Generators & Transformers Maintenance

By

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Topics:
A. Generators, B. Power Transformers

A. Generator Maintenance is key to Diesel Generator Reliability:

- Most common periodic maintenance for Stand By Generators are provided by manufacturers.
- General inspections are generally conducted by inspecting : exhaust system, fuel system, DC electrical system, Engine, Lubrication and many other mechanical parts of the generator when running.
- For power stations / plants it is the same way, however it is more stringent complying to number of hours run per cycle and type of armature being used, etc.

A. GENERATOR TYPICAL PERIODIC MAINTENANCE PROGRAM USED

Maintenance Items	Daily	Weekly	Monthly	Yearly
Inspection	X			
Check Coolant Heater	X			
Check Coolant Level	X			
Check Fuel Level	X			
Check Charge – Air Piping	X			
Check/Clean Air Cleaner		X		
Check Battery Charger		X		
Drain Fuel Filter		X		
Drain Water From Fuel Tank		X		
Check Coolant Concentration		X		
Check Drive Belt Tension		X		
Drain Starting Batteries		X		

Maintenance Items	Daily	Weekly	Monthly	Yearly
Change Oil Filter			X	
Change Coolant Filter			X	
Clean Crankcase Breather			X	
Change Air Cleaner Element			X	
Check Radiator Hoses			X	
Check Fuel Filters			X	
Clean Cooling System				X


VALVE ADJUSTMENT
CAT
DANGER
EXPLOSIVE GAS
NO SMOKING
NO OPEN FLAME

Why Test? Generators / Large Motors?

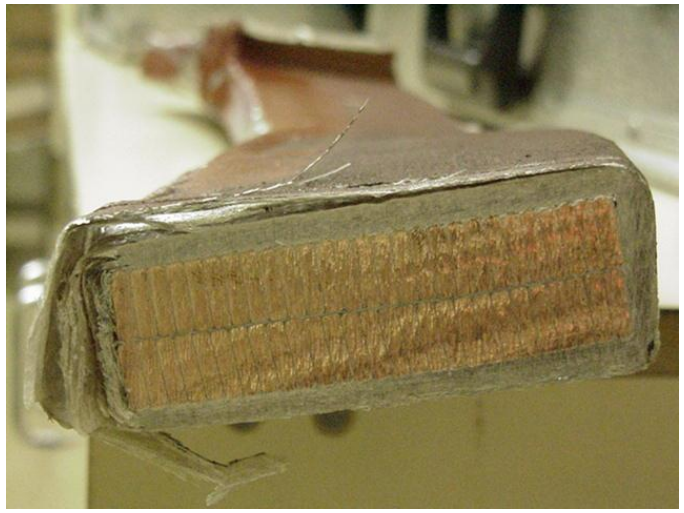
- **Condition monitoring (not only with respect to Motor and Generator insulation) is the continuous evaluation of the machine dielectric integrity throughout its serviceable life**

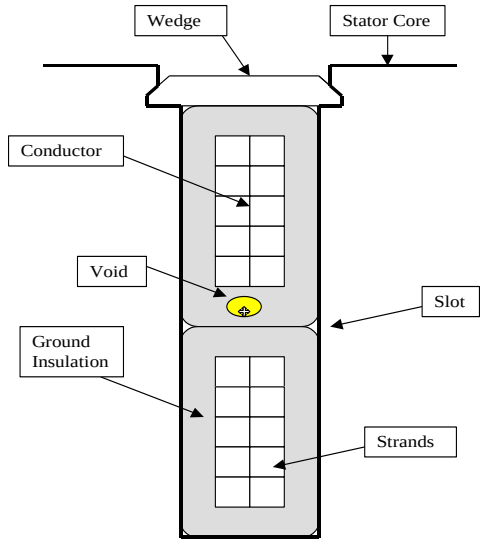
- **There are several key dates in a generators/motors life that call for testing.**

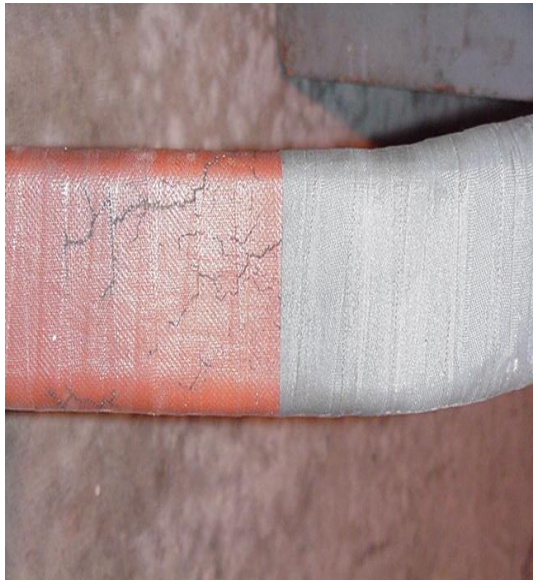
Why Test?

