# AN UNDERSTANDING OF POWER TRANSFORMER PROTECTION

Power transformers are susceptible to various type of faults and disturbances which can lead to power system outages. Therefore, transformer protection is a crucial aspect of power system reliability, as it aims to detect the and respond to these faults in real-time, minimising the risk of damage and ensuring the continued of electricity supply. In this article, the importance of power transformer protection, the types of faults that can occur and the various techniques and technologies used to detect and respond to these faults are presented.

## INTRODUCTION

Transformer faults can arise from a range of causes, including internal faults such as winding faults, core saturation, and turn-to-turn insulation failures, as well as external factors like lightning strikes, short circuits, and over-voltage conditions. If left unchecked, these faults can lead to significant consequences, including reduced transformer lifespan, increased maintenance costs, and even catastrophic failures that can result in extended outages and significant economic losses. To mitigate these risks, power transformer protection systems employ a range of techniques and technologies, including fault detection, isolation, and mitigation strategies. These systems typically incorporate a combination of sensors, relays, and control systems that monitor the transformer's operating conditions and respond to faults in real-time, ensuring that the transformer is safely isolated from the grid and preventing further damage.

## TRANSFORMER PROTECTION OVERVIEW

Power transformers are designed to operate in a wide range of conditions, from normal to faulted states. However, even with proper design and maintenance, transformers can still experience faults and disturbances that can compromise their performance and reliability. Power transformer protection is essential to ensure the continued operation of the power grid and to prevent equipment damage and downtime.

The type of protection for the transformers varies depending on the application and the importance of the transformer. The type of protection used should minimize the time of disconnection for faults within the transformer and to reduce the risk of catastrophic failure to simplify eventual repair. Any extended operation of the transformer under abnormal condition such as faults or overloads compromises the life of the transformer, which means adequate protection should be provided for quicker isolation of the transformer under such conditions. Generally, the protection philosophy are divided based on transformer fault condition; internal and external faults.

| Conditions | Protection Philosophy |
|---|---|
| **Internal** | |
| Winding Phase-Phase, Phase-Ground faults | Differential (87T), overcurrent (51, 51N) Restricted ground fault protection (87RGF) |
| Winding inter-turn faults | Differential (87T), Buchholz relay, |
| Core insulation failure, shorted laminations | Differential (87T), Buchholz relay, sudden pressure relay |
| Tank faults | Differential (87T), Buchholz relay and tank-ground protection |
| Overfluxing | Volts/Hz (24) |
| **External** | |
| Overloads | Thermal (49) |
| Overvoltage | Overvoltage (59) |
| Overfluxing | Volts/Hz (24) |
| External system short circuits | Time overcurrent (51, 51G), Instantaneous overcurrent (50, 50G) |

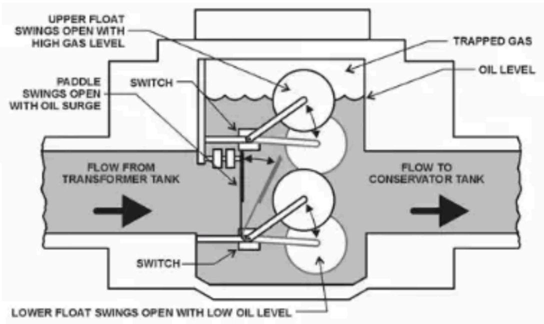
Transformer protection philosophy

## POWER TRANSFORMER PROTECTION TECHNIQUES

Power transformer protection employs a range of techniques and technologies to detect and respond to faults and disturbances. Some of the techniques are explained as follows.

### Buchholz relay

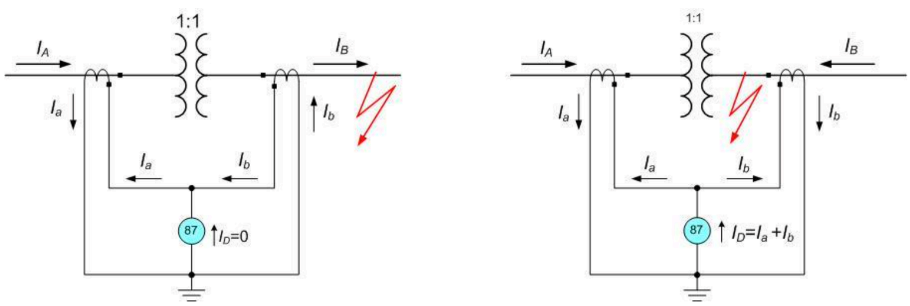
In 1920, Max Buchholz has invented a gas accumulated relay to protect the transformer in the event the fault occurs inside the transformer tank. This relay is connected to the oil piping between the conservator and the main oil tank of a transformer and is arranged so that any gas evolved in the main tank tends to flow upward toward the conservator.




