



Figure 3. The evaluation of relative change in the leakage reactance for the case of the Common Winding Movement

## Appendix 1

### FUNCTIONAL FAILURE MODEL OF POWER TRANSFORMER

SYSTEM, COMPONENTS	DEFECT	FAULT AND FAILURE-MODE
<p><b><u>Electromagnetic circuit</u></b></p> <p>Core Structure insulation Clamping structure Magnetic shields Grounding circuit</p> <p>Windings (turns, parallels)</p>	<p>Loosening clamping Short-circuit(open-circuit) in grounding circuit Abnormal circulating current Floating potential Aging lamination Insulation degradation</p>	<p>General overheating Localized hot spot Sparking/discharges</p> <p>Gassing</p> <p style="text-align: center;">↓</p> <p style="text-align: center;">→ Failure</p>
<p><b><u>Current carrying circuit</u></b></p> <p>Winding strands ,leads, Connection,joins,contacts</p>	<p>Poor joint Poor contacts Contact deterioration</p>	<p>Localized hot spot</p> <p>Open-circuit Short-circuit</p>
<p><b><u>Dielectric system</u></b></p> <ul style="list-style-type: none"> <li>• Major insulation</li> <li>• Minor insulation</li> <li>• Leads insulation</li> <li>• Electrostatic shields</li> </ul>	<p>Excessive water Oil contamination Surface contamination Abnormal aged oil Abnormal cellulose aging PD of low energy</p>	<p>Destructive PD Localized tracking Creeping discharge Excessive aged/overheated cellulose Flashover</p>

**Mechanical**

Windings  
Clamping  
Leads support

Loosening clamping

Winding distortion  
Radial buckling  
axial  
twisting  
Failure of insulation

**Cooling system**

Heat exchanger  
Pumps  
Fans  
Piping external and internal

Contamination  
Wrong rotation, Bearings  
overheating ,failure  
malfunction  
Poor oil f low

Cooling deficiency  
General overheating  
Penetration of decay product  
into oil

**Bushings**

Condenser core

Core surface, oil

Conductor

Local defect: moisture, air,  
overstressing, X-wax  
Aging, oil instability  
oversaturation  
oil contamination ,  
moisture ,  
Aging  
Poor contact, Overheating

Ionization  
Dielectric overheating  
Thermal run away



Flashover  
Explosion

**OLTC**

Motor driver, shaft  
couplings, fixing  
Selector & reversor

Divertor switch

Mechanical damage

Contacts overheating  
Contamination  
Contacts wearing out  
Contamination  
Mechanical deficiency

Cooking  
Discharges  
Malfunction  
Dielectric breakdown

Malfunction

**Oil preservation & expansion**

Tank, conservator,  
Preserving components,  
piping

Low oil level  
Poor sealing