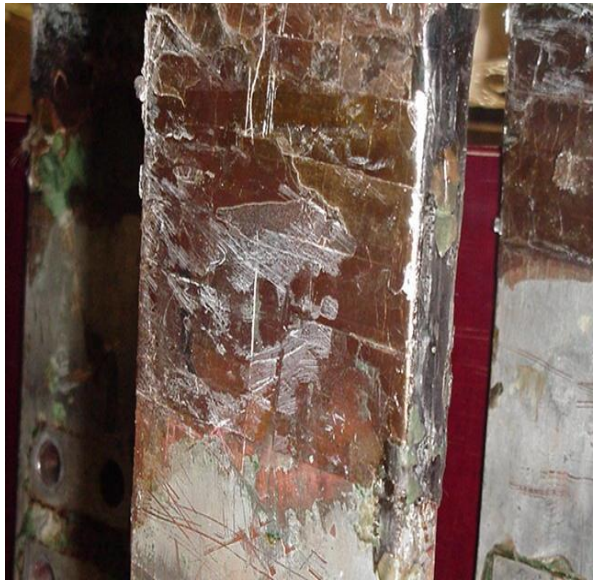
- **Schedule outages in a planned and convenient manner – prevent in service failure**
- **Retire plant or to perform successful repairs before plant failure occurs and extend service life**
- **Insulation Failure can also cause even more costly damage to drive train or stator iron**

