Protection systems for on-load tap-changers
Product information

There are three major protection systems used for on-load tap-changers. This document describes them and the background for the predetermined set levels used by ABB in different applications. It also comments on some of the most common reasons for false tripping and how to avoid them.

Background
Today’s state of the art on-load tap-changers have reached a high level of reliability and it is safe to say that its life expectancy is equivalent to that of the transformer, exceptions may be applications in industrial process transformers. Still tap-changers account for a significant proportion of transformer related failures, although numerous cases of tap-changer failures have also been consequential of tapping winding failures and misdiagnosed as tap-changer failures.

Some of the more common tap-changer related failure modes include:
  • Carbonisation
  • Overloading
  • Misalignment
  • Locked mechanism
  • Fatigue failures of seemingly minor components
  • Reduced electrical withstand in oil, due to moisture ingress

Most serious faults inside a switching compartment generate massive amounts of gas, powerful pressure pulses and a subsequent oil flow to the conservator tank, which all can be detected by various devices and trigger a rapid power switch down.

The current international tap-changer standard, IEC 60214-1, states that in order to minimize the risk of fire or explosion resulting from an internal failure, the diverter or selector switch compartment shall be fitted with one or more of the following protective devices:
  • Pressure relay
  • Pressure relief device
  • Liquid-flow controlled relay
Pressure relay

Principles
The pressure relay shall respond in the event of pressure in the oil exceeding a predetermined value causing the transformer to be tripped. ABB uses this system as the first option on all tap-changer types and in most applications.

The main advantage with the system is the short response time, i.e. the time between a fault start to cascade from anywhere in the tap-changer compartment until a trip signal is triggered. The trip signal is triggered in less than 10 milliseconds after the set pressure is reached.

In order to ensure safe operation the predetermined pressure has to correspond to the actual application and the tap-changer manufacturer needs to be notified about the application in order to select the proper set value. This information is subsequently requested as part of the ordering data before delivering a tap-changer.

Set levels for pressure relay
The predetermined pressure set levels are based on theoretical and experimental results, as well as on continuous evaluation of the feedback received from asset owners and transformer manufacturers.

The set levels are chosen to provide the optimum balance between safe tripping in actual events on one hand, and to avoid false tripping that may occur under certain operation conditions on the other hand.

The primary parameters to consider for the individual application are the static pressure from the conservator tank, the flexibility in the tap-changer compartment itself, and the transformer application. Please refer to Table 1.

In case a pressure relief device is fitted in addition, its set level should be slightly higher than for the pressure relay. Please refer to Table 2.

Table 1. Selection criteria for pressure set levels in pressure relay used on ABB tap-changers.

<table>
<thead>
<tr>
<th>Tap-changer type</th>
<th>Vertical distance between pressure relay and highest oil level in conservator</th>
<th>H × 4 m</th>
<th>4 ≤ H × 7 m</th>
<th>H × 7 m</th>
<th>7 ≤ H × 12 m</th>
<th>12 ≤ H × 17 m</th>
<th>H × 7 m</th>
<th>7 ≤ H × 14 m</th>
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<td>UZ</td>
<td>H × 7 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UB</td>
<td>H × 7 m</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UC (GSU)</td>
<td>H × 7 m</td>
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<tr>
<td>UB (GSU)</td>
<td>H × 7 m</td>
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<tr>
<td>VUBB</td>
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</tr>
<tr>
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<tr>
<td>VUC (GSU)</td>
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<td></td>
<td></td>
</tr>
</tbody>
</table>

GSU = Generator Step Up application.
GSU transformer with converter tank above ≥ 7m please contact ABB.
Pressure relief device

Principles
The pressure relief device shall open when a predetermined pressure is exceeded.

ABB does not recommend this system to be the sole protection device for the tap-changer for several reasons.

- The system is slower triggering the trip signal, compared to the pressure relay.
- The system imposes a risk of water ingress in case of improper resealing after the fault is cleared.
- It will spray volatile gases and oil over the transformer unless redirected.

In the case where a pressure relief system is fitted, the set pressures should be coordinated and preferable slightly higher compared to any of the other two systems described. The primary tripping system should always be the pressure relay or the liquid flow relay.

Set levels for pressure relief device
It is not possible to combine pressure relay 200 kPa with a pressure relief device.

If a one way breather is used, theoretically 4 meters need to be added to the reference height of the converter tank. For instance, if distance to the converter tank is 3 meters, the set-point level for pressure relay and/or pressure relief device is based on a theoretical value of 7 meters. For information about the one way breather please contact ABB.

Table 2. Selection criteria for pressure set levels in pressure relief devices used on ABB tap-changers.

<table>
<thead>
<tr>
<th>Tap-changer type</th>
<th>Vertical distance between pressure relay and highest oil level in conservator</th>
<th>Set-point</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>70 kPa</td>
<td>140 kPa</td>
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<td>UZ</td>
<td>$H &lt; 4 \text{ m}$</td>
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</tr>
<tr>
<td>UB</td>
<td>$H &lt; 7 \text{ m}$</td>
<td>$H &lt; 7 \text{ m}$</td>
</tr>
<tr>
<td>UC</td>
<td>$H &lt; 7 \text{ m}$</td>
<td>$H &lt; 7 \text{ m}$</td>
</tr>
<tr>
<td>UC (GSU)(^1)</td>
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<td>$H &lt; 7 \text{ m}$</td>
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<tr>
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<tr>
<td>VUC</td>
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<td>$H &lt; 7 \text{ m}$</td>
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<tr>
<td>VUC (GSU)(^2)</td>
<td>$H &lt; 7 \text{ m}$</td>
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</tbody>
</table>

\(^1\) GSU = Generator Step Up application.
\(^2\) GSU transformer with converter tank above $\geq 4 \text{ m}$ please contact ABB
Liquid-flow controlled relay

Principles
The liquid-flow controlled relay is installed in the pipe between the top of the tap-changer and the conservator tank, and shall respond at a predetermined oil flow and enable the transformer to be tripped.

This system can be used as an optional primary tripping system instead of the pressure relay.

The advantage is it reacts good to low fault levels and is also robust to false trips.

Tests carried out by ABB shows the system is slower compared to the pressure relay and also dependent on the length of the conservation pipe arrangement and this is the reason why the system is used only on specific request and not as the standard protection system in most applications.

Miscellaneous
The pressure relay used by ABB has been developed and improved over many years to provide for a maximum of reliability and to avoid false tripping.

It is however important to remember it is a calibrated instrument, which has to be handled with care during installation and commissioning to ensure safe operation.

Connection at site should be done with good workmanship practice. It is particularly important that the cable connection is done in such a way that no water can penetrate into the unit, either through the cable gland, which always should be facing downwards, or through the removable cover plate on the front of the unit.

The tripping circuit connected to the pressure relay should not be sensitive enough to trigger a trip from just the small leakage current that may occur from moisture ingress into the pressure relay, if the unit not have been properly sealed as explained above.