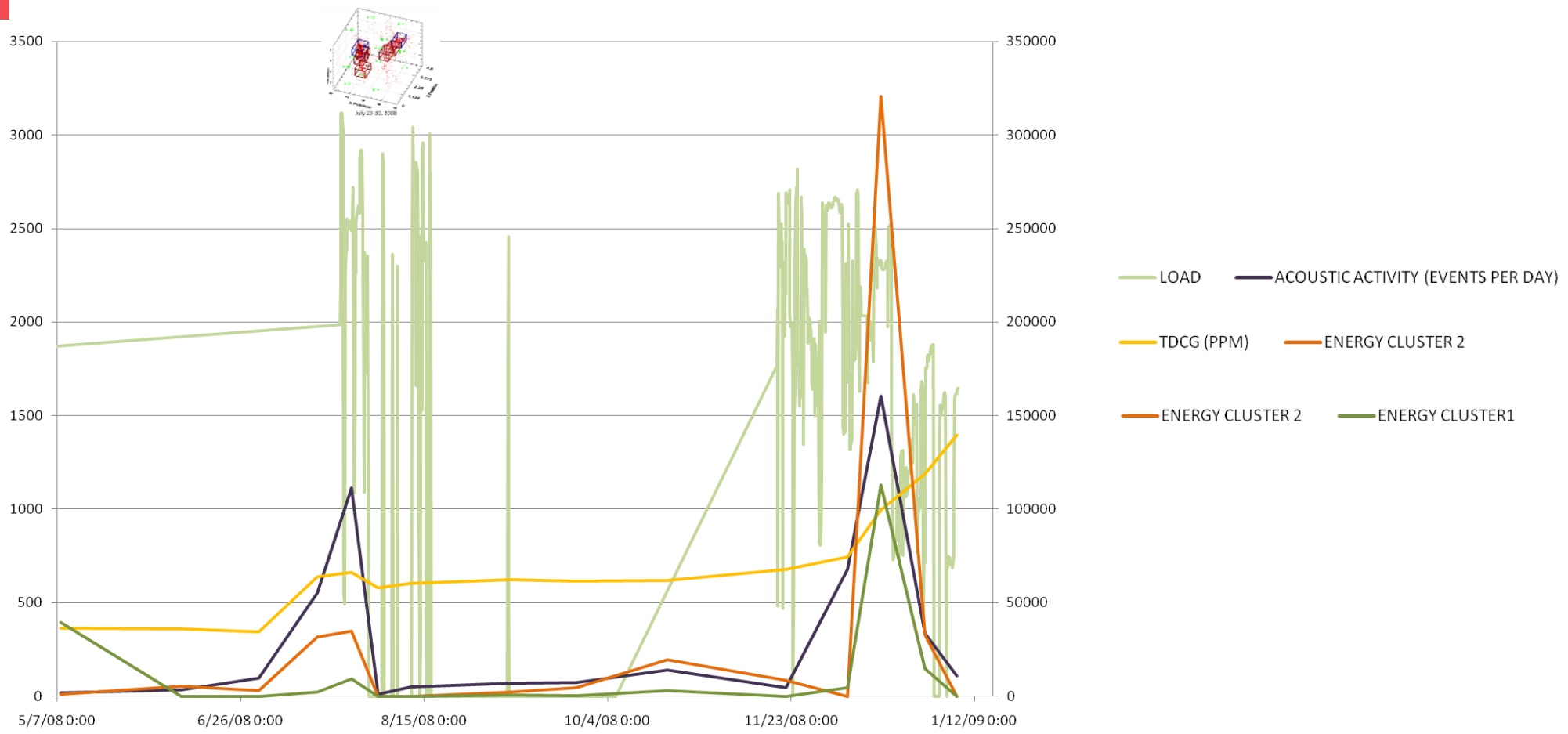

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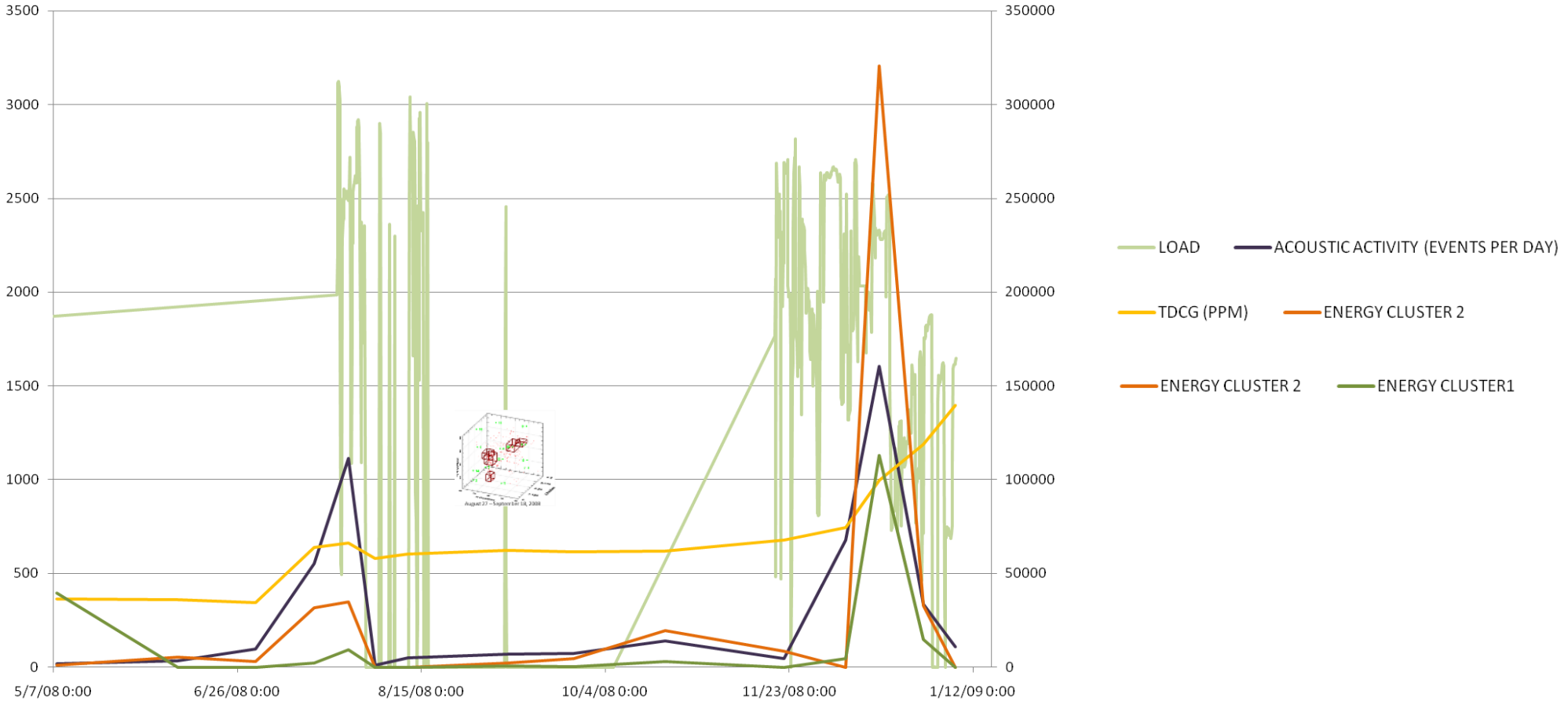

