भारत सरकार
Government of India
विद्युत मंत्रालय
Ministry of Power
केन्द्रीय विद्युत प्राधिकरण
Central Electricity Authority
विद्युत प्रणाली अभियांत्रिकी एवं तकनीक विकास प्रभाग
Power System Engg. & Technology Development Division

सं.: के.वि.प्रा./ पी.एस.ई.टी.डी./220-O दिनांक:16.05.2017

To,
As per attached list

SUB.:- Minutes of Meeting of Standing Committee of Experts to investigate the failure of 220 kV and above voltage class substation equipment held on 01.03.17 in CEA, New Delhi.

Sir,

A meeting of Standing Committee of Experts to investigate the failure of 220 kV and above voltage class substation equipment, in respect of reported failures during September 2015 and December 2016 was held on 1st March, 2017, in CEA, New Delhi. Minutes of the subject meeting are enclosed herewith. Minutes are also available on CEA website.

Yours Faithfully,

16/5/17

(Y.K.Swarnkar)
Director & Member Secretary, Standing Committee to investigate the failure of 220 kV & above substation equipment

Copy to: PPS to Member (PS)

MINUTES OF MEETING OF THE STANDING COMMITTEE OF EXPERTS TO INVESTIGATE THE FAILURE OF 220 KV AND ABOVE VOLTAGE CLASS SUBSTATION EQUIPMENT HELD ON 01.03.2017 IN CEA, NEW DELHI, IN CONNECTION WITH REPORTED FAILURES FROM SEPTEMBER 2015 TO DECEMBER 2016 AT VARIOUS SUBSTATIONS IN THE COUNTRY

The list of participants is enclosed as **Annexure-1.**

(1) Chief Engineer (PSE&TD) & Chairman of the subject Standing Committee welcomed the participants and highlighted the importance of timely reporting of failures to the Committee. He stated that discussing the failures and sharing of operating experiences and maintenance practices of utilities will help in adopting best practices of maintenance and thereby reducing the failures. He further informed that during the period from 1st September 2015 to 31st December 2016, 110 Nos. equipment failures (21 Nos. transformers, 4 Nos. Reactors, 7 Nos. CBs, 26 Nos. CTs, 32 Nos. CVTs/PTs, 17 Nos. LAs, 2 Nos. Coupling Capacitors, one No. Line Isolator) were reported to CEA by Fourteen (14) utilities. He further highlighted that only one incidence of failure has been reported from the Eastern Region that is from OPTCL.

(2) Chairman informed that owing to a large number of failures of CGL make Instrument Transformers (IT) and Surge Arresters (SA), CGL was requested to depute concerned expert for discussion and deliberation. Mr. Yesuraj, GM (R&D), was deputed by CGL to make a presentation before the Committee and for a healthy interaction between manufacturer and utilities for discussing about causes of failure and best maintenance practices required to be adopted to minimize the failures.

(3) Member Secretary informed about the absence of the representatives from KPCL, MPPTCL and GETCO. He further stated that a draft report prepared based on information provided by utilities between September 2015 and December 2016, was uploaded on CEA's website and the same was also communicated to the concerned utilities prior to meeting. He stated that the utilities submit incomplete information about the failure because of which it becomes difficult to analyze the failure cases. He requested to provide adequate information available with them along with test reports and photographs of failed equipment. He informed that in most of the failure reports of CT/CVT/PT/SA, failure type is mentioned as 'Equipment Flashed' which do not convey the actual description of failure. Utilities were requested to describe the failure properly in future reports so that misinterpretation of failure type is avoided.

(4) Mr. Yesuraj gave a presentation pertaining to failures of Instrument Transformers and SA. Some of the significant points/issues highlighted in CGL's presentation are as follows:

(a) At the outset, Mr. Yesuraj informed that most of failures listed in CEA's draft failure report have not been reported to CGL by the utilities, specially by the utilities in the Northern region. Moreover, details of the failure provided by the utilities to CGL are not adequate to pin point the cause of failures. If detailed information about failure is provided, it helps manufacturers to take corrective action for improving the quality of product as well as would help the manufacturer to suggest corrective action to be taken by user to avoid repetition of such failures in future.

(b) He intimated that based on failure of CGL make CVTs, reported by utilities, certain design changes were made in CVT model in 2007. After carrying out modification, not a single incident of CVT failure has been reported to CGL. Hence, intimation of failure to the manufacturer brings positive results.

(c) He also cautioned against use of N_2 gas cushion in CT as the gas is absorbed by oil as temperature rises; the same is released as bubbles when oil cools down leading to partial discharge, which sometimes result in blasting of CT.

(d) Various queries raised by different utilities were discussed during interaction with CGL representatives. CGL presentation included various suggestions to improve reliability and availability of Instrument Transformers & Surge Arresters. A copy of the presentation has been uploaded on CEA website (www.cea.nic.in) for the benefit of the utilities.

(5) After CGL's presentation, PGCIL's representative made a brief presentation on failure of transformer & reactors in PGCIL substations.

(a) Presentation included the technical details of failed equipment, observations made during internal inspection & various tests carried out after failure, and conclusion derived based on the observations and tests. PGCIL representative presented about the pre-commissioning procedures and condition based monitoring procedures followed in PGCIL including various offline condition assessment & diagnostic techniques. He also informed about standard proforma of PGCIL for reporting of failure of substation equipment which can be filled up easily by a junior level officer without making mistakes to avoid misreporting.

(b) The Chairman requested PGCIL to report all failures of equipment of 220 kV and above voltage class to CEA's Standing Committee, participate regularly in the meeting and share their experiences highlighting the remedial action taken, which will benefit other participating utilities.

(c) During presentation it was informed that the problems in bushing & winding (for both transformers & reactors) and OLTC (in transformers) leads to failure of transformers & reactors.

(6) Due to paucity of time, it was not possible to discuss each & every case of failure. However, during the course of presentations by CGL & PGCIL representatives, various critical issues relating to failure of Transformers, Reactors, Instrument Transformers and Surge Arresters were discussed and following points emerged:

(a) The utilities must be careful while storing the equipment as spare or keeping transformer in the yard for long time before putting in to service.

(b) The utilities should report OEMs about the failure of equipment even after expiry of warranty period, which may help the manufacturers to take corrective action for improving the product design.

(c) Utilities should make it a practice to carry out various tests on major electrical equipment at sites one or two months before the expiry of warranty period of respective equipment.

(d) Shortage of operation and maintenance personnel and lack of proper training are matter of concern. Utilities should look into such issues with seriousness.

Instrument Transformers:

(e) Oil level should be checked before charging. For CTs with metallic bellows, the oil should be present upto the top of the bellow for proper functioning. The oil leakage needs to be checked periodically. Bellow level should be closely watched. The level of bellows of all CTs in one bay should be same at any time. Different bellow level may be an indicator of oil leakage, gassing or fault. Similarly, Capacitor units & EMU of CVTs in one bay should have same oil level indication at any time.

(f) Varistors protect the CVT from over voltage due to Ferro-resonance (FR) oscillations. They may fail in service if FR is sustained or the energy to be discharged is beyond its designed capacity. Simple visual check will ensure the healthiness. A varistor should be replaced by the varistor of the same voltage rating, as secondary voltage is tuned to a varistor.

(g) The secondary voltage of CVT is an indicator of health of CVT and drifting of secondary voltage beyond a certain limit is a clear indication of problem in CVT.

Surge Arresters:

(h) Before erection, the condition of the Arrester unit should be checked and it should be ensured that there is no damage during erection. If SA is kept on an uneven surface, it is likely to damage the pressure relief diaphragm. Any damage to this thin & sensitive material while handling & erecting will result into moisture entry into Surge Arrester, which will lead to its failure.

(i) Thermal scanning is another simple on-line check often used on SAs to locate hot spot due to improper/defective terminations/excessive watt loss.

(j) Monitoring of Leakage Current and IR value are essential for accessing the healthiness of Surge Arrestors (SAs). Measurement of the 3rd harmonic resistive component of leakage current is a very good method for assessing healthiness of SA which can be done on-line. If 3rd harmonic component of resistive current is more than 150 µA then Insulation Resistance (IR) value test should also be conducted and if current exceeds 350 µA then LA should be removed from service and replaced. The measurement of leakage current before and after the monsoon should be carried out so as to ascertain the effect of moisture.

(k) The specification of SA should include Sealing Test which can be carried out at manufacturer's works to ensure proper sealing against ingress of moisture.

(l) Digital surge counter's employment in substations could be explored.

The meeting ended with vote of thanks to the Chair.

Annexure - I

LIST OF PARTICIPANTS

Central Electricity Authority, New Delhi

1. Shri S.K.Ray Mohapatra, Chief Engineer, PSETD ....in the Chair
2. Shri Y.K.Swarnkar, Director, PSETD
3. Shri Faraz, Assistant Director, PSETD
4. Ms. Bhaavya Pandey, Assistant Director, PSETD
5. Shri. Santosh Kumar, Dy. Director, CEI
6. Shri. Krishnanand Pal, Assistant Director R&D
7. Shri. Deepak Sharma, Assistant Director, R&D

Central Power Research Institute

1. Shri. B.M. Mehra, Joint Director
2. Shri. S. Bhattacharyya, Joint Director

Bhakra Beas Management Board

1. Shri Sanjeev Kumar Saini, SSE
2. Shri. Harpreet Singh, SSE
3. Shri. Shiv Ram Agarwal, SSE
4. Shri. Harish Garg, SSE
5. Shri. Bhoop Singh Gulia SSE
6. Shri. Parveen K. Dhiman, AEE/ MTC
7. Shri. Vishal Dahiya Dy. Director- P&T Cell
8. Shri. Sunil Siwach, Dy.Director- P&T
9. Shri. Rakesh Singla
10. Shri. Ashok Gahlawat
11. Shri. R.K.Gupta, Sr. XEN

TANTRANSCO

Shri. T. Sakthivel

Kerala State Electricity Board

Shri. James. M. David, Chief Engineer (Tr. North)

Transmission Corporation of Andhra Pradesh Ltd.

Shri. T. Udhaya Kumar ADE/MRT/

Karnataka Power Transmission Corporation Ltd.

Shri. B.V. Girish, E.E.

CGL

1. Sh. John Yesuraj, GM- R&D
2. Gautam Tewari, AGM- NR

Delhi Transmission Corporation Ltd.

1. Sh. S.K. Sharma, GM (O&M)-II
2. Sh. Loveleen Singh, GM (O&M)-I
3. Sh. Roop Singh, DGM (O&M)- W
4. Sh. L.P.Kushwaha, DGM (O&M)- S

HVPN

1. Sh. Ashok Singla, SE
2. Sh. A.P.Singh, XEN TS

POWERGRID

1. Sh. Jiten Dan DGM/AM
2. Sh. Amandeep Singh DY. MANAGERCC-AM

OPTCL

Sh. Swarup Ku. Harichandan G.M.Maintenance

NHDC Ltd.

