Selection of MO surge arresters
Overvoltage protection
The APPLICATION NOTES (AN) are intended to be used in conjunction with the

APPLICATION GUIDELINES

Overvoltage protection
Metal-oxide surge arresters in medium-voltage systems.

Each APPLICATION NOTE gives in a concentrated form additional and more detailed information for the selection and application of MO surge arresters in general or for a specific equipment.

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Selection of MO surge arresters

The task of MO surge arresters is to protect other electrical equipment against dangerous overvoltages.

1 Introduction

The protection level $U_{pl}$ of an MO surge arrester has to be well below the LIWV of the equipment to be protected. On the other hand the MO surge arrester has to withstand all stresses from the system. Therefore, the continuous operating voltage $U_c$ has to be well above the maximum power frequency voltage of the system $U_s$ (or $U_{TOV}$).

Simply said: the MO surge arrester has to protect and not to cause problems.

The chosen value for $U_c$ should be in all cases higher than the minimum calculated value see Figure 1.

The following Table 1 shows typical values of the lightning impulse withstand voltage LIWV of the equipment (based on $U_m$) and the lightning impulse protection level $U_{pl}$ of the MO surge arrester. As can be seen, there is in all distribution systems a safe margin between LIWV and $U_{pl}$.

For standardized nominal voltages $U_n$, highest system voltages $U_s$, highest voltage for equipment $U_m$ and withstand voltages ACWV and LIWV, see Application Note Annex 1.1 A2 and Application Note Annex 1.1 A3.

The selection of MO surge arresters should be done step by step according the attached flow chart.

Table 1: Typical values of the lightning impulse withstanding voltage LIWV and the lightning impulse protection level $U_{pl} = 4$ p.u.

<table>
<thead>
<tr>
<th>$U_m$, in kV rms</th>
<th>3.6</th>
<th>7.2</th>
<th>12</th>
<th>17.5</th>
<th>24</th>
<th>36</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIWV in kV pv</td>
<td>40</td>
<td>60</td>
<td>75</td>
<td>95</td>
<td>125</td>
<td>170</td>
</tr>
<tr>
<td>$U_{pl}$ in kV pv</td>
<td>11.8</td>
<td>23.5</td>
<td>39.2</td>
<td>57.2</td>
<td>78.4</td>
<td>117.6</td>
</tr>
<tr>
<td>LIWV/ $U_{pl}$</td>
<td>3.39</td>
<td>2.55</td>
<td>1.91</td>
<td>1.66</td>
<td>1.59</td>
<td>1.45</td>
</tr>
</tbody>
</table>
2 Required information

In an ideal case all the following information should be given with inquiries.

System Data
- Highest system voltage $U_s$
- Frequency
- Earth fault factor or type of neutral earthing
- Maximum duration of earth fault (clearing time)
- Maximum value of $U_{TOV}$
- Short circuit current $I_s$ of the system (per phase)
- Load rejection factor (in case of generator protection)

Service conditions
- Normal ambient conditions acc. IEC?
- Pollution class or creepage distance
- Insulation withstand voltage or flash over distance
- Altitude
- Ambient temperature
- Abnormal earthing conditions
- Mechanical requirements

Arrester application
- Connection phase to earth
- Connection neutral to earth (transformer)
- Connection phase to phase

Equipment to be protected
- Highest voltage for equipment $U_m$
- Lightning Impulse Withstand Voltage (LIWV) of equipment to be protected

Type of equipment
- Transformer (directly connected to line or via cable)
- Rotating machines
- Cables
- Cable sheath (length of cable and short circuit current per phase)
- Capacitors
- Etc.

3 Selection of $U_c$

The calculation of the continuous operating voltage $U_c$, which depends on the maximum system voltage $U_s$ and the earthing conditions, is explained in Application Note 1.2. See also Application Note 1.2 A1.

As mentioned in AN 1.2, the $U_c$ should be generally chosen 10% higher than the calculated minimum, and then the next higher value from the data sheet should be taken.

4 Selection of arrester class

The class is given by the nominal discharge current $I_n$, the repetitive charge transfer rating $Q_{rs}$, the thermal charge transfer rating $Q_{th}$ for distribution class arresters or the thermal energy rating $W_{th}$ for station class arresters, respectively.