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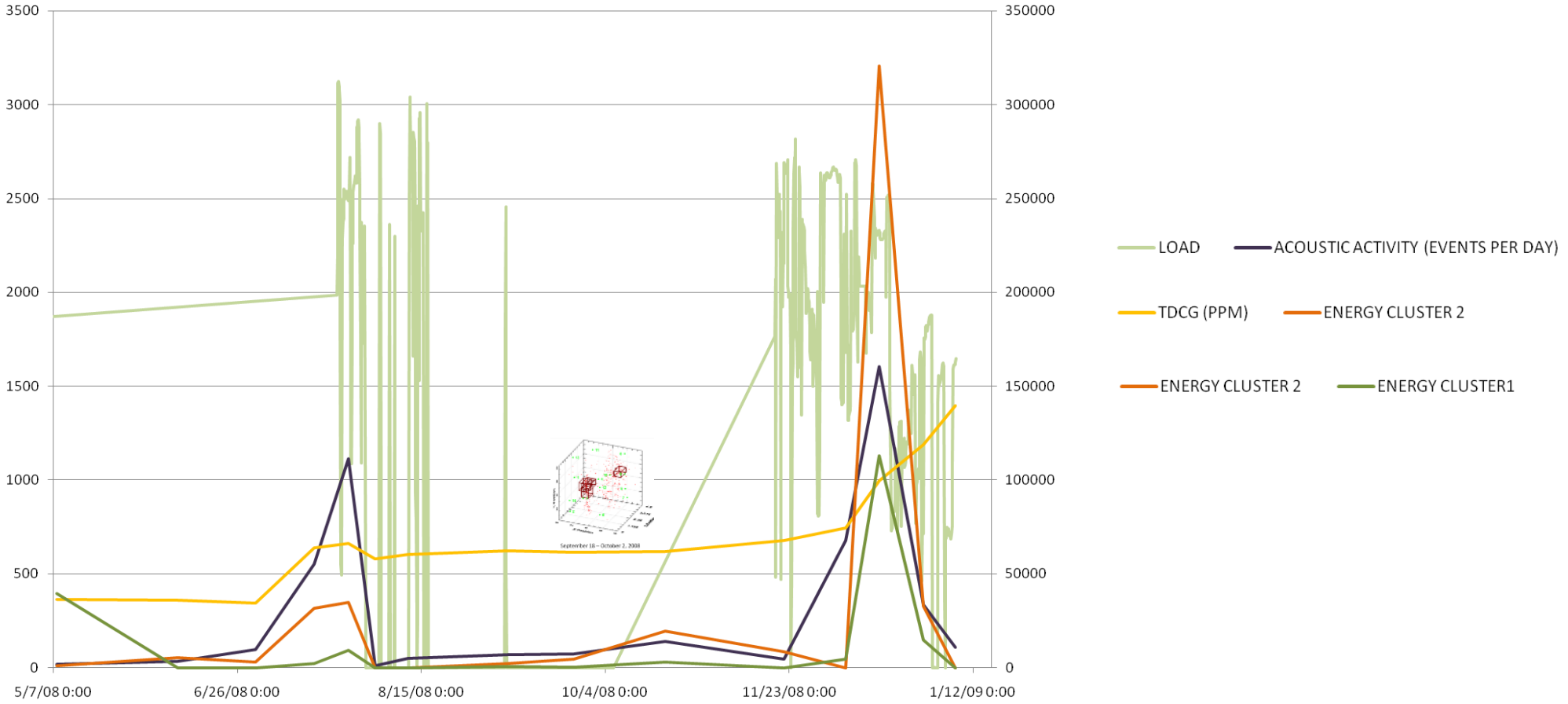

