Transformer Protection
Transformer Protection

The protection method used for power transformers depends on the transformer ratings. Transformers are usually categorized according to their ratings as follows:

<table>
<thead>
<tr>
<th>Category</th>
<th>Transformer Rating – KVA</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>5 – 500</td>
</tr>
<tr>
<td>II</td>
<td>501 – 1,667</td>
</tr>
<tr>
<td>III</td>
<td>1668 – 10,000</td>
</tr>
<tr>
<td>IV</td>
<td>&gt; 10,000</td>
</tr>
</tbody>
</table>

- Transformers below 5000 KVA (Category I & II) are protected using Fuses. Fuses and MV circuit breakers are often used to protect transformers up to 1000 kVA (distribution transformers for 11kV and 33kV).

- For transformers 10 MVA and above (Category III & IV), differential relay are commonly used to protect them. Current differential relays are applied for transformers as main protection. In regard to backup protection, distance protection or overcurrent (phase current, zero sequence current) protection or both are mainly applied.

In addition to the above, mechanical relays such as **Buchholtz** relays and sudden pressure relays are widely applied to transformer protection, and are particular to application to transformer protection. Mechanical relays are intended to detect faults which the main relay could not detect. In addition to these relays, thermal overload protection is often applied for the purpose of extending a transformer’s life time rather than for detecting faults.
Main Electrical Protection

(1) Percentage Biased Current Differential protection
Differential Protection provides the best overall protection. Biased current differential protection is most commonly applied for transformer protection. Fig. 1 shows typical application for a star-delta transformer. Fig. 2 shows typical connections of the percentage differential relays with their associated current transformers.

![Transformer Protection Diagram]

Fig. 1 Typical Application
Transformer Differential Relay Connections

Fig. 2 Protection of delta – Star transformer bank by percentage differential relays.
Phase Shifting in Star-Delta Connected Transformer

Between the primary and secondary current of the transformer of a star-delta connection is a phase angle difference of 30°. For this reason, a method that aligns the current phase by differing from the connection of the CT secondary circuit of both sides is taken. The following describes the concept of such a connection.

The transformer unit is connected to the CT secondary circuit on the star connection side by a delta connection and to the CT secondary circuit on the delta connection side by a star connection, thereby acquiring a correct phase relationship with respect to load current and external fault current. **Fig.2** shows the correct phase relationship with respect to a three-phase current.

*(2) Restricted Earth Fault Protection*

A very large fault current can flow when a fault occurs at the transformer bushing. In that case, the fault must be cleared as quickly as possible. It can be difficult for phase current differential protection to detect faults to earth near transformer neutral points. In this case zero sequence current differential protection comparing the neutral current with the residual current of three phases, which is often called restricted earth fault protection (REF) is suitable to be applied. This function can be combined with phase current differential protection in a single unit as shown in **Fig.3**.

![Fig.3 Typical Application with REF.](image-url)
Example

Assume that a three-phase delta–wye-connected, 30-MVA, 69/34.5-kV power transformer is protected by the use of percentage differential relays, as shown in Figure 7.70. If the CTs located on the delta and wye sides are of 300/5 and 1200/5 A, respectively, determine the following:

(a) Output currents of both CTs at full load.
(b) Relay current at full load.
(c) Minimum relay current setting to permit 25 percent overload.

Solution

(a) The high-voltage side line current is

\[ I_{HV} = \frac{30 \times 10^6}{\sqrt{3}(69 \times 10^3)} = 251.02 \text{ A} \]

The low-voltage side line current is

\[ I_{LV} = \frac{30 \times 10^6}{\sqrt{3}(34.5 \times 10^3)} = 502.04 \text{ A} \]

Therefore, the output current of the CT located on the high-voltage side is

\[ 251.02 \left( \frac{5}{300} \right) = 4.1837 \text{ A} \]

and the output current of the CT located on the low-voltage side is

\[ 502.04 \left( \frac{5}{1200} \right) \sqrt{3} = 3.6232 \text{ A} \]

Note that the winding current of the delta-connected CT is multiplied by \(\sqrt{3}\) to obtain its line current.

(b) The relay current at full load is

\[ 4.1837 - 3.6232 = 0.5605 \text{ A} \]

(c) Thus, the minimum relay current setting to permit 25 percent overload is

\[ (1.25)(0.5605) = 0.7007 \text{ A} \]
Backup Protection

(1) Overcurrent Protection

It is quite common that overcurrent relays are applied to the high voltage side for transformer backup protection. It is especially suitable when there is no power source on the lower voltage side, because the overcurrent protection will operate only for faults in the transformer or on the low voltage side. Inverse overcurrent relays are sometimes applied to the lower voltage side for back up protection for the lower voltage lines rather than for the transformer.

(2) Distance Protection

If VTs are available, distance relays can be applied for backup protection. An advantage of distance protection is that it can distinguish forward faults from reverse faults. Therefore, distance protection can be applied for backup protection even when there are power sources on the lower voltage side. It is also possible that distance protection is applied as second main protection of a transformer if the zone 1 reach is set to less than the total impedance of the transformer. (e.g. 80%)

Mechanical Protection

Insulation deterioration of the electrical circuit or the iron core may cause vaporization of insulation fluid. Since differential protection for transformer cannot detect such an event, the following mechanical protection should be used.

(1) Buchholtz Relay

The Buchholtz relay is installed at the pipe between the main unit and the conservator, and it detects resolved gas by the float switch when a fault occurs within the transformer.

- A Buchholz relay is a gas and oil operated device installed in the pipe between the top of the transformer main tank and the conservator.
- The function of the relay is to detect an abnormal condition within the tank and send an alarm or trip signal.
• Under normal conditions the relay is completely full of oil. Operation occurs when floats are displaced by an accumulation of gas, or a flap is moved by a surge of oil.
• Almost all large oil-filled transformers (above 500kVA – category-II) are equipped with a Buchholz relay. A general view of the relay is shown in Fig.1.

![Buchholz relay Front View (A - Gas Collection Chamber).](image)

**Principle of operation**

A Buchholz relay will detect:

- Gas produced within the transformer
- **An oil surge from the tank to the conservator**
- A complete loss of oil from the conservator (very low oil level)

Fault conditions within a transformer produce gases such as carbon monoxide, hydrogen and a range of hydrocarbons.

- A small fault produces a small volume of gas that is deliberately trapped in the gas collection chamber (A) built into the relay. The oil level will be lowered and the oil in the bucket (B) will tilt the
counter weight C.W., thus switch Hg1 operates alarm circuit to send an alarm (see Fig. 2).

- A large fault produces a large volume of gas which drives a surge of oil towards the conservator. This surge moves a flap (P) in the relay to operate switch Hg2 and send a trip signal to open the main circuit breaker.
- The device will also respond to a severe reduction in the oil level due to oil leakage from the tank.

![Construction of Buchholz relay](image)

**Fig. 2 Construction of Buchholz relay.**

(2) Sudden-Pressure Relay

The sudden-pressure relay is installed in the upper part of a bursting tube, and it detects the sudden increase of internal pressure by the bellows when a fault occurs within the transformer.