Sh. Ashok Kumar Singh, Sr. Manager (E)

RELIANCE

Sh. Atul Sanghrajka, GM (O&M)

Condition Monitoring of EHV Instrument Transformers & Surge Arresters

Presentation to CEA & Utilities
Delhi
1st March 2017

D. John Yesuraj
General Manager – R&D
Crompton Greaves Limited, India
Johnyesuraj.d@cgglobal.com

Condition Monitoring
Of
High Voltage Products

Some Important Definitions

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➢ Ageing

Refers to passage of ***time*** and is only linked to changes of properties in presence of influencing factor (stress)

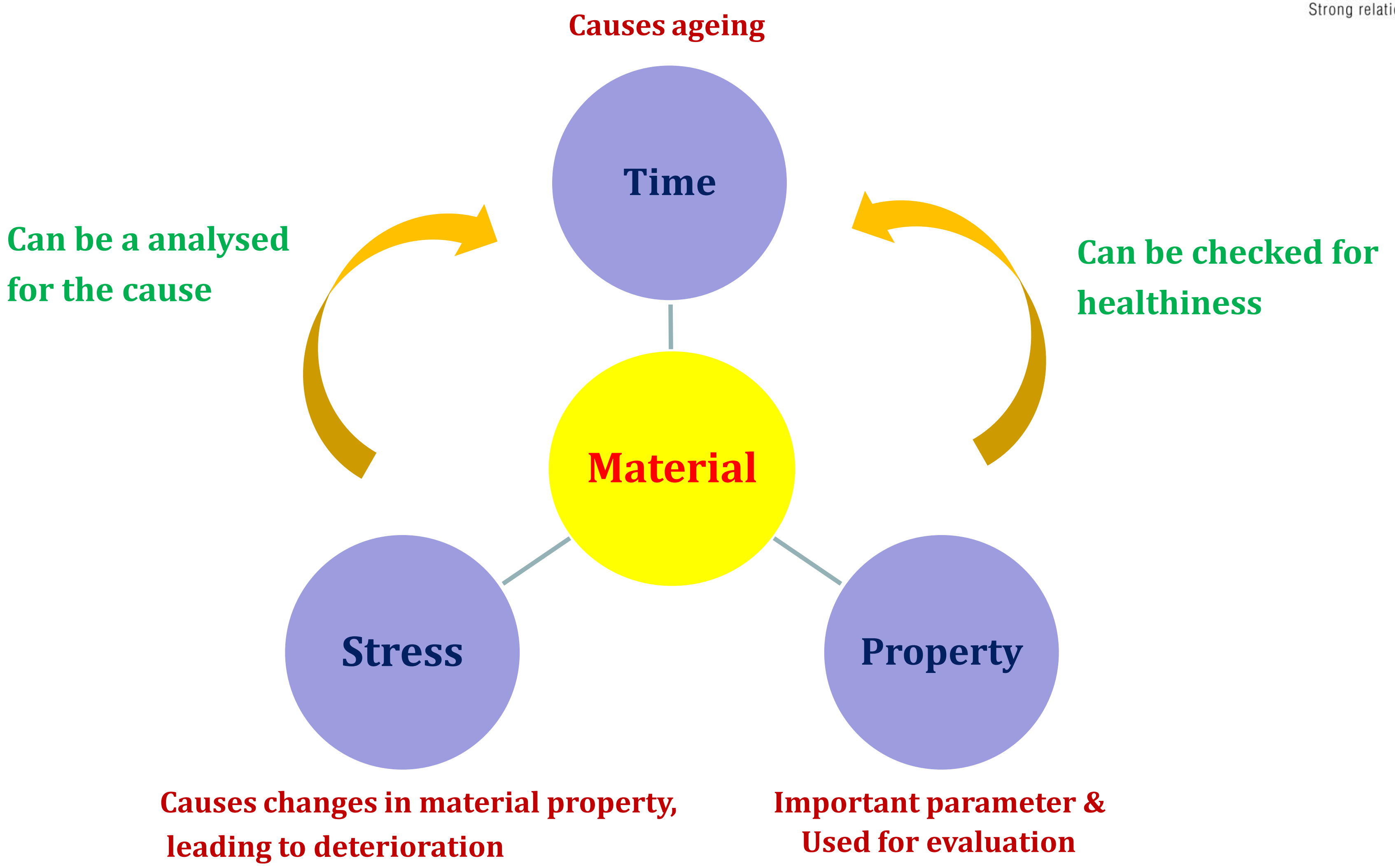
➢ Degradation

Any ***temporary*** reduction of property which disappears with the removal of the influencing factor/ stress (eg - Pollution)

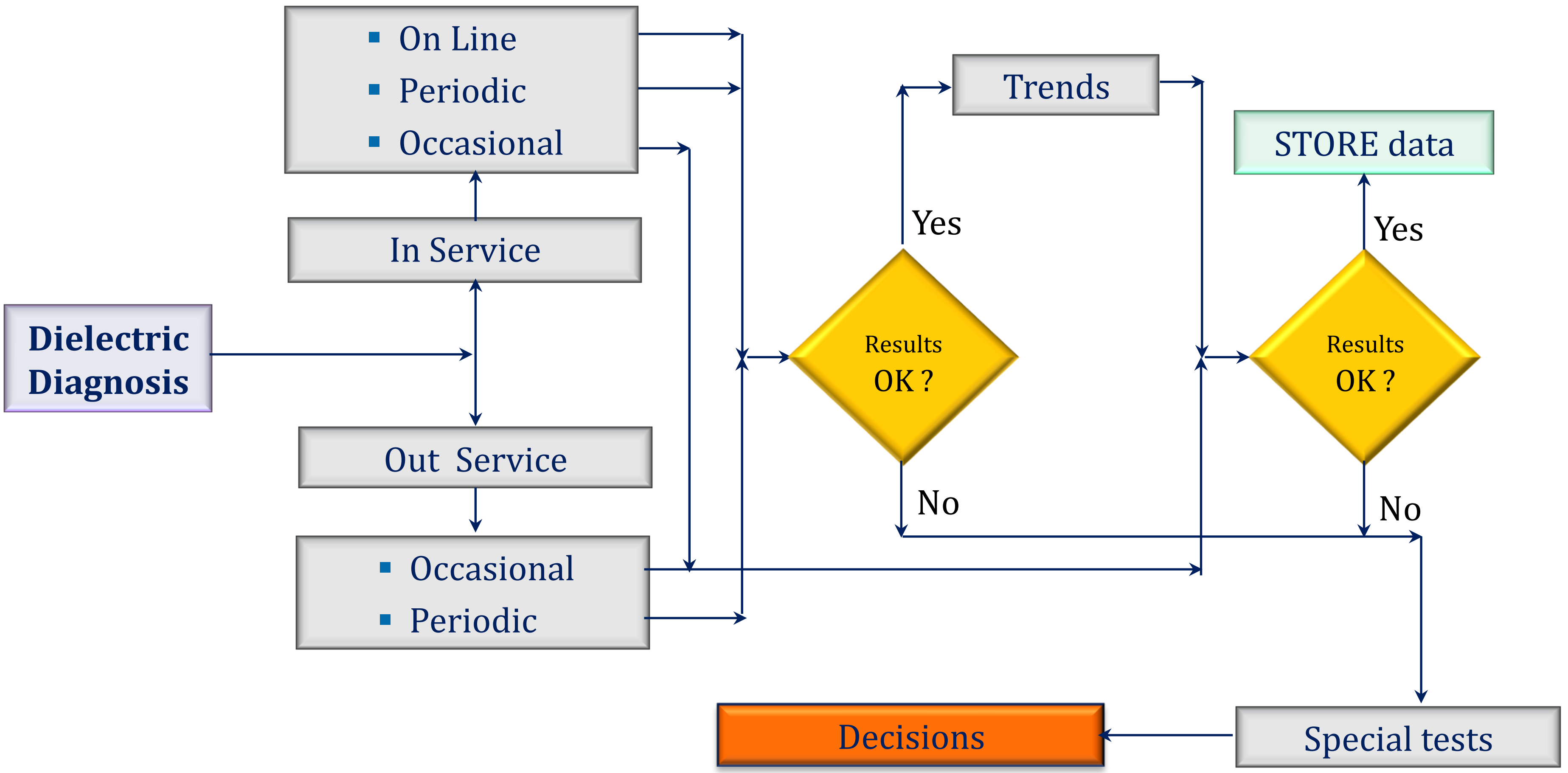
➢ Deterioration

Any ***permanent*** reduction of property (physical / Chemical) by the application of the influencing factor /stress during that time (eg - tracking)

3 Dimensional Analysis



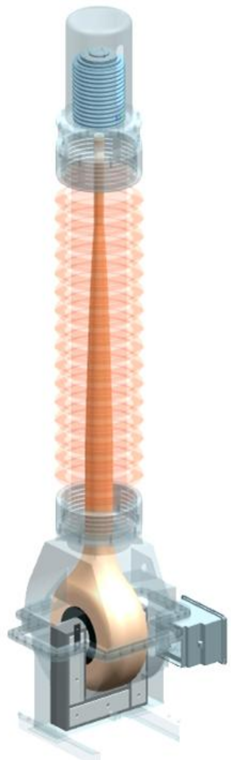
Condition Monitoring Process



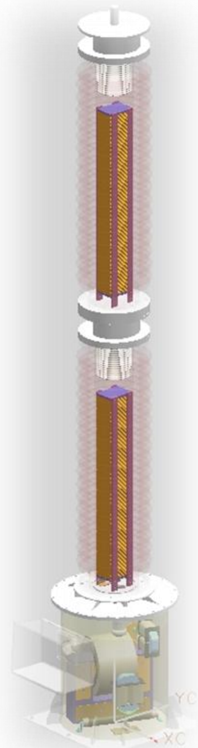
Condition Monitoring Techniques
for
Instrument Transformers
External Monitoring

EHV Current Transformers

CT



IVT



CVT

Primary Cause of failure

Majority of the failures of High Voltage Instrument Transformers are due to deterioration / failure of HV insulation

(Causes could be Electrical , Thermal, Mechanical, Environmental)

Condition Monitoring of EHV ITs

		Method	CT	IVT	CVT	Online	Off line
External Monitoring (EM)	1	Physical damages	✓	✓	✓		✓
	2	Oil leakage	✓	✓	✓	✓	✓
	3	Secondary Current	✓			✓	
	4	Secondary voltage		✓	✓	✓	
	5	Thermo vision	✓	✓	✓	✓	
	6	Bellow / Oil level	✓	✓	✓	✓	✓
	7	Varistor condition			✓		✓
Insulation Monitoring (IM)	1	Insulation Resistance	✓	✓	✓		✓
	2	Cap & Tan delta	✓	✓	✓		✓
	3	Sec. Ratio test	✓	✓	✓		✓
	4	Electrical discharges	✓	✓	✓	✓	
	5	DGA	✓				✓

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EM : Check for oil _ CT

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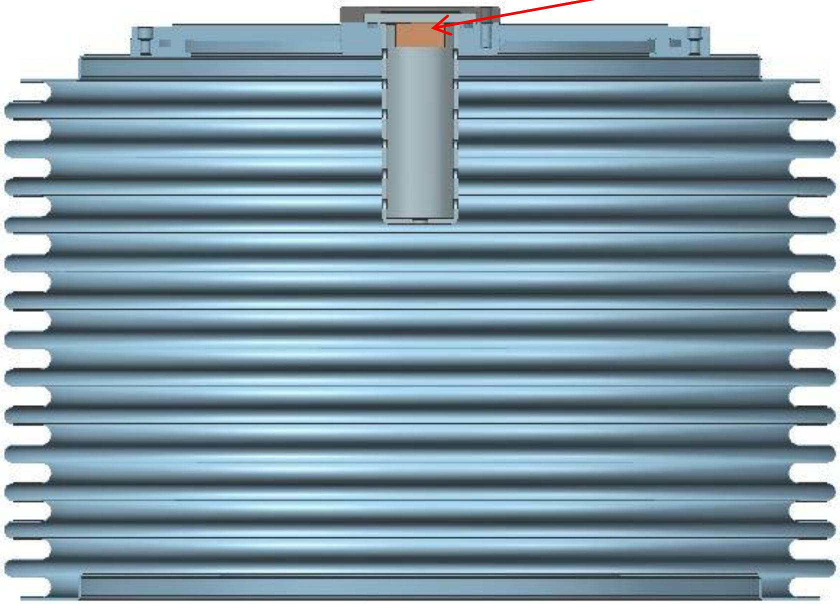
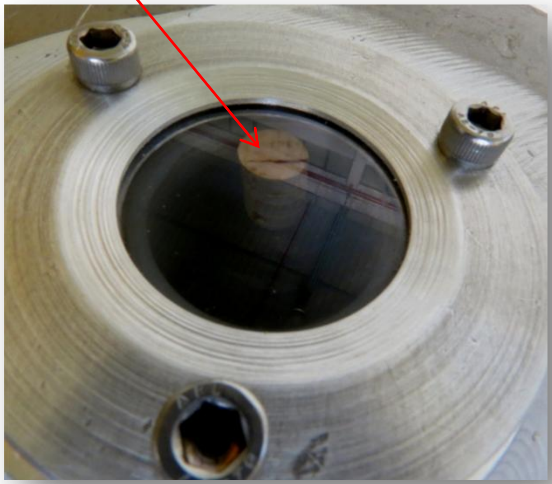
Check for oil before erection on structure or charging

- The oil should be present till the top of the bellow to function as desired

The float should be seen at the top.





