Functions of Surge Arresters

- Mounted in parallel to the transformer/equipment
- Handle over voltage surge, clamp it down
- Absorb energy from the surge
- Discharge the surge current to the ground
- Protect the transformer / equipment
- Dissipate the energy and remain thermally stable
- Provide reliable & predictable service, safe performance
Sources of Surges

- Lightning
- Switching
- System generated TOV
Fundamentals of Insulation Coordination

- **Possible voltages without arresters**
- **Withstand voltage of equipment**
- **Voltages limited by arresters**

Time duration of over-voltage

- Lightning overvoltages (Microseconds)
- Switching overvoltages (Milliseconds)
- Temporary overvoltages (Seconds)
- Highest system voltage (Continuously)
Design Transformations

- SiC + Porcelain (thru 1978)
- MOV + Porcelain (1978 thru 1986)
- MOV + Polymer (1986 thru now)
Internal Elements and Housing

- MOV Vs SiC
- Porc Vs SR
- SR Vs EPDM
Silicone Carbide Gapped Arrester

- SiC blocks in Porcelain housing with gap structure
- Design prior to mid 70s
- Had serious problems of
  - Moisture Ingress
  - Unstable Protective Levels
  - Violent Failures
Discharge Voltage

IR₁

IR₂

ZnO

SiC

MOV

< 1 mA

50 A

100 - 500 Amps

1-10 kA

© 2009 Siemens Energy, Inc. All rights reserved
Silicone Housed Surge Arresters
- Effect of Hydrophobicity
Different Polymers: Silicone vs. EPDM

Silicone (+++)

- Highly Hydrophobic (water-repellent)
- UV-resistant
  - the best pollution & long-term stability

EPDM (- - -)

- Non-hydrophobic
- Low UV Rating
  - poor pollution and long-term stability

Refer to Dow Corning R & D Paper
Silicone rubber for electrical insulators

The market for composite insulators is growing steadily, both in long rod line applications and hollow core station insulators. Composite designs typically use engineered polymers which offer higher mechanical strength, greater design flexibility, reduced weight, and lower breakage rates than ceramic components. The emerging shift to composites adds new importance to the debate over which polymeric material should be used for the housing. Insulator field experience and extensive, multi-stress lab testing of different elastomer formulations have shown silicone’s unique surface behavior to be an advantage in these applications.

Most utilities prefer SR for housings and insulators

- Test data Compare SR against EPDM and PORCELAIN
- Recommends SR as the best insulation for Power Systems Applications
Types of Surge Arresters

- Station Class
- Intermediate Class
- Distribution Class (HD, ND, RP)
- Transmission Line Arresters (TLA)
IEEE Standard for Metal-Oxide Surge Arresters for AC Power Circuits (> 1 kV)

IEEE Power Engineering Society

Sponsored by the Surge Protective Devices Committee

IEEE Std C62.11™-2005
(Revision of IEEE Std C62.11-1999)
IEEE Guide for the Application of Metal-Oxide Surge Arresters for Alternating-Current Systems

IEEE Power & Energy Society
Sponsored by the Surge Protective Devices Committee
## Surge Arresters Classification