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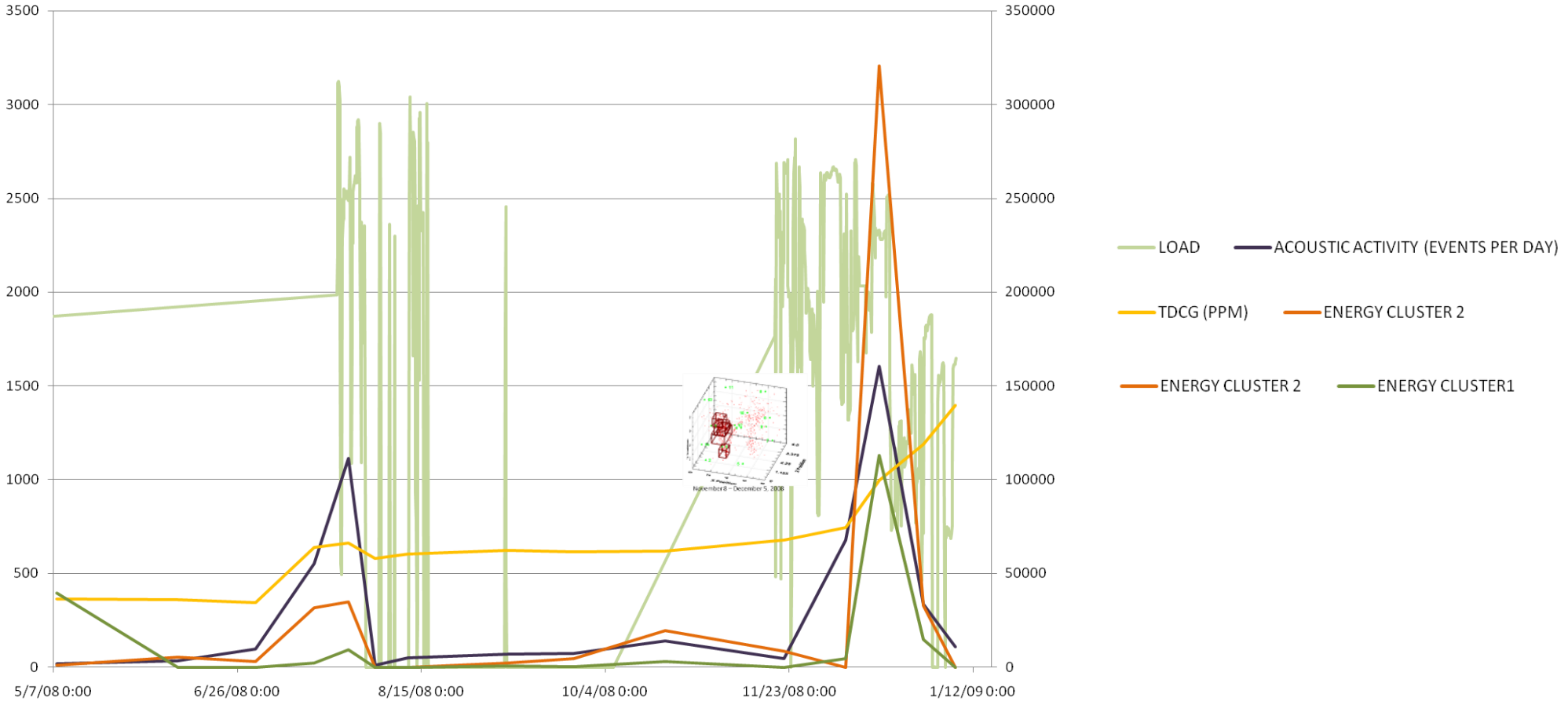

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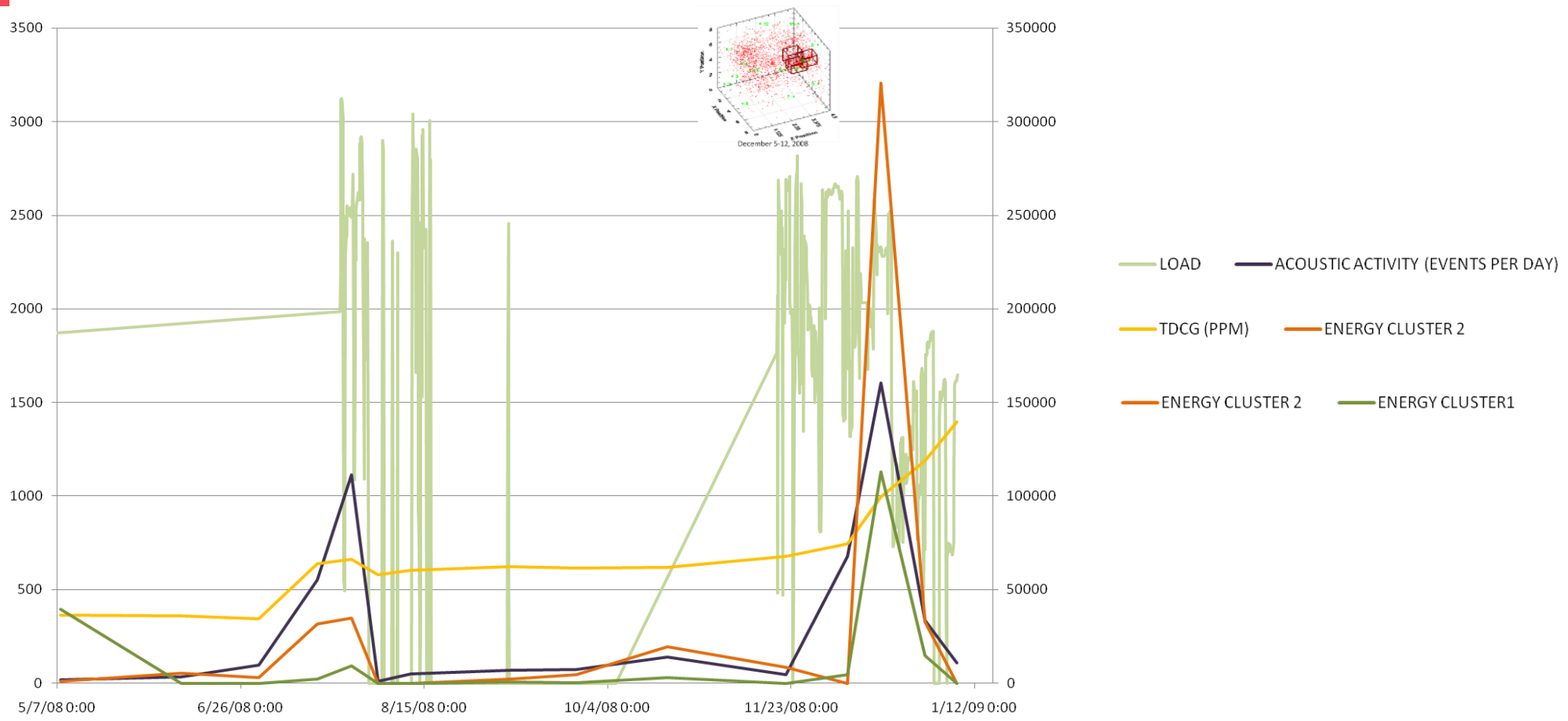

