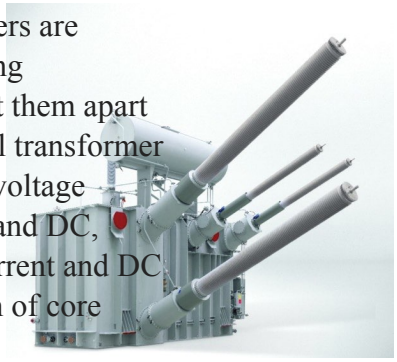
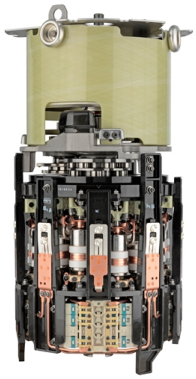
Quick Info

HVDC transformers are subject to operating conditions that set them apart from conventional transformer include combine voltage stresses both AC and DC, high harmonic current and DC pre-magnetization of core



Next Issue



Tap Changer: Design, Maintenance and Monitoring

EDITION 2/2021 - ISSUE 1

POWER TRANSFORMER FAILURES : WHY DO TRANSFORMER FAILS?

Transformer provides important link between the electricity generation plant and end customers. It is considered as most efficient and reliable high voltage electrical equipment in the network. Presently, the health condition of power transformer was assessed by various diagnostic tool and techniques. Changes in the measurement parameters require maintenance action performed on the transformer by the asset owner. Nonetheless, transformer also prone to failures due to many factors both internal and external. Thus, the analysis of failures is an important aspect of asset management where it can improve the ability to identify and eliminate the root cause of the failure and prevent its recurrence.

WHAT CAUSES TRANSFORMERS TO FAIL?

Transformers are complex equipment with different components and require synergy of multiple systems for full operating capacity. Determining the weak link that caused a failure isn't always easy. There are several factors that can cause a failure such as mechanical or electrical defaults, overvoltages, lightning or even human error. Fortunately, a long history of failure documentation and improved maintenance standards can help to prevent failures or detect them before catastrophic failure occurs. The transformer can fail due to failure of any component as discusses below:

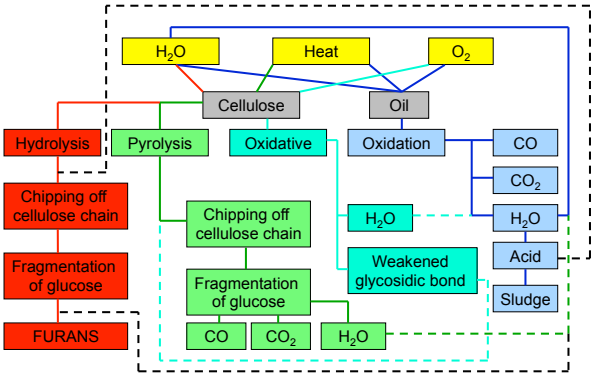
Ageing of Insulation System

Solid and oil insulation are the main insulation used in power transformers. The solid insulation made of cellulose fibre such as pressboard and paper is used between the winding and conductor for electrical isolation. Cellulose consists of long chain of glucose rings which degrades with time leading to shorter chains.

The life of in-service power transformers are governed by the life of insulation system

Meanwhile, the transformer oil provides insulation between winding and as cooling mechanism for dissipated heat losses in transformer. Transformer oil is highly refined product from mineral crude oil and consists of hydrocarbon composition such as paraffin, naphthenic and aromatic.

Moisture, heat and oxygen is the key factors that causes the degradation of transformer insulation system. The oil will be oxidised and contaminated leading to generation of ageing-by-product such as acids, sludge and other conducting particles. This leads to increased viscosity of the oil and increases the temperature inside the transformer. The malfunction of the oil circulation or poor heat transfer to secondary cooling unit results in short circuit.



Insulation Longevity & Transformer Life: Accelerated in the presence of moisture, oxygen and acids.

Solid insulation is the weakest link in transformer insulation system. The condition of paper is indicated by Degree of Polymerization (DP) as average of glucose rings in cellulose polymer chains. Ageing of paper insulation will open and break the cellulose chain and reduce the mechanical strength of solid insulation. It may no longer withstand short circuit and other mechanical forces. Faults in insulating material may occur due to generation of CuSO4 or hot spots created due to low quantity of oil or overloading of transformer.

Winding Failure

Transformer winding is used to carry current and each of conductor strands is wrapped with paper insulation; while each winding phases is separated by pressboard paper. It is designed to withstand thermal and dielectric stresses as well as mechanical forces. Thermal and dielectric stress cause ageing of paper insulation and mechanical forces may cause winding displacement. Such forces can appear during short circuit or transient over voltage due to lightning and switching. The short circuit of windings may also occur due to various reasons such as failure in insulating material, hot spot or deposited of sludge at cooling duct.