### Performance Requirements

*(Table B.1 of Annex B from IEEE Std C62.11)*

<table>
<thead>
<tr>
<th>Class</th>
<th>Rated voltage (kV)</th>
<th>Lightning impulse classifying current (kA)</th>
<th>Switching surge classifying current (A)</th>
<th>Minimum high-current short-duration withstand (kA)</th>
<th>Minimum low-current long-duration withstand (A, μs)</th>
<th>Minimum line discharge capability</th>
<th>High-current pressure relief (kA)*</th>
<th>Low current pressure relief (A)*</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Station</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3–48</td>
<td>2.55–39</td>
<td>10</td>
<td>500</td>
<td>65</td>
<td>—</td>
<td>Table 11</td>
<td>40–65</td>
<td>400–800</td>
</tr>
<tr>
<td>54–312</td>
<td>42–245</td>
<td>10</td>
<td>500–1000</td>
<td>65</td>
<td>—</td>
<td>Table 11</td>
<td>40–65</td>
<td>400–800</td>
</tr>
<tr>
<td>396–564</td>
<td>318–448</td>
<td>15</td>
<td>2000</td>
<td>65</td>
<td>—</td>
<td>Table 11</td>
<td>40–65</td>
<td>400–800</td>
</tr>
<tr>
<td>576–612</td>
<td>462–485</td>
<td>20</td>
<td>2000</td>
<td>65</td>
<td>—</td>
<td>Table 11</td>
<td>40–65</td>
<td>400–800</td>
</tr>
<tr>
<td><strong>Intermediate</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3–144</td>
<td>2.55–115</td>
<td>5</td>
<td>500</td>
<td>65</td>
<td>—</td>
<td>Table 11</td>
<td>40–65</td>
<td>400–800</td>
</tr>
<tr>
<td><strong>Distribution, heavy duty</strong></td>
<td>3–36</td>
<td>2.55–29</td>
<td>10</td>
<td>—</td>
<td>100</td>
<td>—</td>
<td>—</td>
<td>—</td>
</tr>
<tr>
<td><strong>Distribution, normal duty</strong></td>
<td>3–36</td>
<td>2.55–29</td>
<td>5</td>
<td>—</td>
<td>65</td>
<td>—</td>
<td>75, 2000</td>
<td>—</td>
</tr>
<tr>
<td><strong>Distribution, light duty</strong></td>
<td>3–36</td>
<td>2.55–29</td>
<td>5</td>
<td>—</td>
<td>40</td>
<td>—</td>
<td>75, 2000</td>
<td>—</td>
</tr>
</tbody>
</table>

* Test values for arresters with porcelain tops have not been standardized.

b Riser pole, liquid immersed, and deadfront are arrester types, not classifications.
Key Features for Arrester Selection

- Protection (IR, TOV, Energy)
- Durability (MOV blocks, Construction, Mechanical strength, Creepage distance, PD level)
- Safety (Non-fragmenting design, Moisture proof)
Current Designs

- Gapless MOV
- Poly Wrapped with Grease or Dry interface
- Poly Cage – Directly molded
- Poly Tube – Directly molded
- Metal Enclosed (GIS)
Porcelain Housed Surge Arresters for High Voltage

- O-ring seal
- Sulphur cement bonding (non-porous)
- Housing filled with nitrogen to avoid oxygen (causing moisture)
- Porcelain housing
- MO column
- Support for MO column Material: FRP rods
- Fixing plate (FRP)
- Aluminium flange
- Bolt terminal (flat terminal available)
- Pressure relief diaphragm Material: Stainless steel
- Pressure relief vent Material: Aluminium
- Housing filled with nitrogen to avoid oxygen (causing moisture)

Dimensions:
- Ø 2.3 in
- Ø 4 in
- Ø 2.6 in
- Ø 2 in
- Ø 1.6 in
- Ø 1.3 in
- Ø 3 in
Silicone Housed Surge Arresters for High Voltage
High Strength Cage Design, Directly Molded

Silicone rubber housing
Material: LSR
directly molded onto the active part

Cage of 8 FRP rods
as reinforcement structure

Column of MO resistors
totally surrounded by silicone rubber (SR)
Polymer Housed Surge Arresters for High Voltage
- Wrapped Design with Grease Interface

- EPDM housing in multiple units
- Not directly moulded
- No mechanical member inside
- Deflects under load -- potential for moisture ingress
## Cantilever Strength Compared

<table>
<thead>
<tr>
<th></th>
<th>MFR - 1</th>
<th>MFR - 2</th>
<th>MFR - 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Directly Molded</td>
<td>Wrapped (*)</td>
<td>Directly Molded</td>
</tr>
<tr>
<td></td>
<td>SR</td>
<td>EPDM</td>
<td>SR</td>
</tr>
<tr>
<td>WORKING</td>
<td>24,782</td>
<td>10,000 – 3,000</td>
<td>22,125 – 7,000</td>
</tr>
<tr>
<td>ULTIMATE</td>
<td>35,400</td>
<td>20,000 – 5,000</td>
<td>35,400 – 11,500</td>
</tr>
</tbody>
</table>

\( \star \) JOINTS BETWEEN THE RUBBERS – POOR MECHANICALS -- HIGH DEFLECTION
Silicone Housed Surge Arresters for High Voltage
Extra High Strength Tube Design