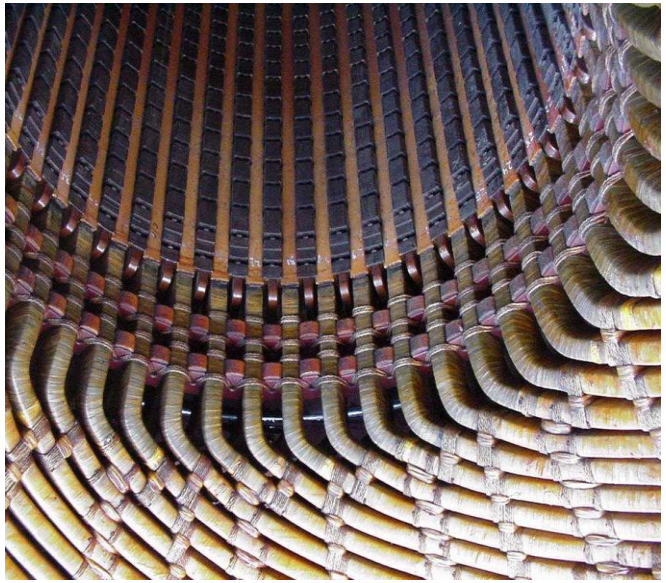
Insulation System of Stator



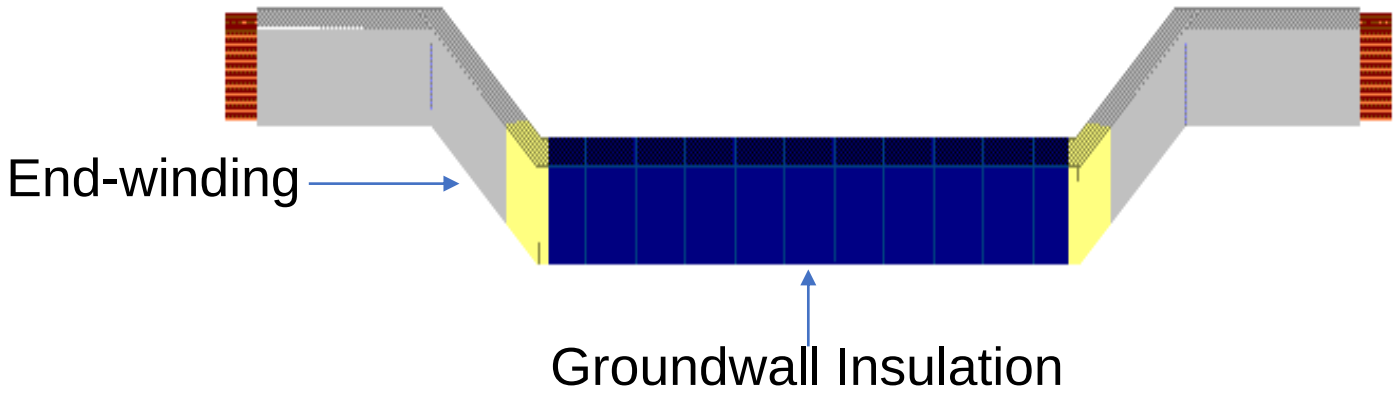






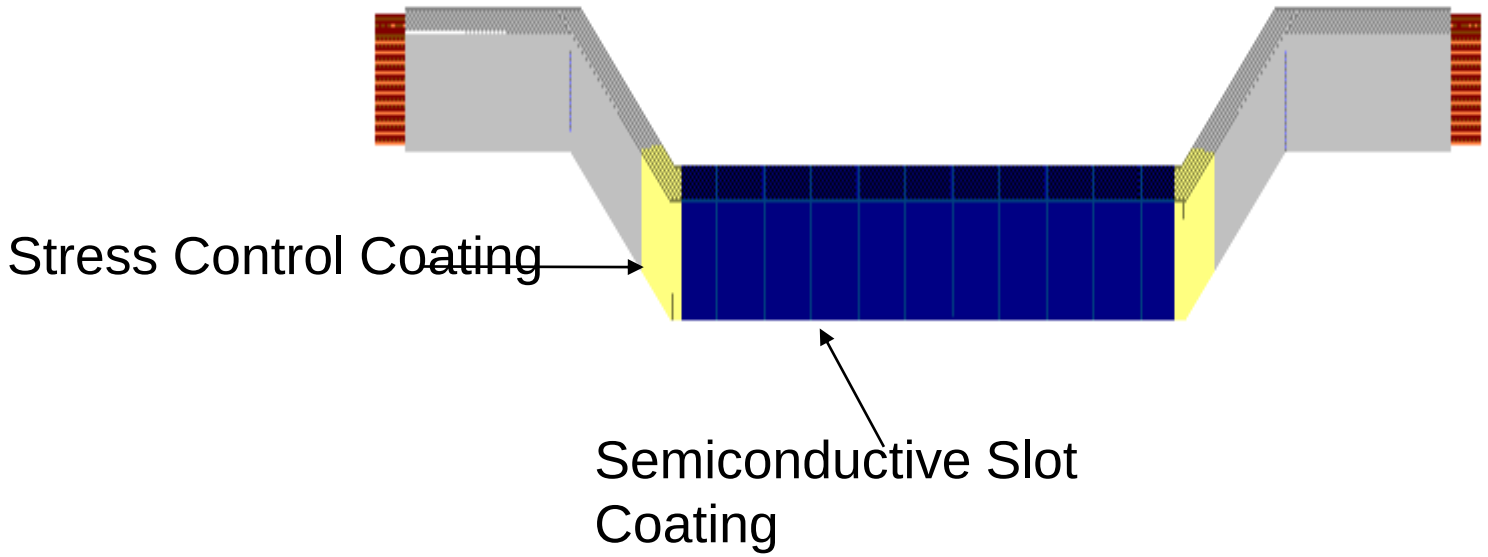


Stator Coil (BAR) Construction



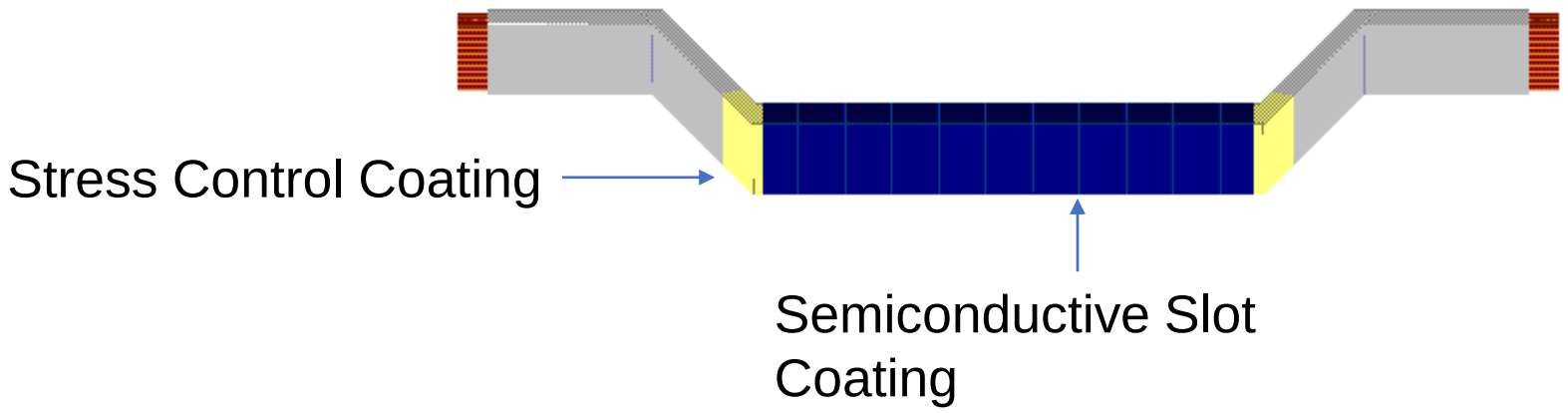
- **End-Winding: The Portion of the Stator Winding That Extends Beyond the Ends of the Stator Core**
- **Groundwall Insulation: The Main High-Voltage Electrical Insulation That Separates the Copper Conductors in Motor and Generator Stator Windings From the Grounded Stator Core**