Design and working principle of Buchholz relay

Under different fault condition, the hydrocarbon chain of insulation oil will be disintegrates and gases by-product are formed and accumulate in the relay. On a slow accumulation of gas, the gas trapped in the top of the relay forces the oil level down. A float switch in the relay is used to initiate an alarm signal. Depending on the design, the relay may equipped with second float switch and paddle. If an electrical arc form, gas accumulation is rapid and oil flows rapidly into the conservator and operate this switch. The circuit breaker will immediately operated and isolate the transformer before the fault causes additional damage.

### Differential protection relay




Principle of transformer differential protection

Differential protection for transformers is a critical aspect of power system protection, as it helps to detect faults in the transformer and prevent further damage from occurring. The working principle of differential protection is based on the concept of differential current, which is the difference between the current flowing into and out of the transformer. According to the Kirchhoff's current law, the sum of all the currents flowing to a node is zero; similarly, the sum of all the currents flowing into the transformer is zero except when there is a fault in the transformer. Therefore, current will flows in the differential relay when there is a fault in the protection zone of a transformer and no current flows in the relay when there is a fault outside the protection zone of a transformer.

**Overfluxing protection**

Transformer overfluxing protection is a type of protection that detects and responds to excessive magnetic flux in a transformer. This can occur when the transformer is subjected to a sudden increase in load or voltage, causing the magnetic flux to exceed the designed limits of the transformer. Modern transformer designs keep the peak flux density around 1.7 to 1.8 Tesla, while the core's saturation flux density is about 1.9 to 2 Tesla. Over fluxing happens when a electrical power transformer experiences flux density beyond these design limits. The flux density in transformer can be expressed by, B = V/f and proportional to the voltage-to-frequency ratio. Over fluxing can happen if the voltage increases or the frequency decreases.

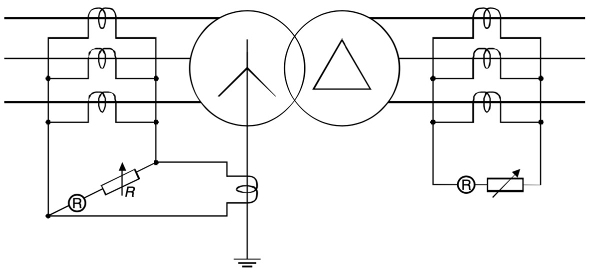
The magnetising flux will also enters in other structural parts of the transformer as well and results in additional eddy current losses. Because of increased losses, the temperature of the iron winding and some structural parts increases. Physical evidences of damage due to over fluxing will very with the degree of over excitation, the time applied and the particular design of transformer.

| Component involved | Physical evidences | Consequences |
|---|---|---|
| Metallic support and surfaces structure for core and coils | Discoloration or metallic parts and adjacent insulation.Possible carbonized material in oil. Evolution of combustible gas. | Contamination of a oil and surfaces of insulation. Mechanical weakening of insulation Loosing of structure. Mechanical structure |
| Windings | Discoloration winding insulation evolution of gas. | Electrical and mechanical weakling of winding insulation |
| Lead conductors. | Discoloration of conductor insulation or support, evolution of gas. | Electrical and mechanical weakening of insulation, Mechanical Weakening of support. |
| Core lamination. | Discoloration of insulating material in contact with core. Discoloration and carbonization of organic/lamination insulation Evaluation of gas. | Electrical weakening of major insulation (winding to core) increased interlaminar eddy loss. |

Physical damage and probable consequences due to overfluxing in transformer

**Restricted earth fault protection**

Earth full protection is used to detect faults in grounded wye connected transformer windings. During an internal fault, the neutral current transformer will carries the unbalance fault current and operate the relay. In this protection scheme, the CT secondaries of each transformer phase are connected together. These common terminals are then connected to the secondary of a Neutral Current Transformer (NCT).



Restricted earth fault system

When there is an unbalance between the three phases of the transformer, an unbalanced current flows through the closed path connected to the CT secondaries' common terminals. This unbalanced current also flows through the transformer's neutral, causing a secondary current in the NCT.

