

## **POF = Probability of failure of a High voltage Distribution Network**

PQSynergy 11<sup>th</sup> International Conference and Exhibition  
19th - 21st September 2011, Le Meridien, Chiang Mai

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# Introduction

The bases of this presentation comes from an actual job where the client had inherited a large industrial installation where the overall condition of entire HV installation was un maintained due to past maintenance practices by his predecessor.

# Site Facts

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- The site consisted of High Voltage cables & switchgear with an original installation date of 1950-60
- Maintenance Strategy's varied during this period.
- Increasing failures starting to occur
- Management concerned about workforce H &S
- Management concerned about maintaining production
- High Voltage Solution appointed
- In 2010 new concepts put in place.

# Addition Client Requirements

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**EOL= End of life for each circuit breaker and ancillary systems**

*PD Levels (A) & Infra Red Levels (B)*

**POF=Probability of failure**

*PD Levels (A)*

**HI= Health index of equipment for each circuit breaker and ancillary systems**

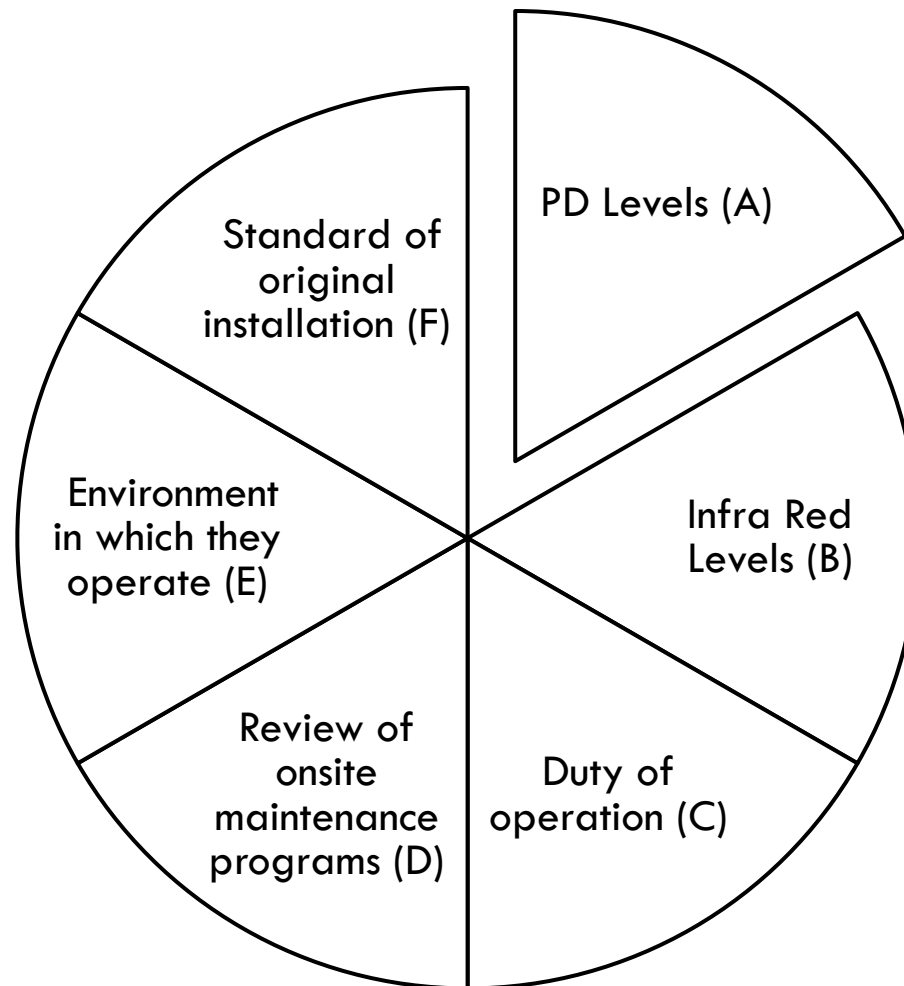
*Duty of operation (C) / Review of onsite maintenance programs (D) / Review of onsite maintenance programs (D) / Environment in which they operate (E) / Standard of original installation (F)*

# The Journey

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- Each asset was evaluated using the following matrix
- *PD Levels (A)*
- *Infra Red Levels (B)*
- *Duty of operation (C)*
- *Review of onsite maintenance programs (D)*
- *Environment in which they operate (E)*
- *Standard of original installation (F)*

# Areas of inspection





PD Levels (A)

We used Partial Discharge (PD) to evaluate :  
the condition of switch rooms / Ring Main Units /  
Underground cables / Outdoor switchyards &  
transformers on this site.

# Typical Condition of Plant

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**PD Levels (A)**

	CB1	CB2	CB3	CB 4	CB 5	CB 6	CB 7
1. Withdrawable circuit breaker	2	0	0	2	2	2	2
2. Rear cable box	0	2	0	0	0	0	0
3. Cable	6	0	2	0	0	0	0
4. Bus chamber	0	0	0	6	0	0	0
5. Voltage transformers / current transformer	0	0	0	0	0	0	0
6. Auxiliary wiring panel / Protection	0	0	0	0	0	0	0
<b>Total</b>	<b>8</b>	<b>2</b>	<b>2</b>	<b>8</b>	<b>2</b>	<b>2</b>	<b>2</b>

Nil	0
Low	2
High	6

1 ----- 5 (Acceptable)

6 ----- 12 (Requires maintenance)

13 -----18 (Failing urgent maintenance or replacement)

# Summary

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EOL / POF / HI Rating System	Factor Number	CB1	CB2	CB3	CB 4	CB 5	CB 6	CB 7
EOL=End of life for each circuit breaker and ancillary systems <i>PD Levels (A) &amp; Infra Red Levels (B)</i>	A & B	< 5 years	> 5 years	> 5 years	< 5 years	> 5 years	> 5 years	> 5 years
<b>POF=Probability of failure</b> <i>PD Levels (A)</i>	A	Hi	Lo	Lo	Hi	Lo	Lo	Lo
HI=Health index of equipment for each circuit breaker and ancillary systems  <i>Duty of operation (C) / Review of onsite maintenance programs (D) Review of onsite maintenance programs (D) / Environment in which they operate (E) / Standard of original installation (F)</i>	C; D, E & F	Requires Maintenance	Requires Maintenance	Requires Maintenance	Failed	Acceptable	Acceptable	Acceptable

Overall recommendation		Requires Maintenance	Requires Maintenance	Requires Maintenance	Replace	Acceptable	Acceptable	Acceptable
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So How do use PD to evaluate HV  
Plant ?