- **Pressure relief diaphragm**
  Material: Stainless steel

- **Silicone rubber sheds**
  Material: SR directly molded onto FRP tube

- **Housing filled with nitrogen**
  to avoid oxygen

- **MO column**

- **Support for MO column**
  Material: FRP rods

- **FRP tube** for extra – high mechanical strength

- **Pressure relief vent**
  Material: Aluminium
Silicone Housed Surge Arresters for High Voltage
Comparison of Cantilever Strength Compared

Cantilever Strength (inch - lbs)

<table>
<thead>
<tr>
<th>MFR - 1</th>
<th>MFR - 2</th>
<th>MFR - 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tube Design</td>
<td>Hollow Core</td>
<td>Tube Design</td>
</tr>
<tr>
<td>SR SR SR</td>
<td>SR SR SR</td>
<td>SR SR SR</td>
</tr>
<tr>
<td>WORKING</td>
<td>ULTIMATE</td>
<td></td>
</tr>
<tr>
<td>446,000</td>
<td>35,000</td>
<td>168,000</td>
</tr>
<tr>
<td>637,000</td>
<td>70,800</td>
<td>240,000</td>
</tr>
</tbody>
</table>

Typical porcelain arresters:
Ultimate 150,000 in-lbf
Working 60,000 in-lbf
Directly Molded SR Housed Surge Arresters for Distribution Systems
(Completely sealed, one piece construction)

- Silicone Rubber sheds directly molded on active part
- Glass coating on MOV block
- Metal oxide varistor (MOV)
- Cage of FRP Rods surrounding MOV column
- Aluminium end fitting
- Stainless steel stud

Horizontal cross sectional view of surge arrester
“Gapped” SR housed Surge Arrester for Distribution Systems
Wrapped Design, EPDM Housed Surge Arrester for Distribution Systems

Fibre-glass wrapped around MOV resistor column

Pre-manufactured EPDM-housing pushed over the wrapped core impregnated with grease

Cover plate with grease

Screw used for “sealing” with Top Cap plate
Arrester Terms and Definitions

- MOV
- MCOV
- Duty Cycle voltage
- Discharge Voltage
- BIL
- Protective Margin
- TOV

- Short circuit / Pressure relief rating
- Creepage distance
- Cantilever Strength
- Grading Ring
- Corona Ring
Arresters Ratings
Duty Cycle and MCOV
( Table 1. of IEEE Std C62.11 )

<table>
<thead>
<tr>
<th>Duty-cycle voltage (kV rms)</th>
<th>MCOV (kV rms)</th>
<th>Duty-cycle voltage (kV rms)</th>
<th>MCOV (kV rms)</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>2.55</td>
<td>144</td>
<td>115</td>
</tr>
<tr>
<td>6</td>
<td>5.1</td>
<td>168</td>
<td>131</td>
</tr>
<tr>
<td>9</td>
<td>7.65</td>
<td>172</td>
<td>140</td>
</tr>
<tr>
<td>10</td>
<td>8.4</td>
<td>180</td>
<td>144</td>
</tr>
<tr>
<td>12</td>
<td>10.2</td>
<td>192</td>
<td>152</td>
</tr>
<tr>
<td>15</td>
<td>12.7</td>
<td>228</td>
<td>180</td>
</tr>
<tr>
<td>18</td>
<td>15.3</td>
<td>240</td>
<td>190</td>
</tr>
<tr>
<td>21</td>
<td>17</td>
<td>258</td>
<td>209</td>
</tr>
<tr>
<td>24</td>
<td>19.5</td>
<td>264</td>
<td>212</td>
</tr>
<tr>
<td>27</td>
<td>22</td>
<td>276</td>
<td>220</td>
</tr>
<tr>
<td>30</td>
<td>24.4</td>
<td>288</td>
<td>230</td>
</tr>
<tr>
<td>36</td>
<td>29</td>
<td>294</td>
<td>235</td>
</tr>
<tr>
<td>39</td>
<td>31.5</td>
<td>312</td>
<td>245</td>
</tr>
<tr>
<td>45</td>
<td>36.5</td>
<td>396</td>
<td>318</td>
</tr>
<tr>
<td>48</td>
<td>39</td>
<td>420</td>
<td>335</td>
</tr>
<tr>
<td>54</td>
<td>42</td>
<td>444</td>
<td>353</td>
</tr>
<tr>
<td>60</td>
<td>48</td>
<td>468</td>
<td>372</td>
</tr>
<tr>
<td>72</td>
<td>57</td>
<td>492</td>
<td>392</td>
</tr>
<tr>
<td>90</td>
<td>70</td>
<td>540</td>
<td>428</td>
</tr>
<tr>
<td>96</td>
<td>76</td>
<td>564</td>
<td>448</td>
</tr>
<tr>
<td>108</td>
<td>84</td>
<td>576</td>
<td>462</td>
</tr>
<tr>
<td>120</td>
<td>98</td>
<td>588</td>
<td>470</td>
</tr>
<tr>
<td>132</td>
<td>106</td>
<td>612</td>
<td>485</td>
</tr>
</tbody>
</table>