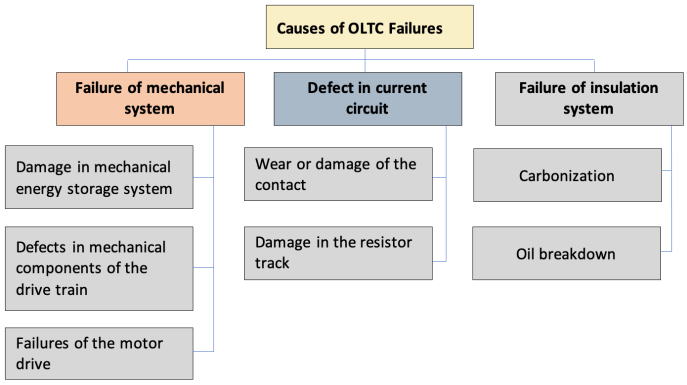
Winding failure due to short circuit between turn conductors

OLTC Failure

Tap changer is the only moving components in power transformer and used to regulate the output voltage of the system to stipulated value. Tap changer can failed for a number of reasons and typically can be divided into three main categories; mechanical system failures, damages produced in the main current path caused by wear or damage of the contacts and problems in the insulation system. When switching occur in oil, there will be some carbon deposited at the switching contacts and cause coking of the contact. In addition, the carbon will drastically affect the properties of insulation oil such as reduce the dielectric strength. This impure oil will lead to

overheating of the entire tap changer and unwanted flashover during operation and finally cause explosion of tap changer.

Surface erosion with pitted mark and coking of roller contact (left) and deposited of carbon on OLTC cylinder (right)



Typical failure causes of on-load tap changer

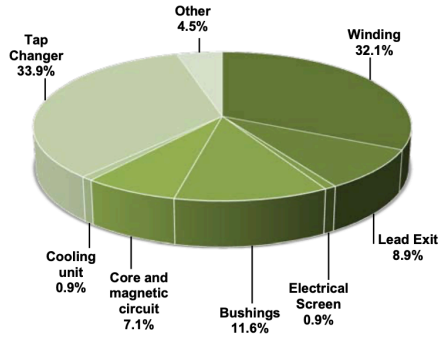
Bushing Failure

Transformer bushings connect the windings to the electrical network through conductor insulated from the transformer main tank. From the physical and electrical point of view, bushing appears to be the weakest part of the transformer. Similar to winding conductor, bushing experiences thermal and electrical stress due to short circuits and heavy loading conditions. This will cause ageing of multilayer insulation and expands under high temperature. The penetration of moisture into the bushing through leaky gasket or other opening will accelerate the insulation ageing and also associated with partial discharge activity across the internal surface of bushing. Finally, this will cause failure of high voltage bushing.

Bushing failure of generator transformer

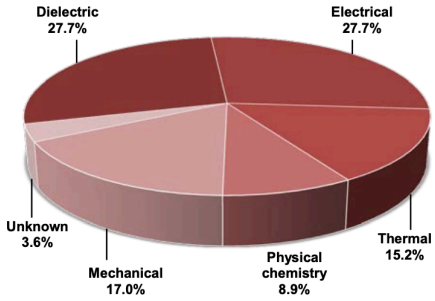
TRANSFORMER FAILURE MODE AND CAUSES ANALYSIS

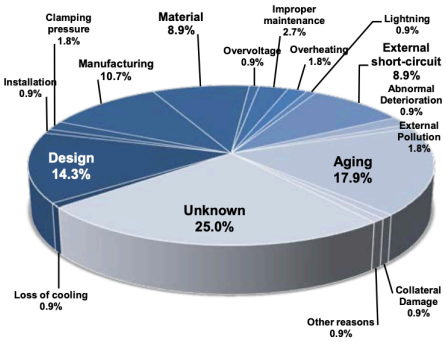
A survey on transformer population of failure data and published by CIGRE WGA2.37 has classified various groups of transformers in terms of failure locations, failure causes, failure modes, actions and external effects.



Tap changer and winding are the main component that cause the failure of power transformer. Bushing, leads and magnetic circuit are listed with a minor percentage as a reason for major failures.

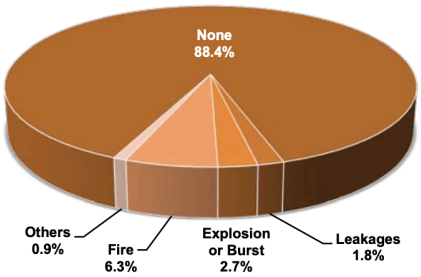
There is no single prominent of transformer failure mode. The categories of dielectric and electrical are with 27% each the most dominant. Dielectric failure means PD, tracking, flashover. Electrical failure means open circuit, short circuit, poor joint, poor contact, ground deterioration, floating potential.