What is PD?

# Topics of Discussion

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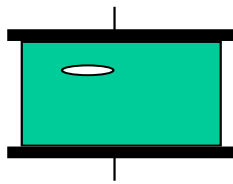
- What is Partial Discharge (PD)?
- Why use PD to reduce risk to personnel
- The failure mechanism
- Equipment used to locate PD
- Distinguish between Internal and External Partial Discharges
- Case Study

# What is Partial Discharge In Cables (PD)?

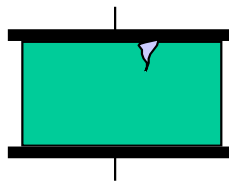
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- Partial discharge is the partial failure of medium- and high-voltage insulation.
- As the insulation fails, it produces signals that can be detected using advanced transducers designed to monitor PD.

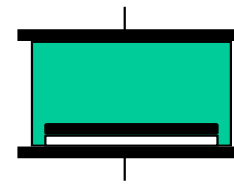
# Types of partial discharges



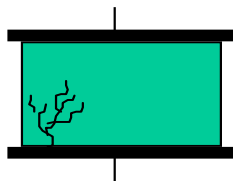
Void in Insulation



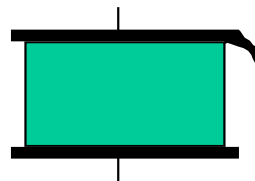
Sharp irregular surface on conductor



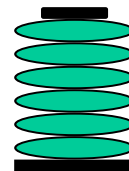
Floating metalwork near conductors



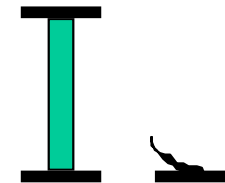
Tree Growth in insulation



Corona from sharp objects at high voltage



Surface discharges



Discharges from field induced situations

# Key Asset Areas:

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- High Voltage Switch Yards
- Cables
- High Voltage Switch Boards

# Why use PD to reduce risk to personnel in HV Switch yards

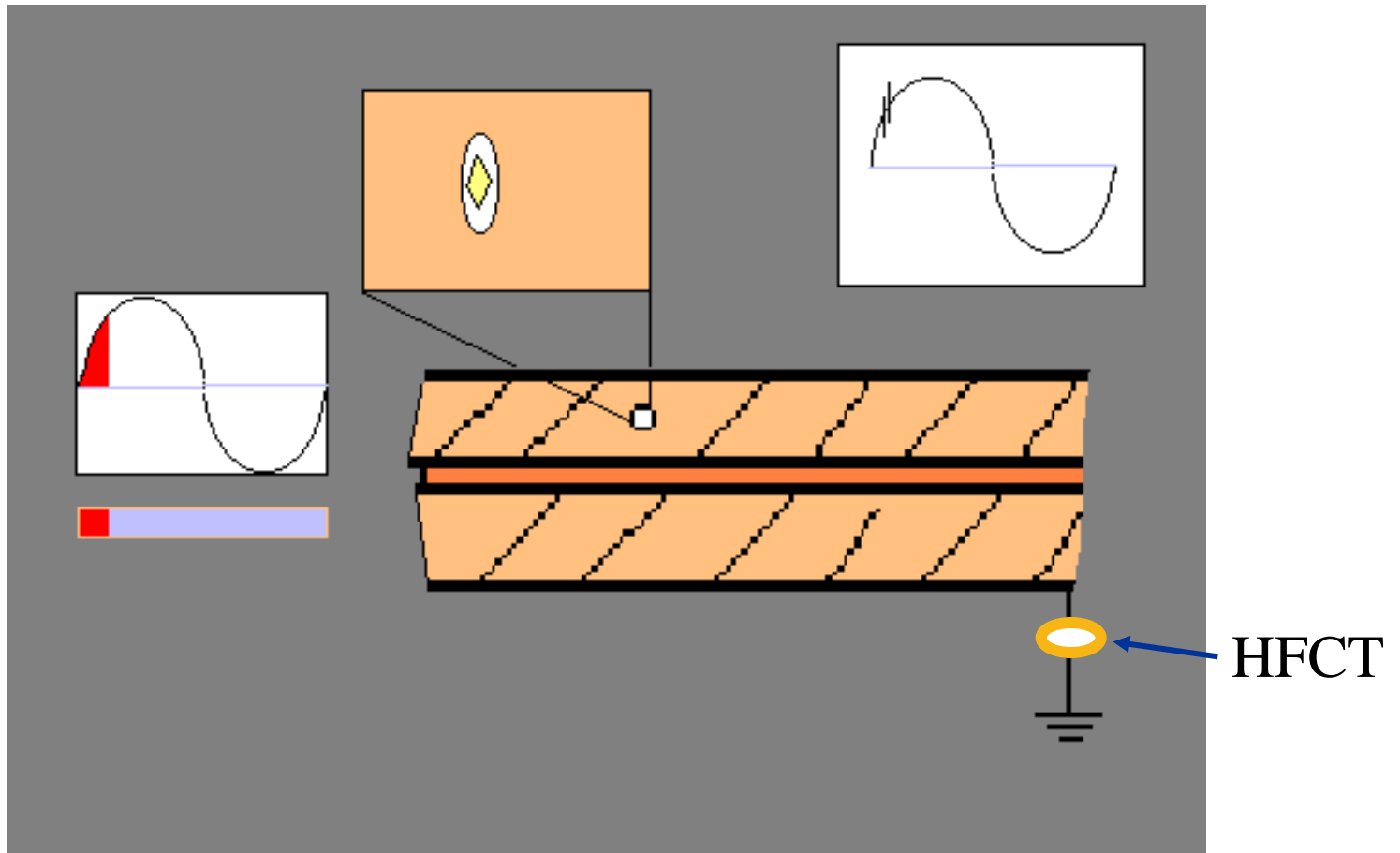
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This allows the identification / location of PD particles & mechanical defects in HV Switchyards of:

1. GIS, SF6 filled dead tank circuit breakers
1. Bulk Oil & Vacuum circuit breakers
2. Voltage Transformers
3. Current Transformers
4. HV Cable Terminations / cable box / bus chambers

## Staff Safety While Working in Live Switchyards.

It is not uncommon for VT;s or CT;s to fail while in-service. If a failure occurred while staff were in the switch yard there is a high risk of porcelain particles permanently injuring your staff. By identifying suspect HV equipment in advance it will be possible to reduce this risk, with the added benefit of not having to take this equipment out of service to perform traditional testing.