Nominal discharge current $I_n$

The choice acc. IEC 60099-4, Ed. 3.0 is between $I_n = 2.5 \, \text{kA}$, $5 \, \text{kA}$, $10 \, \text{kA}$ and $20 \, \text{kA}$.

ABB in Switzerland produces only MO surge arresters with $I_n = 10 \, \text{kA}$ and $20 \, \text{kA}$.

Therefore, the choice is reduced to two values. For MO surge arresters for application in medium voltage systems the nominal current is $I_n = 10 \, \text{kA}$. This is true for distribution class arresters DH and all station class arresters (except for station class arresters SH with $I_n = 20 \, \text{kA}$).

Repetitive charge transfer rating $Q_{rs}$

$Q_{rs}$ is defined as the maximum charge transfer capability in the form of a single current impulse or group of current impulses that may be transferred through the arrester without causing mechanical damages or unacceptable electrical changes. This rating is verified on single MO resistors and, therefore, is a MO resistor-related material test. It can be compared with the long duration current withstand test (e.g. $I_{ld}, 2 \, \text{ms}$) in the previous Ed. 2.2 of IEC 60099-4, see Table 2.
Thermal charge transfer rating \(Q_{th}\) and thermal energy rating \(W_{th}\)

\(Q_{th}\) and \(W_{th}\) are the maximum thermal charge transfer rating and maximum thermal energy rating, respectively, that may be injected in an MO surge arrester without causing thermal runaway. These tests are thermal stability tests, and the results can be compared with the values of the operating duty tests \((W\ in\ kJ/kV,\ U_c)\ acc.\ Ed.2.2\) of IEC 60099-4, see Table 2.

Note that in IEC 60099-4, Ed. 3.0 the values for \(W_{th}\) are given in relation to \(U_r\), while practice of ABB in Switzerland is to give the value related to \(U_c\). For comparison both values are given in the table above.

5 Selection of housing

The housing of MO surge arresters has to fulfill two requirements, the creepage distance (depends on the pollution class) and the flashover distance (depends on the required external withstand voltage of the insulation).

The pollution classes and the corresponding reference unified specific creepage distances (RUSCD) are specified in IEC 60507:2013 and IEC/TS 60815-1:2008, see Table 3.

IEC/TS 60815-3:2008 refers to polymer insulators for AC systems. For the purpose of standardization, five classes of pollution characterizing the site severity are qualitatively defined. It is possible, however, to specify the reductions of the creepage distances for synthetic materials that have a regenerative hydrophobicity, such as silicone, towards ceramic insulations. These reductions, as seen in Table 3, are based on general recommendations given in IEC 60815-3, results from tests and field experience.

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### Table 2: Arrester classes, Comparison IEC 60099-4, Ed. 2.2 and IEC 60099-4, Ed. 3.0

<table>
<thead>
<tr>
<th>Old: classification acc. IEC 60099-4, Ed. 2.2, Line Discharge Classes (LD classes)</th>
<th>New: classification acc. IEC 60099-4, Ed. 3.0, thermal rating (W_{th}), (Q_{th}) and charge transfer (Q_{rs})</th>
</tr>
</thead>
<tbody>
<tr>
<td>LD</td>
<td>Class DH SL SL SM SH</td>
</tr>
<tr>
<td>(I_n) (8/20) in kA</td>
<td>10 10 10 10 20</td>
</tr>
<tr>
<td>(I_{hc}) (4/10) in kA</td>
<td>100 100 100 100 100</td>
</tr>
<tr>
<td>(I_{fs}), 2 ms in A</td>
<td>250 500 550 800 1350</td>
</tr>
<tr>
<td>(W) in kJ/kV, (U_c)</td>
<td>3.0 5.2 5.5 9.0 13.3</td>
</tr>
<tr>
<td>ABB Type (choice)</td>
<td>POLIM-D POLIM-K POLIM-I POLIM-S POLIM-H</td>
</tr>
</tbody>
</table>

| LD                              |                  |
| \(I_n\) (8/20) in kA           |                  |
| \(Q_{rs}\) in C                | 0.5 1.0 1.6 2.0 2.4 |
| \(Q_{th}\) in C                | 1.1 -/- -/- -/- -/- |
| \(W_{th}\) in kJ/kV, \(U_r\)   | -/- 4.5 5.0 8.0 12.0 |
| \(W_{th}\) in kJ/kV, \(U_c\)   | -/- 5.6 6.25 10.0 15.0 |

