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REVIEW OF FAULTS IN TRANSFORMERS

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Abstract— **The focus of this paper is to classify different types of disturbances/faults in transformers, their protection schemes.**

Keywords— **Faults, Disturbance, Protection, windings.**

I. INTRODUCTION

Transformers are a very important constituent of the Power system. Without it, it would have been very difficult to provide the need for low voltage or high voltage. In the modern electrical distribution system, transformers are utilized to increase the voltage to reduce losses during transmission. At the Generation level transformer steps up the voltage to allow minimum transmission losses. On the distribution side, the transformer steps down for industrial and residential usage either single-phase or three-phase.

The rest of the paper is will discuss the basic transformer disturbances/faults. We will also discuss the features of transformers due to the faults and type of protection.

II. LITERATURE REVIEW

Since power transformer converts Alternating Current voltage and current for transmission, distribution, and utilization of electric power to a level where the losses are very negligible. The AC transformers are far more advantageous than DC systems, with increased load levels and transmission distances. To understand Faults on a transformer and its performance we need to review failures and degradation of transformers. A recent case study conducted by PJM (Pennsylvania-New Jersey Interconnection) in 2007 experienced both failures and degradation of older transmission transformers. Congestion on the electric system occurs when the transformer unit is removed for service or repair. The redirected electricity flow may exceed the transmission. To keep the demand supply meet, the high-end generation must continue to generate. Transformer condition assessment are the primary method for failure predictions. Unless the transformer exhibits signs of complete failure or reduced efficiency, faults detection and system reliability issues are unable to detect faults and disturbances. Today, technology is advanced, and we have improved continuous parameter monitoring of transformers, enabling us to detect faults, disturbances, and transformer efficiency in real time. For an ideal transformer, as we usually assume the windings have no resistance, the infinite core permeability leads to zero core reluctance, and the entire leakage flux is associated with the core and links the windings, the leakage part is neglected.

III. TYPES OF TRANSFORMER FAULTS

A. Overheating fault –

There are load and no-load losses for Transformers. The temperature of the transformer core, windings, core, and structural paths. When the temperature of the transformer core and windings increases, it increases the temperature of the air surrounding the parts increases and which dissipates the heat to the air through the oil tank and cooling device.

The overheating might be caused because of the following:

- Cooling fans are not working properly
- Radiator is not clean
- The surrounding atmosphere temperature affects the Transformer temperature.
- Low oil level, oil main purpose is cooling the Transformer.

B. Earth fault -

The Earth fault occurs due to earthing of transformer windings to the ground. It is also due to one of the cores is leaked to Earth. One of the reasons for Earth faults to occur is when insulation is damaged and when the coil is in direct contact of ground. There are sometimes slow leakages in an Transformer, but if not rectified can lead to major fault issue.

In a normal operating Transformer, the Vector sum of phase currents is zero or in a permissible range. F one of the phase currents is unbalanced which can be due to the core associated with ground.

C. Interturnes fault -

Interturnes Faults are one of the main causes of Transformer's failure. If not detected in early stages can cause severe damages to transformers and its efficiency.

This fault is caused when turns in same windings short circuit, decrease in terminal ratio occurs, leading to decreasing terminal currents. This fault is caused due to some of the following reasons:

- Lightning strike
- Low winding Insulation
- Transformer aging

IV. PROTECTION SCHEMES FOR FAULTS IN TRANSFORMERS

The principle of Percentage differential protection or Merz-price protection is based on the currents entering and leaving the ends of the transformer. Through the operating coil the difference of the vector currents and through restraining coil the average current passes. So, at normal operating condition of transformer, end currents of the transformers are balanced and the relay remains inoperative due to no differential current flow through its operating coil.

The balance in the end currents is disturbed when phase to phase or phase-to-ground current flows through operating coil of relay resulting in circuit break. Below are the certain important points required while using protection for power transformer.

- To compensate the difference in the current in the primary and secondary ends of the power transformer, Current transformers of appropriate turns ration are to be used to compensate the current difference.
- The phase difference of the primary and secondary ends of the transformer’s voltages, causes phase differences in line currents. Hence appropriate Delta to Star or Star to Delta connections are to be used for Current transformers.
- The neutrals connections of the Current transformer star and power transformer star are to be properly grounded.
- For Power transformers with tap-changing arrangements, there is a possibility of differential current. Hence Current transformers with tap changing facilities are also to be provided.

A. **Merz-Price differential protection –**

1. FOR STAR - DELTA TRANSFORMER:

The primary windings of the transformer is STAR connected and the secondary windings are DELTA connected.

To compensate the difference between phase, the secondary of the Current transformer for the primary side of the power transformer must be connected in Delta and the secondary of the Current transformer for the secondary side of the power transformer must be connected in Star. The star point of the power transformer primary and star connected of the secondary Current transformer must be grounded.