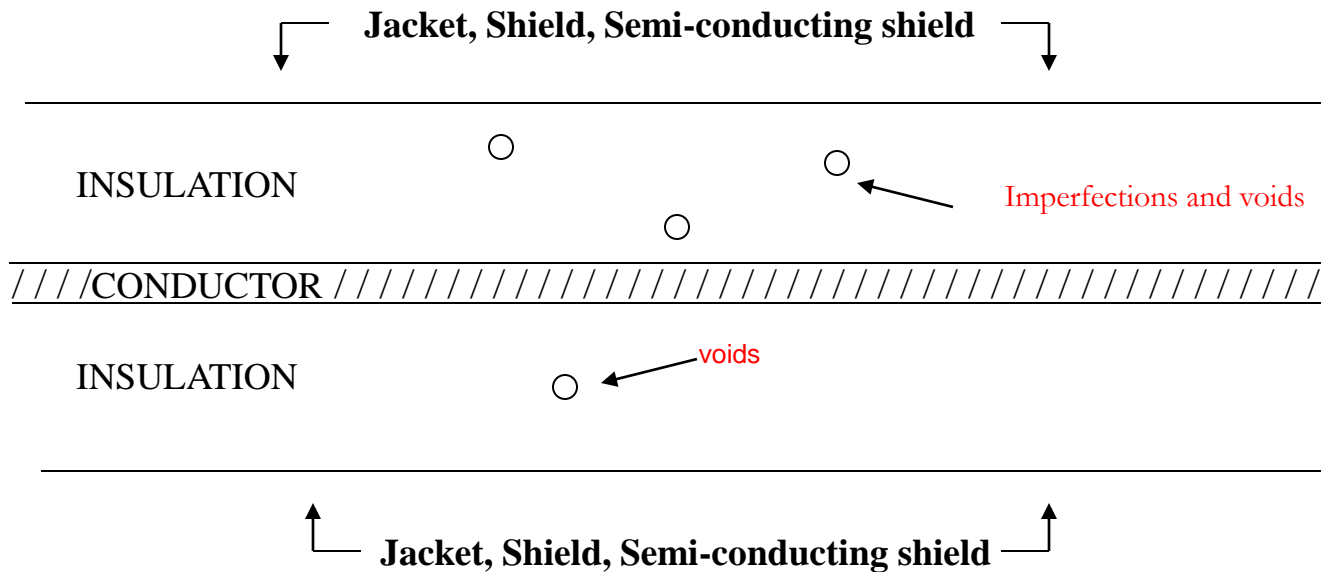


# 3 STAGES OF CABLE INSULATION FAILURE

# STAGE 1

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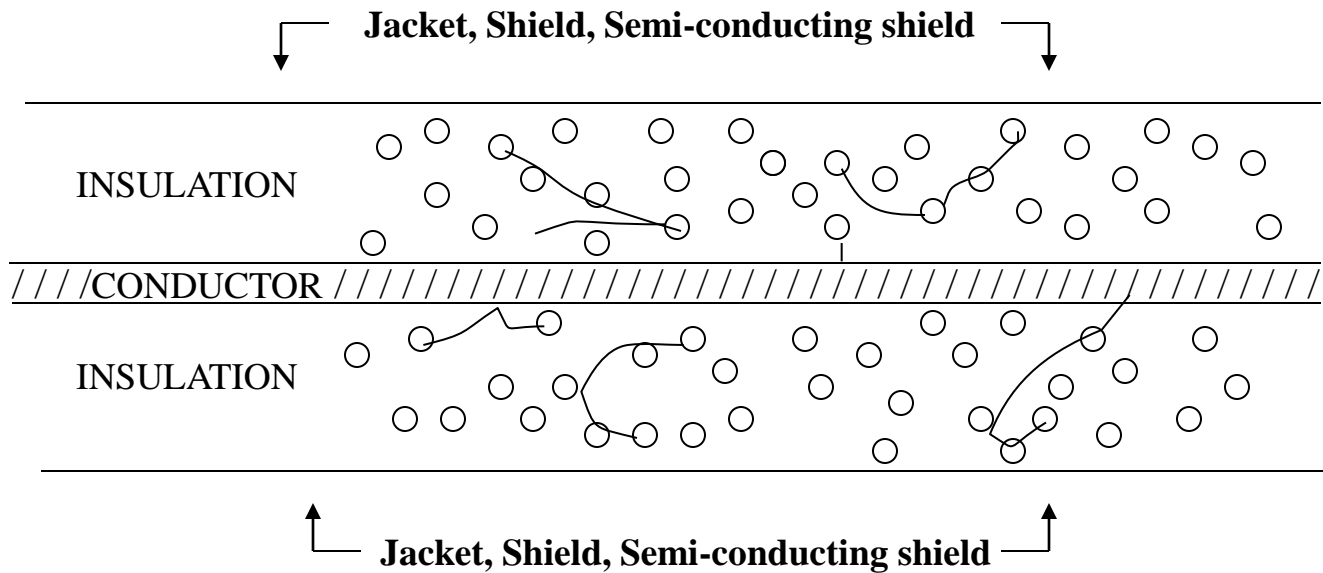
No problems, minor voids therefore minor partial discharges



