On-load tap-changers for industrial applications

Product information

On-load tap-changers for industrial applications require different specification parameters compared to those for network transformers. Arc furnace and rectifier applications especially, put high demands on the tap-changers. This product information provides the general guidelines for selecting an ABB tap-changer for industrial transformers.

For data not given in this report, the values stated in the appropriate Technical Guide are valid. In borderline cases and when uncertainty exists, please contact ABB Components for advice.

The service conditions for industrial transformers differ in many ways from those in a normal network transformer. A tap-changer in a network transformer makes approximately 5–20 operations a day in a stable network and the average load is normally far below the rated load. This low operation frequency means that the maintenance interval is 7 years and the contact life is normally as long as the transformer’s.

In an industrial application, the conditions are very different. The number of operations is typically up to 200,000 operations a year, overloads are much more common and current peaks occur. These conditions mean that the number of operations, not the age, determines the maintenance intervals and that maintenance has to be carried out once or twice a year.
The following types of ABB on-load tap-changers are suitable for industrial applications. For applications where tap-changers connect and disconnect reactances and capacitances, please consult ABB Components for advice.

**Tap-changer type UZ**
The type UZ is suitable for smaller transformers with relatively low currents, since the available contact material does not give a satisfactory contact life at high currents in this demanding application. The mechanical parts are very simple and have a long life.

**Tap-changer type UC**
The type UC has long contact life, which means long maintenance intervals and long time between contact replacements.

By having a spare diverter switch combined with on-line oil filtration, the maintenance time can be considerably reduced. The diverter switch that is to be maintained is lifted out and the spare unit is put into the housing and the transformer is ready for operation again. In the meantime, the first diverter switch can be maintained so it is ready for use at next maintenance occasion. Even without on-line oil filtration, time is saved with two diverter switches, but less since oil draining and cleaning has to be carried out.

The UC tap selectors can be operated 1 500 000 times before maintenance. For inspection purposes, a manhole in the transformer tank is recommended.

The ABB tap-changers suitable for industrial transformers are available for the following connections:

<table>
<thead>
<tr>
<th>Type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neutral point</td>
<td>UZ, UCG, UCL, UCD</td>
</tr>
<tr>
<td>Single phase</td>
<td>UZ, UCG, UCL, UCD</td>
</tr>
<tr>
<td>Three phase fully insulated</td>
<td>UZ, UCG, UCL</td>
</tr>
<tr>
<td>Delta type</td>
<td>UCG, UCL</td>
</tr>
<tr>
<td>Star-delta</td>
<td>UZ, UCG, UCL, UCD</td>
</tr>
<tr>
<td>With bias-winding</td>
<td>UCG, UCL, UCD</td>
</tr>
</tbody>
</table>

1) For UC that means three tap-changer units driven by a common motor-drive. For UCD there is usually one motor-drive for each tap-changer unit but in some cases one motor-drive is sufficient. Please consult ABB Components in this matter. UZ has always one unit for all connections.

2) Delta type means that the regulating windings for two phases are placed in the same corner of the delta meaning that one UC tap-changer unit can operate in two phases and the second unit in the remaining phase. See the appropriate Technical Guide.

3) Bias winding is a winding connected between one of the tap selector arms and the diverter switch with the number of turns corresponding to half a loop of the regulating winding. Even called ticklet winding.

**Contact life**
The contact life is dependent of the rated through-current relatively the current capacity of the selected tap-changer. By selecting an tap-changer type designed for higher current, the contact life will be longer but it will never exceed 500 000 operations. Please refer to the appropriate Technical Guide.

**Limits in system voltage with star-delta connection**
For star-delta connection, an tap-changer with full insulation between phases must be used. The motor-drive is interlocked such that the star-delta change-over operation is effected only with the transformer disconnected.

When the change-over selector in the tap-changer is used for switching the transformer between star and delta connection in order to increase the voltage regulating range, the system voltage (phase-to-phase voltage) divided by square root of three occurs over the change-over selector. This voltage must not exceed the values presented below.

The change-over selector will also be subjected to the test voltages to earth and between phases. The voltages that should not be exceeded are also presented below and are thus the maximum voltages to earth for all of them and between phases for UZ. For UC, each phase has its own compartment and the transformer manufacturer decides the insulation distances between them.

<table>
<thead>
<tr>
<th>On-load</th>
<th>Tap selector</th>
<th>Max. system voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>tap-changer</td>
<td></td>
<td>[kV]</td>
</tr>
<tr>
<td>UZE/UZF</td>
<td>-</td>
<td>38</td>
</tr>
<tr>
<td>UCG I</td>
<td></td>
<td>60</td>
</tr>
<tr>
<td>UCG I</td>
<td>C</td>
<td>60</td>
</tr>
<tr>
<td>UCG III</td>
<td></td>
<td>104</td>
</tr>
<tr>
<td>UCL III</td>
<td></td>
<td>104</td>
</tr>
<tr>
<td>UCD III</td>
<td></td>
<td>104</td>
</tr>
</tbody>
</table>

**Change-over selector, test voltages**

<table>
<thead>
<tr>
<th>C</th>
<th>400–150</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>350–140</td>
</tr>
<tr>
<td>III</td>
<td>600–200</td>
</tr>
</tbody>
</table>

For UZ, the value is 200–60 kV.