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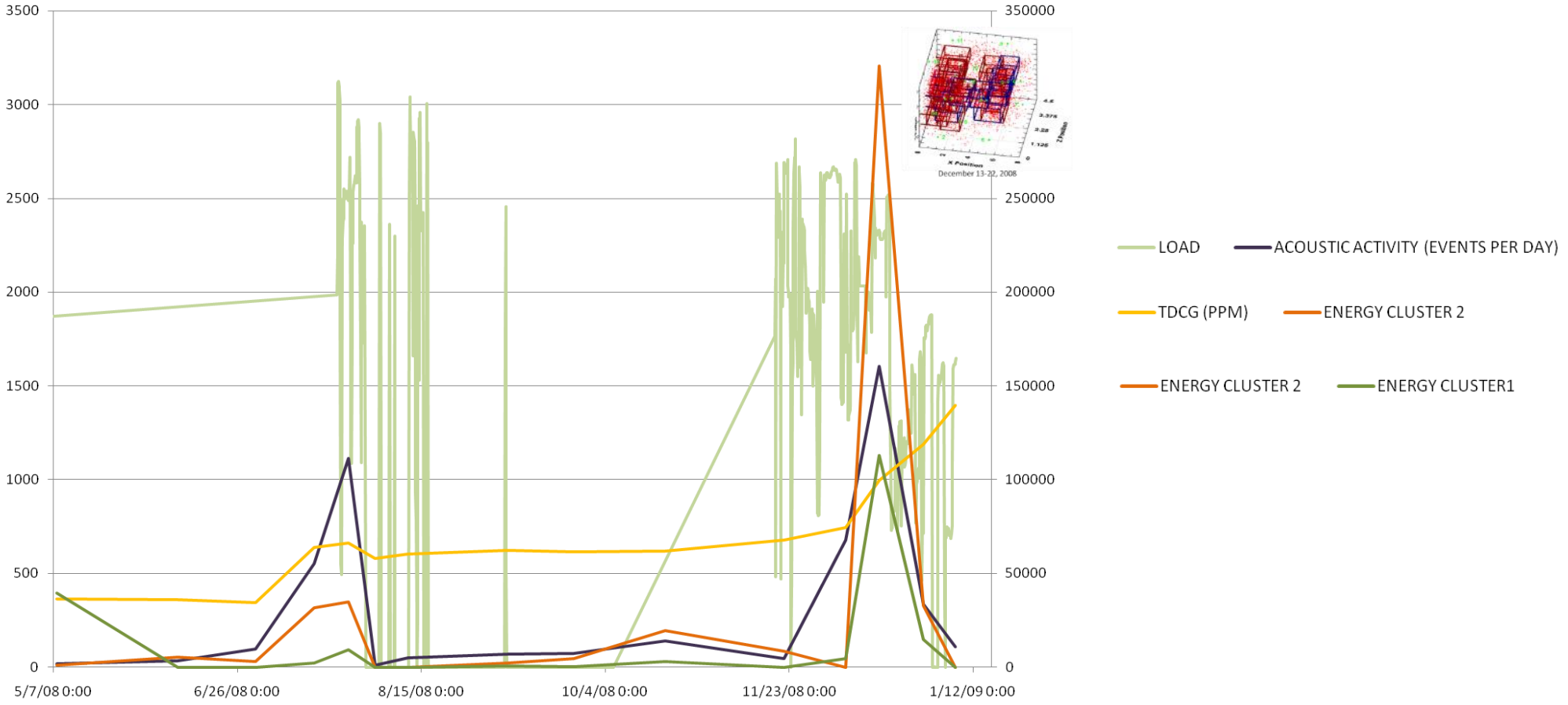

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Provide Early Fault Detection

TRANSFORMER CLINIC

DGA Data

How to Maximize Transformer Reliability and In-Market Availability

Sample Date	Top Oil Temp. °C	Hydrogen (H2)	Methane (CH4)	Carbon Monox. (CO)	Ethane (C2H6)	Carbon Dioxide (CO2)	Ethylene (C2H4)	Acetylene (C2H2)	COMB GAS	Comb Gas Rate
										ppm/day
01/12/2009	**28**	**48**	**187**	**125**	**0**	**1620**	**1020**	**16**	**1396**	**34.67**
01/06/2009	28	44	164	133	0	1660	834	13	1188	24.25
12/29/2008		37	129	145	0	1720	673	10	994	11.90
12/08/2008	26	18	79	139	0	1680	502	5.5	744	3.24
11/17/2008	35	19	79	138	0	1780	435	5.2	676	1.53
10/10/2008	35	18	77	128	0	1560	389	5.8	618	0.18
09/23/2008	30	20	72	129	0	1620	388	6.4	615	-0.64
09/12/2008	38	19	74	133	0	1700	390	6.4	622	1.13
08/27/2008	35	17	69	131	0	1850	380	7.2	604	1.14
08/05/2008	42	18	69	121	2.6	1800	361	7.8	579	

TRANSFORMER CLINIC

DGA Data

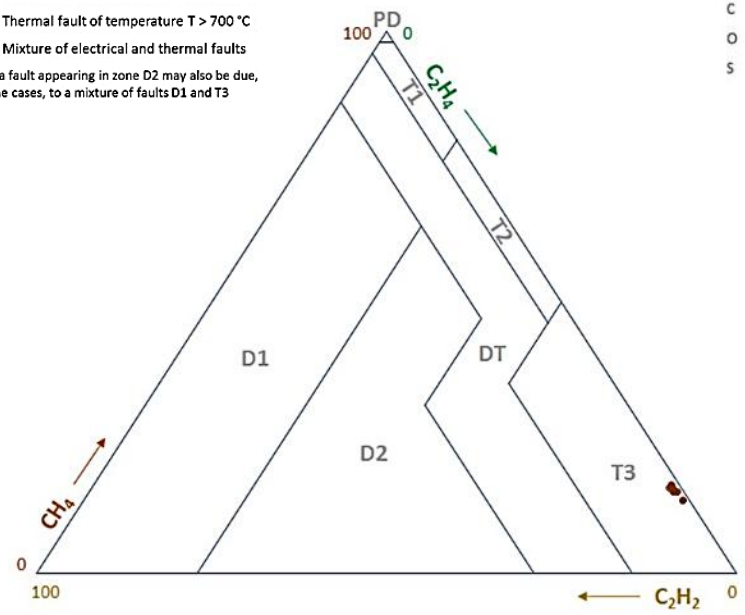
How to Maximize Transformer Reliability and In-Market Availability