# STAGE 2

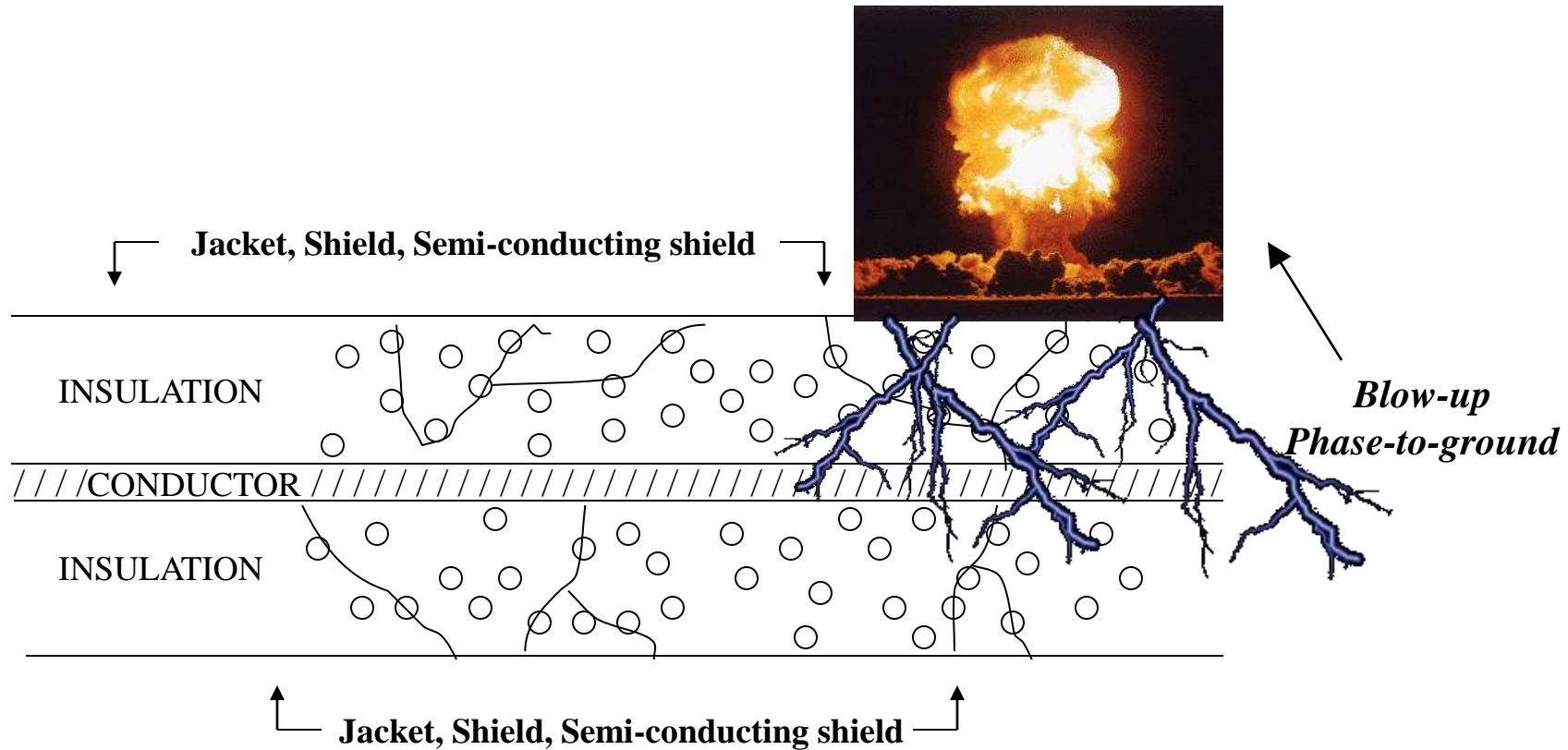
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## Tracking begins



# STAGE 3

## CABLE FAILURE!



# Asset Management of Existing Switchgear

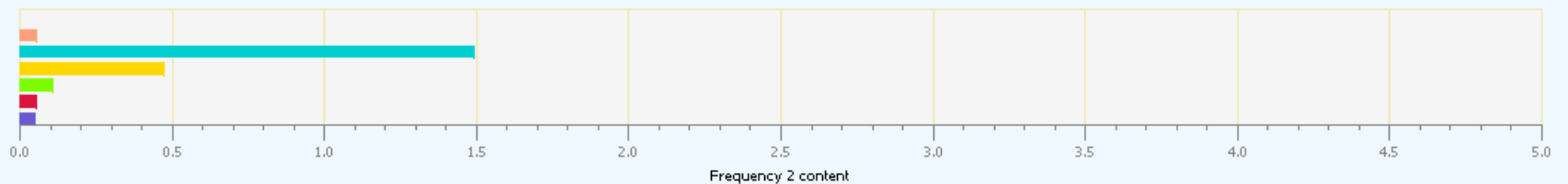
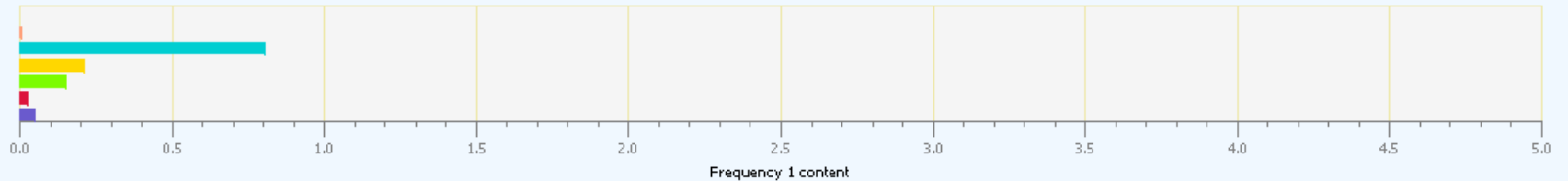
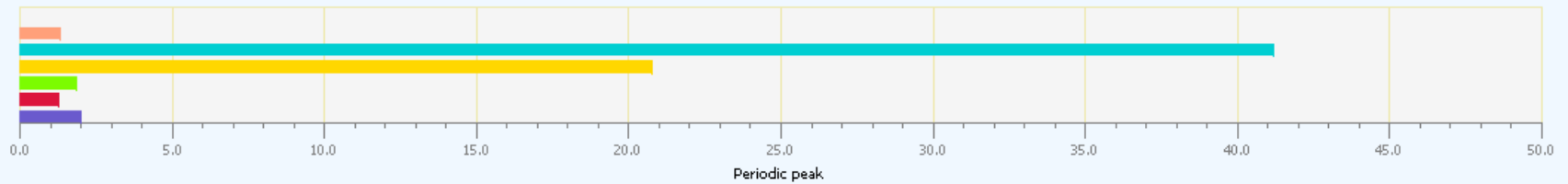
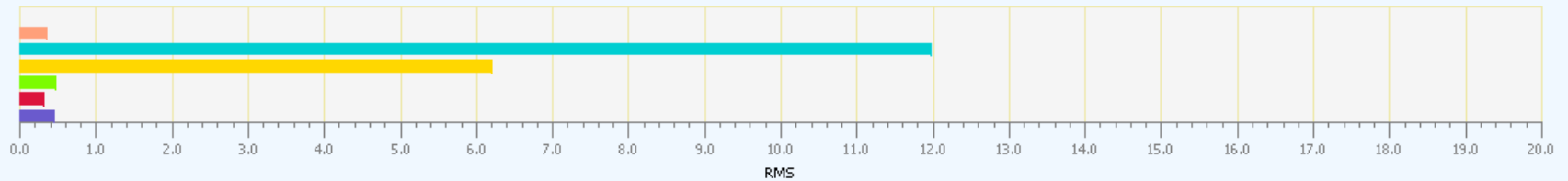
- Principals of Switchgear Management
  - Is it safe for personnel to operate
  - Will it fail in service?
  - Understand the basis for replacement and deferment - using PD testing program