### Table 3: Correlation of pollution class and creepage distance.

<table>
<thead>
<tr>
<th>Pollution class</th>
<th>Minimum recommended specific creepage distance in mm/kV*</th>
<th>Possible reduction of the creepage distance with silicone insulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>a – Very light</td>
<td>22.0</td>
<td>30%</td>
</tr>
<tr>
<td>b – Light</td>
<td>27.8</td>
<td>30%</td>
</tr>
<tr>
<td>c – Medium</td>
<td>34.7</td>
<td>20%</td>
</tr>
<tr>
<td>d – Heavy</td>
<td>43.3</td>
<td>No reduction recommended</td>
</tr>
<tr>
<td>e – Very heavy</td>
<td>53.7</td>
<td>No reduction</td>
</tr>
</tbody>
</table>

* the shortest specific creepage distance for insulators between phase and earth.
Note: The creepage distance for a MO surge arrester is sometimes specified in relation to the continuous operating voltage \( U_{c} \). Therefore, it is important to carefully consider the voltage to which the creepage requirements are related.

The **flashover distance** of the external insulation is generally not critical for MO surge arresters for application in distribution systems. The required values of the designs are verified during the insulation withstand tests under dry and wet conditions. MO surge arresters made by ABB in Switzerland can be used without any housing adjustment up to a height of 1,800 m above sea level.

Care has to be taken if the MO surge arresters are installed in altitudes higher than 1,800 m above sea level. In such cases the required flashover distance has to be recalculated, using an altitude correction factor. It is proposed that for every 1,000 m above 1,800 m above sea level an increase of the flashover distance by 10 percent should be considered. For example, at an altitude of 3,300 m above sea level the flashover distance of the housing should be 15 percent longer than that of a standard arrester. It is necessary to observe here that the flashover distances of surge arresters for lower voltage levels are initially relatively large, exceeding the minimum requirements of the withstand voltage. Thus, in each individual case it should be checked whether the normal housing possesses a sufficient withstand voltage for application at higher altitudes.

### 6 Mechanical requirements

The mechanical requirements for MO surge arresters in distribution systems are generally not critical.

- Normally the short circuit requirements are given by the customer in the inquiries, or not mentioned at all.
- Seismic loads can be normally neglected.
- Wind loads are not critical, terminal loads in standard applications are not critical as well.
- In all cases the requirements are given in the inquiries.

### 7 Final check

As a final check the following should be considered:

- Is the required ambient temperature higher than the standard value of 40°C? If yes, the continuous operating voltage has to be increased accordingly, or the MO arrester (thermal rating \( W_{th} \) or \( Q_{th} \), respectively) derated.
- Installation in altitudes above 1,800 m? If yes, check if flash over distance has to be increased.
- Check if the residual voltage \( U_{pl} \) is well below the required LIWV of the equipment.
- Any other special requirements by the client?
Flow chart selection of MO surge arresters for medium-voltage 3-phase a.c. systems

1. Selection of active part electrical data
   - a) Continuous operating voltage $U_c$
   - b) Rated voltage $U_r$
   - c) Nominal discharge current $I_n$
   - d) Charge and thermal rating $Q_{rs}, W_{th}, Q_{th}$
   - e) Check lightning impulse protection level $U_{pl}$ and withstand voltage LIWV

Comments
- Generally not critical in medium voltage distribution systems.
- In $I_n = 10$ kA for all MO arresters, except for station class SH (POLIM-H..N): $I_n = 20$ kA.
- See AN 1.2
- $U_r = 1.25 \times U_c$, fixed ratio, see also data sheets.

Active part selected

2. Selection of arrester housing mechanical data
   - f) Creepage distance
   - g) Flashover distance
   - h) Consider short circuit rating $I_s$
   - i) Consider mechanical loads

Comments
- Generally not critical. Only to be considered if installed in altitudes above 1800 m.
- See data sheets.
- See Application Guidelines section 3.

