OUTDOOR INSULATORS AND HOUSINGS BREAKDOWNS CAUSED BY POLLUTION

K.L. Chrzan[1*] and R. Znaidi[2]
[1] Wroclaw University of Technology, Institute I – 7, 50-370 Wroclaw, Poland
[2]Consultant & INMR Contibutor, 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 (Figure1). 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.

Figure 1: Erosion of Glass insulators in coastal area [1].

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 1: Dimensions of DT 30NF/630 insulator

Dimension	mm
Leakage distance	640
Core diameter	88
Shed dimeter	180
Number of sheds	4
Height	522

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.

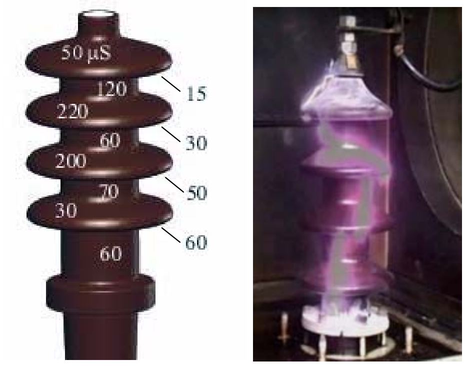
The surface conductivity measurements by means of strip probe revealed the surprisingly high values in the range of 200 μS (Figure 3a). The pollution layer was very thin and had acidic character pH = 2. After voltage application the very intensive discharges developed up to the flashover (Figure 3b).

Figure 2: Typical breakdowns at the top shed [2]

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.



a b

Figure 3: Results of surface conductivity measurements in µS (a) and intensive discharges after voltage application on bushing insulator (b).

3 FAILURE OF PORCELAIN CUTOUTS

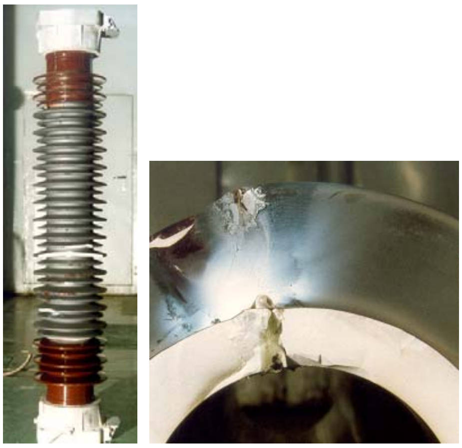
The Tunisia environment is dominated by Desert, marine and industrial pollution with the high or very high pollution levels. The ESDD and NSDD maximum values are in the range of 0,6 mg/cm^2 and 1,3 mg/cm^2 respectively. The unexpected salt proportion in the sand is relatively very high and may contain up to 18% salt. Almost all destroyed fuse cutouts were installed on the 33 kV earthed systems (17,5 kV phase-earth) along the coast and close to industrial and desert areas (Figure. 4). The creepage distance is in the range of 800 mm corresponding to the new standardized USCD of 46 mm/kV. This design of fuse cutout , especially with regular sheds and short spacing distance, is not suitable to such specific pollution environment with dominant solid layer heavy deposit.

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.

Figure 4: Typical Failure of 33 kV fuse cutout in coastal areas in Tunisia.

4 BREAKDOWNS OF PORCELAIN HOUSINGS OF 110 KV ARRESTERS

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.



a b

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

5 BREAKDOWNS OF POLYMER CONCRETE INSULATORS

Polymer concrete (PC) is a composite material in which an organic resin system bounds together non-organic components. The content of mineral fillers is very high, in the range of 80-95% [6]. A very important property of polymer concrete is its high impact strength. These insulators are therefore more vandalism resistant than ceramic insulators. Similar as in the case of other thermoset polymers, the metal parts can be inserted in the material during its forming process. This operation is simpler than the necessary cementing of metal hardware to porcelain. Polymer concrete erodes under the influence of intensive surface discharges. However, no conductive tracking is formed as is the case for many other polymers.

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.

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

Insulator string and its leakage distance L (cm)	Observation date	Service duration (months)	Description
3 insulators, L = 3 · 45 = 135	27.09.2001	24	Breakdown of lower shed
3 insulators L = 3 · 45 = 135	23.08.2006	4	Flashover
3 insulators L = 3 · 45 = 135	17.10.2007	18	Breakdown of lower insulator
4 insulators L = 4 · 45 = 180	4.04.2007	12	Breakdown of lower insulator
3 insulators L = 3 · 52 = 156	29.05.2009	24	Flashover, depth of surface erosion 3 mm

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].