Triangle 1

FAULT ZONES

PD	Corona partial discharges
D1	Electrical discharges of low energy
D2	Electrical discharges of high energy
T1	Thermal fault of temperature T < 300°C
T2	Thermal fault between 300°C and 700 °C
T3	Thermal fault of temperature T > 700 °C
DT	Mixture of electrical and thermal faults

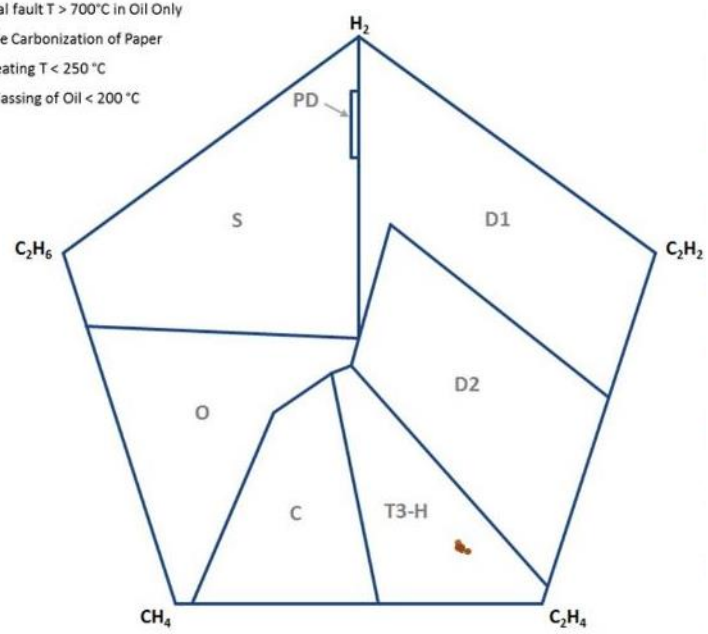
Note: a fault appearing in zone D2 may also be due, in some cases, to a mixture of faults D1 and T3



Pentagon 2

FAULT ZONES

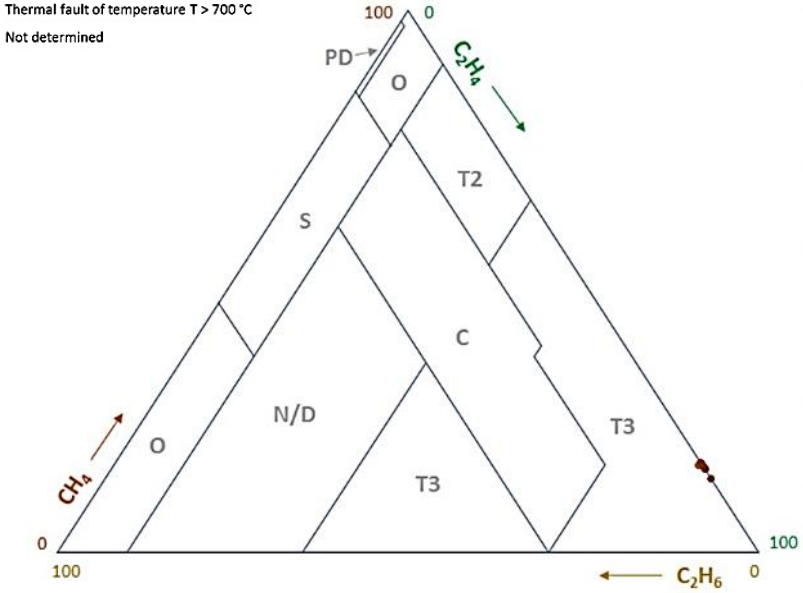
PD	Corona partial discharges
D1	Electrical discharges of low energy
D2	Electrical discharges of high energy
T3-H	Thermal fault T > 700°C in Oil Only
C	Possible Carbonization of Paper
O	Overheating T < 250 °C
S	Stray Gassing of Oil < 200 °C



Triangle 5

FAULT ZONES

PD	Corona partial discharges
S	Stray gassing of mineral oil (T < 200 °C)
C	Hot spots with carbonization of paper (T > 300 °C)
O	Overheating (T < 250 °C)
T2	Thermal fault between 300°C and 700 °C
T3	Thermal fault of temperature T > 700 °C
N/D	Not determined



SAMPLE | SCREEN | OBSERVE | MONITOR

Provide Early Fault Detection

TRANSFORMER CLINIC

Evidence prior to teardown

Removed from operation after 8 months of continuous monitoring

Electrical tests applied at manufacturer's facility.
All tests passed, except core insulation resistance.

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Transformer tear-down in progress