*For ratings not shown, consult with manufacturer.
Surge Arrester’s Application Data
Refer to Manufacturers’ Catalog
### Electrical Characteristics

<table>
<thead>
<tr>
<th>Duty cycle voltage</th>
<th>MCOV</th>
<th>TOV Capability</th>
<th>Protective level</th>
<th>Maximum discharge voltage</th>
<th>Arrester order number</th>
<th>Creepage distance</th>
<th>Flashover distance</th>
<th>LWY</th>
<th>Height ( &quot;H&quot; )</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>[kV]</td>
<td>[kV]</td>
<td>[kV] cr</td>
<td></td>
<td></td>
<td></td>
<td>[inch]</td>
<td>[inch]</td>
<td>[inch]</td>
<td>[inch]</td>
<td>[lbs]</td>
</tr>
<tr>
<td>9</td>
<td>7.65</td>
<td>11.9</td>
<td>24.2</td>
<td>19.0</td>
<td>19.8</td>
<td>20.7</td>
<td>22.0</td>
<td>24.5</td>
<td>27.8</td>
<td>17.2</td>
</tr>
<tr>
<td>10</td>
<td>8.15</td>
<td>13.1</td>
<td>26.4</td>
<td>20.7</td>
<td>21.6</td>
<td>22.6</td>
<td>24.0</td>
<td>26.7</td>
<td>30.3</td>
<td>18.8</td>
</tr>
<tr>
<td>12</td>
<td>10.2</td>
<td>15.9</td>
<td>31.9</td>
<td>25.0</td>
<td>26.1</td>
<td>27.3</td>
<td>29.0</td>
<td>32.2</td>
<td>36.6</td>
<td>22.7</td>
</tr>
<tr>
<td>15</td>
<td>12.7</td>
<td>19.8</td>
<td>39.6</td>
<td>31.0</td>
<td>32.4</td>
<td>33.9</td>
<td>36.0</td>
<td>40.0</td>
<td>45.4</td>
<td>28.1</td>
</tr>
<tr>
<td>18</td>
<td>15.3</td>
<td>23.9</td>
<td>47.3</td>
<td>37.0</td>
<td>38.7</td>
<td>40.5</td>
<td>43.0</td>
<td>47.8</td>
<td>54.2</td>
<td>33.6</td>
</tr>
<tr>
<td>21</td>
<td>17.0</td>
<td>26.5</td>
<td>55.0</td>
<td>43.0</td>
<td>45.0</td>
<td>47.0</td>
<td>50.0</td>
<td>55.5</td>
<td>63.0</td>
<td>39.0</td>
</tr>
<tr>
<td>24</td>
<td>19.5</td>
<td>30.4</td>
<td>63.8</td>
<td>49.9</td>
<td>52.2</td>
<td>54.6</td>
<td>58.0</td>
<td>64.4</td>
<td>73.1</td>
<td>45.3</td>
</tr>
<tr>
<td>27</td>
<td>22</td>
<td>34.3</td>
<td>71.5</td>
<td>55.9</td>
<td>58.5</td>
<td>61.1</td>
<td>65.0</td>
<td>72.2</td>
<td>81.7</td>
<td>50.7</td>
</tr>
<tr>
<td>30</td>
<td>24.4</td>
<td>38.1</td>
<td>79.2</td>
<td>62.0</td>
<td>64.8</td>
<td>67.7</td>
<td>72.0</td>
<td>80.0</td>
<td>90.8</td>
<td>56.2</td>
</tr>
<tr>
<td>36</td>
<td>29.0</td>
<td>45.2</td>
<td>94.6</td>
<td>74.0</td>
<td>77.4</td>
<td>80.9</td>
<td>86.0</td>