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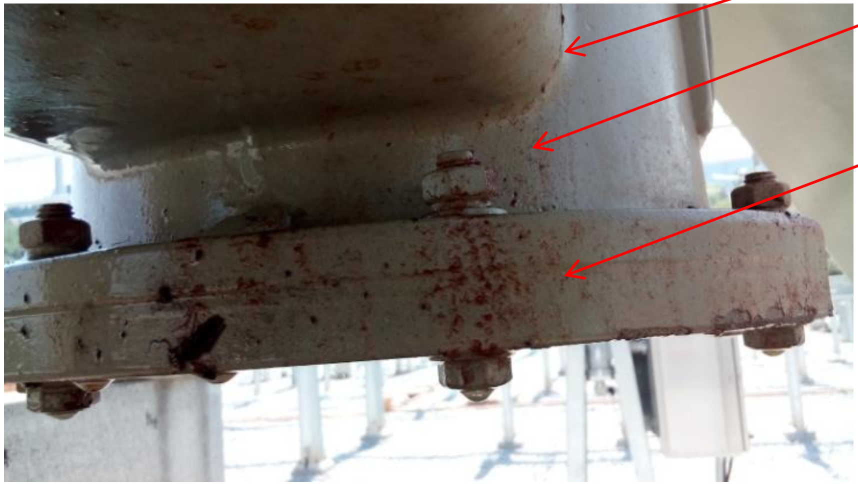
Check for oil leakage during service

- The oil leakage needs to be checked periodically



- at the welded joints (Fabrication)
- on the walls & joints (castings)
- at the sealing joints

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EM : Monitor Bellow Level

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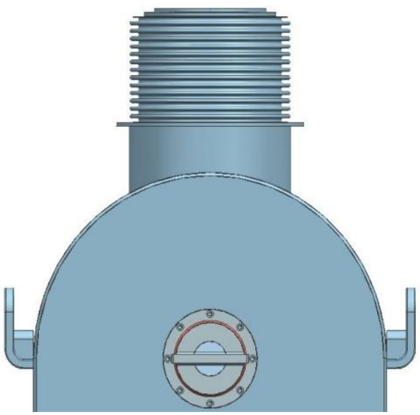
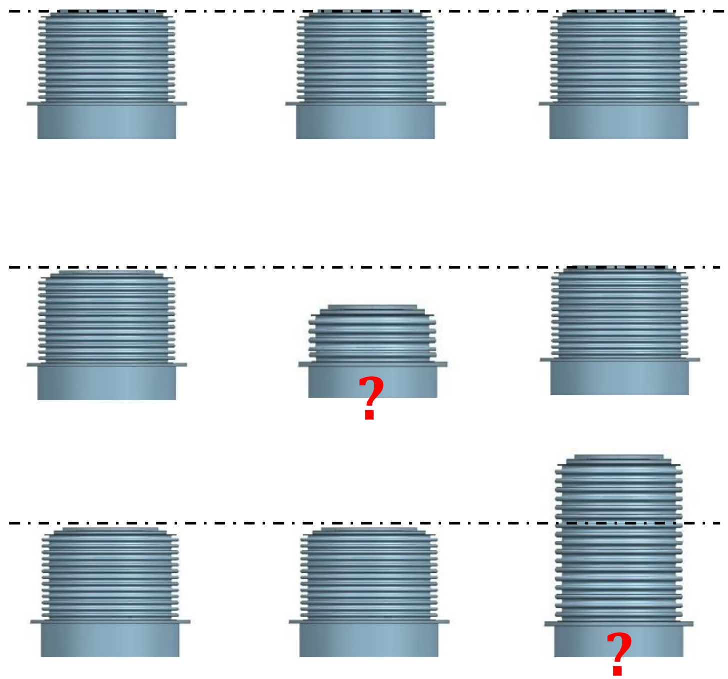
Bellow Function : CT

- Compensates for the volumetric variation in oil volume due to temp. variation
- Maintains the desired pressure within the product & enhances PD inception voltage

Keep a close watch on bellow level





Case A :

- All CTs in the same bay have same bellow level at any time
- **Conclusion :**
  - **Everything is normal**

Case B :

- Bellow level is lower than others in same bay & Not varying with temp.
- **Conclusion :**
  - **May be leaking**

Case C :

- Bellow level is higher than others in same bay
- **Conclusion :**
  - **Gassing & Faulty**

EM : Bellow Level Monitoring

Smart solutions. Strong relationships.

Bellow Function : CVT

- Compensates for the volumetric variation in oil volume due to temp. variation
- Maintains the desired pressure within the product & enhances PD inception voltage

Case A :

- All CVTs' Capacitor units & EMU units in the same bay have same oil level indication at any time
- **Conclusion :**
  - **Everything is normal**

Case B :

- A Capacitor unit's indication is abnormally either lower or higher than others.
- **Conclusion :**
  - **Lower …… Leaking**
  - **Higher ……. Gassing**

Case C :

- A Capacitor unit's (on EMU) indication is lower & EMU unit's indication is higher than others.
- **Conclusion :**
  - **CC unit Leaking**

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EM : Off service Varistor Monitoring

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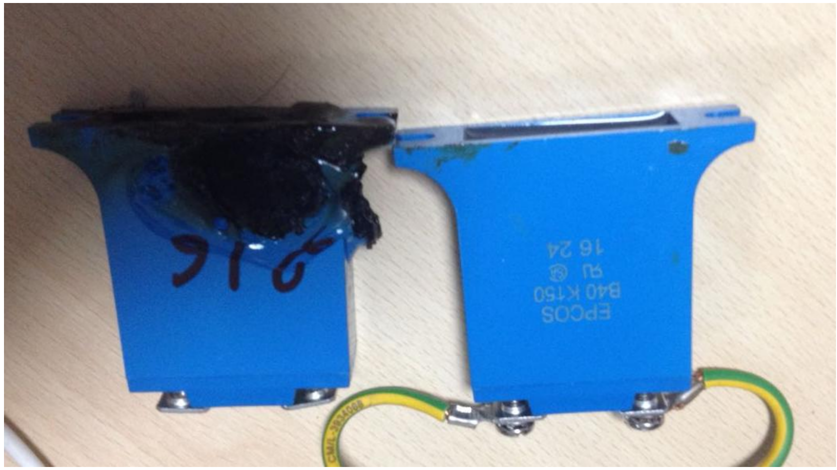
Varistor condition : CVT

- Varistors protect the CVT from over voltage due to Ferro-resonance (FR) oscillations
- They may fail in service if FR is sustained or the energy to be discharged is beyond its designed capacity
- Simple visual check will ensure the healthiness



Damaged mode A :

- If the varistor damage results into open circuit then the CVT is not protected against over voltages during next system disturbance

Damaged mode B :

- If the varistor damage results into short circuit then the CVT secondary will draw sustained heavy current , which will either damage the varistor further or the EMU coil itself

- ***Both the conditions needs attention and needs replacement immediately***
- ***A varistor can not be replaced by any varistor, as sec. voltage is tuned to a varistor. Hence the same voltage rating (marked on the varistor) needs to be ensured during replacement***

EM : Secondary output checks

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Monitoring of output : CT, CVT, IVT

- Any improper change or no output from the secondary windings is an indication of evolving defect inside the product
  - In CTs ……………..…. The secondary current
  - In CVTs / IVTs …… The secondary Voltage

Note :

- **No output can mean disconnection of secondary circuit**
  - More dangerous in CTs. The line should be shut down immediately
  - In VTs, it could be due to tripping of MCB, which needs to be analyzed before charging again

- The sec. output : **1 unit** : Monitor for changes against the rated value
- The sec. output : **3 unit** : Monitor for difference by comparison (same bay)

In CVTs,

- the secondary output is also linked to the healthiness of the capacitor unit.
- any abnormal increase or decrease over 5 % of rated value needs immediate attention and to be removed from line for investigation

- **Any abnormality needs to be correlated & confirmed through other tests too**

Condition Monitoring Techniques

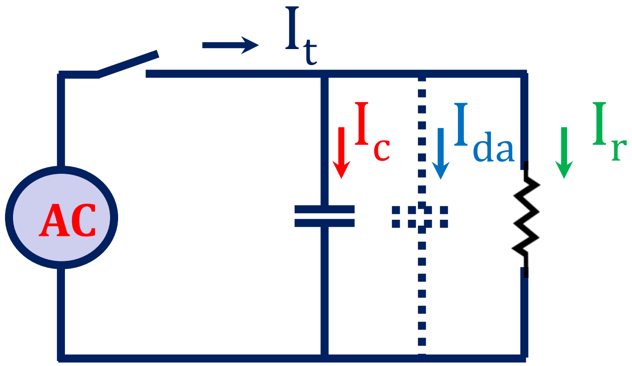
Insulation Monitoring (IM)

Insulation Resistance (IR) :

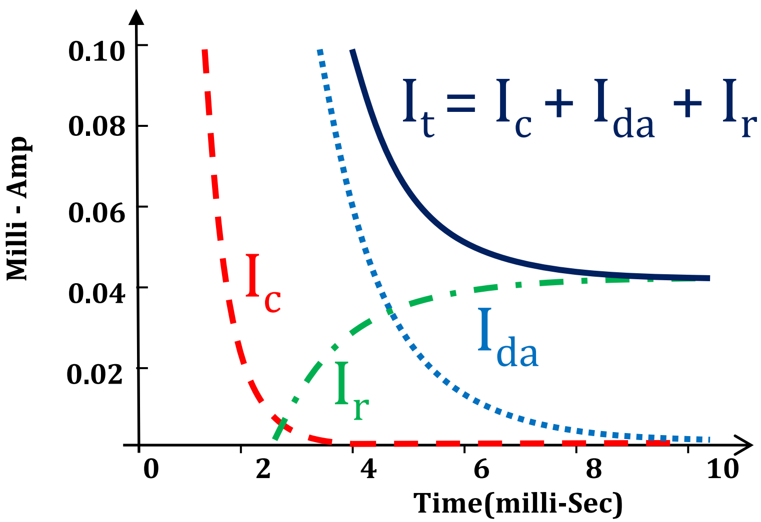
- Oldest and simplest & quick check method & No absolute value to decide the healthiness
- Usually for a good insulation it is > Mohm
- Can be used effectively through comparison method

Insulation Model :

- The behavior under DC (IR) with 'time' is used as Polarization Index



- *where,*
  - Ic = capacitive current
  - Ida = dielectric absorption current
  - Ir = loss current



IM : Insulation Resistance (IR)

