OUTDOOR INSULATORS AND HOUSINGS BREAKDOWNS CAUSED BY POLLUTION

K.L. Chrzan1* and R. Znaidi2
1 Wroclaw University of Technology, Institute I – 7, 50-370 Wroclaw, Poland
2 Consultant & INMR Contributor, Dar Abou Zakaria, Kélibia la Blanche 8090 Kélibia, Tunisia
*krystian.chrzan@pwr.wroc.pl

Abstract: A heavy pollution on outdoor insulators causes electrical discharges, flashovers, surface erosion or tracking. In extremely cases the dielectric breakdowns occur. In this paper the breakdowns of four insulators has been shown: porcelain bushing insulators on rectifier set ups of electrostatic precipitators, the porcelain fuse cutouts, a porcelain housing of metal oxide surge arrester and polymer concrete insulators. The analysis of other damages of condenser bushings and instrument transformers published in the literature has led us to a hypothesis that a part of these failures could be initiated or accelerated by external pollution.

1 INTRODUCTION

The pollution flashover causes a short current in the network and the resulting switching off by protection circuit. If the breaker operation is enough quick, the short current arc does not damage the insulators and the autoreclosing is able again to switch on the supply voltage. The discharges on polluted surfaces usually do not impair ceramic insulators (made of porcelain or glass) but they form the conducting traces (tracking) or erode the polymer materials. However, under very heavy pollution the long-term discharges erode both glass as well as porcelain (Figure 1). In some cases the non-uniform pollution, non-uniform electric field and surface discharges on insulators can cause the dielectric breakdowns and damage of insulators. In this paper the breakdowns of four insulators has been shown: porcelain bushing insulators on rectifier set ups of electrostatic precipitators, the porcelain fuse cutouts, a porcelain housing of metal oxide surge arrester and polymer concrete insulators. The analysis of another damages of condenser bushings and instrument transformers published in the literature has led us to a hypothesis that a part of these failures could be initiated or accelerated by external pollution.

2 DAMAGE OF PORCELAIN BUSHINGS

The set ups consisted of 110 kV/380 V, 84 kVA transformer and rectifier are used for supply DC voltage to electrostatic precipitators. DC voltage is led out of metal transformer cage by a vertical porcelain bushing DT 30NF/630. The dimensions of DT 30NF/630 insulator shows the table 1.

<table>
<thead>
<tr>
<th>Dimension</th>
<th>mm</th>
</tr>
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<tbody>
<tr>
<td>Leakage distance</td>
<td>640</td>
</tr>
<tr>
<td>Core diameter</td>
<td>88</td>
</tr>
<tr>
<td>Shed diameter</td>
<td>180</td>
</tr>
<tr>
<td>Number of sheds</td>
<td>4</td>
</tr>
<tr>
<td>Height</td>
<td>522</td>
</tr>
</tbody>
</table>

The frequently insulator damages in the form of porcelain puncture or cracks are caused by intensive discharges on polluted surface. The transformers are located under an umbrella roof, thus the wetting by rain droplets is impossible. Additionally, to decrease the contamination, a metal stall was build around the bushings. The air is pumped to the metal stalls under small over-pressure. Unfortunately, even so complicated measures did not come to be helpful. Therefore, since over 10 years the insulators are cleaned every 2 weeks and covered by a hydrophobic paste. In spite of these all mitigation options the breakdowns still occur especially at the top shed. Two such cases are shown in Figure 2. The visible black channel suggests the thermal breakdown.

The surface conductivity measurements by means of strip probe revealed the surprisingly high values in the range of 200 µS (Figure 3a). The pollution layer was very thin and had acidic character pH = 2. After voltage application the very intensive discharges developed up to the flashover (Figure 3b).
Porcelain bushings DT 30NF/630 have the leakage distance of 64 cm, on the other hand the DC operating voltage reaches sometimes the value of 70 kV. It means that the specific leakage distance is very short, about 0.9 cm/kV. For DC outdoor insulators the specific leakage distance should be longer than 3 cm/kV (pollution level light) or even 7 cm/kV (pollution level very heavy). The operation of insulators with so short leakage distance under heavy pollution is here possible because they work indoors with a very small wetting rate.

The pollution layer absorbs water from humid air [3]. Therefore, electrical discharges can burn on insulators under indoor conditions. The dry band forms usually at the insulator top because there is a higher temperature and the greater current density (smaller diameter) there. If the pollution layer in the middle and bottom part of insulator is sufficiently wet, then the discharges on the top can ignite.

The transformer cage and bushing insulator are filled with oil. Unfortunately, some gas volume can be collected inside the bushing top due to oil gassing. The dry band at the top causes a radial field stress because the wet part of pollution layer moves up the ground potential. As a result, internal partial discharges, high temperature and radial field stress can lead to porcelain breakdown.

