Risk Assessment of Aging Power Transformers in the Transmission Network

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Outage reasons & effects of power transformer

Cause for major faults

- Winding: 34%
- Coolig unit: 32%
- Core and magnetic circuit: 12%
- Busings: 9%
- Lead Exit: 7%
- Tap changer: 5%
- Onsite Repair: 25%
- Repair in workshop: 36%
- Scrapping: 39%

Onsite Repair
Repair in workshop
Scrapping
Risk Assessment of the assets in the TNM

Single asset risk determination with:

- Distribution function of Repair costs
- Age-dependent outage rates with distribution function
- Reliability data of all load & power plant scenarios
- Monte Carlo Simulation used for asset risk $V(i)$ and overall risk $V$ determination
- Value at Risk Method used to sort out extraordinary combinations with a confidence interval of 0.95
Power Transformers in the 380kV-level in the TNM

Age distribution of power transformer

- 103 Power transformers
  - 25 380kV/220kV PTR
  - 78 380kV/110kV PTR

- Investment Costs:
  - 380 kV / 110 kV (350 MVA) 3,500,000 €
  - 380 kV / 220 kV (1000 MVA) 9,000,000 €

Number of PTR

<table>
<thead>
<tr>
<th>Age Range</th>
<th>380 kV / 220 kV</th>
<th>380 kV / 110 kV</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 years &amp; above</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td>35 - 40 years</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>30 - 35 years</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>25 - 30 years</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>20 - 25 years</td>
<td>5</td>
<td>8</td>
</tr>
<tr>
<td>15 - 20 years</td>
<td>7</td>
<td>9</td>
</tr>
<tr>
<td>10 - 15 years</td>
<td>9</td>
<td>10</td>
</tr>
<tr>
<td>5 - 10 years</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>0 - 5 years</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>
Comparison VDN & CIGRE

- Young PTR overrated
- Old PTR (AGE > 35 Years) underrated

Risk Assessment is wrong with VDN
## Different activities of PTR investment strategies

<table>
<thead>
<tr>
<th></th>
<th>Replacement (RP)</th>
<th>Refurbishment (RF)</th>
<th>Usual Treatment (UT)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Immediate renewal of the asset</td>
<td>Renewal of bushings &amp; tap changer</td>
<td>Normal inspection</td>
</tr>
<tr>
<td></td>
<td>Hazard rate of new asset</td>
<td>Hazard rate reduction</td>
<td>No costs allocated to CAPEX</td>
</tr>
<tr>
<td></td>
<td>Original price to CAPEX</td>
<td>20% Original price to CAPEX</td>
<td>No Scrapping Risk</td>
</tr>
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<td></td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>
Different activities of PTR investment strategies

- PTR (Mid Age) on important position
- PTR (40+) on a less important position
- PTR with an complete redundancy

**Legend:**
- UT: Usual Treatment
- RF: Refurbishment
- NEW: New Power Transformer

**Graph Details:**
- **Axes:**
  - Y-axis: \( V / \text{€} \)
  - X-axis: PTR (Mid Age), PTR (40+)...
- **Colors:**
  - UT: Blue
  - RF: Red
  - NEW: Green

**Note:**
- The graph visually represents the investment strategies for different PTRs, indicating costs associated with Usual Treatment (UT), Refurbishment (RF), and New Power Transformers (NEW).
For an efficient solution of the equations the solution algorithm of Sinha and Zolters is used.

\[
\begin{align*}
\text{Min } \text{VaR} &= \sum_{i=1}^{N} \sum_{j=1}^{3} V_{ij} \cdot x_{ij} \\
\sum_{i=1}^{N} \sum_{j=1}^{3} C_{ij} \cdot x_{ij} &\leq \text{LB} \\
\sum_{j=1}^{3} x_{ij} &= 1 \\
x_{ij} &\in \{0,1\}
\end{align*}
\]
Conclusions & further work

- Refurbishment for old PTR (AGE 40+) is an bad investment
  - Residual risk through scrapping by core failures is to high
- the CIGRE hazard rate values have an higher age-dependency
- Change in legal situation to promote refurbishment
- 380 kV /220 kV PTR outages have an higher impact on the transmission system

Revised risk assessment for power transformers is needed!
Refurbishment only for mid age PTR (30-40)
Thank you for your attention.