How to Maximize Transformer Reliability and In-Market Availability

TRANSFORMER CLINIC

Transformer tear-down in progress

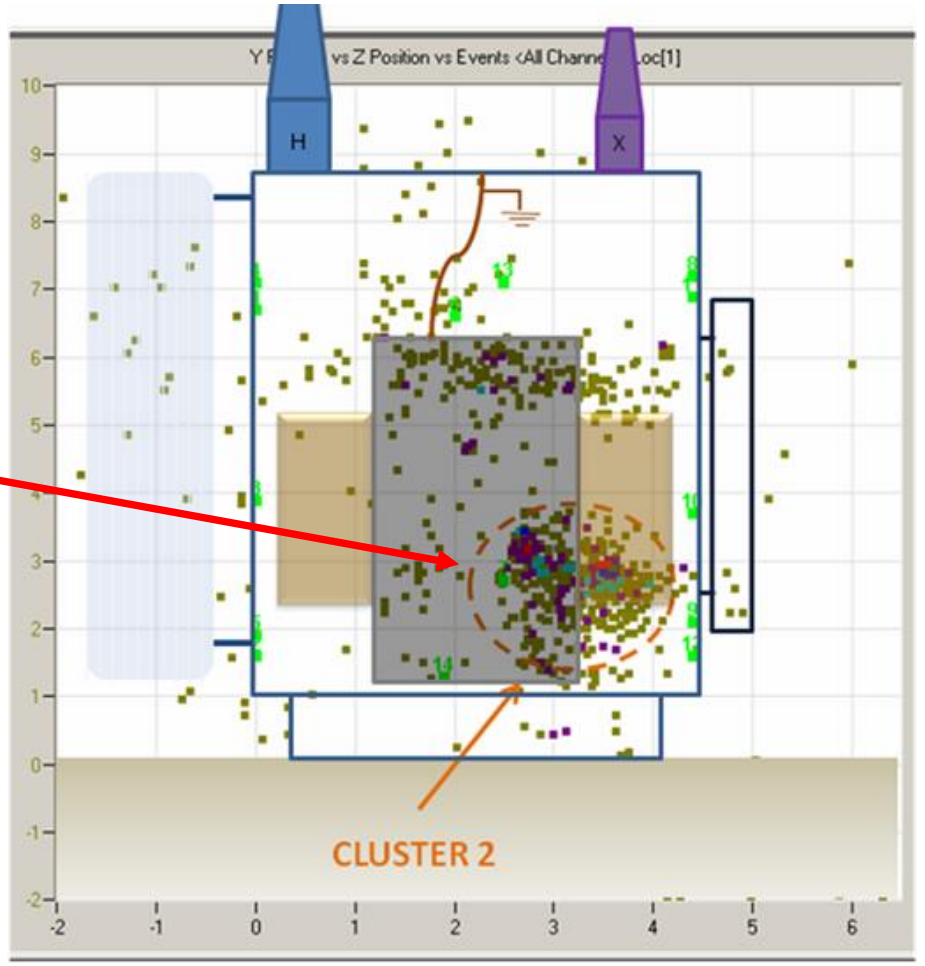
How to Maximize Transformer Reliability and In-Market Availability

SAMPLE | SCREEN | OBSERVE | MONITOR

Provide Early Fault Detection

Transformer tear-down in progress

TRANSFORMER CLINIC



Good correlation of the fault with the predicted area

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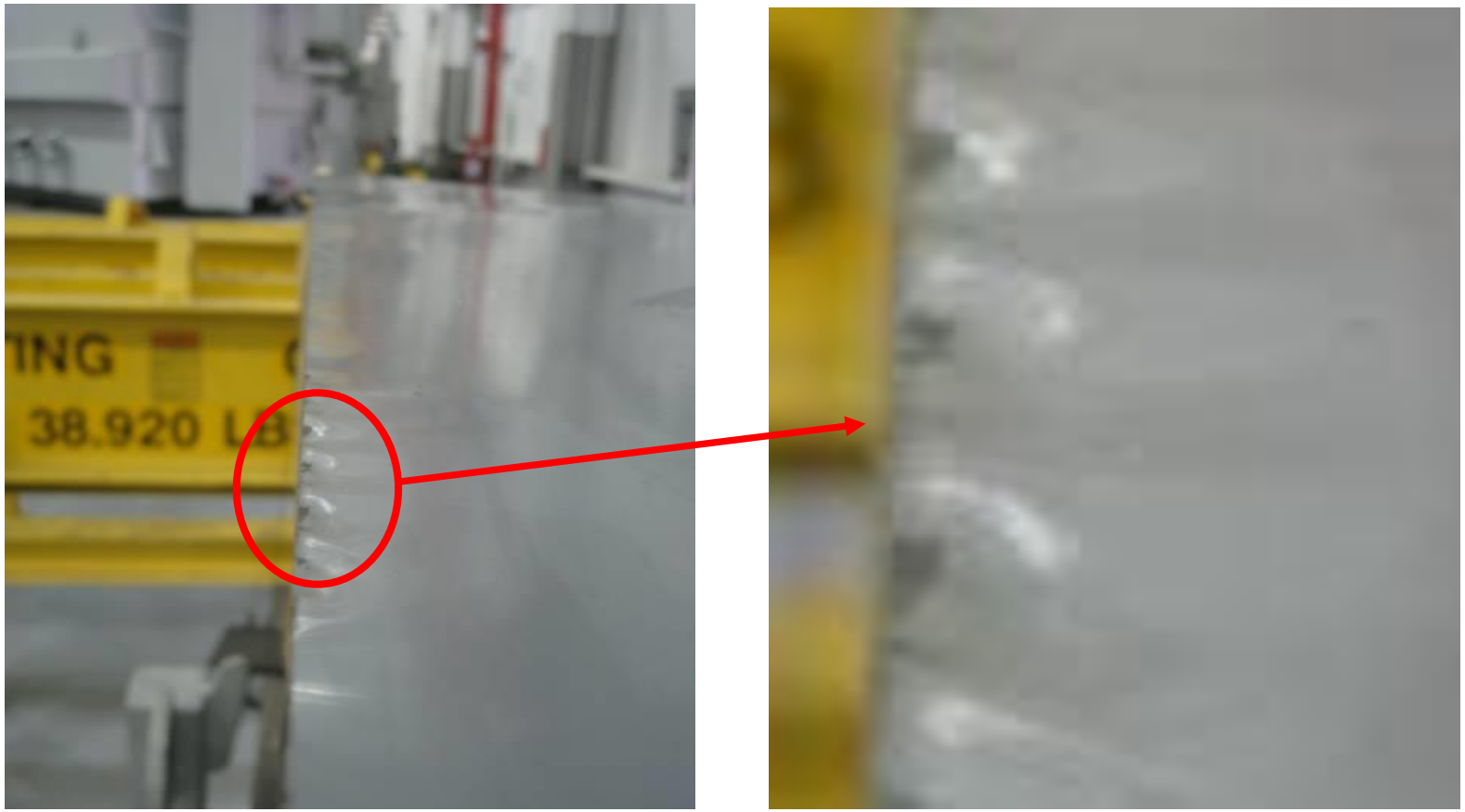
Location of the problem