As elsewhere in many countries in Middle East & Northern Africa, the pollution performance of outdoor insulation is mainly influenced by their material, their position in service, their shed profile, inclination and configuration. Consequently, the design geometry in general, and the self cleaning ability in particular of fuse cutout should be considered as one of the main selection criteria of external insulation than the sole creepage distance.

The varistor temperature of metal oxide surge arresters increases under pollution conditions. This thermal behaviour is especially important for multi-unit arresters. Additionally, due to a high radial field stress, the internal partial discharges could damage Zno varistors. Some special laboratory tests (radial field test or internal arcing test) were proposed to check the resistance of varistors and arrester to this pollution influence [4]. Internal arcing test model the critical conditions by formation of single artificial dry band representing approximately 10% of the leakage path. During testing of 110 kV surge arrester the 30 mm thick porcelain housing was punctured (Figure 5). The varistor temperature exceeded 160°C. This damage could be caused by a manufacture fault because such breakdown never occurred during many similar tests of surge arresters produced by other company.
Five strings consisted of three or four such insulators were tested at Glogow test station under 75 kV from 1999 to 2010. The specific leakage distance of the string consisted of three insulators was very short and amounted 18 mm/kV phase to ground (11 mm/kV phase to phase). Unfortunately, the string of four insulators with the specific leakage distance of 24 mm/kV phase to ground failed after 12 months. The results of these long term experiments are shown in table 2.

Table 2: Test results of polymer concrete insulators at Glogow station under 75 kV

<table>
<thead>
<tr>
<th>Insulator string and its leakage distance L (cm)</th>
<th>Observation date</th>
<th>Service duration (months)</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3 insulators, ( L = 3 \times 45 = 135 )</td>
<td>27.09.2001</td>
<td>24</td>
<td>Breakdown of lower shed</td>
</tr>
<tr>
<td>3 insulators, ( L = 3 \times 45 = 135 )</td>
<td>23.08.2006</td>
<td>4</td>
<td>Flashover</td>
</tr>
<tr>
<td>3 insulators, ( L = 3 \times 45 = 135 )</td>
<td>17.10.2007</td>
<td>18</td>
<td>Breakdown of lower insulator</td>
</tr>
<tr>
<td>4 insulators, ( L = 4 \times 45 = 180 )</td>
<td>04.04.2007</td>
<td>12</td>
<td>Breakdown of lower insulator</td>
</tr>
<tr>
<td>3 insulators, ( L = 3 \times 52 = 156 )</td>
<td>29.05.2009</td>
<td>24</td>
<td>Flashover, depth of surface erosion 3 mm</td>
</tr>
</tbody>
</table>

Two flashovers occurred in August 2006 and in May 2009 on insulators with the leakage distance of 135 cm and 156 cm. It is important that in the period of 11 years no flashovers were noted on silicone insulators without sheds, with leakage distance of 105 cm and diameter of 3 cm. No flashovers occurred also on identical porcelain rods without sheds in the period of 2005-2010.

Three insulators were damaged by breakdown of dielectric material from the surface to the inserted metal parts. Figure 7 shows the breakdown channel as the diagonal of the marked square. These test have shown that polymer concrete insulators can be used in clean pollution site on 20 kV lines. However, the application on 110 kV lines could be risky even in clean pollution site. The experiences with PC insulators in USA in clean conditions is positive and bad in heavily polluted sites in Mexico and Great Britain [6].

Figure 5: The damaged surge arrester during an internal arcing test (a) and the breakdown trace in porcelain (b) [5].

Figure 6: Polymer concrete insulator (on the left) and porcelain insulator of 20 kV line.

Twenty of prototype PC insulators manufactured in Poland were installed on 20 kV lines near Glogow in 1999 (Figure 6). The specific leakage distance of insulators on overhead line amounted 38 mm/kV phase to ground (22 mm/kV phase to phase). The overhead 20 kV lines are situated in clean rural areas and any traces of erosion were found on these insulators after 11 years of service.

Figure 7: Roentgen pictures of insulators with metallic inserts and breakdown channel.
The daily maximum currents measured in November 2007 on the string of 3 PC insulators (leakage distance of 156 cm) and on porcelain rod with the diameter of 3 cm and leakage distance of 105 cm are shown in Figure 8. The maximum current value on PC insulator was 34 mA. The maximum current on porcelain rod found on the same day was two times lower. However, the opposite relation was noted on November, 1. The maximum current value of 18 mA occurred on porcelain rod and only 3 mA on PC insulator.

![Figure 8: Leakage currents on polymer concrete insulator and on porcelain rod measured at Glogow test station in November 2007.](image)

Under clean conditions polymer concrete insulators work well on distribution line with a specific leakage distance of 38 mm/kV of phase to ground but fail under high voltage with the specific leakage distance of 24 mm/kV of phase to ground.

The mitigation option should be carefully selected for every particular case to improve insulator performance in polluted conditions.

### 8 ACKNOWLEDGMENTS

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### 9 REFERENCES