<td>95.5</td>
<td>108</td>
<td>67.1</td>
</tr>
<tr>
<td>39.5</td>
<td>31.5</td>
<td>49.1</td>
<td>103</td>
<td>80.9</td>
<td>84.6</td>
<td>88.4</td>
<td>94.0</td>
<td>104</td>
<td>119</td>
<td>73.4</td>
</tr>
<tr>
<td>45</td>
<td>36.5</td>
<td>56.9</td>
<td>119</td>
<td>92.9</td>
<td>97.2</td>
<td>102</td>
<td>108</td>
<td>120</td>
<td>136</td>
<td>84.3</td>
</tr>
<tr>
<td>48</td>
<td>39</td>
<td>60.8</td>
<td>127</td>
<td>104</td>
<td>108</td>
<td>115</td>
<td>128</td>
<td>145</td>
<td>157</td>
<td>89.7</td>
</tr>
<tr>
<td>54</td>
<td>42</td>
<td>65.5</td>
<td>143</td>
<td>117</td>
<td>112</td>
<td>122</td>
<td>130</td>
<td>146</td>
<td>164</td>
<td>101.4</td>
</tr>
<tr>
<td>60</td>
<td>48</td>
<td>74.9</td>
<td>158</td>
<td>124</td>
<td>130</td>
<td>135</td>
<td>144</td>
<td>160</td>
<td>182</td>
<td>112.0</td>
</tr>
<tr>
<td>72</td>
<td>57</td>
<td>88.9</td>
<td>190</td>
<td>149</td>
<td>156</td>
<td>163</td>
<td>173</td>
<td>192</td>
<td>218</td>
<td>135.8</td>
</tr>
<tr>
<td>90</td>
<td>70</td>
<td>109</td>
<td>238</td>
<td>186</td>
<td>194</td>
<td>203</td>
<td>216</td>
<td>240</td>
<td>272</td>
<td>169.2</td>
</tr>
<tr>
<td>108</td>
<td>76</td>
<td>119</td>
<td>253</td>
<td>198</td>
<td>207</td>
<td>216</td>
<td>230</td>
<td>255</td>
<td>290</td>
<td>179.4</td>
</tr>
<tr>
<td>111</td>
<td>84</td>
<td>131</td>
<td>285</td>
<td>223</td>
<td>233</td>
<td>244</td>
<td>259</td>
<td>288</td>
<td>326</td>
<td>202.7</td>
</tr>
<tr>
<td>120</td>
<td>88</td>
<td>137</td>
<td>293</td>
<td>229</td>
<td>239</td>
<td>250</td>
<td>266</td>
<td>295</td>
<td>335</td>
<td>208.1</td>
</tr>
<tr>
<td>128</td>
<td>98</td>
<td>153</td>
<td>317</td>
<td>248</td>
<td>259</td>
<td>271</td>
<td>288</td>
<td>320</td>
<td>363</td>
<td>218.5</td>
</tr>
<tr>
<td>132</td>
<td>106</td>
<td>165</td>
<td>349</td>
<td>273</td>
<td>285</td>
<td>298</td>
<td>317</td>
<td>352</td>
<td>400</td>
<td>247.5</td>
</tr>
<tr>
<td>144</td>
<td>115</td>
<td>179</td>
<td>381</td>
<td>298</td>
<td>311</td>
<td>325</td>
<td>346</td>
<td>384</td>
<td>436</td>
<td>270.5</td>
</tr>
<tr>
<td>168</td>
<td>131</td>
<td>204</td>
<td>443</td>
<td>363</td>
<td>379</td>
<td>403</td>
<td>447</td>
<td>508</td>
<td>584</td>
<td>314.5</td>