- To Identify suspect 11kV Switch board

# “T1” 11kV Terminations

This chart summarises the “external” Acoustic results from T1 11kV termination

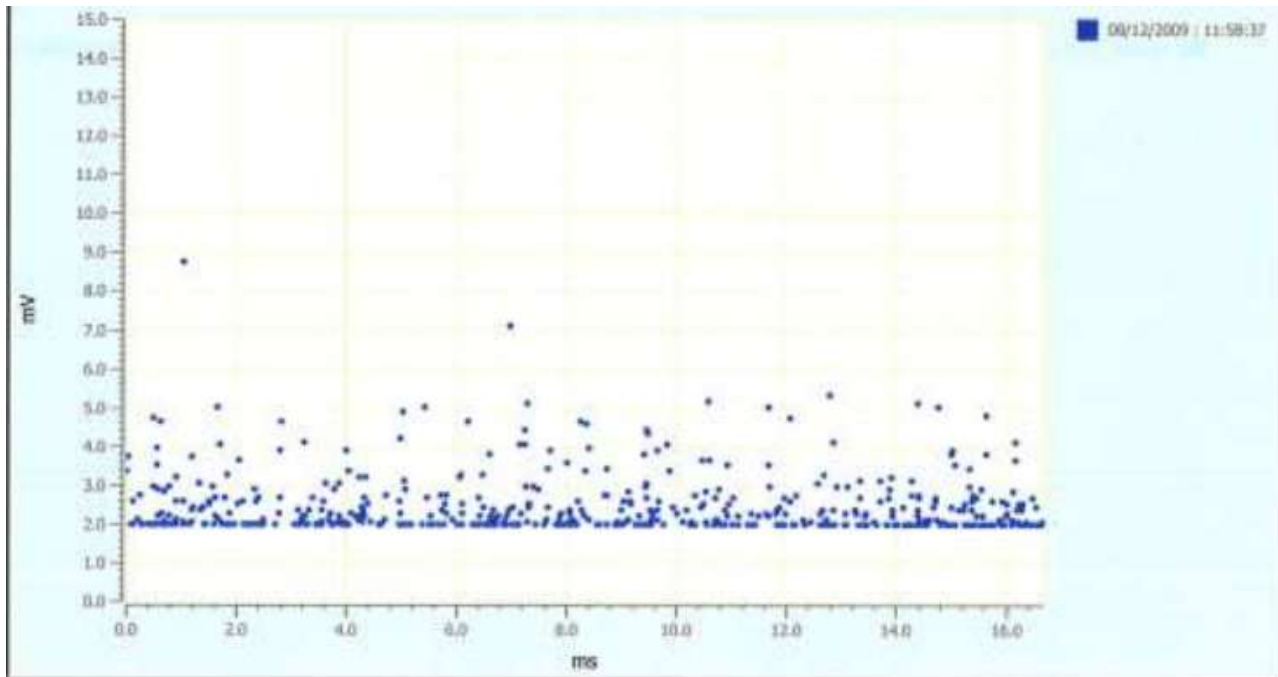
## CONTINUOUS MODE



# “T1” 11kV Terminations

This chart summarises the “external” Acoustic results from T1 11kV termination

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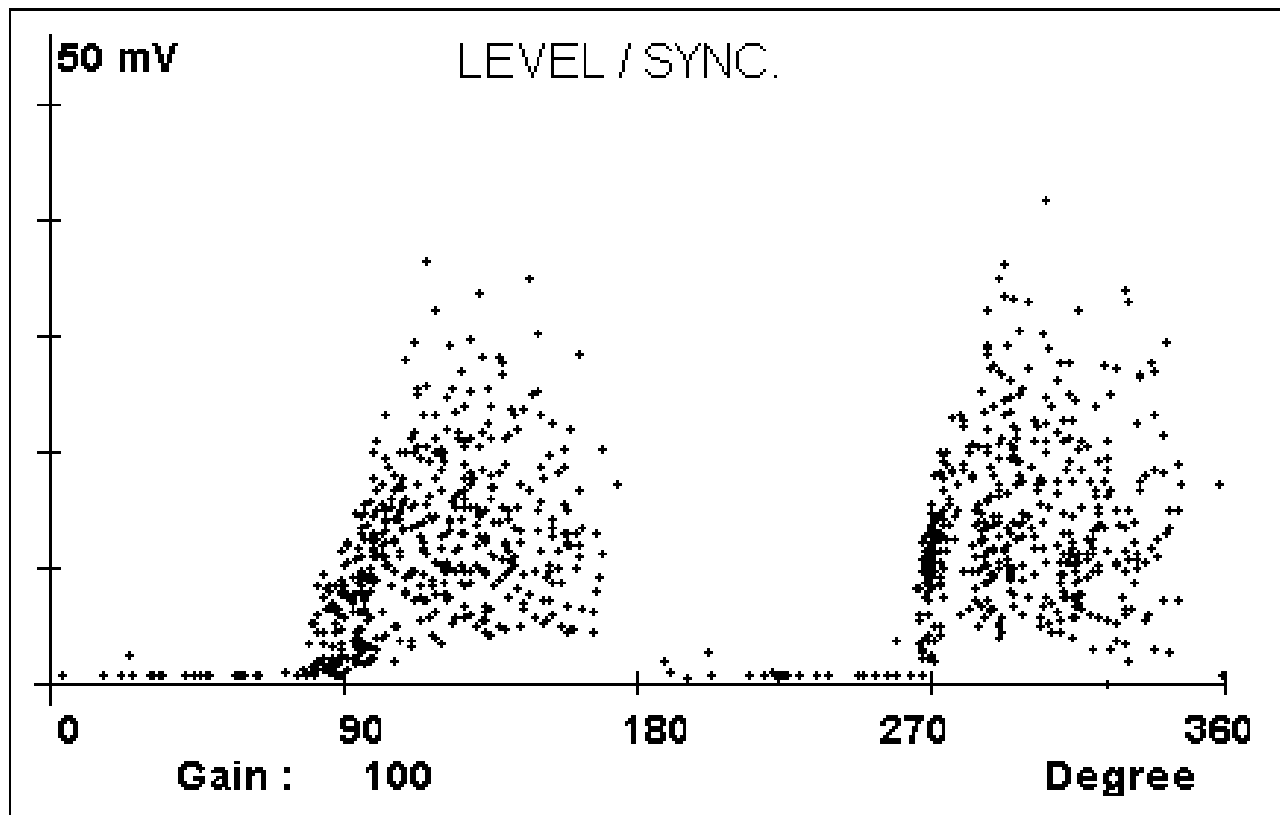


