A Case Study on The Protection Scheme of Transformer At V.I.P.L.

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Abstract- *This paper acquaints few case studies on protective devices installed at Buttibori, V.I.P.L that recognizes the faults in power transformers quickly and prevent them from unnecessary tripping or disconnections. The paper displays the various classes of protection and the operation of the respective classes for the transformer protection. The paper contains the detailed information about how differential protection and restricted earth fault protection works for the transformer. The paper also portrays the effect of magnetizing inrush current in the system. It also describes the causes of over-current, over-voltage and over-fluxing. In addition, the paper discusses the role of Buchholz Relay for the transformer protection.*

Keywords- Transformer protection, Faults, Magnetizing inrush current, Restricted earth fault, Buchholz relay

I. INTRODUCTION

Vidarbha Industries Power Limited (VIPL) is a 600 MW coal based Thermal Power Plant with 2 units of 300 MW. It has one Generator Transformer (GT) and two Unit Auxiliary Transformers (UATs) for each unit. One Station Transformer common for both the units. Generator transformer used in *VIPL is of "AREVA" make.*

Following are the ratings of each type of transformer installed at VIPL:

Generator Transformer:

Rated Voltage	
HV Side	230 kV
LV Side	20 kV
Rated Current	
HV Windings	928.8 Amp
LV Windings	10680.9 Amp
Rated Frequency	50 Hz

Station Transformer:

Rated Capacity	20/25 MVA
Rated Voltage HV side	220 kV
Rated Voltage LV side	6.6 kV

Unit Auxiliary Transformer:

HV side (Nom./Max.)	6.6 kV / 7.2 kV
LV side (Nom./Max.)	433 V / 456 V

[A].Causes of Failure:

Transformer is a static electrical device which is used to transfer energy by the principle of electromagnetic induction between two or more circuits. So like other electrical devices, occurrence of faults in transformer is frequent which causes failure.

Following are the causes of failure:

- Bad environmental conditions.
- Mal-operation of the device.
- Wrong design by the manufacturer.
- Material quality used.
- Irregular maintenance.

Classification of failure:

(1). Internal Failure:

Causes of internal failures are as given below:

- Winding and terminal faults.
- Core faults.
- On load tap-changer faults.
- Overheating faults.

(2). External Failure:

Causes of the external failures are as given below:

- Abnormal operating conditions.
- Sustained or unclear faults.

[B].Vector Group:

Group 1 0° Phase displacement	Yy0 Dd0 Zd0
Group 2 180° Phase displacement	Yy6 Dd6 Dz6
Group 3 30° Lag phase displacement	Yd1 Dy1 Yz1
Group 4 30° Lead phase displacement	Yd11 Dy11 Yz11

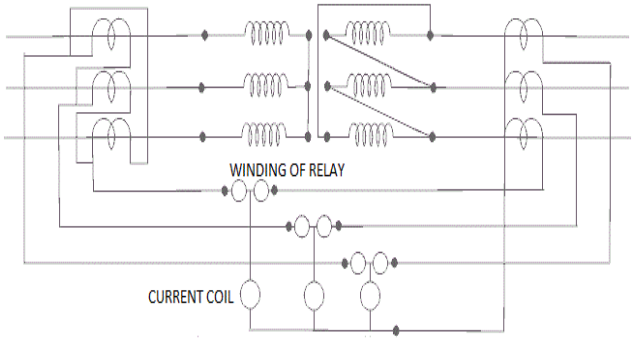
If any of the above mentioned types of failure occur in the Generator Transformer, then it may damage the insulation, deteriorate the windings. If this fault becomes severe then it may damage the transformer itself or the neighboring equipment. For these reasons, protection of the transformers is essential. The protection scheme installed at the power station helps to prevent the fault occurrence and damage to the equipment. It trips the equipment from the circuit and in this way restricts the fault. Various types of protections are used as per the type of fault occurred.

II. TYPES OF PROTECTION

(1). DIFFFERENTIAL PROTECTION

Differential protection is required in the electrical power transformer whose rating is more than 5MVA. If the fault occurs in the transformer but not in oil then it is detected by differential relays. Differential relay also detects the flash-over at the bushings.

The transformer has a turn's ratio so it is not necessary that input current is equal to output current. The differential relay compares between primary current and secondary current of power transformer. If any unbalance found in between primary and secondary currents the relay will actuate and inter trip both the primary and secondary circuit breaker of the transformer.



SCHEMATIC DIAGRAM OF DIFFERENTIAL RELAY

(2).BUCHHOLZ PROTECTION

Buchholz relay is an oil container which is connected between conservator tank and transformer.