Stator Coil (BAR) Construction



- **Semiconductive Slot Coating: The Partially Conductive Paint or Tape Layer in Intimate Contact with the Groundwall Insulation in the Slot Portion of the Stator Core**
- **This Coating Ensures That There is Little Voltage Between the Surface of the Coil or Bar and the Grounded Stator Core**

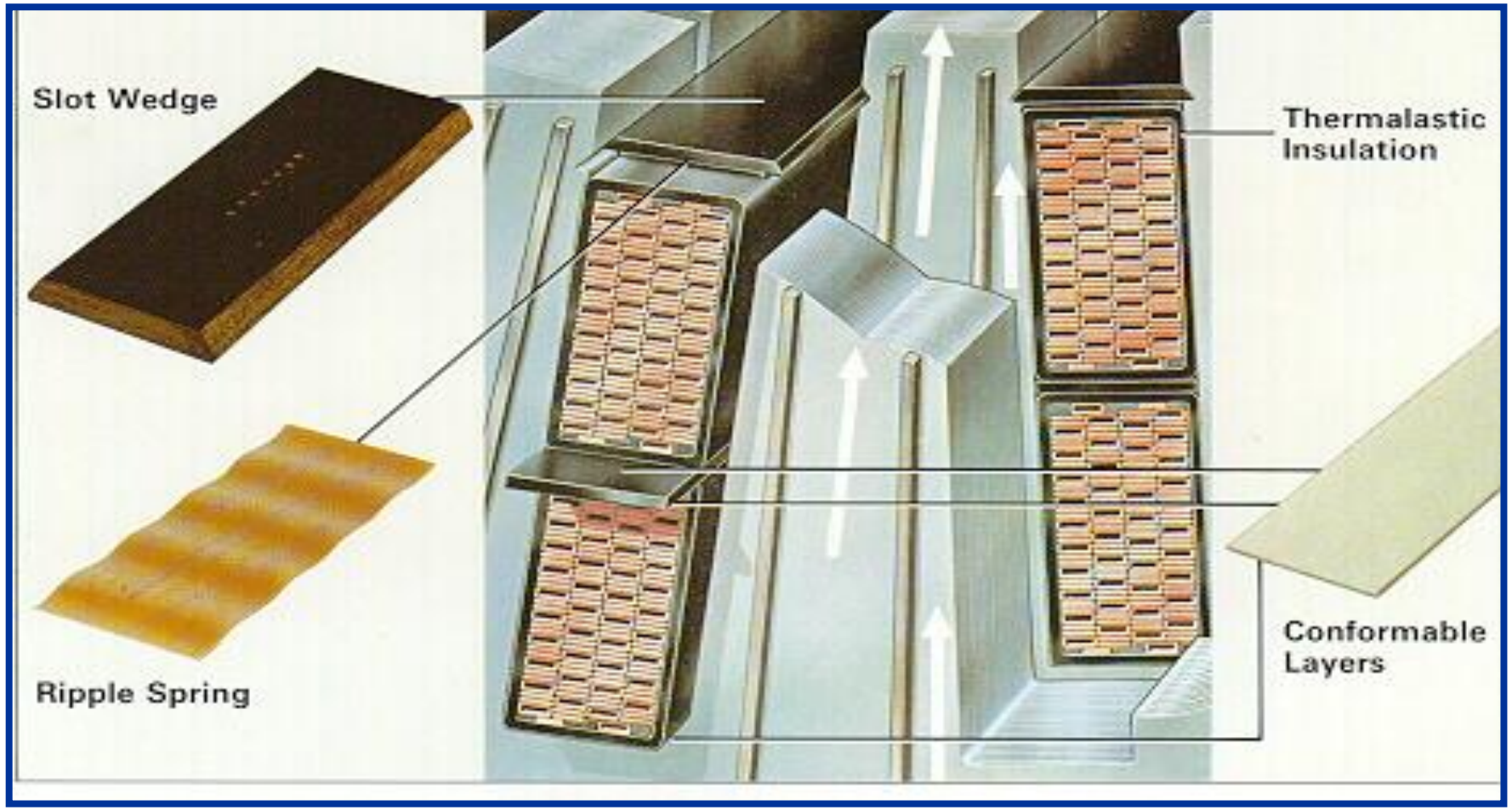
Stator Coil (BAR) Construction



•Stress Control Coating: The Paint or Tape on the Outside of the Groundwall Insulation That Extends Several