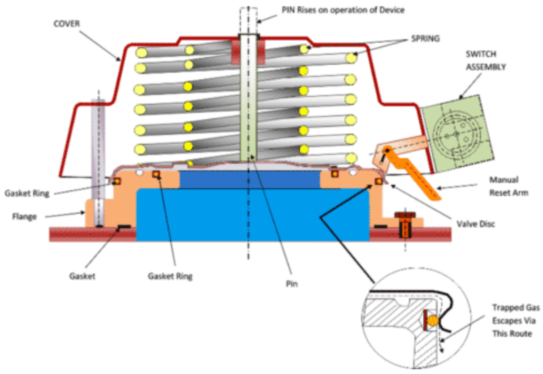
## Overcurrent protection

Overcurrent protection is commonly used for protection of transformer from phase and ground faults. Typically, fuses are used as primary protection for transformers below 10MVA. However, above 10MVA over current relays are used as back up along with differential relays. In most cases overcurrent relays are applied on both sides of network transformers.

In general, overcurrent relays can be inverse time or definite-time delay types and sometimes instantaneous overcurrent relays are also provided. Instantaneous trip units are set at a level that is higher than the maximum inrush current that might be experienced by a transformer as well as higher than the maximum short circuit current on the low voltage bus. These units are typically set in the range of 8 to 13 times the rated current of the transformer. These relays are coordinated with the upstream instantaneous relays. The time delayed overcurrent relays are provided to provide protection in case of failure of other relays to detect faults. These relays are set at approximately one-half of the rated current of the transformer and coordinated with other relays on the system to avoid undesired tripping.

## Pressure relief device

A transformer Pressure Relief Device (PRD) is a safety device designed to prevent excessive pressure buildup in a transformer due to internal faults, such as a short circuit or an electrical discharge. The device is typically installed in the transformer tank and is designed to relieve the pressure by venting the gas or oil that builds up inside the transformer.

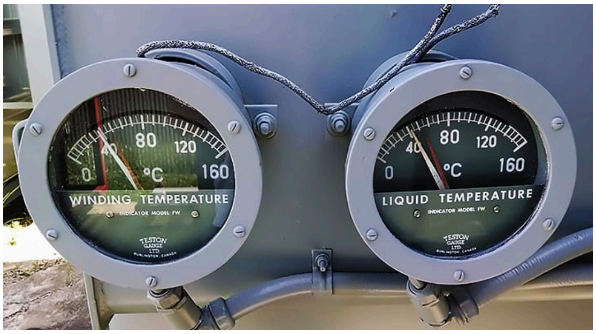


Construction of Pressure Relief Device (PRD)

The construction of transformer PRDs is similar to a standard spring loaded safety relief valve (SRV). A large metal plate attached to a central shaft is held closed by a spring. The spring tension is calculated to be overcome at a certain pressure. Should the tank pressure increase above the set pressure of the PRD, the spring will be compressed and the plate will move to the open position. The greater the tank pressure, the greater the spring compression. Once the tank pressure has reduced, the spring tension will automatically move the plate back to the closed position. A rod connected to a colored indicator usually informs personnel that the PRD has actuated, this is useful as personnel are unlikely to be in the area during the time of actuation. Aside from the local visual display, the PRD will almost certainly be connected to the alarm monitoring system as well as the transformer tripping circuit.

## Thermal overload protection

Thermal overload protection for transformers is a safety feature designed to prevent damage to the transformer due to excessive heat generated by overloading or other faults. Typically, the thermal overload protection consists of sensors, control unit and relay unit. The sensors are normally thermocouples installed within the transformer to



Oil and winding temperature gauge for overload protection monitor the temperature and later will be compared to a set point or threshold value by control unit. If the temperature exceeds the set point, the control unit sends a signal to the relay, which then provide an alarms or trips the transformer.

## CONCLUSIONS

This article explains the basic information and provides an overview of different types and schemes for power transformer protection. The protection schemes so far designed can successfully protect the transformer and mitigate the risk of enormous destruction that can be caused by transformer explosion. The engineers and researchers are still working on utilising the new technologies for protecting transformers more successfully and more cost effectively.

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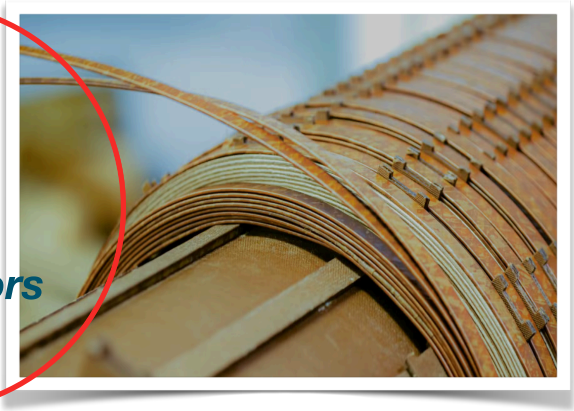
**Next Issue : Oct-Dec 2024**

***Assessing the Ageing of Transformer Insulation System Using Different Ageing Indicators***



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