Insulation quality thro Polarization Index (PI) :

- The time taken for Ic and Ida to disappear is quite long , specially for large size insulations
- To measure the insulation quality in a short period, PI is used

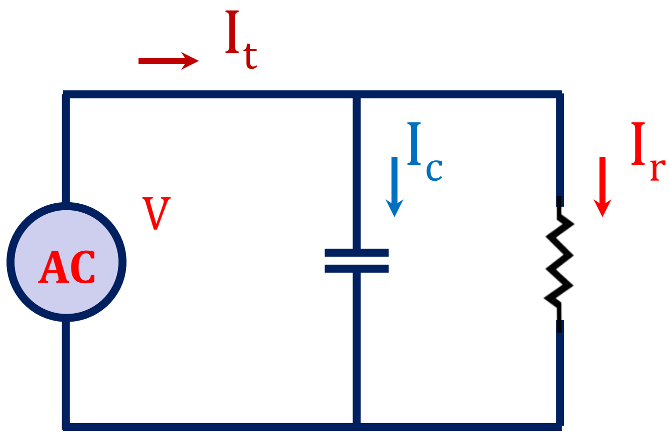
<table>
<tr><th>Step</th><th>Description</th><th colspan="2">Comments</th></tr>
<tr><td>1</td><td>Apply the DC voltage</td><td colspan="2">Usually applied with a Ohmmeter or high potential test set</td></tr>
<tr><td>2</td><td>Wait for 1 minute for the Ic and Ida to decay. Read & record the insulation resistance (R_1)</td><td colspan="2">If using a high voltage test set, monitor current closely for indications of insulation failure</td></tr>
<tr><td>3</td><td>Wait for 9 additional minutes and Read & record the insulation resistance (R_{10})</td><td colspan="2">If using a high voltage test set, monitor current closely for indications of insulation failure</td></tr>
<tr><td rowspan="6">4</td><td rowspan="6">Calculate the Polarization Index</td><td colspan="2">$PI = R_{10} / R_1$</td></tr>
<tr><td>< 1</td><td>Dangerous</td></tr>
<tr><td>< 2</td><td>Poor</td></tr>
<tr><td>3 - 4</td><td>Good</td></tr>
<tr><td>4</td><td>Excellent</td></tr>
<tr><td>> 5</td><td>Insulation may be dry & brittle</td></tr>
</table>

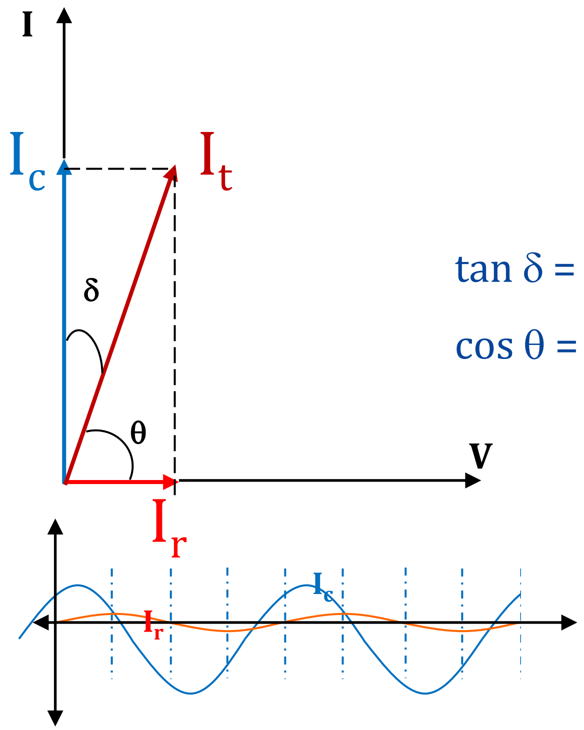
IM : Capacitance & tan D measurements

Smart solutions. Strong relationships.

Insulation behavior under AC :

- A dielectric can be modeled as a capacitor in parallel with a resistor for AC behavior





$\tan\delta = Ir/I_c = 1/\omega CR$

$\cos\theta = I_r/I_t$

- ***For a good dielectric***
  - Ic > 100 * Ir
  - Ic lead Ir and very close to 90 deg.

- ***For a marginally good dielectric***
  - Ic > 50 * Ir
  - Ic lead Ir and < 80 deg.

IM : Capacitance & tan D values

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Value of Capacitance and tan D for condition monitoring purpose

	Depends on	Capacitance	Tan D	Used for CM	Remarks
1	**Dielectric Material**	Yes (OIP)	Yes (quality of material & mfging)	Yes	*Increase in values*
2	**Product Configuration**	Yes	No	No	*Atmosphere & polluted surface influence tan D*
3	**Frequency**	Variation nil in moderate range	Dependent, Variation low in moderate range	No (Can be)	*Usually at 50/60 Hz*
4	**Test Voltage**	No	Limited Variation in operating range	No	▪ *at Vrat in Lab* ▪ *at 10 kV at site*
5	**Temperature**	No	Limited Variation in operating range	No	*Some use correction factors*
6	**Service duration (yrs)**	No	Yes	Yes	*Rate of change is used*
7	**Absolute Value**	Fixed for a particular kV & design	Depends on type of dielectric material	Yes	*Both cases*

IM : Capacitance & tan D measurements

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Condition Monitoring : OIP Products

Influencing parameter	Capacitance	Tan D
Temp.	▪ For a moderate difference in temp. range there will not be any change in the value	• For a moderate difference in temp. range there will not be any change in the value • In CGL ITs, no correction needs to be applied
Service duration (yrs)	• If there is no defect, the value will not change appreciably. Minor change could be due to normal ageing	• If there is no defect, the value will not change appreciably. . Minor change could be due to normal ageing
Absolute Value	▪ Absolute value is not a criteria for defect ▪ Any increase in value indicates a problem. Needs evaluation in association with tan d	▪ Absolute value should be as close to lab value (new) ▪ Absolute limiting value = 0.7 % ▪ Absolute value should not increase by 0.1 % in one year

- During commissioning ;
  - Measure C and tan D & keep it as ref. value for future references
  - Usually C value will not change, as the product is not charged yet
  - tan D could increase if there was any transit damage, moisture increase etc.

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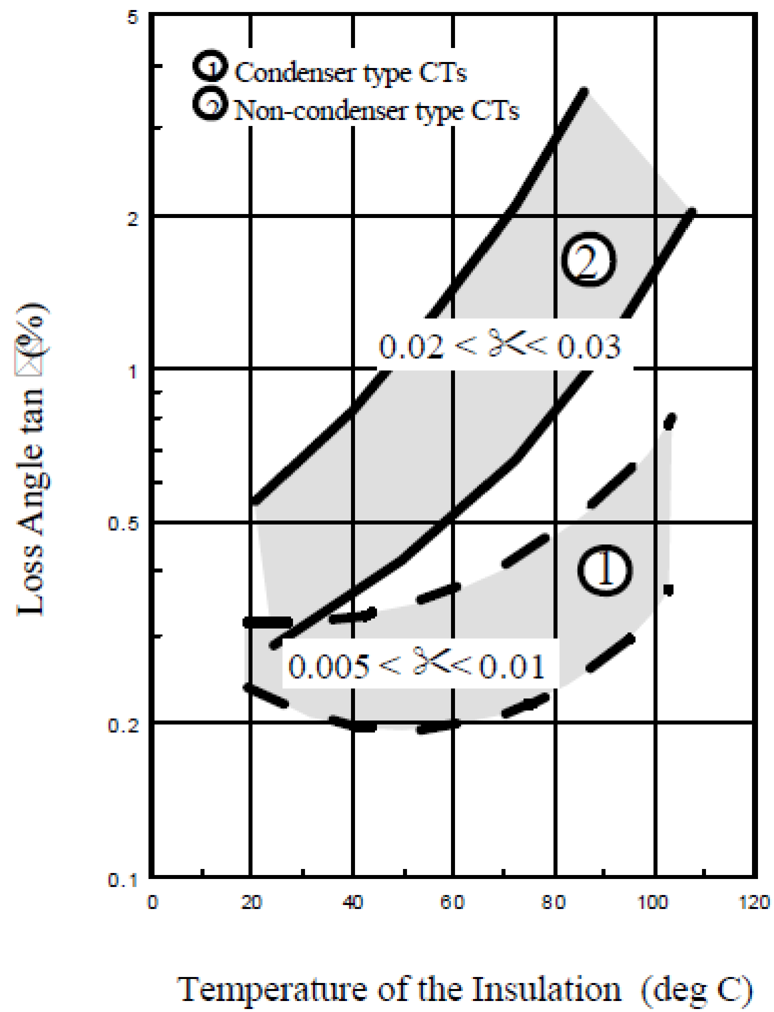
Few comments on tan D (OIP) :

- Test has to be conducted in a dry weather and dust free atmosphere and with clean external insulation
- New ITs (max) …. < 0.4 % (usually)
- While the Cap & tan D measurement in CT & IVT straight forward, in CVTs, due to interconnected EMU components, it can not be measured directly.
- Avoid testing during rainy or moist whether
- Keep a record of temp. at the time of testing
- However, if the delta change is constant for all new products at the same site the it is error in the test equipment. Record it as a remark.



Dissolved Gas Analysis

Different service conditions generate different gases in the product and they get dissolved in the oil …

Examination of that gases

extracted from oil

to retrieve information

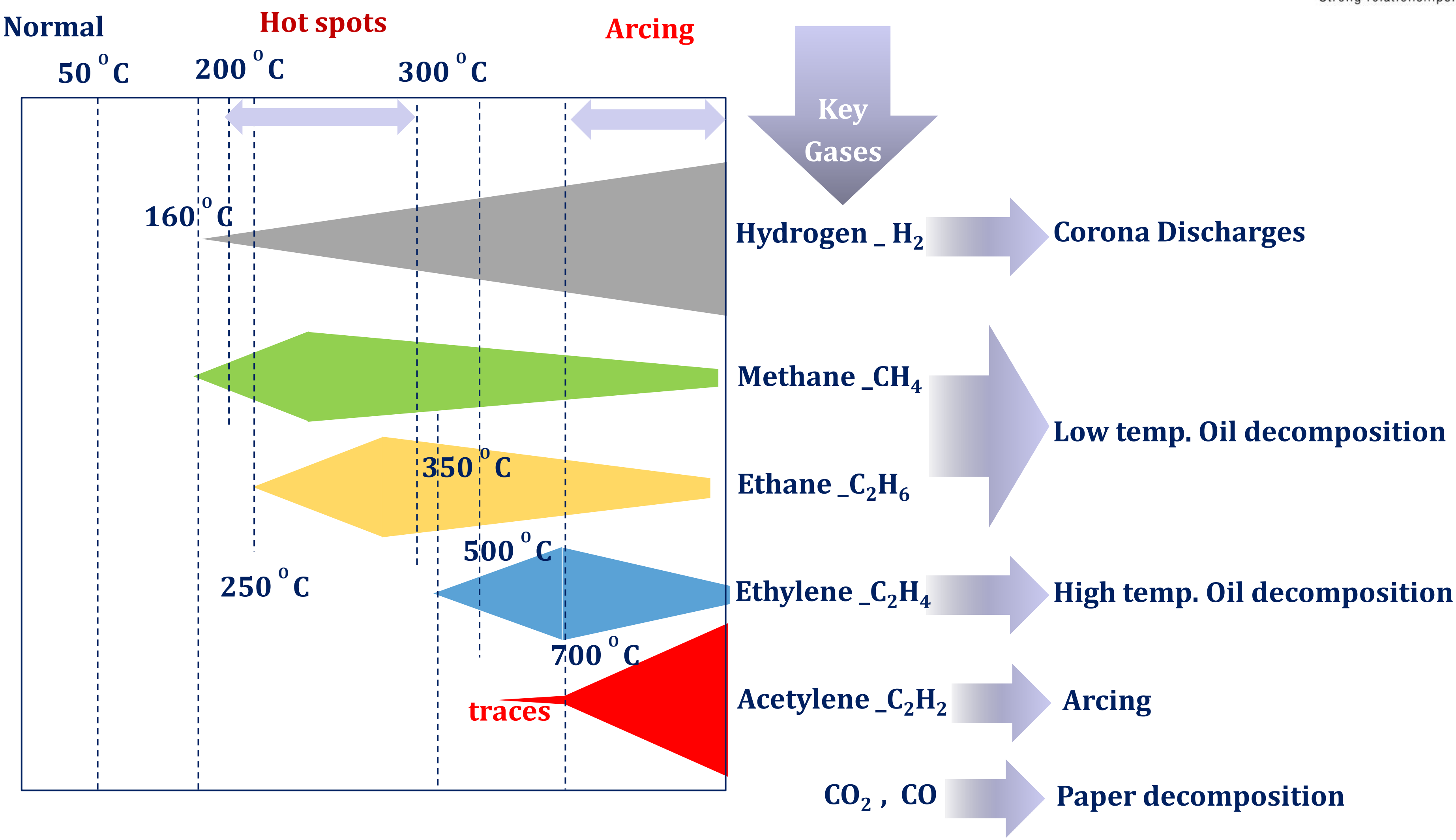
about the health of the equipment

is known as

DGA

(Dissolved Gas Analysis)