Centimeters Beyond the Semiconductive Slot Coating in High-Voltage Stator Bars and Coils

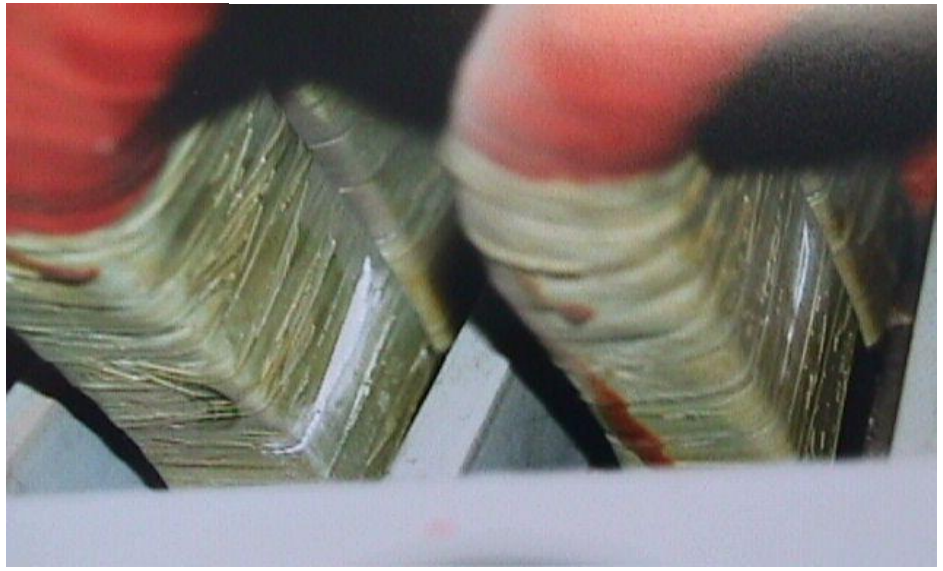
- **•Contains Silicon Carbide Particles That Linearize the Electric Field Distribution Along the Coil or Bar Endturn**
- **•Overlaps the Semiconductive Slot Coating to Provide Electrical Contact Between Them.**

Slot Wedging System - Typical

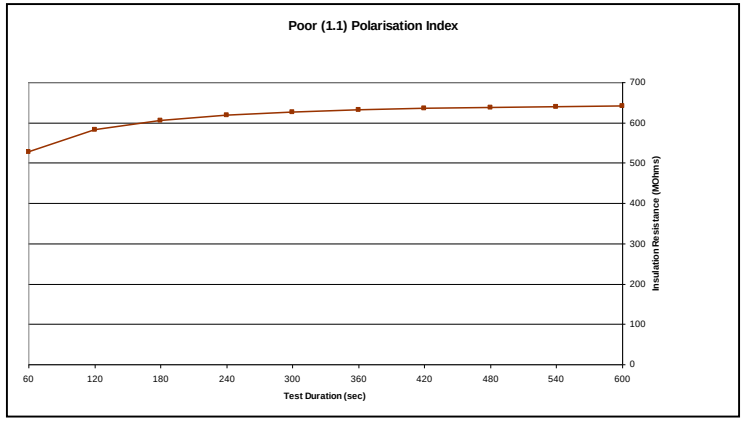


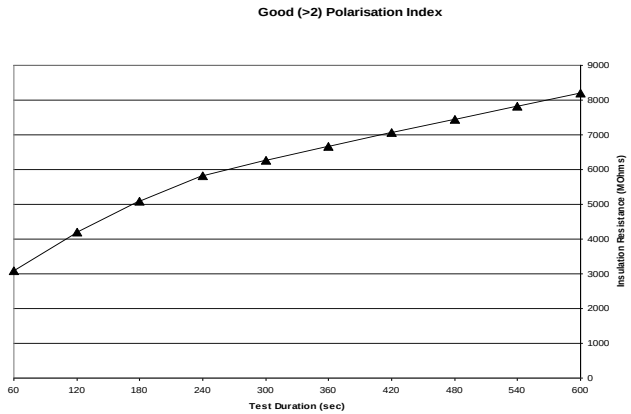
Examples of insulation deterioration
Surface Tracking & Treeing