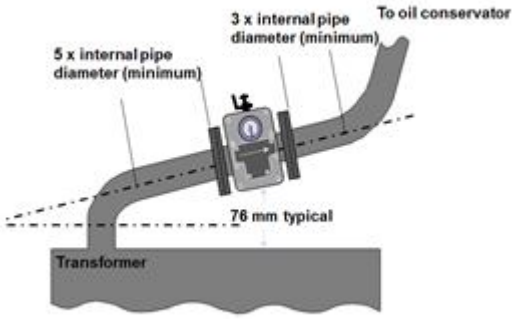


Fig. Buchholz relay installation.

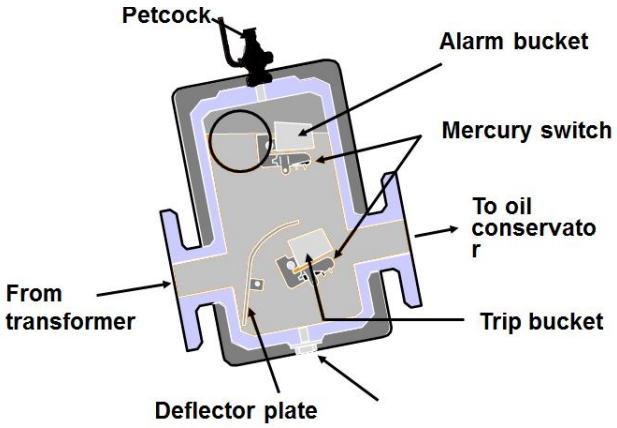


Fig. Buchholz relay

Buchholz relay finds its application for any of the following conditions:

Accumulation of gas

Accumulation of gas is due to inter-turn faults or winding faults to earth with a low power.

The color of gas indicates the type of fault:

- White or yellow color means insulation burnt.
-Grey color indicates dissociated oil.

The gas can be extracted from the petcock for detailed analysis.

Oilleakage

If there is some leakage in conservator tank then the level of oil may go down and the supply of oil through buchholz relay will be discontinued. This may cause the drastic lowering of oil level in buchholz relay which will actuate the mercury switch and trip the circuit.

It has mainly two elements viz, float and the baffle plate. The float is on the upper side with a mercury switch. The float is attached in such a way that it can move up and down depending upon the oil level in the Buchholzrelay Container. The baffle plate is on the lower side, again connected with a mercury switch. When the oil level goes down, the upper mercury switch gives an alarm signal. When the oil level goes severely down below the second mercury switch then the relay trip command.

(3). OVER-FLUXING PROTECTION

Over-fluxing is caused due to the following circumstances:

- Low frequency.
- High voltage.
- Geomagnetic disturbances.

The flux and the applied voltage in a transformer are related through the following expression:

$$V=4.44\,\phi_m f\,N$$

Thus we can write flux as

$$\phi_m = V/4.44\,f\,N$$

Whenever there is an overvoltage (frequency remaining constant), the transformer core is subjected to a higher value of flux in order to be able to support the higher applied voltage. By design, power transformer operate at knee of the saturation curve at normal voltage, Hence, any increase in the applied voltage, and the consequent increase in flux density, drives the transformer deeper into saturation. The transformer, therefore, draws an excessive magnetization current. Hence, this condition is describes as over-excitation. This, considerably, increases the core losses giving rise to over-heating of the transformer. Further, saturation of the core causes the flux to flow into adjacent structures, causing high eddy current losses in the core and adjacent conducting material. Such an operating condition cannot be allowed to continue for long and the transformer should be tripped it there is prolonged over-excitation. Figure shows a typical allowable over-excitation limit curve.

It can be easily seen that over-excitation can also occur in case of low frequency operation of the transformer at rated voltage.

Therefore, to keep the working flux within the permissible design limits, the V/f ratio must not exceed the permissible limits. For example, a transformer designed for a per unit voltage limit of 1.25 per unit (125%) at rated frequency will experience over-fluxing whenever the per unit volts/hertz exceeds 1.25 (125%) i.e. whenever the voltage exceeds 125% at rated frequency falls below approximately 80% (below approximately 40 Hz on 50 Hz basis) at rated voltage. Thus over-excitation can be detected by using V/f ratio by a so-called colts/hertz relay. Microprocessor based volts/hertz relays have been developed and are in use.

(4). RESTRICTED EARTH-FAULT PROTECTION

Restricted earth fault is the fault in any restricted zone of the circuit. The restricted earth fault protection defines itself as, not to sense any earth fault outside this restricted zone. This protection is mainly applicable to the Dyn type transformer (delta primary and star secondary). This type of protection is very much sensitive in case of internal earth fault. The faults which are covered by restricted earth protection are as follows:

Winding to core faults, that are phase to ground

When an external fault will occur in the star side the current flowing in the line current transformer of the phase in which fault has occurred and at the same time a balanced current will flow in the neutral current transformer, hence the resultant current in the relay will be zero. And restricted earth fault relay will not actuate for this fault. But, when any internal fault occurs the neutral current transformer only