Gas Generation & Key gases



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EHV Instrument Transformers

- Unlike Power Transformers, EHV ITs are hermetically sealed products and with low qty of oil within. Hence separate oil testing should be considered only if absolutely necessary

Caution :

- Oil (500 ml) can be taken out from only CT, IVT or EMU
- No oil should be taken out from CC units
- Oil should be taken out with proper instrumentations

- **DGA in ITs to be done only if necessary as a confirmatory test, when normal monitoring tests indicate a problem**

Key Gases … Instrument Transformers

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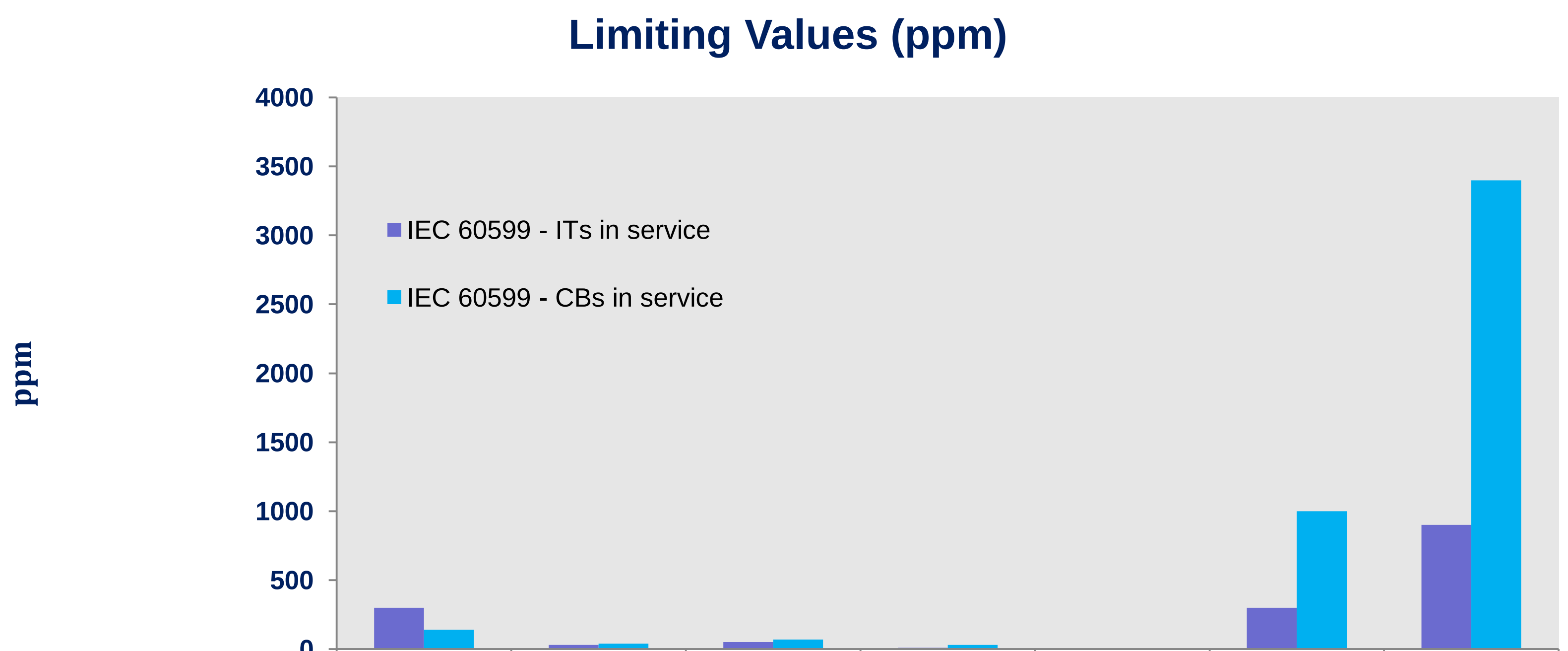
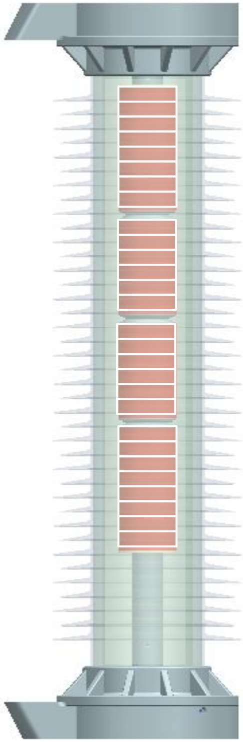
Typical limiting values for CTs : IEC 60599

- These values are for hermetically sealed HEALTHY ITs
- **Typical values for a particular network. Networks need to establish their own limits**



	H2	CH4	C2H6	C2H4	C2H2	CO	CO2
IEC 60599 - ITs in service	300	30	50	10	2	300	900
IEC 60599 - CBs in service	140	40	70	30	2	1000	3400

Condition Monitoring Techniques
for
Surge Arresters



LA

Primary Cause of failure

Majority of the failures of High Voltage Surge Arresters are due to deterioration of ZnO blocks or degradation due to moisture or thermal runaway of SA

(Causes could be Electrical , Thermal, Mechanical, Environmental)

Energy Handling Capability

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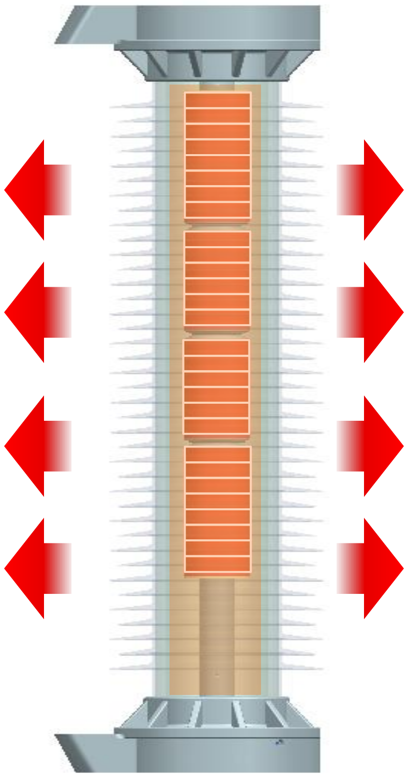
In simple terms…..

Total Energy	=	Diverted	+	Absorbed	+	Passed On
(input at the terminal)		(no worry)		(Hot ZnO blocks)		(to be withstood)



- **ZnO Block integrity (thermal)**
  - The block has to withstand the impulse energy without failing (puncture or crack)
- **Thermal Stability (entire product)**
  - The heat generated within the body of the LA has to be dissipated to the surrounding. Otherwise thermal runaway of the block can happen which will lead to failure of the block.

ZnO Block integrity (thermal)

The block has to withstand the impulse energy without failing .

- Cracking : due to huge thermal stresses
- Puncture : due to Current concentration

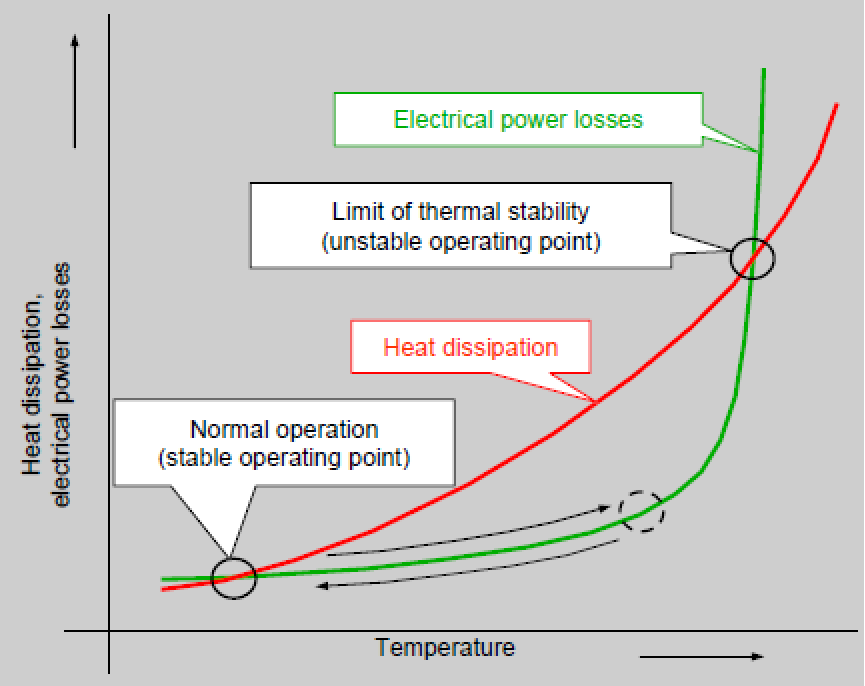
- Known as **Energy Absorption Capability**
- It is the energy in joules (current density, or amp seconds) and duration of energy injection, required to damage an arrester permanently. The damage can be at a macroscopic level or a microscopic level.

