Using high-voltage polymer housed surge arresters as post insulators

Normally surge arresters should not be used as post insulators. In the very rare (but nevertheless possible) event of an arrester failure the arrester housing may break and completely lose its mechanical integrity. This behaviour is permitted by the arrester standards IEC 60099-4 and 60099-1 respectively, which only exclude explosive, violent shattering. Background of this philosophy of the standards is the fact that porcelain, which has been the predominant material for arrester housings for decades, is a brittle material suffering from the thermal stress of an arc burning close to its surface. Thus even after a successful pressure relief the burning arc may cause thermal breaking of the housing. As this behaviour is statistical, no guarantee on mechanical integrity of a porcelain housed arrester after pressure relief can be given even in those cases where pressure relief type tests have shown that the housing remained intact. Keeping these facts in mind, the risk of applying the arrester as post insulator is usually not taken.

On the other hand, achieving this additional function is a favourable goal for economical as well as for technical reasons. A post insulator including a pedestal and the required foundation work can easily cause costs of several thousand Euros. It is a simple calculation to demonstrate that drastic cost reductions may be achieved when using arresters as post insulators. In nearly all cases this is true even if the necessary arresters, which have to fulfil some additional requirements compared to standard equipment, are more expensive than standard ones. Saving space is just another economical point. From a technical point of view, omitting post insulators helps to reduce the length of lines and bus bars in a substation, and in many cases this may improve the lightning over-voltage protection of the equipment, as distances between the arrester and the equipment to be protected become shorter.

In the late eighties and beginning nineties high-voltage MO arresters with housings made from composite hollow insulators were introduced to the market. This particular design, which uses a mechanically strong fiber glass reinforced plastic (FRP) tube covered by silicone rubber sheds (Fig. 1), provides the high mechanical strengths required for post insulators (application example see Fig. 2), and for the first time mechanical integrity after an arrester overloading could be guaranteed [1]. This is much more difficult for designs with the MO resistor column directly covered by the housing. Their mechanical strength is limited to values below 10 kNm, and after overloading the housing tears open, often including those components, which provide the mechanical strength.

![Fig. 1: Cross sectional drawing of a high-voltage MO arrester using a composite hollow insulator as housing](image-url)
Since the introduction of the design shown in Fig. 1 several types of different housing diameters and mechanical strengths have been developed, optimized for all system voltages up to 800 kV, and nearly ten years of successful service experience – including post insulator applications – give confidence in a reliable performance of this type of arrester. A high quantity of pressure relief tests with high currents in the range of 40 kA/200 ms to 80 kA/200 ms and low current 600 A/1 s have been performed. No fracture of the housing or ejection of any internal components has ever been observed. In a couple of cases mechanical breaking tests were performed following the pressure relief tests. Thus the results of similar investigations obtained for the first design (published in [1]) can now be extended by nearly 30 breaking values. They were obtained from tests on different housing diameters and mostly on the longest housing of the type (Fig. 3). The lowest mechanical breaking value measured after pressure relief was 75% of the Maximum Permissible Service Load (MPSL; definition see [2]).

Table I: Technical data of the arrester housings

<table>
<thead>
<tr>
<th></th>
<th>Type 1</th>
<th>Type 2</th>
<th>Type 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Internal housing diameter / mm</td>
<td>80</td>
<td>160</td>
<td>250</td>
</tr>
<tr>
<td>Wall thickness of the FRP tube / mm</td>
<td>5</td>
<td>6</td>
<td>6</td>
</tr>
<tr>
<td>Longest unit / mm</td>
<td>1635</td>
<td>2450</td>
<td>2700</td>
</tr>
<tr>
<td>Rated short circuit current / kA (r.m.s)</td>
<td>40</td>
<td>65</td>
<td>65</td>
</tr>
<tr>
<td>MPSL acc. to [2] / kNm</td>
<td>6</td>
<td>21</td>
<td>42/72 *)</td>
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*) ... depending on type of bottom flange

Fig. 2: Arresters used as post insulators in a 420-kV substation

Fig. 3: Breaking values after pressure relief tests on three different types of arresters with composite housing (for information on the housings see Table I)
Conclusion

Service experience and test results have shown that arresters with composite housing made from a FRP tube and covered by silicone rubber sheds
- can provide the high mechanical strength required for post insulators in many applications;
- do not lose their mechanical integrity and do not eject internal parts in case of pressure relief;
- exhibit a mechanical strength of not less than 75% of the new condition after pressure relief;
- can therefore additionally be used as post insulators, saving space and cost of equipment and installation work and providing better lightning overvoltage protection in many cases.

References

[1] Hinrichsen, Fien, Solbach, Priebe
Metal Oxide Surge Arresters with Composite Hollow Insulators for High-Voltage Systems
CIGRÉ conference Paris 1994, paper 33-203

[2] 37/231/CDV
Amendment 2 to IEC 60099-4
Section 13: Mechanical considerations for surge arresters
High-Voltage Surge Arresters as Post Insulators

Benefits

• **Economical**
  - saves space in the substation
  - saves costs of equipment and installation
    Costs for a set of post insulators (foundation, installation, steel structure, insulators, clamps) between
    \[ \approx 2.500 \text{ € } (U_m = 123 \text{ kV}) \text{ and } \approx 20.000 \text{ € } (U_m = 420 \text{ kV}) \]

• **Technical**
  - improved lightning overvoltage protection by
    - shorter lines and busbars
    - shorter distances between arrester and equipment to be protected
High-Voltage Surge Arresters as Post Insulators

Requirements

- High mechanical strength
  
e.g.
  
  - 12 kNm ... 15 kNm in $U_m = 123$ kV
  - 20 kNm ... 25 kNm in $U_m = 245$ kV
  - $\approx 35$ kNm in $U_m = 420$ kV

- Breaking resistant in case of failure

$\Rightarrow$ Porcelain housed arresters generally not suited
High-Voltage Surge Arresters as Post Insulators
Cross Sectional Drawing of Polymer Housed Arrester

- Mechanical strength adjustable in a wide range by choice of housing diameter and structure of the glass fibers
- No breaking in case of failure
High-Voltage Surge Arresters as Post Insulators
Results of ≈ 30 Breaking Tests after Pressure Relief

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75% of MPSL
Conclusions

Arresters with polymer housing made from a composite hollow tube insulator

- are able to provide the necessary mechanical strength required for use as post insulator
- are breaking resistant in case of failure
- can provide 75% of their original mechanical strength after pressure relief
High-Voltage Surge Arresters as Post Insulators
Station Layout with Polymer Housed Arresters

Example: $U_m = 420 \text{ kV}$