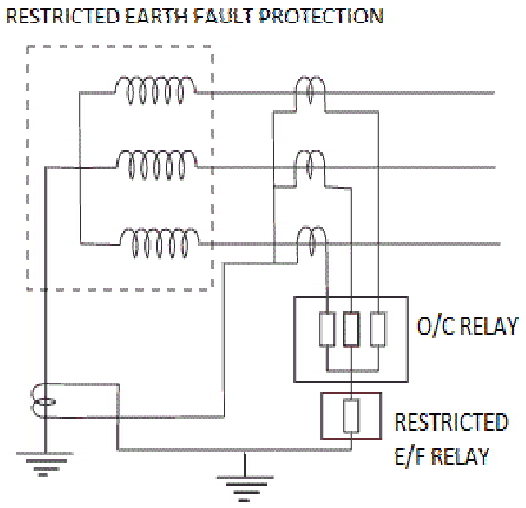
carries the unbalance fault current and therefore Restricted Earth Fault Relay will operate.

Earth fault relay is very much sensitive for internal faults. This type of protection is comparatively cheaper than differential protection. In this protection the secondary of CT of each phase of transformer are joined together. Then the terminals which are common are connected to the secondary of a Neutral Current Transformer.

Theneutral current transformer is nothing but the current transformer connected to neutral of transformer. Whenever there will be an unbalancing between the three phases of transformer, a resultant unbalance current will flow through the close path which is connected to the common terminals of thesecondary of CT. An unbalance current will also flow through the neutral of power transformer and hence there will be a secondary current in Neutral current transformer because of this unbalance neutral current. In Restricted Earth Fault protection the terminals which are common to phaseof CTs are connected to the secondary of neutral of current transformer in such a way that secondary unbalance current of phase CTs and the secondary current of CT at neutral will oppose each other. If these both currents are equal then there will beno consequent current circulating through the close path. The RestrictedEarth FaultRelay is connected in this close path. Hence the relay will not response even there is an unbalance in phase current of the power transformer.

In short, in this type of protection the current transformer on secondary side of each phase are connected together. The common terminals are connected to the secondary of neutral current transformer, which a CT connected to neutral of transformer. According to Kirchhoff's current law, the sum of current in both current transformer i.e. CT on primary and CT on secondary will be zero. At this relay will not actuate.

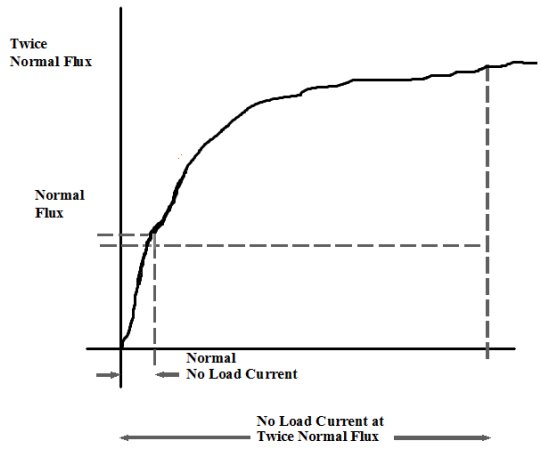
But when any internal fault occurs an unbalanced current flows through the neutral current transformer, at that time restricted earth fault relay operates.



- **Magnetizing Inrush:**

A power transformer, when switched ON and when load isn't connected to secondary, its primary draws a peaky and very high current from the source. This current is transient in nature. This means there is inrush of current when a power transformer is switched ON. This current is therefore referred as 'inrush current'. This magnetizing inrush current can cause unwanted tripping of circuit breakers of the transformer at the time of its charging.

Thus, during switching on of the power transformer, the maximum value of flux will directly jump to double of its steady state maximum value and after this steady state, the core becomes saturated. The figures illustrates the no load current and the respective magnetic flux.



In case of three phase transformers, the point of start of wave at the switching ON of the transformer differs for each case and so the inrush currents differ.

Following are the effects of magnetizing inrush current:

- Since it appears only on one side of transformer, it is seen as a fault on differential relay.
- Magnetizing inrush could cause relay to operate.
- Magnetizing inrush causes CT transient saturation.
- Thus, it can make mal operation of zero sequence relay at the primary side.

- **Magnetic Inrush Restrain:**

(2^{nd} and 5^{th} harmonic restrain)

- Makes relay immune to magnetizing inrush, however its slow operation may result for genuine transformer faults if CT saturation occurs.

III. CONCLUSION

The Paper displays the detailed information about the protection scheme of the Transformer and illustrates various points regarding all the protections assembled in the plant. Following conclusions are thus obtained:

- Buchholz protection is a major protection. It serves protection from oil leakage, over current and gas accumulation.
- Restricted earth fault is used to minimize magnetizing inrush current.
- Over Fluxing protection and the Differential protection is used to prevent imbalance in frequency and current respectively.

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