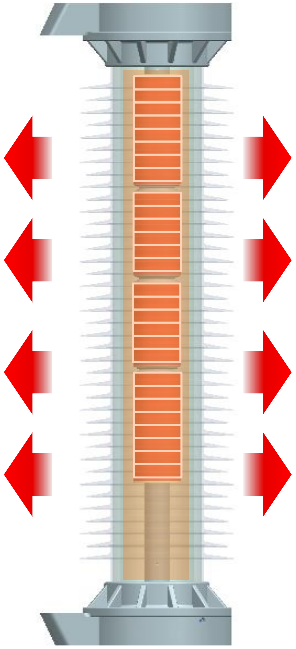
Thermal Stability Management

Thermal Stability (entire product)

- The heat generated within the body of the LA has to be dissipated to the surrounding. Otherwise thermal runaway of the block can happen which will lead to failure of the block.
  - Thermal runaway is related to Voltage and Current instability

- Known as **Thermal Energy Absorption Capability**





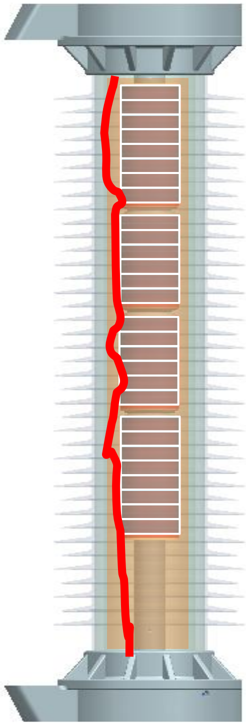
Internal flashover

Surface Flashover (entire product)

- The primary reasons are
  - Moisture entry into the product
  - Highly polluted external surface

- Due to the above reasons the external coating over the block could track and short circuit elements
- Then the remaining good elements can not withstand the stress and fail, leading to complete product failure

- The PD between the highly polluted external surface and internally good elements can result into the same failure mode



- **Internal arc along the full length of the unit**

Condition Monitoring of SAs

		Test	Off-line	Online
External Monitoring (EM)	1	Physical damage		
	2	Thermo vision		
	3	Surge Counter total leakage current		
	4	Total surge counts		
Internal Monitoring (IM)	1	Total Resistive leakage current measurement (LCM)		
	2	Third harmonic resistive leakage current measurement (LCM)		
	3	Real time total leakage current measurement through digital Surge Counter		
	4	Real time resistive leakage current measurement through digital Surge Counter		
	5	Real time total surge counts and with magnitude through digital Surge Counter		

EM : Physical Check _ LA

PRD condition : LA

- Pressure relief diaphragm ruptures when the internal pressure exceeds due to SA failure
- Any damage to this thin & sensitive material while handling & erecting will result into moisture entry into Arrester, which will lead to SA failure.

Pressure relief diaphragm

- If SA is kept on a uneven surface , it is likely to damage this PR diaphragm

- Check the condition before erecting the Arrester unit
- Ensure no damage during erection

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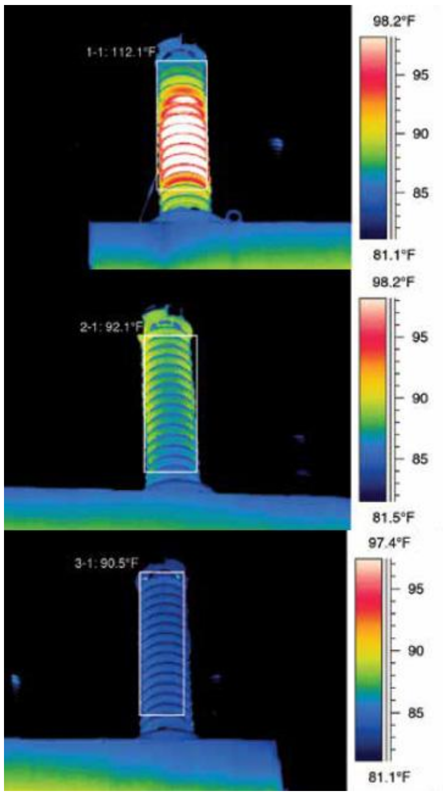
Abnormal Heating : LA

- Thermal scanning is another simple on-line check to locate any defect
- Most often used on LAs to locate improper/defective terminations/excessive watt loss



Note :

- Most effective check than leakage current monitoring

IM : Surge History & Block Characteristic _ LA

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Surge Count & Leakage Current : LA

- Currently the method of monitoring is :

A : Surge Counter :

- Most primitive type of indication
- It just indicates the no. of times the SA operated
- If the SA failed, without even any conduction, it can point towards some conclusions, like moisture ingress & PD

B : Leakage Current :

- It indicates the total leakage current
- If there is any degradation in the ZnO blocks, for any reason, can indicate the integrity of the blocks
- It is still a primitive type of health monitoring

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IM : Leakage Current measurement _ LA

Properties of Online leakage current measurement methods as per IEC: 60099-5

Leakage Current measurement Method		Sensitivity to: Harmonics in the voltage	Sensitivity to: Phase shift in measurement of voltage or current	Sensitivity to: Surface Current	Diagnostic Efficiency: Information quality	Diagnostic Efficiency: Handling complexity	Service Experience
Separate d.c voltage source		n.a	n.a	high	high	high	limited
Service voltage or separate a.c voltage source							
Measurement of total leakage current		**low**	**low**	**mean**	**low**	**low**	**extensive**
Measurement of resistive current	using voltage reference	mean	high	high	mean	high	limited
	using capacitor compensation	mean	high	high	mean	high	limited
	using synthetic compensation	mean	high	high	mean	low	-
	using capacitive current cancellation	high	high	high	low	low	limited
Harmonic Analysis of leakage current	using third harmonic	high	low	low	mean	low	extensive
	using third harmonic with compensation	low	low	low	high	mean	limited
	using first harmonic	low	high	high	mean	high	limited
Measurement of power loss		low	high	high	mean	high	-

Condition Monitoring Summary

Summary : CTs

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	Test	Pre-Commissioning	After 1 month in service	After 1 Year in service	After 5 Year in service	Remarks
	Current Transformers					
1	Bellow Position	√	√	√	√	Can be weekly
2	Oil leakages	√	√	√	√	Can be Monthly
3	Capacitance & tan D	√	√	√	√	
4	Insulation resistance	√		√	√	
5	Transformation Ratio	√			√	Earlier if needed
6	Tightness of Primary Terminal	√	√	√	√	
7	Thermal scanning		√	√	√	Can be Monthly
8	Dissolved Gas Analysis					Only if suspected

Pl refer CGL Document : S1/IT/T/001

Summary : IVTs

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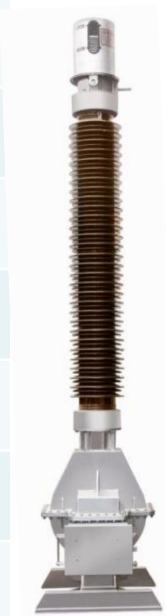
	Test	Pre-Commissioning	After 1 month in service	After 1 Year in service	After 5 Year in service	Remarks
	Inductive Voltage Transformers					
1	Bellow Position	√	√	√	√	Can be weekly
2	Oil leakages	√	√	√	√	Can be Monthly
3	Capacitance & tan D	√	√	√	√	
4	Insulation resistance	√		√	√	
5	Transformation Ratio	√			√	Earlier if needed
6	Tightness of Primary Terminal	√	√	√	√	
7	Thermal scanning		√	√	√	Can be Monthly



Pl refer CGL Document : S1/IT/T/001

Summary : CVTs

	Test	Pre-Commissioning	After 1 month in service	After 1 Year in service	After 5 Year in service	Remarks
	Capacitive Voltage Transformers					
1	Oil level in CC & EMU	√	√	√	√	Can be weekly
2	Oil leakages (CC & EMU)	√	√	√	√	Can be Monthly
3	Capacitance & tan D	√	√	√	√	
4	Insulation resistance	√	√	√	√	
5	Transformation Ratio	√			√	Earlier if needed
6	Condition of Varistor	√	√	√	√	
7	Tightness of Primary Terminal	√	√	√	√	
8	Thermal Scanning					Can be Monthly

Pl refer CGL Document : S1/IT/T/001

Summary : SAs

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	Test	Pre-Commissioning	After 1 month in service	After 1 Year in service	After 5 Year in service	Remarks
	Lightning Arrester					
1	Insulation resistance measurement	√	-	√	√	5 kV - DC
2	Total Leakage Current (mA)	-	√	√	√	Can be Monthly
3	Total surge Count (number)	√	√	√	√	Can be Monthly
4	Total Resistive leakage current	-	√	√	√	Can be Monthly / Quarterly
5	Third Harmonic resistive current measurement (THRC)	-	√	√	√	Can be Monthly / Quarterly

Note: Trend of leakage current should be monitored for health assessment

Factors
for enhanced reliability

CIGRÉ WORKING GROUP 12.16 … ITs

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Primary Cause of failure	Failures in first 3 years of service	Failures in first 10 years of service	Failures between 11 to 30 years of service	Failures after 30 years of service
	(Total 445 of 2636 = 17 %)	(Total 1242 = 17 %)	(Total 1130 = 43 %)	(Total 264 = 10 %)
	%	%	%	%
Design Fault	67.0	67.9	56.1	43.6
Inadequate Quality at Manufacture	7.2	7.7	18.0	25.6
Ageing	0.0	0.3	5.0	8.3
Lightning	2.7	2.3	1.6	0.8
Operation outside Specification	2.5	3.9	5.6	9.8
Inadequate maintenance	0.4	0.6	1.5	0.0
Unknown	20.2	17.2	14.1	11.7

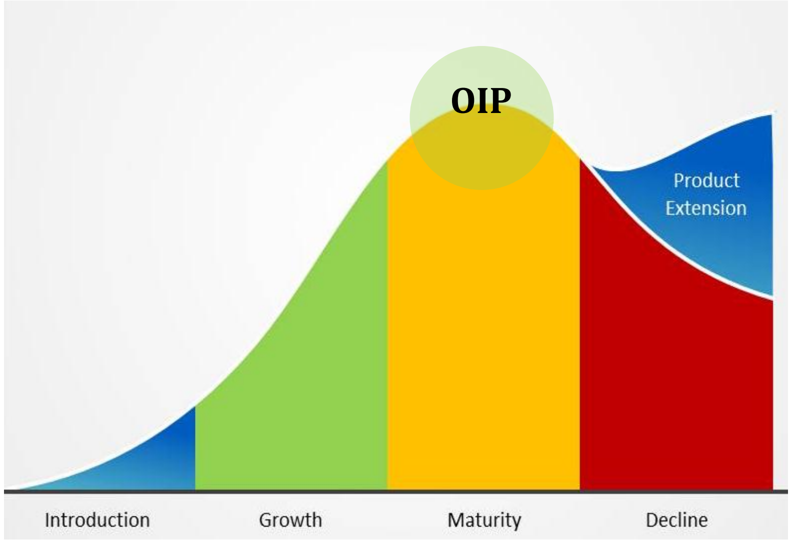
CIGRÉ WORKING GROUP 12.16 … ITs

Smart solutions. Strong relationships.