Examples of insulation deterioration
Corona Damage to stress relief



Tests to determine insulation condition
1. DC Insulation Resistance





- **Simple method**
- **Readings are time dependent**
- **Readings are temperature dependent**
- **Polarisation Index (Ratio 10min:1min) test is largely temperature independent and can assist with the analysis**

Tests to determine insulation condition
1. DC Insulation Resistance

- **Readings will vary with humidity depending on surface contamination**
- **Insulation Resistance & Polarisation Index data is mainly indicative of surface condition**
- **Can not detect clean punctures, breaks or separations in the dielectric**

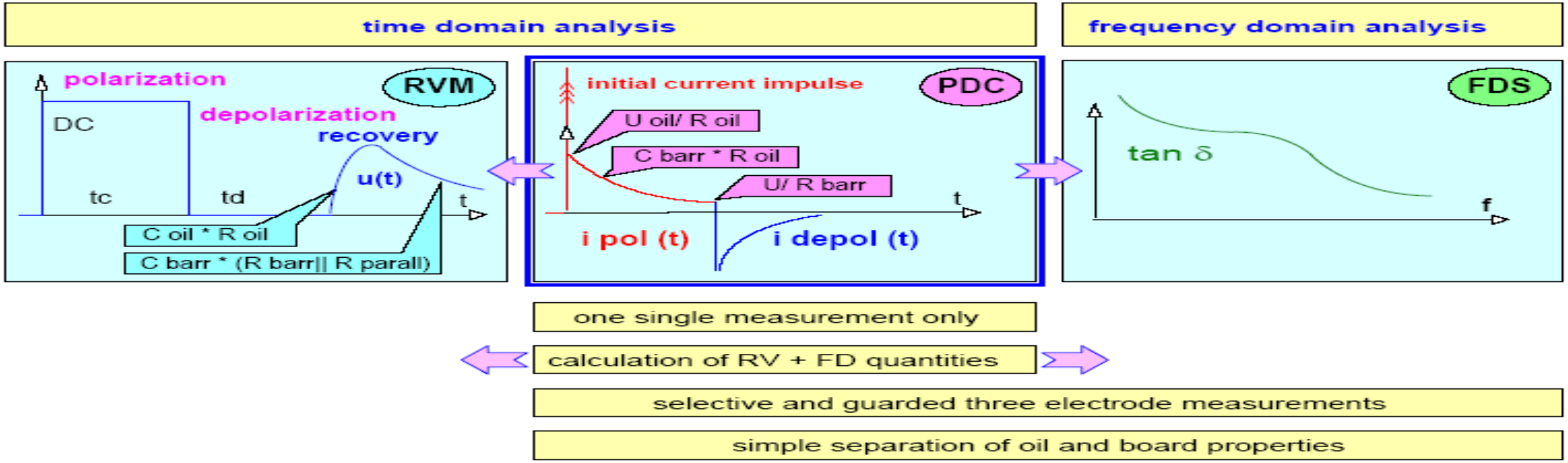
Tests to determine insulation condition
1. DC Insulation Resistance

Insulation Condition	PI Value
Poor	<1
Questionable	1-2
Fair	2-4
Good	> 4

- (however note that a very high PI can also indicate dry brittle insulation)
- Also note that the PI is strongly effected by humidity

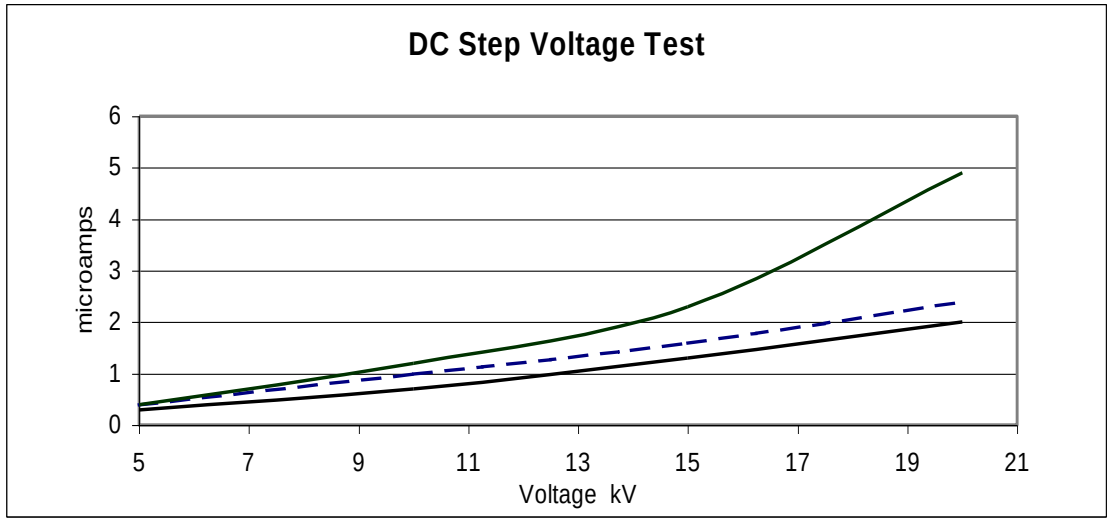
Tests to determine insulation condition
1. DC Insulation Resistance