</tr>
<tr>
<td>172</td>
<td>140</td>
<td>218</td>
<td>454</td>
<td>355</td>
<td>372</td>
<td>388</td>
<td>413</td>
<td>459</td>
<td>520</td>
<td>322.0</td>
</tr>
<tr>
<td>180</td>
<td>144</td>
<td>225</td>
<td>475</td>
<td>372</td>
<td>389</td>
<td>406</td>
<td>432</td>
<td>480</td>
<td>544</td>
<td>337.0</td>
</tr>
<tr>
<td>192</td>
<td>152</td>
<td>237</td>
<td>507</td>
<td>397</td>
<td>415</td>
<td>433</td>
<td>461</td>
<td>512</td>
<td>581</td>
<td>360.0</td>
</tr>
<tr>
<td>228</td>
<td>180</td>
<td>281</td>
<td>602</td>
<td>471</td>
<td>492</td>
<td>514</td>
<td>547</td>
<td>607</td>
<td>689</td>
<td>427.3</td>
</tr>
<tr>
<td>240</td>
<td>190</td>
<td>296</td>
<td>634</td>
<td>495</td>
<td>534</td>
<td>542</td>
<td>567</td>
<td>639</td>
<td>726</td>
<td>449.6</td>
</tr>
<tr>
<td>258</td>
<td>209</td>
<td>326</td>
<td>652</td>
<td>516</td>
<td>534</td>
<td>558</td>
<td>593</td>
<td>652</td>
<td>712</td>
<td>469.0</td>
</tr>
<tr>
<td>264</td>
<td>212</td>
<td>331</td>
<td>668</td>
<td>528</td>
<td>546</td>
<td>571</td>
<td>607</td>
<td>688</td>
<td>728</td>
<td>480.2</td>
</tr>
<tr>
<td>276</td>
<td>220</td>
<td>343</td>
<td>699</td>
<td>553</td>
<td>572</td>
<td>597</td>
<td>635</td>
<td>699</td>
<td>762</td>
<td>502.4</td>
</tr>
<tr>
<td>288</td>
<td>230</td>
<td>359</td>
<td>726</td>
<td>582</td>
<td>606</td>
<td>632</td>
<td>674</td>
<td>744</td>
<td>811</td>
<td>534.8</td>
</tr>
<tr>
<td>306</td>
<td>243</td>
<td>375</td>
<td>744</td>
<td>608</td>
<td>636</td>
<td>667</td>
<td>706</td>
<td>774</td>
<td>848</td>
<td>567.0</td>
</tr>
<tr>
<td>316</td>
<td>248</td>
<td>384</td>
<td>768</td>
<td>636</td>
<td>666</td>
<td>699</td>
<td>737</td>
<td>798</td>
<td>884</td>
<td>597.5</td>
</tr>
<tr>
<td>328</td>
<td>254</td>
<td>397</td>
<td>795</td>
<td>664</td>
<td>702</td>
<td>732</td>
<td>776</td>
<td>826</td>
<td>915</td>
<td>626.5</td>
</tr>
<tr>
<td>340</td>
<td>262</td>
<td>411</td>
<td>823</td>
<td>694</td>
<td>732</td>
<td>769</td>
<td>810</td>
<td>857</td>
<td>948</td>
<td>658.5</td>
</tr>
<tr>
<td>356</td>
<td>270</td>
<td>429</td>
<td>856</td>
<td>724</td>
<td>772</td>
<td>810</td>
<td>857</td>
<td>889</td>
<td>983</td>
<td>688.5</td>
</tr>
</tbody>
</table>