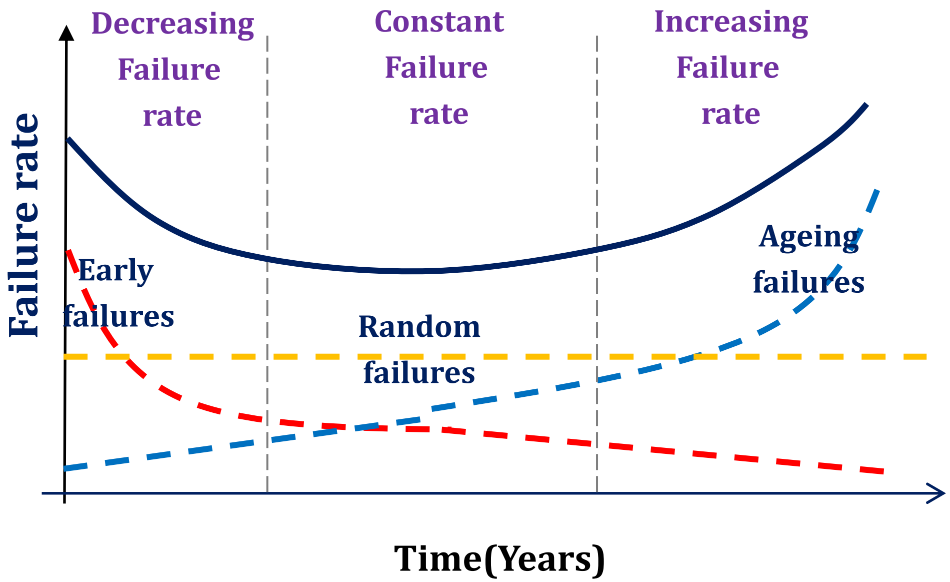
Primary Cause of failure	Major Failure (Total 460)	Minor Failure (Total 415)	Defects (Total 2129)	All Defects and Failures (Total 3004)
Design Fault	%	%	%	%
Electrical	40.0	15.9	12.2	17.0
Mechanical	2.0	10.5	11.1	9.6
Material	0.2	2.5	7.0	5.3
Oil Leaks	0.0	15.0	35.2	27.0
Total	**42.2**	**43.9**	**65.5**	**58.9**
Inadequate Quality at Manufacture	%	%	%	%
General Quality	4.3	1.4	1.3	1.8
Moisture Ingress	3.3	0.5	1.8	1.9
Oil Leaks	5.7	8.9	6.3	6.5
Gas Leaks	0.0	0.0	0.8	0.6
Corrosion	0.0	0.3	3.6	2.5
Total	**13.3**	**11.1**	**13.8**	**13.3**
Others	%	%	%	%
Ageing	9.6	12.3	2.8	5.1
Lightning	12.0	2.4	0.3	2.4
Operation outside Specification	5.7	14.7	4.0	5.7
Inadequate maintenance	0.4	0.7	1.0	0.9
Unknown	**17.0**	**14.7**	**12.6**	**13.6**

Reliability of Products

Product / Technology
Life Cycle Curve

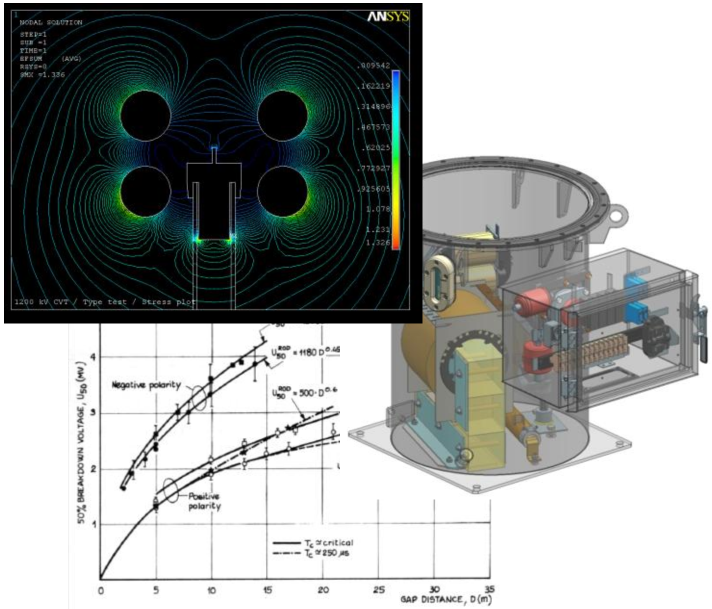


New Product / Technology failure
Bathtub Curve



- **Oil Impregnated Paper (OIP) insulated ITs is a matured technology**
- **Any failure needs to be analyzed with respect to manufacturer / design adequacy / manufacturing practices / site conditions / age of the product**

Factors that affect reliability of products

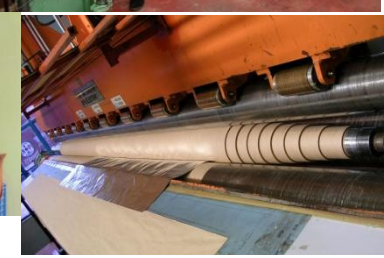


➢ Inadequate Product knowledge

- Oil impregnated Paper (OIP) Technology
- High Voltage Insulation Design & Configuration
- Design features to ensure insulation integrity
- Material selection & criteria
- High Voltage Testing & Evaluation

➢ Inadequate Manufacturing facility & Controls

- Processing of OIP Insulation
- Manufacturing process automation
- In-Process Control mechanisms and stage tests



Factors that affect reliability of Products

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➢ Inadequate Product Evaluations

- In-process / material testing facilities
- EHV Testing Infrastructure
- Test Data Evaluation Expertise

➢ Inadequate Quality Systems

- Defined quality systems
- Focused management control
- Periodic evaluation of adequacy & Revalidation

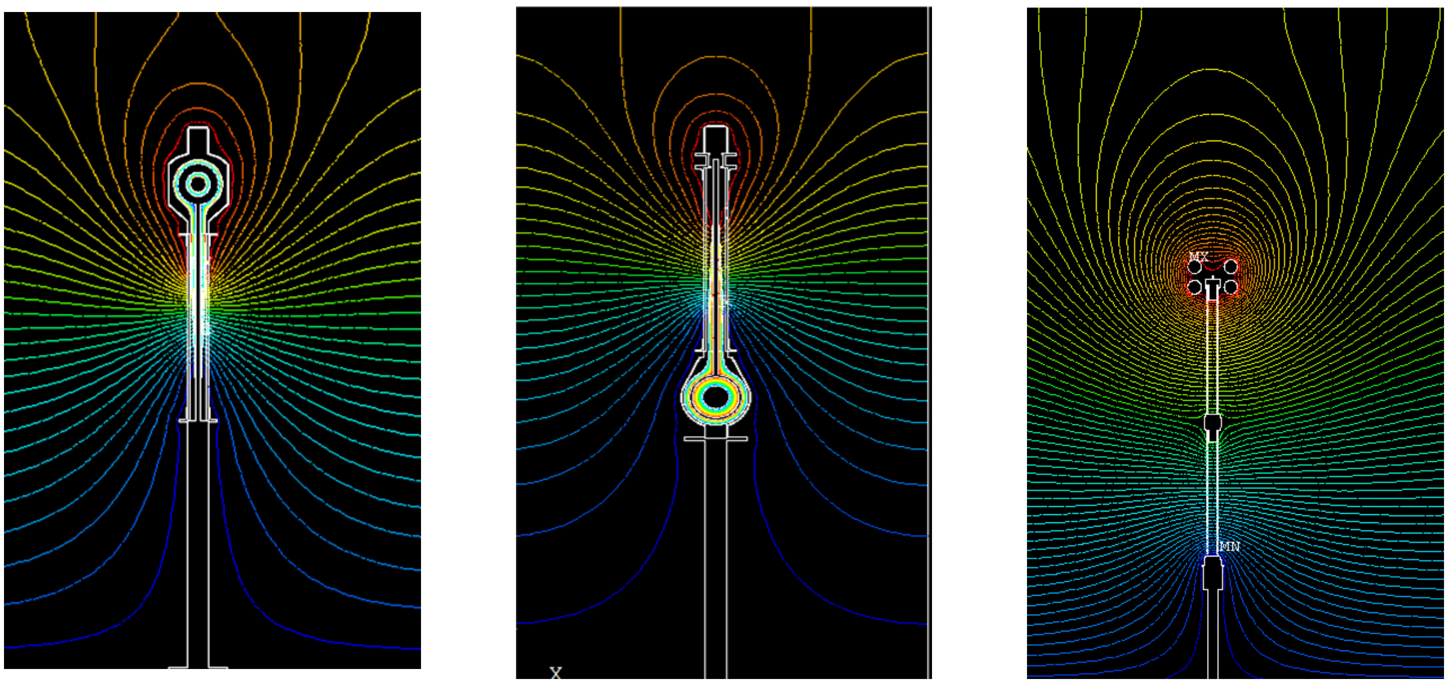
Designed in features for enhanced reliability

Instrument Transformers

Reliability : Product features

Feature : ***Fine & Uniform electrical grading***

➢ **The life of HV product is defined by the design of High Voltage insulation**



High degree of HV insulation design knowledge is required to,

- make the stress uniform & finer
- achieve higher PD inception voltage
- coordinate internal & external insulation withstandabilities

Reliability : Product features

Feature : ***Fine & Uniform electrical grading***

➢ **The life of HV product is defined by the manufacture of High Voltage insulation**

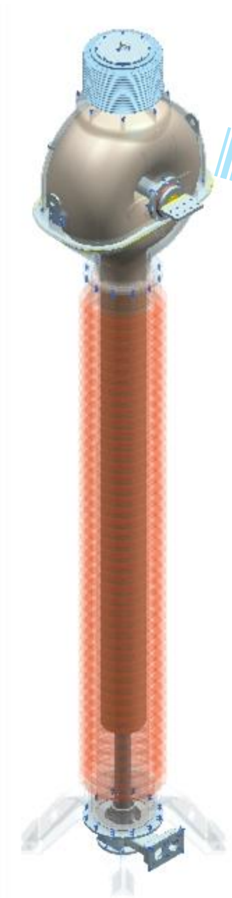
High degree sophistication is required in the manufacture of HV insulation

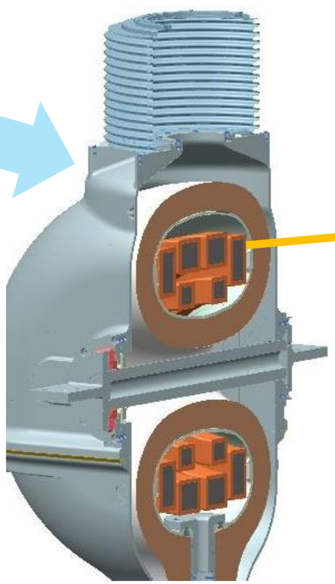
- Numerically controlled winding m/c to insert many no.of field control foils
- Manufacture of head insulation requires intricate & fine control of contours
- Clean and environmentally controlled clean rooms for insulation building

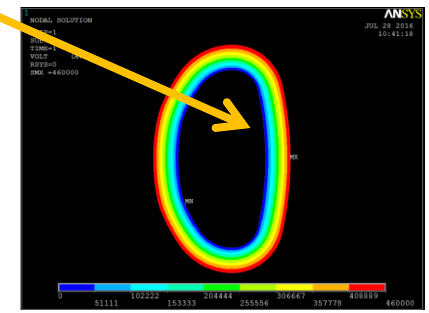
Reliability : Product features

Feature : Protection for Secondary circuits

➢ **Metallic enclosure serves dual purpose of electrode & protective cover to LV**







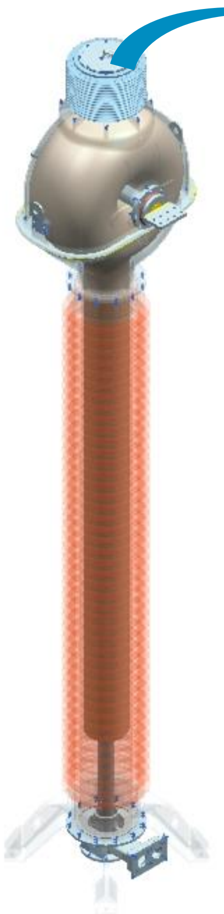
The metallic enclosure,

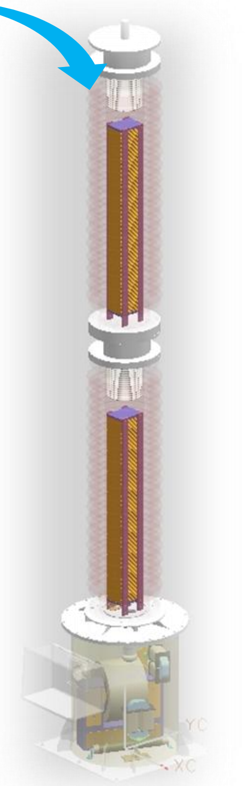
- houses the secondary cores
- provides a uniform ground electrode (uniform stress)
- ensures, the sec. circuit in case of a high voltage failure in service and diverts the fault current to ground (protection)