- More complex methods analysing return current and identifying different time constants and their cause are under development



Tests to determine insulation condition
2. DC High Voltage Step Voltage

- Check for non-linear slope which indicates poor insulation
- Higher Voltage is able to detect clean breaks or punctures as air in break is ionised.
- DC Step Voltage Test is normally carried out at lower voltages than HV withstand test values



Tests to determine insulation condition
2. DC High Voltage Step Voltage, cont….

- Check for non-linear slope which indicates poor insulation
- Higher Voltage is able to detect clean breaks or punctures as air in break is ionised.
- DC Step Voltage Test is normally carried out at lower voltages than HV withstand test values

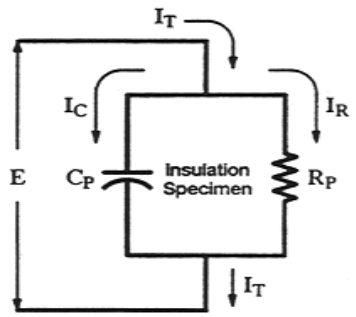
Tests to determine insulation condition
3. High Voltage Withstand Tests

- Checks suitability to withstand operational stresses by application of much higher voltage (2 x U_{line}+1kV ac) for new machines
- Go-NoGo Test
- Care is required as test can be destructive in nature
- Can be AC or DC (x1.6) or VLF -0,1Hz (x1.63)
- Each test voltage has advantages and disadvantages- know what you apply or request!

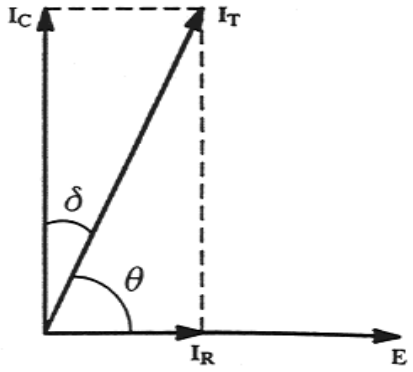
4. Dielectric Dissipation Factor also called (DDF,DLA, tan δ, Power factor)

- DDF is the ratio between the resistive power loss and the reactive power loss of the insulation material

Tan δ = *I resistive* / *I capacitive* $\cos\theta$ = *I resistive* / *I total*



Schematic Representation of an Insulation Specimen Showing Components of the Insulation Current with Test Voltage E Applied



Vector Diagram Showing the Relationship of Insulation Current Components to Applied Test Voltage E

$$\tan\delta = \frac{P_{RV}}{Q_C} = \frac{I_{RV}}{I_C} = \frac{X_C}{R_V} = \frac{1}{\omega \cdot C \cdot R_V}$$

B. Transformer Maintenance - What Is “Condition Assessment”

A comprehensive condition assessment provides you with the knowledge necessary to make informed decisions for maintenance, operation and life expectancy planning, while avoiding costly and unnecessary shutdowns.

It is essential to intelligent operations.

A Healthy Transformer?

Only A Qualified Professional Knows

- DGA, Furans, DP, LRx, SFRA, TTR, MΩ, PF, etc.
- Transformer History
- Manufacturer/Design History
- Load Profile
- Deregulation, Capital Budget Cuts
- Location
- Maintenance Programs, Condition Assessment

The Methodology is Similar

- Blood Tests, Urinalysis, CAT Scan, MRI, X-Ray, etc.
- Patient History Questionnaire
- Genetic Predisposition
- Job Stress, Risk, Hazard
- Financial Pressures
- Location
- Lifestyle