**Base line absent of partial discharge**

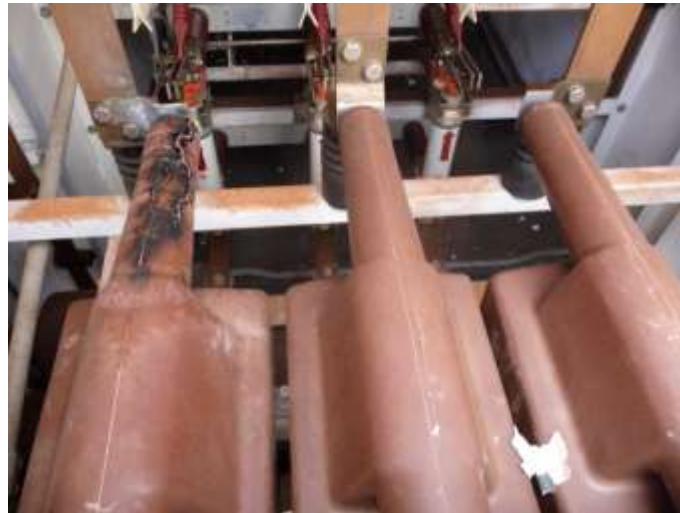
# “T1” 11kV Terminations

This chart summarises the “external” Acoustic results from T1 11kV termination

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## View of extensive external tracking



# View of failed Sw Bd Spout

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# View of failed Sw Bd connection

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# Recommended repairs not carried out

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# Damage in excess of 1 Million US Dollars

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# 11kV Termination failure lead to substation failure

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# Recommended repairs not carried out

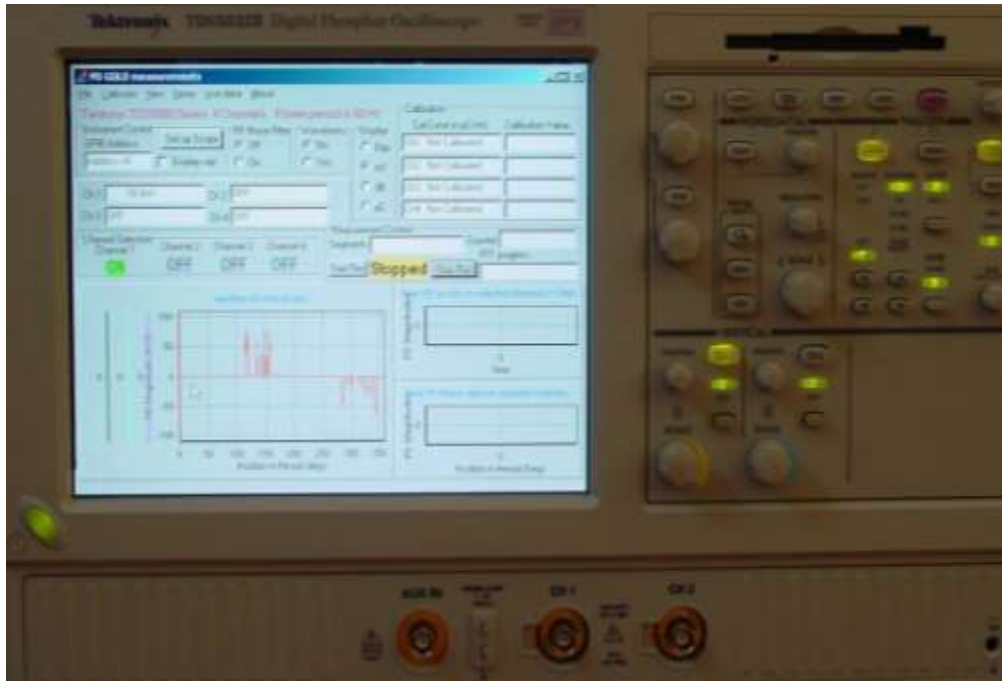
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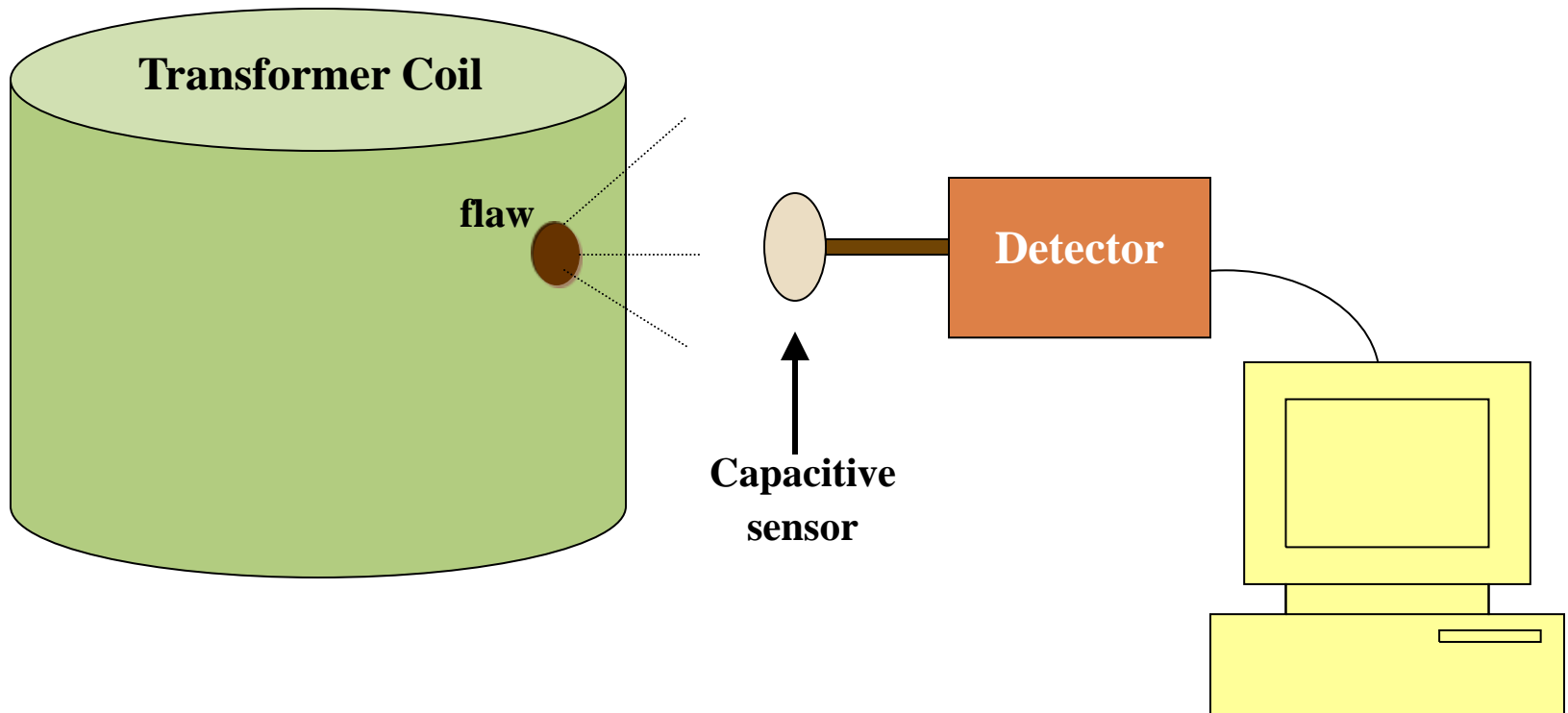