Reliability : Product features

Feature : ***Oil Compensation & protection against PD***

➢ **Metallic bellow enhances life**





The metallic bellow ,

- compensates the oil volume , due to temp. variation (requirement)
- keeps the product hermetically sealed (life)
- enhances higher PD inception voltage (reliability)
- being metallic, rather than gas cushion/rubber bellow , gives higher life. (CG tests bellows for 10000 cycle to ensure mechanical stability)
- is also used for visual condition monitoring (CM)

Reliability : Product features

Feature : Oil Compensation & protection against PD

➢ **Metallic bellow enhances life & Gas cushion reduces life**

- Gas pressure is depended on the product oil volume
- However, the gas gets absorbed into oil during hot temperature conditions, till oil saturates
- When the product cools down, the absorbed gas is liberated as bubbles
- If the gas volume (bubble), which is of low dielectric constant is near a high electric stress zone, they breakdown resulting into PD
- This can multiply and eventually lead to a pressure build up and ultimate failure

(most of these failures will happen at early mornings, after a hot day)

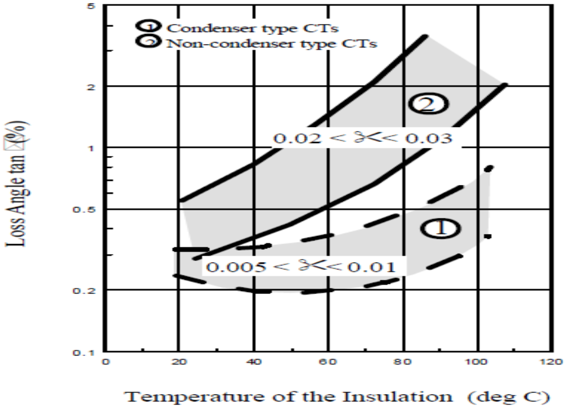
- **Since bellow is fully filled with only oil, the above phenomenon does not happen and hence the PD inception voltage is always higher & hence longer Life**

Reliability : Product features

Feature : ***Environmentally controlled processing of paper insulation***

➢ **Moisture kills the product in service**

- One of the main reasons for HV product failure is the presence of moisture
- The method used for paper processing & subsequent assembly process used, determine the start of life
- Moisture migration between paper and oil is a phenomenon that can affect insulation at service. Hence paper & oil needs careful processing before impregnation.
- **Tan Delta of < 0.35 % at Um** …. A best insulation condition for a fresh unit



- **Negligible variation in measured Tan delta, between 10 kV – Um , indicates a well processed unit**

Reliability : Product features

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Strong relationships.

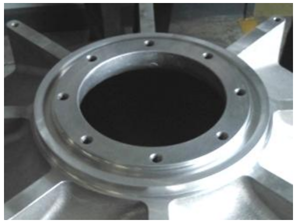
Feature : Sealing System

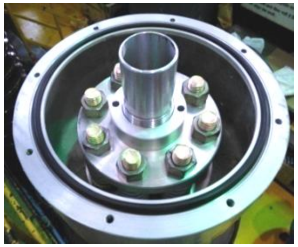
➢ **Ensuring the processed insulation's integrity enhances the life**

- One of the main reasons for HV product failure is the ingress of moisture

- Can be ensured by
  - Selection of sealing material
  - Designed O- rings & machined O ring grooves
  - Method of component leak testing (Helium leak test of critical component is necessary)
  - Method of complete product leak testing

- **Un-machined surfaces, poor sealing materials like cork gaskets, reduce the life of OIP products**





- **Selection of sealing material & design of sealing surfaces is a crucial requirement for longer life**

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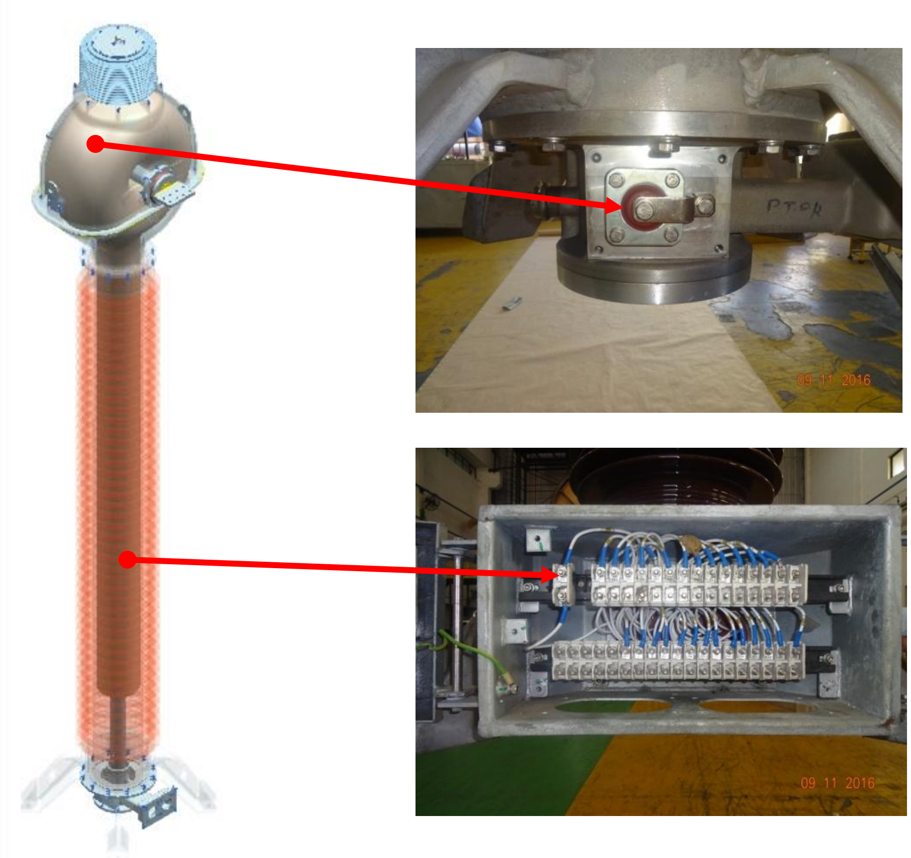
Strong relationships.

Feature : Insulation Condition Monitoring at site

➢ ***Exclusive terminals to test internal insulation's integrity***



- Exclusive **HEAD** insulation checking terminal
  (also designed to divert fault current)

- Exclusive **BUSHING** insulation checking terminal

- **No interference of external surface condition during measurements**

Reliability : Questionable !!!

Smart solutions.
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Poor Designs & practices

- Cycle valve for pressure release … Poor sealing

- Gas Cushion

- Oil sampling valve ?
- Rusted already

- Not machined sealing surface

- No enclosure for Sec circuit

- MS bolt at current carrying junction

- Bolt Projection… Poor HV design

Designed in features for enhanced reliability

Surge Arresters

Smart solutions.
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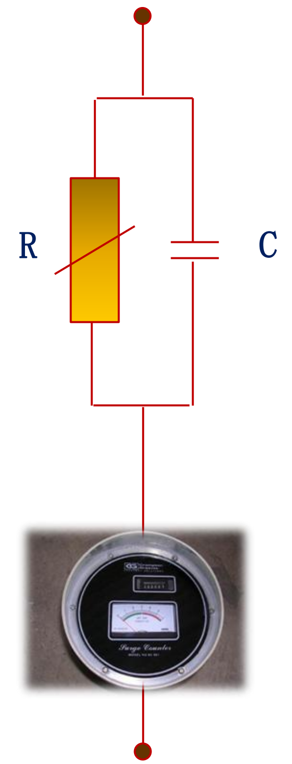
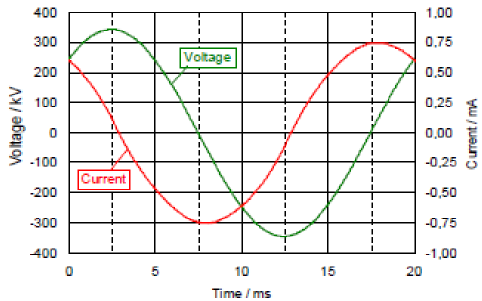
Surge Count & Leakage Current : SA

Limitation of conventional measurement of total leakage Current is ....

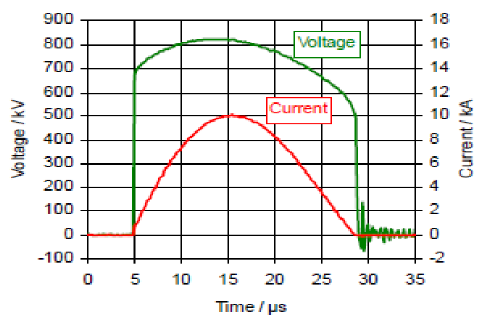
- The total leakage current does not indicate the change is characteristics signature of the SA, if there is a degradation
- The increase in the resistive current is the true measure of degradation of the ZnO blocks, in non-conducting period
- It also does not provide any information of the surge that was conducted , except for the count

Equivalent circuit





In non-conducting zone : The current is more capacitive in nature



In conduction zone : The current is resistive in nature

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Closing Comments

Reliability : Questionable !!!

Smart solutions.
Strong relationships.

Poor Designs & practices


- Cycle valve for pressure release ... Poor sealing

- Gas Cushion

- Oil sampling valve ?
- Rusted already

- Not machined sealing surface

- No enclosure for Sec circuit

- MS bolt at current carrying junction

- Bolt Projection... Poor HV design

Concluding comments

Failures & Maintenance :

- **Failure Reporting :**

: Failed / Blasted / Flashed over ... All mean different modes

: Include the location .... Line / Bus / Tranf. etc

: Include the time/ scenario .... Steady state / switched in / line fault etc

: Inform the failure to manufacturer, irrespective of product age

- **Periodic Testing :**

: Maintain the initial commissioning results

: Add on the periodic maintenance test results to that

: Apart from absolute values , observe the trends

- **Others :**

: Check the product receipt data (date)

: Use proper tools & methods during erecting the product (use manual)

: Ensure product is stored as per requirements (vertical / horizontal)

: Check the product grounding periodically

Thank you

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12.	BBMB	Director(P&C), Bhakra Beas Management Board SLDC Complex, 66 kV substation, Industrial Area, Phase-I Chandigarh-160002
13.	KPTCL	Chief Engineer (Electricity), RT and R&D,

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14.	MPPTCL	Chief Engineer (T&C), MP Power Transmission Corporation Ltd, Block No.4, Shakti Bhawan, Jabalpur-482 008 (MP)
15.	KPCL	Chief Engineer (Elecl Designs), Karnataka Power Corporation Ltd. 22/23, Sudarshan Complex, III Floor Shashadri Road, Bangalore-560001
16.	APTRANSCO	Chief Engineer (Transmission) Transmission Corporation of Andhra Pradesh Ltd. Room No. 218, B-Block, Vidyut Soudha, Khairathabad, Hyderabad- 500 082.
17.	KSEB	Chief Engineer (Trans), Kerala State Elecy. Board, Vidyut Bhavanam Gandhi Road Kozhikode- 673011
18.	GETCO	Chief Engineer(TR), Gujarat Energy Transmission Corporation Ltd., Sardar Patel Vidyut Bhavan, Race Course, Vadodara-390007
19.	HVPNL	Chief Engineer/ TS HVPNL, Shakti Bhawan, Sector-6 Panchkula- 134 109
20.	OPTCL	CGM (O&M) Janapath, Bhoi Nagar, Bhubaneswar Odisha 751022
21.	NHDC	GM (T) NHDC Limited NHDC Parisar, Shyamla Hills, Bhopal – 462013
22.	Reliance	DGM, Transmission O&M Reliance Infrastructure Limited H Block, 1st floor Dhirubhai Ambani Knowledge City Navi Mumbai 400 710