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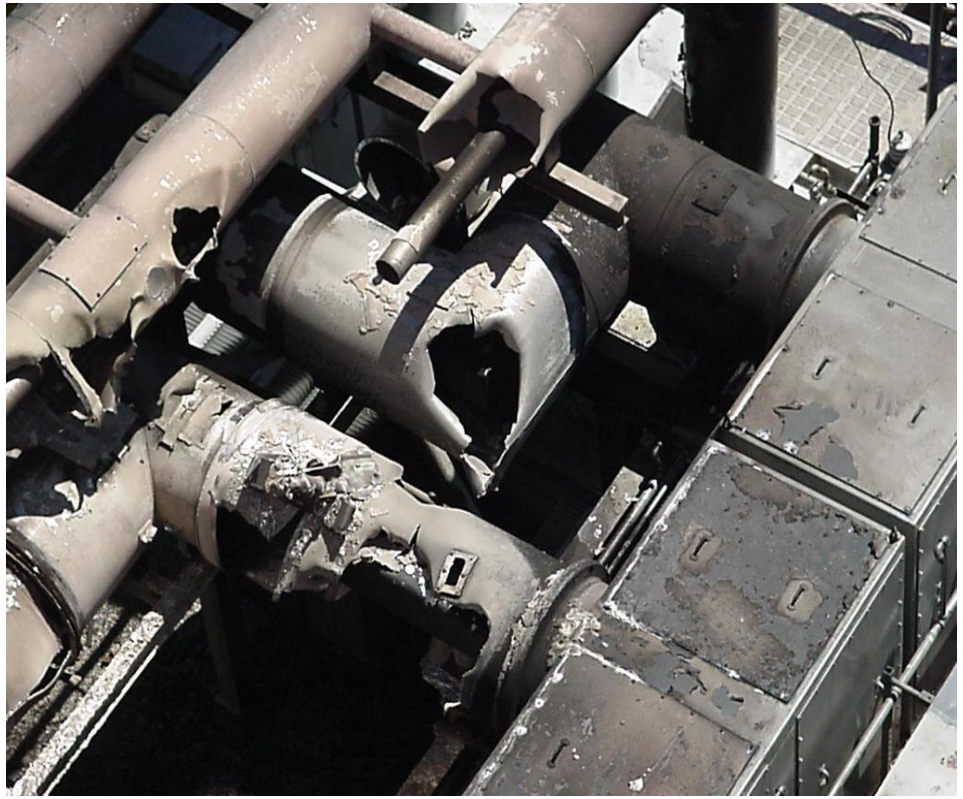
Why Do We Test?

The Final Product

Why Do We Test?



Doble Testing Protocol for Transformers

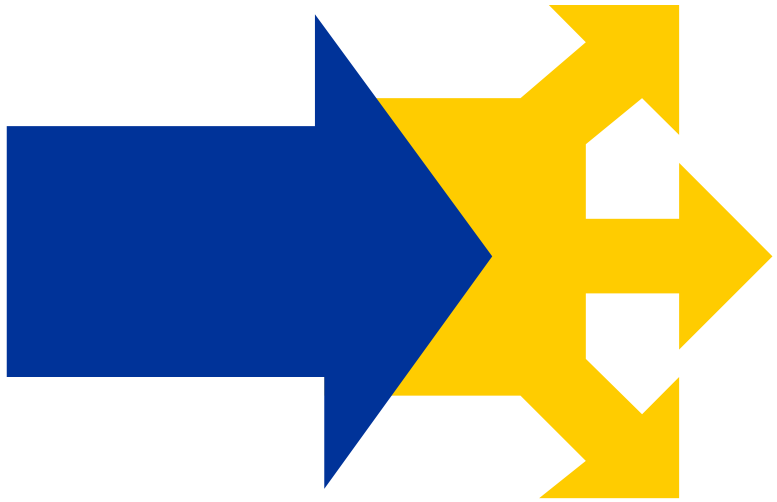
- **Power Factor & Capacitance:**
  - Insulation Deterioration - Winding Distortion
- **Excitation Current:**
  - Core or Winding Problems (open circuit, multiple core grounds, shorted turns, shorted laminations) - LTC Problems - Manufacturing Defects
- **High Voltage TTR:**
  - Shorted Turns - Open Circuits

Doble Testing Protocol for Transformers

- **Leakage Reactance:**
  - Winding Distortion - Nameplate Impedance Confirmation
- **Frequency Response Analysis (SFRA):**
  - Shorted Turns - Coil and Core Movement - Localized Winding Distortion
- **Materials Laboratory Analysis:**
  - Incipient Fault Detection - Insulation Deterioration

Power and Distribution Transformers

The Doble Test as applied to transformers is the most comprehensive tests for insulation assessment



Moisture/Contamination

Carbonization

Mechanical Failure

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Thank you!