Arrester selected
Voltages in 3-phase a.c. distribution systems above 1000 V

<table>
<thead>
<tr>
<th>System IEC 60038</th>
<th>Equipment IEC 60071-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>( U_n ) kV rms</td>
<td>( U_m ) kV rms</td>
</tr>
<tr>
<td>3</td>
<td>3.6</td>
</tr>
<tr>
<td>6</td>
<td>7.2</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>15</td>
<td>17.5</td>
</tr>
<tr>
<td>20</td>
<td>24</td>
</tr>
<tr>
<td>30</td>
<td>36</td>
</tr>
</tbody>
</table>

\( U_n \) nominal system voltage
\( U_s \) highest voltage of a system, needed for estimation of \( U_c \)
\( U_m \) highest voltage for equipment
ACWV standard rated short-duration (60 s) power frequency withstand voltage of an equipment or insulation configuration
LIWV standard rated lightning impulse withstand voltage of an equipment or insulation configuration, needed to check lightning impulse protection level \( U_{pl} \) of MO surge arrester
SIWV standard rated switching impulse withstand voltage of an equipment or insulation

The above table is an extract of the more complete table given in Application Note Annex 1.1 A3. For practical use in distribution systems the above table is sufficient. The columns \( U_s \) and LIWV give the needed figures for the calculation of the continuous operating voltage \( U_c \) and for the needed lightning impulse protection level \( U_{pl} \) of the MO surge arrester.

The following commonly used voltage ranges are given for completeness, see also Application Note Annex 1.1 A3.

**System voltages acc. IEC 60038:**
IEC standard voltages

- Distribution: voltage range between \( U_s = 3.6 \) kV and \( U_s = 40.5 \) kV
- Sub transmission: voltage range between \( U_s = 3.6 \) kV and \( U_s = 145 \) kV
- Transmission: voltage range between \( U_s = 170 \) kV and \( U_s = 1200 \) kV

**Voltages for equipment acc. IEC 60071-1:**
Insulation co-ordination

- Range I: voltage range between \( U_m = 3.6 \) kV and \( U_m = 245 \) kV
- Range II: voltage range between \( U_m = 300 \) kV and \( U_m = 1200 \) kV
Nominal voltages (and related voltages) above 1000 V a.c., 3phase systems

<table>
<thead>
<tr>
<th>System IEC 60038</th>
<th>Equipment IEC 60071-1</th>
</tr>
</thead>
<tbody>
<tr>
<td>$U_n$ kV rms</td>
<td>$U_s$ kV rms</td>
</tr>
<tr>
<td>3</td>
<td>3.6</td>
</tr>
<tr>
<td>6</td>
<td>7.2</td>
</tr>
<tr>
<td>10</td>
<td>12</td>
</tr>
<tr>
<td>15</td>
<td>17.5</td>
</tr>
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<td>20</td>
<td>24</td>
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<tr>
<td>30</td>
<td>36</td>
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<tr>
<td>35</td>
<td>40.5</td>
</tr>
<tr>
<td>45</td>
<td>52</td>
</tr>
<tr>
<td>66</td>
<td>72.5</td>
</tr>
<tr>
<td>-/ -</td>
<td>-/ -</td>
</tr>
<tr>
<td>110</td>
<td>123</td>
</tr>
<tr>
<td>132</td>
<td>145</td>
</tr>
<tr>
<td>150</td>
<td>170</td>
</tr>
<tr>
<td>220</td>
<td>245</td>
</tr>
<tr>
<td>-/ -</td>
<td>300</td>
</tr>
<tr>
<td>-/ -</td>
<td>362</td>
</tr>
<tr>
<td>380</td>
<td>420</td>
</tr>
<tr>
<td>-/ -</td>
<td>550</td>
</tr>
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<td>-/ -</td>
<td>800</td>
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<td>300</td>
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<td>-/ -</td>
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<td>420</td>
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<td>-/ -</td>
<td>1100</td>
</tr>
<tr>
<td>-/ -</td>
<td>1200</td>
</tr>
</tbody>
</table>

For more and detailed information see IEC 60071-1, Edition 8.1 2011-03, Table 2 and Table 3.
Additional information

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