# Test Equipment & Sensors

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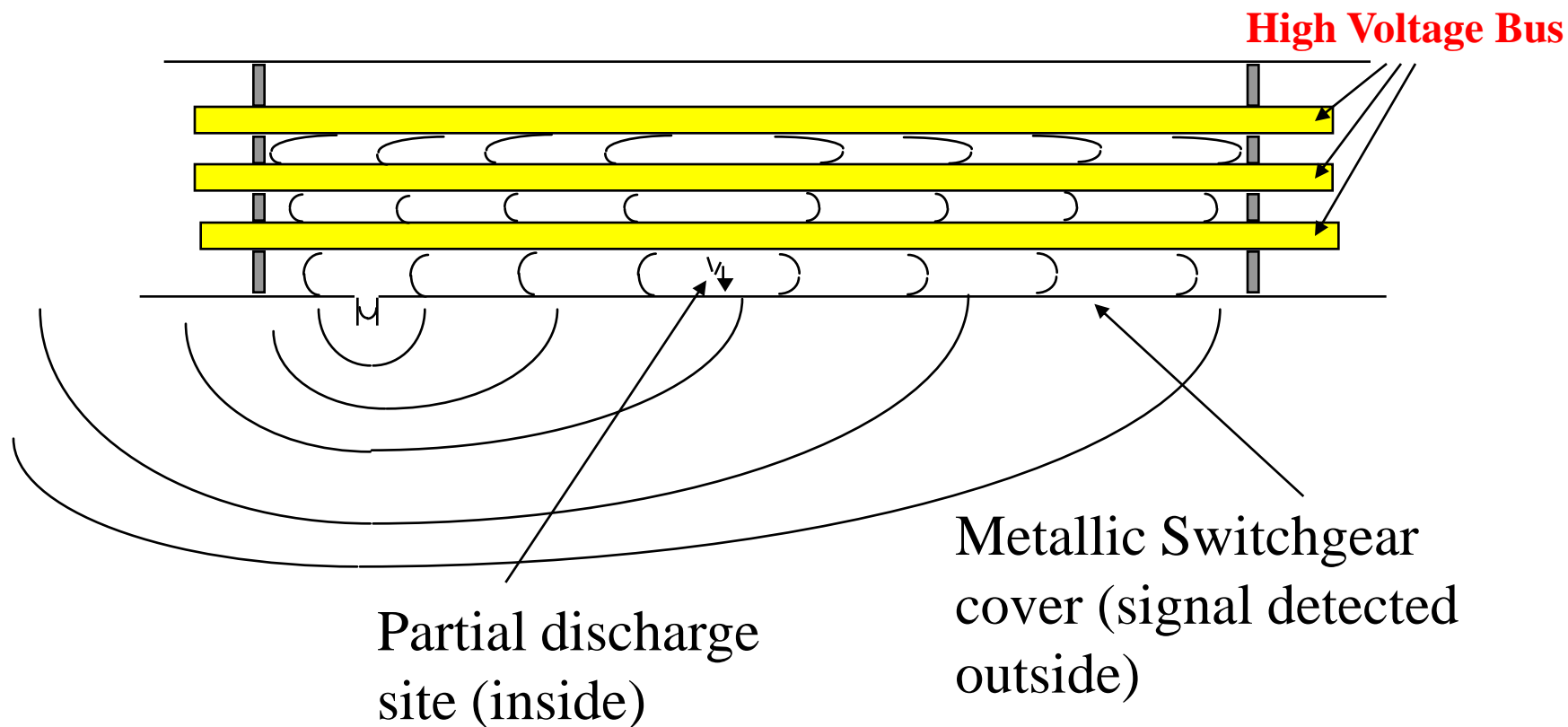


# Partial Discharge detection of a flaw in a “dry type” transformer using capacitive coupling



# Propagation of Transient Earth Voltages (TEV) in Switchgear

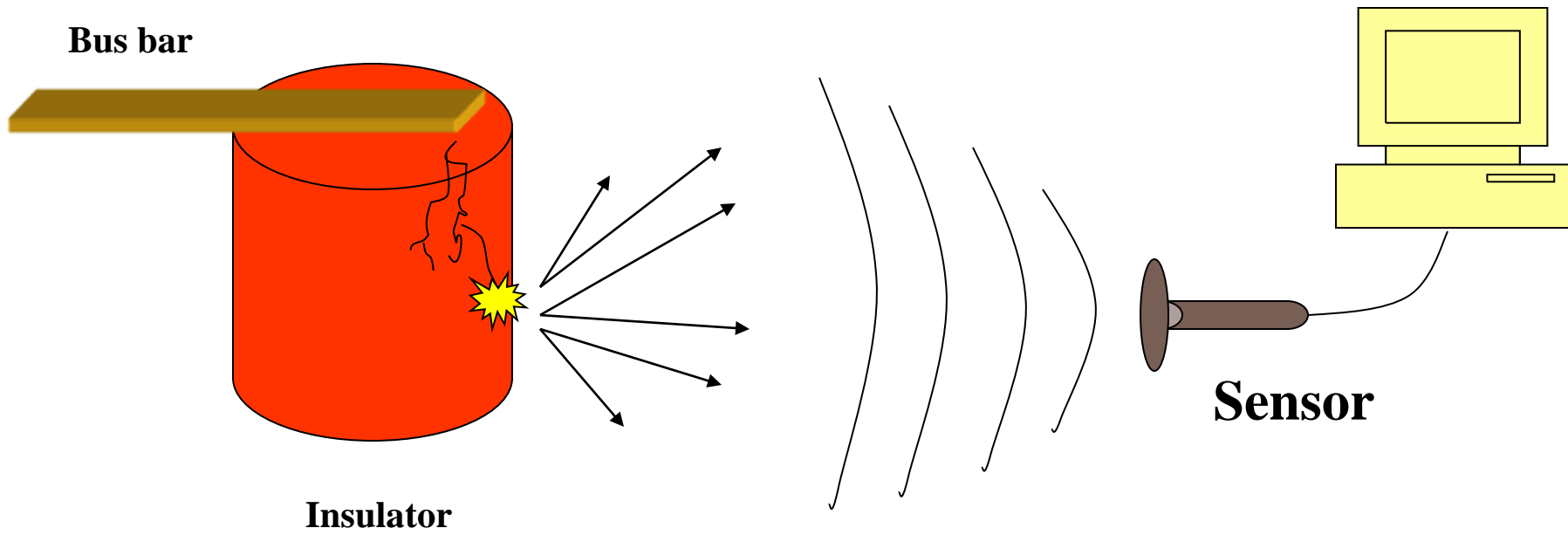
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# Measurements using Capacitive PD sensors