All voltages given as “Lightning impulse (1,2/50) in kV and power frequency (AC 1 min) in kV”.

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2 On-load tap-changers for industrial applications
Different kinds of furnace applications
There are different kinds of furnace applications that put different demands on the tap-changer.

Arc furnace applications
Arc furnace is probably the most demanding application for a tap-changer because of the high number of operations, the frequent overload and the peak currents from the short-circuits of the furnace electrodes during melting.

The maximum permitted step voltage is reduced to 75% of the normal value given in the Technical Guide in order never to exceed the values of the type tests and with regards to the presence of harmonics.

Rated through-current
The rated through-current ($I_{\text{rated}}$) of the tap-changer is chosen as the highest current ($I_{\text{max}}$) in any tap of the regulating winding including continuous overload. This is valid as long as the current during short-circuit of the furnace electrodes does not exceed $2 \cdot I_{\text{max}}$.

Example 1:
200 A +30 % continuous overload (= 260 A), short-circuit current 500 A.
Since 500/2 is less than 260, $I_{\text{rated}}$ will be 260 A.

Example 2:
200 A +30 % continuous overload (= 260 A), short-circuit current 600 A.
Since 600/2 exceeds 260, $I_{\text{rated}}$ will be 600/2 = 300 A.

Step voltage
The maximum permitted step voltage for the rated through-current as calculated in the previous section shall be limited to 75% of that found in the appropriate Technical Guide. (Use the value for the rated through-current for the tap-changer as calculated above when establishing max. permitted step voltage). Step voltage means the step voltage between a connected tap and an adjacent tap. If a step, two or more positions away, has a higher value, that value is not relevant.

Since many arc furnace transformers have steps with different number of loops, the maximum current does not necessarily occur together with the highest step voltage. Find what looks like a suitable tap-changer and check that the reduced step voltage curve is not exceeded in any position. If any uncertainty arises, send the table of step voltages and load currents to ABB Components for advice.

Other types of furnaces applications
For other types of furnaces operated by normal sine wave shaped currents and that has no short-circuits of electrodes, the data in the appropriate Technical Guide are valid.

Rectifier transformers
Some industrial processes are supplied by DC-current, subsequently tap-changers for rectifier transformers should be specially dimensioned due to the presence of harmonics. However, there are no automatic limits in currents or step voltages as for arc furnace transformers.

Rated through-current
The rated through-current ($I_{\text{rated}}$) of the tap-changer is chosen as the highest current ($I_{\text{max}}$) in any tap of the regulating winding including continuous overload.

Step voltage
The harmonics change the shape of the current from a sine wave to something less smooth. If the $\partial I/\partial t$ of the current exceeds that of a sine wave somewhere between 0-5 ms after the current zero with more than 10%, the dimensioning of the diverter switch should be done according to the following:

Calculate the recovery voltage over the contacts as:
\[
\frac{\partial I}{\partial t} \cdot \frac{444 \cdot I_{\text{OLTC}}}{\text{Step voltage}}
\]
Where
- $\partial I/\partial t$ is the value for the actual current at zero crossing in A/s, including continuous overload.
- $444 \cdot I_{\text{OLTC}}$ is the $\partial I/\partial t$ for a normal sine wave current with the value of $I_{\text{OLTC}}$.
- $I_{\text{OLTC}}$ is the calculated rated through-current for the tap-changer.
- Step voltage is the actual step voltage for the transformer in question.

Check if the recovery voltage is below the curve for step voltages versus rated through-currents shown in the appropriate Technical Guide. The rated through-current for the tap-changer is the one calculated in the section above.

If it is still below, that tap-changer can be chosen. If it is not, please consult ABB Components for advice. Normally the table of different harmonics is given. Since the $\partial I/\partial t$ is the important parameter for the tap-changer, a table of harmonics is not so useful. A $\partial I/\partial t$ can be calculated from the harmonics if it is assumed that all harmonics goes through zero simultaneously, but that is not the case normally so the consequence will be an over dimensioned tap-changer.
**Maintenance**

Maintenance should be carried out 5 times during the estimated contact life or every seventh year whichever comes first. For users that operate the tap-changers very frequently in continuous processes, this interval might be too short since they might have only one or two outages per year that allow for maintenance work.

In such cases, the maintenance interval will be doubled provided that oil filter units for continuous oil filtration from ABB Components is installed, see also section Oil filter unit. The oil filter removes the particles produced by the arcing and thereby the mechanical wear is considerably reduced.

**Oil filter unit**

The ABB oil filter unit operates continuously providing very good filtration, low flow rate and simple control equipment. The oil filter unit reduces the amount of particles to approximately 0.1 % of that of non-filtered oil. At maintenance, no oil filtration or cleaning of the tap-changer compartment is necessary which reduces the maintenance time and cost considerably.

The filter cartridge is easily replaced since the oil filter unit should be positioned on transformer base level and it is replaced without taking the transformer out of service. The oil filter unit also provides a convenient way of taking oil samples. The control equipment is housed in the motor-drive mechanism cabinet. This must be considered when selecting type and size of motor-drive mechanism.

**Ordering information**

It is important to specify in the ordering data that the tap-changer is going to be used in an industrial application. Provide the data for overloads, currents at short-circuit of the electrodes the $\frac{di}{dt}$ for the current and in relevant cases, the table with currents and step voltages.