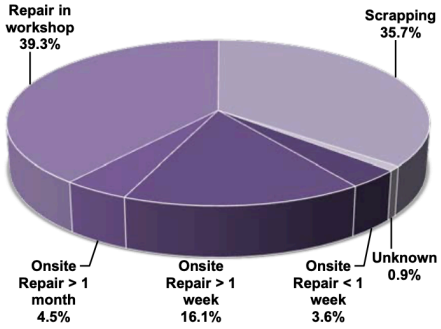




25% of transformer failure causes are unknown. The circumstances during design, manufacturing and operation that led to the failure are difficult to determined. The ageing of insulation system contribute about 17.9% the failure causes of power transformers. Astonishingly design and manufacturing are mentioned quite often as a failure cause and contribute to 14.3% and 10.7% of transformer failure.

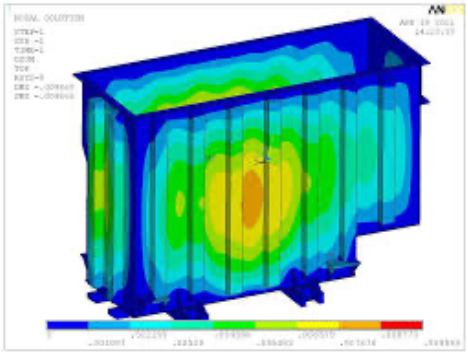
Most of the transformer major failure do not result in external effects. Some other external effects which are detected in some cases are “Fire” with 6.3% and “Explosion or Burst” with 2.7%.



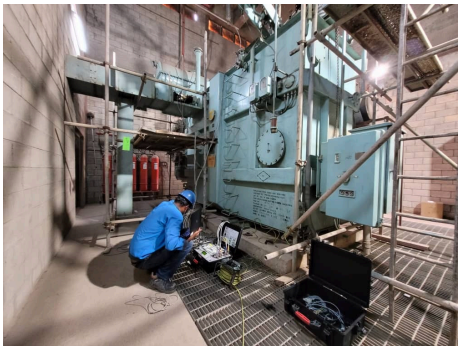


The analysis of the actions taken after transformer failure shows that 63.5% can be repaired either in workshop or on-site, whereas only 35.7% of the transformers are suggested to be scrapped.

HOW TO REDUCE TRANSFORMER FAILURE?

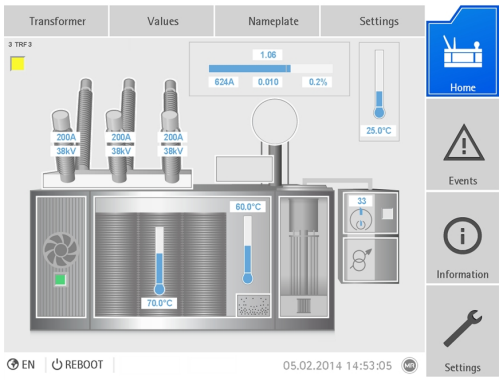


Any failure of the transformers cause interruption of power supply, great inconvenience to the consumers and huge financial losses to the utilities. It is therefore extremely important to avoid transformer failure. To some extend, the transformer failures can be reduced or avoided through a several strategies. Firstly, it is vital to ensure transformers are designed and manufactured for its intended application. A well construction transformer fit for purpose should not fail. Transformer have a long life expectancy unless something outside the design specification happens. In addition, throughout the life-cycle of the transformer it is important to keep electrical loading within the design.



Secondly, planned maintenance, inspection and testing will significantly reduce the number of transformer failures. For a safe and reliable operation of transformers, preventive maintenance is must. The maintenance detects problems at an early stage and can prevent further deterioration. Preventive maintenance includes oil sampling and analysis (oil quality, fault gases analysis, insulation degradation) and electrical measurements (routine and advance diagnostic testing).

In the recent years, significant breakthrough in developing ways and means of assessing condition of the in-service power transformers. As a result, catastrophic failures can be easily detected and remedial actions can be taken timely to save both human life and other capital losses in addition to preventing electric supply failures and economic losses to state electricity boards and utilities. The transition into Industrial Revolution (IR4.0) where online and connected technologies becoming norm has changed the operation and management of power transformers. Through Internet of Things (IoT) facilitated by online remote monitoring functionality, it has enabling issues to be identified in advance and helping to prevent operation downtime caused by transformer breakdown.



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