### Mechanical Characteristics

- Creepage distance
- Flashover distance
- LWY
- Height \( "H" \)
- Weight
Recommended Installation Points

- generally at transitions overhead line - cable
- generally at the entrance of overhead lines into a station
- usually in the HV-bushing area of transformers
- additionally at breakers
Service Conditions
Arresters Applications
Per IEEE Std. C62.11

Usual Service Conditions:

- Temperature: \((-\) 40 to \((+\) 40 degrees C ambient air; arresters max. 60 C
- Altitude 1800 meters (6000 ft.)
- 48 – 62 Hz
- Upright mounting

Unusual Service Conditions:

- Higher temperatures
- Higher altitude
- Highly contaminated environments
- High mechanical, wind, and seismic loads
- Underhung, horizontal mounting
Arrester Selection
System Parameters Required

- Equipment being protected and its BIL
- Nominal System Voltage - $U_n$
- Maximum System Voltage - $U_m = U_n \times 1.05$
- Maximum L – G voltage, i.e. MCOV
- Grounding Condition (grounded system ?)
- Expected fault current level
- Expected TOV
- Expected switching surge energy
- Pollution level and creepage distance
- Excessive mechanical loadings (wind, ice, seismic)
- Application altitude
- Temperature range
- Mounting – Underhung, horizontal?
- Cap bank ?
Effects of Separation Distance
230 kV System - 950 kV BIL Station
192 kV Rated Arresters / 152 kV MCOV

Steepness of voltage wave
= 11 kV/μs, per kV MCOV

Distance \( \ell = 10 \) meters
10 kA, 8/20 μs Discharge Voltage of = 461 kV

\[ V_2 = \text{Voltage stress at the equipment 10 meters away from the arrester} \]
\[ = V_1 + \frac{2 \times S \times \ell}{c} \]
\[ = 461 + \frac{2 \times (11 \times 152) \text{ kV/μs} \times 10 \text{ meters}}{300 \text{ meters/μs}} \]
\[ = 461 + 112 \]
\[ = 573 \text{ kV} \]

Protective Margin
\[ PM \% = \frac{950 - 573}{573} \times 100 \]
\[ = \frac{377}{573} \times 100 \]
\[ = 66\% \]
Effects of Lead Length
230 kV System - 950 kV BIL
192 kV Rated Arresters / 152 kV MCOV

Steepness of voltage wave \( (S) = 11 \text{ kV/ } \mu \text{s, per kV MCOV} \)

\[ Z = \text{Surge Impedance} = 350 \ \Omega \]

25 ft. long lead

\[ L = \text{Inductance of the lead} \]

\[ = 25 \text{ ft} \times 0.4 \mu \text{H} / \text{ft} \]

\[ = 10 \mu \text{H} \]

\[ \frac{di}{dt} = \frac{2 \times S}{Z} = \frac{2 \times (11 \text{ kV} / \mu \text{s} \times 152)}{350 \Omega} \]

\[ = \frac{2 \times 1672}{350} = 9.55 \text{kA} / \mu \text{s} \]

Voltage drop due to 25 ft. lead length

\[ = L \times \frac{di}{dt} \]

\[ = 10 \times 9.55 \]

\[ = 95.5 \text{ kV} \]
Arresters Clearances
Arrester Clearance Calculation

1. Recommended Clearance Table 5 in Application Guide C62.22
2. Quick rough calculation for minimum clearance:
   Use (20 kA, 8/20 Discharge Voltage – IR), air insulation strength of 500 kV/meter, factor for safety of 1.30 to account for variation in atmospheric conditions and discharge current higher than normal

\[
\text{Minimum Clearance} = \left[ \frac{20 \ \text{kA}}{8/20} \right] \times 1.30 \times \frac{1}{500} \times 30.1512 = 512 	imes 1.30 = 665.6 \text{ inches}
\]

Divided by Insulation strength of air

\[
= \frac{665.6}{30.1512} = 22.04 \text{ inches}
\]
Altitude Correction for Clearance

- IEEE / ANSI standard considers 1800 meters as normal application altitude.
- Insulation strength of air diminishes with higher altitude.
- Allow 1% additional clearance for every 100 meters beyond 1800 meters.

Example: 10,000 ft. altitude
≈3,000 meters

Therefore, \[
\frac{3000 - 1800}{100} = 12\% \text{ additional clearance}
\]
BIL of Arresters Housing

1. Surge Arresters are voltage sensitive devices
2. Clamp the over voltage down below the BIL of the equipment
3. BIL of the Arresters’ housing is irrelevant
4. Check insulator withstand capability of the housing (Use paragraph 8.1.2.4 of C62.11 and manufacturer’s data sheet).