Burn marks on deformed core-steel



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Benefits for End Users

Case Study 5

Added Value of a Comprehensive Reliability Program

- Provide Early Fault Detection
- Lower Operating Risk
- Alert Operating Teams of Potential Issues
- Prevent Negative Profit Impact
- Prevent Loss of Revenue
- Maximize In-Market Availability
- Extend Asset Lifecycle
- Avoid Legal Actions
- Avoid EPA Fines

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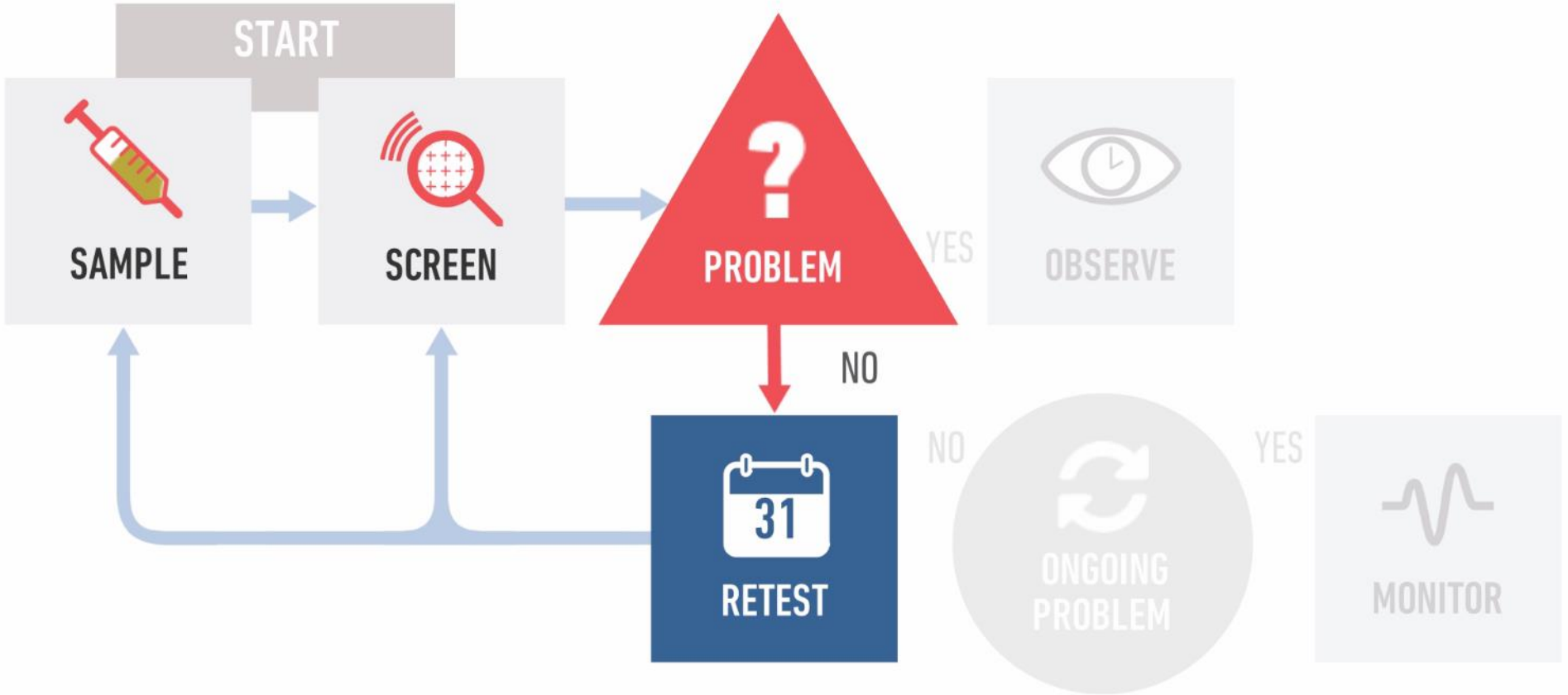
Analysis Flowchart

How to Maximize Transformer Reliability and In-Market Availability



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Provide Early Fault Detection

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Analysis Flowchart

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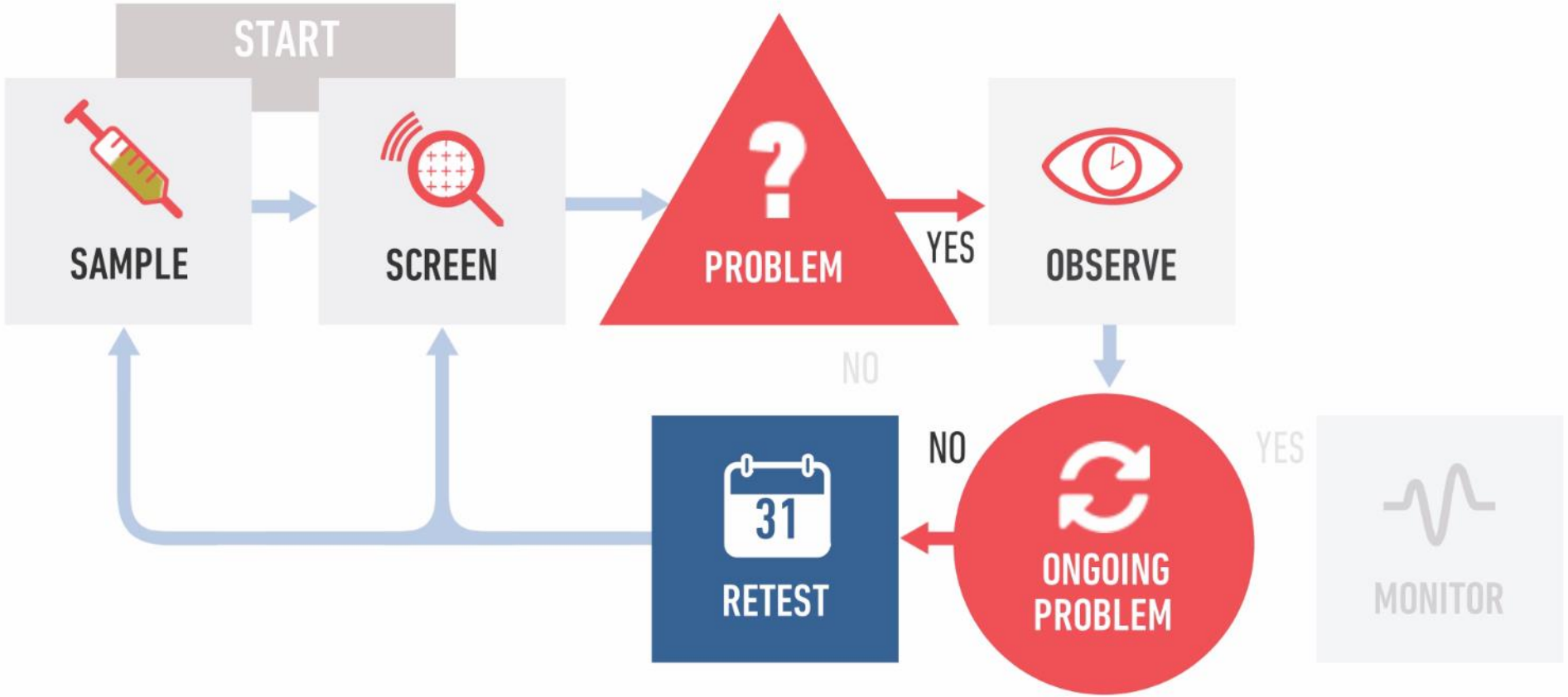