The restraining coils are connected to the secondary windings of Current Transformer and the Operating coils are connected between tapping points between the restraining coils and star point of Current transformer secondary windings. During normal working conditions of the transformer, with the proper selection of turns ratio of Current Transformer, the secondaries of Current transformer carry equal currents in phase so the relay doesn’t operate.

Due to internal faults in Transformer the balance in Current Transformers gets disturbed. The operating coils of the differential relay carry current proportional to the current difference between both the sides of the transformer. It is important to note that Merz-Price protection gives protection to interturn faults.

2. FOR STAR - STAR TRANSFORMER:

Primary and Secondary side of the transformer is STAR connected. To compensate the phase difference, the secondary of current transformers are connected in delta form to both the sides of power transformer.

The star connection points of the windings of the power transformer are to be grounded. The secondaries of the current transformers are connected to the restraining coils of the relay. The operating coils are connected to the tapping of the restraining coils and the ground.

Shortcomings of differential protection –

- Current transformer characteristics differences due to error of ratio at high short circuit current values, can lead to a considerable imbalance in the currents in the secondary windings which can lead to the operation of relay.
- Ratio change for Current transformers will also need to be varied as per change in ratio of power transformers. This is not preferrable for Current transformers.
- The length of pilot wires on both the sides of power transformers are not same which can cause unbalance condition. This situation is tackled by adding balancing resistors to the pilot wires.
- When the transformer is energized, the magnetizing inrush current which can as greater as ten times the current during full load.

To overcome most of the above shortcomings percentage differential relay are used.

B. **Buchholz Relay protection –**

Buchholz Relay is a distinct gas featured relay, used to protect oil-immersed transformers for all types of internal faults. When the oil is level goes below a specific set parameter the relay gives off the alarm, for more severe faults the relay disconnects the transformer supply.

The principle used in the Buchholz relay used is based on oil decomposition in the Transformer tank. When the oil decomposes most part of the gas is hydrogen, which is light. When it rises through pipe to the conservator and due the collection of the gas in the conservator part, the relay gives off alarm.

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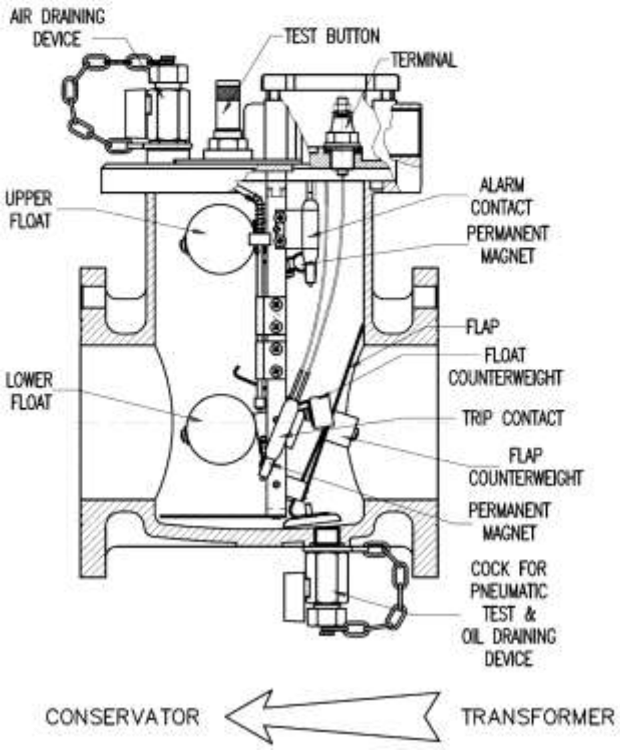

FIG (1) BUCHHOLZ RELAY

Source: https://www.electricalclassroom.com/buchholz-relay-working-principle/

The Buchholz relay triggers alarm for following conditions

- Hot spots occurred on core due to lamination short circuit.
- Insulation failure of the core bolt
- Faulty joints
- Faults within turns, Interturn faults
- Local Overheating

The gas trapped in the Buchholz relay due to the occurrence of a fault indicates the type of fault.

- White colour gas: While colour gas is generated when in contact of paper, cotton causes electric arcing.
- Yellow colour gas: Yellow colour gas is generated when in contact with wood and cardboard causes electric arcing.
- Grey colour gas: This is caused due to the breakdown of the magnetic parts or circuits.
- Black colour gas: Black colour gas is generated when electric arcing is caused in the oil of the transformer.

Recently Buchholz relay are designed with sensors for detecting the moisture and Transformer oil parameters and the gas accumulated in the conservator. The sensors send the continuously monitored parameters of the transformers to the programmable logic controllers or control systems in substations which helps in predicting major faults in transformers.

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