# Detecting PD Using Airborne Acoustic (Ultrasonic) Sensors

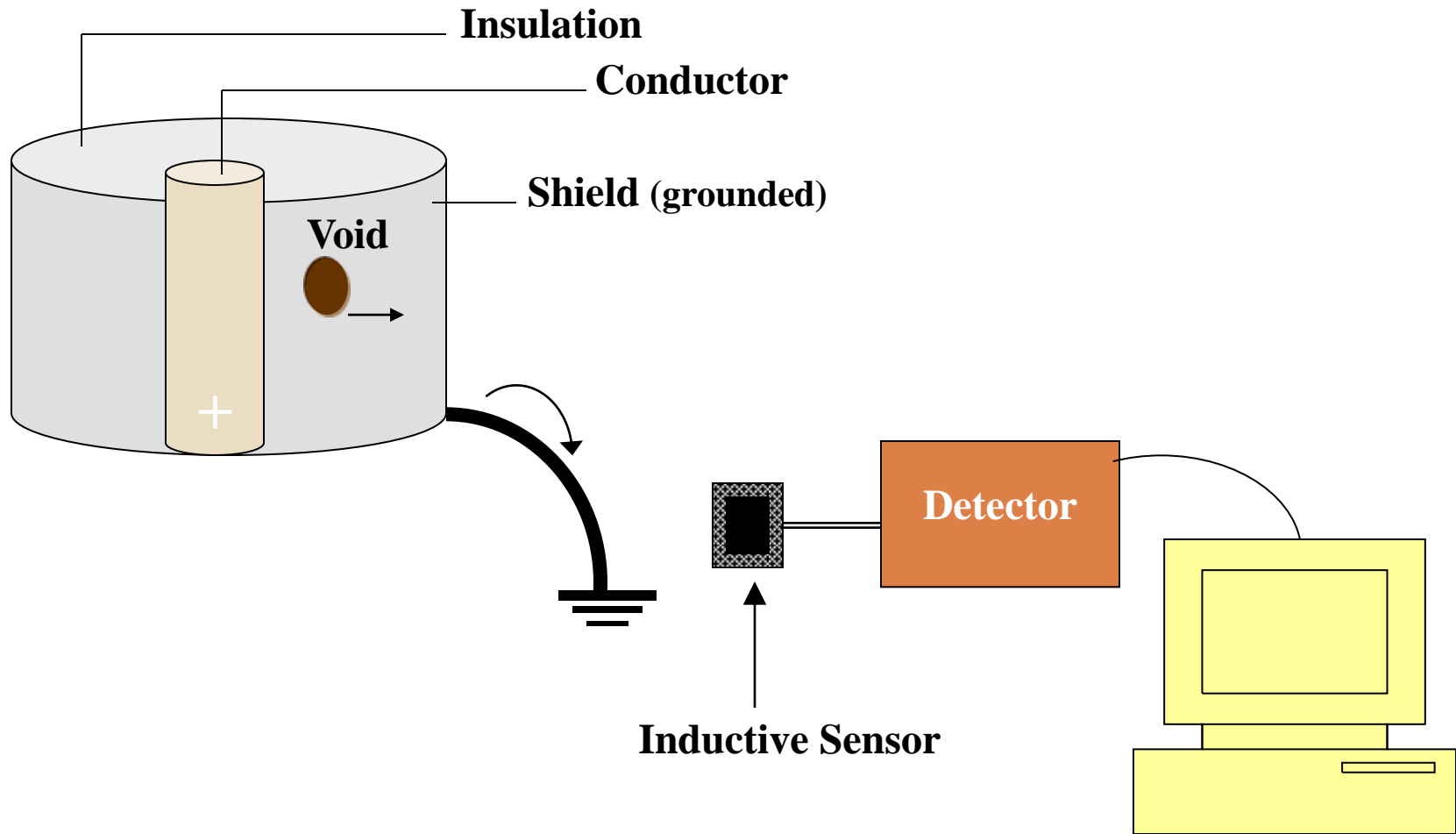


# Airborne Acoustic Sensor



# Partial Discharge detection of a void in a shielded cable using inductive coupling.

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# ADVANTAGES OF PARTIAL DISCHARGE SURVEYS

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- **PREDICTIVE** - failures can be prevented.
- **NO OUTAGE NECESSARY** - does not interrupt operations.
- **NON-DESTRUCTIVE** - no damage to electrical system.
- **TRENDING** - comparison to previous tests possible
- **PRIORITIZE MAINTENANCE ACTIVITIES** - determine which equipment to service first.
- **PLANNING** - allows time to schedule repairs.
- **FINANCIAL CONTROL** – repairs can be budgeted.

- Reduce maintenance costs and improve network reliability by replacing sections and not the entire cable.
  
- Quality checks on newly installed cables can identify defective plant that may cause risk to a network.
  
- PD mapping provides valuable information on the condition of existing cable circuits.

# Photos of the dead













# Questions



For further information & documented case histories please refer to: [www.highvoltagesolution.com](http://www.highvoltagesolution.com) or visit my stand No 14

# “About High Voltage Solution”

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- Service available in Australia, New Zealand Middle East, Singapore, and Malaysia,
  - Focused on mining industry (Surface & Underground)
  - Using state of the art technology
  - Dedicated, experienced team with passion
  - Available to locate PD & undertake repairs
  - Provide well written report with quantitative information