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Provide Early Fault Detection

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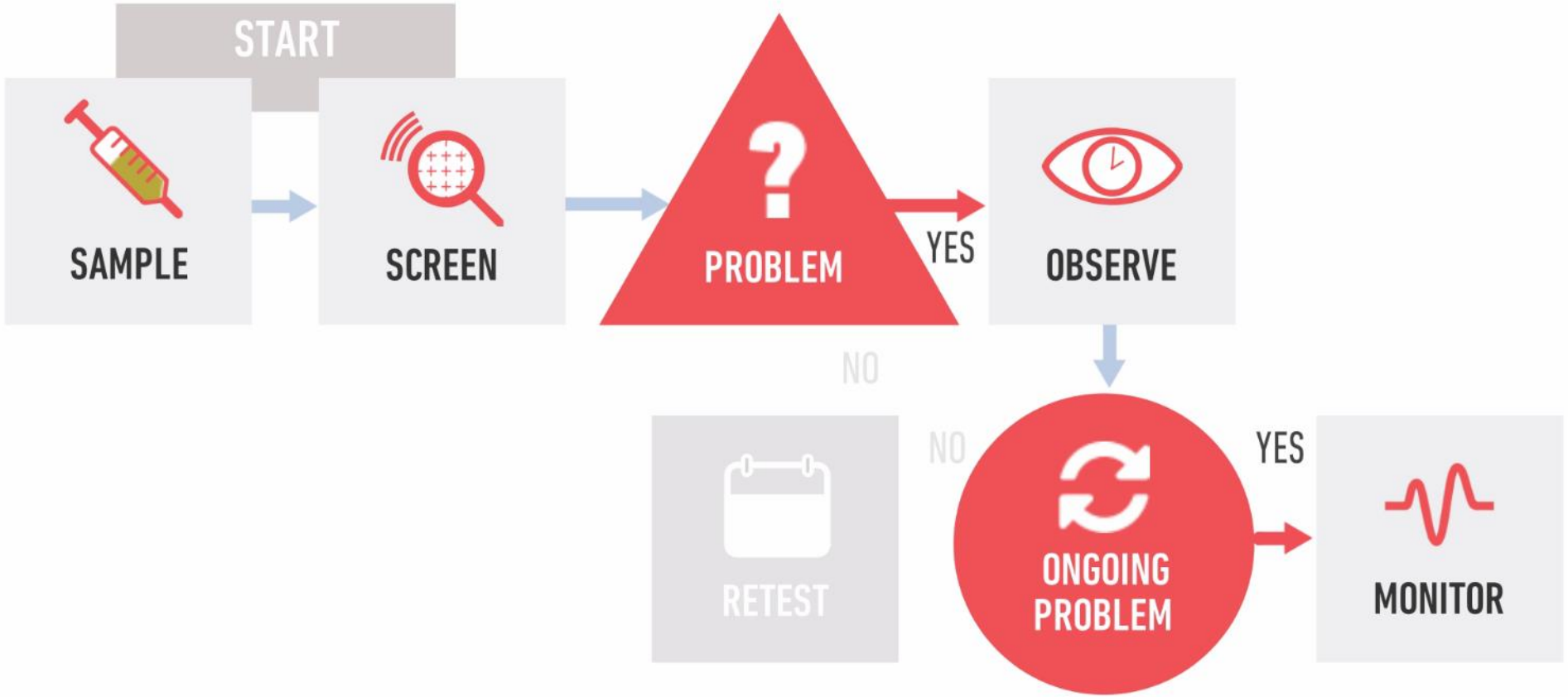

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Provide Early Fault Detection

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When Can AE Be Used?

Transformers in service

- Screening tests
  - Baseline data
  - Identify abnormal activity over time
- Gassing units to locate source of gassing
- Critical units that require nursing until spare arrives or outage is possible
- Special operating concerns:
  - Overloading
  - Solar storms
  - Static Electrification

Brand new units

- Factory testing (induced voltage)
- During commissioning

Acoustic Emission

Allows to detect, locate and trend faults inside power transformers **in-service**

Severity of the fault can be determined

When used along with other techniques allows the maintenance engineer to **understand what is triggering the activity** and **take remedial action**

Q&A

Do the speakers have experience with on-line bushing monitoring devices?
Can they speak to the devices' ability to detect bushing failures prior to their occurrence?

I have the next values of gases in an transformer: H2=17.654, CH4=22.509, C2H4=32.010, C2H6=3.851, C2H2=0.307.

Can you tell me the diagnostic about this equipment?

Your impressions about it and recommendations?

Can MISTRAS use DGA data supplied by the customer?

Can Real-Time information be sent to the Load Dispatch (Control Center) and implemented as alarms ?

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THANK YOU FOR YOUR TIME

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Hydro Québec
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