****Lightning Impulse withstand value must be > 20 kA 8/20 IR x 1.42****

\[ = 512 \times 1.42 \left[ \begin{array}{c} \text{Actual} \\ 850 \text{kV} \end{array} \right] \]

\[ = 727 \text{kV} \]

**** Wet power-frequency withstand value > switching impulse discharge voltage x 0.82

\[ = 378 \times 0.82 \left[ \begin{array}{c} \text{Actual} \\ 400 \text{kV} \end{array} \right] \]

\[ = 310 \text{kV} \]
Energy from Switching Surge
(Refer Annex G of IEEE Application Guide C62.22)
Switching Surge
Energy Calculation

Energy Discharged into the arrester

\[ = \text{Voltage} \times \text{Current} \times (\text{Duration of Switching Surge}) \times \text{Time} \]

\[ = U_{res} \times \frac{U_L - U_{res}}{Z} \times \frac{2 \times L}{C} \quad \text{watt - sec. (or Joules)} \]

\[ = 0.021 \times MCOV \times \frac{L}{Z} \quad \text{kJ/kV of MCOV} \]

\[ U_{L-G} = \text{Max rms L - G voltage i.e. MCOV} \]
\[ U_L = \text{Line charging voltage} \approx \left( U_{L-G} \times \sqrt{2} \right) \times 2.6 \approx \left( MCOV \times \sqrt{2} \right) \times 2.6 \]
\[ U_{res} = \text{Switching Surge Discharge Voltage} = \left( MCOV \times \sqrt{2} \right) \times 1.64 \]

\[ I = \text{Switching Surge Current} \]
\[ L = \text{Length of line in km} . \]
\[ Z = \text{Surge Impedance of the line} \approx 350 - 400 \, \Omega \]
\[ C = \text{Speed of light} = 300,000 \, \text{km / sec.} \]
Transmission Line Arresters for Increased System Reliability
Solution for unshielded or poorly shielded Transmission Lines
TLA Application – Cross Arm Mounted
TLA Application – Suspended from phase conductor
Routine Factory Tests
Per IEEE Std. C62.11

- Discharge Voltage Test
  On MOV blocks, arrester sections, or complete arresters

- Partial Discharge (PD) Test
  Very important test, Less than 2 pC preferred

- Sealing Test
  Vacuum decay test method preferred

- Watt Loss Test @ MCOV x 1.20 to 1.25

{ Diagrams or pictures of test set ups, raw test data, and oscillograms can substitute for pre-shipment inspections and acceptance tests. }
Pressure Relief Testing - - Failure Mode
Avoid Potentials of Violent Failures with Porcelain Housing

Before the test
Successful
Arc burns through silicone

After the test
Successful
No mechanical structure left
Multiple-segment arresters are generally not recommended as their electrical and mechanical performance is poor!

Preferred

Example left side (Preferred):
2 segments for up to 550 kV system voltage

Example right side (avoid them):
4 units per stack for the same voltage level or arrester with additional insulators for stabilization or multiple segment arrester built up with MV arresters

Minimizing the number of segments per arrester means:
- more stability
  - = higher cantilever strength
- less segments to mount
  - = less installation time / costs
- better voltage distribution

Multiple-segment arresters are generally not recommended as their electrical and mechanical performance is poor!
Silicone Housed Surge Arresters for High Voltage
IEEE 693 of 2005 - Seismic Performance Level
Shake Table Test
Monitoring Devices

Control Spark Gap
3EX6 040

Surge Counter
3EX5 030

Surge Counter with leakage current meter
3EX5 050

Arrester monitor with remote indication
3EX5 060/062

Arrester Condition Indicator
3EX5 070
Display of surge counts
The number of all registered surges higher than a certain level are displayed alternating to the leakage current.

Display of leakage current

Contents of leakage current
Possible degradation can be obtained on the long-term measurement of the resistive component.
Field Testing Arresters

- Understanding remaining life of a critical component – IMPORTANT
- Common Methods for Sensing Gapless MOV Arresters
  1. Infrared Thermography
  2. Leakage Current – resistive component
  3. Watt Loss
- Surge Counters with Leakage Current Meter
  - not very effective
Surge Arresters are the Best Insurance for Your Assets

Surge arrester protects your costly equipment (like transformers, breakers) from damage due to switching or lightning over voltages.

DO NOT ECONOMIZE ON SURGE ARRSTERS !

Source: APS
For additional information call me:

Adria D. Jones
Application Engineer
Jackson, MS

E-mail: adria.jones@siemens.com


Thank you for your time!