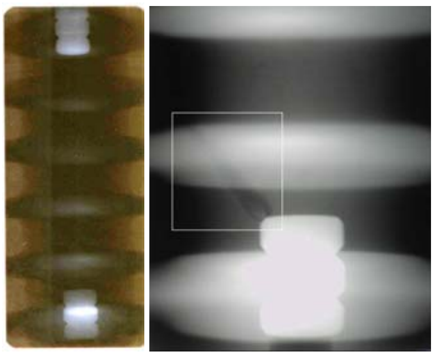


Figure 7: Roentgen pictures of insulators with metallic inserts and breakdown channel.

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.

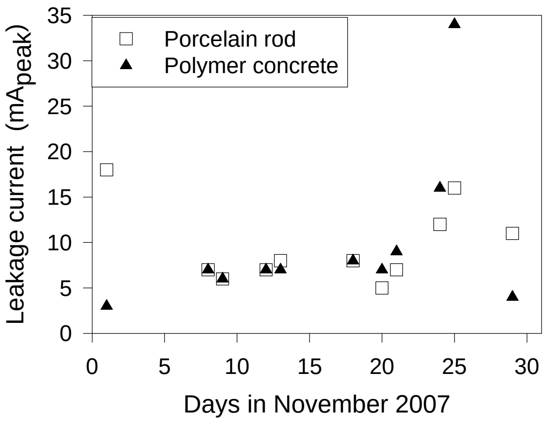


Figure 8: Leakage currents on polymer concrete insulator and on porcelain rod measured at Glogow test station in November 2007.

6 CASES FROM LITERATURE

Some papers describe the breakdowns of condenser bushings [7], bushings of 138 kV switchgears [8] and voltage and current transformers for at least 220 kV [9]. A high attention attracted the breakdowns of bushings in 500 kV DC stations. During rain and unfavorable wind direction, a part of insulator could be protected by station wall. The non-uniform wetting caused flashovers and even porcelain breakdowns [10]. The degradation of semi-conductive glazes and even porcelain breakdown of special disc insulators under heavy pollution was also observed [11].

The manufacture faults, slow ageing of oil-paper insulation and overvoltages are recognized as the breakdown causes of condenser bushing and voltage transformers. It should be underlined that the failure cause is unknown in 26% cases [9]. In our opinion a very non-uniform voltage distribution on housing caused by concentrated dry bands is still an underestimated phenomenon. This process generates a high radial field stress inside the housing and intensive internal partial discharges. The phenomenon of concentrated dry bands was documented last time in Poland [12].

7 CONCLUSION

Under heavy pollution the breakdowns of porcelain material of insulators and the surface erosion of glass are possible.

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

Authors wish to acknowledge the help of Advisory Board of Legnica and Glogow Copper Works especially Antoni Kramarzewski, Jerzy Weiske, Jacek Rzepecki and Lech Sieczko in the investigations.

9 REFERENCES

[1] R. Znaidi, „Service experience & maintenance requirements for different types of insulators in Tunisia”. Insulator News & Marker Report Vol. 14, No. 2, pp. 34-43, 2006

[2] K.L. Chrzan, A. Turek, L. Sieczko, “Damage of bushings on rectifier set ups of dust precipitators” (in Polish). Conference Inzynieria Wysokich Napiec, Poznan-Bedlewo, Electrotechnical Review No 11b, pp. 193-197, 2010

[3] K. Chrzan, T. Kowalak, “Hygroscopic properties of pollutants on HV insulators”. IEEE Trans. on Electrical Insulation, Vol. 24, No. 1, pp. 107-112, 1989

[4] K. Chrzan, W. Koehler, K. Feser, “Internal arcing test on polluted high voltage surge arresters”. 9 th Int. Symposium on High Voltage Engineering, Graz, paper 3220, 1995

[5] K.L. Chrzan, “Internal partial discharges test for metal oxide surge arresters”. Technicna Elektrodinamika (Kiev), part 8, pp. 93-96, 2002

[6] K.L. Chrzan, M. Skoczylas, “Performance of polymer concrete insulators under light pollution”. 15th Int. Symposium on HV Engineering, Ljubljana, paper T4-114, 2007

[7] A.K. Lokhain, T.I. Morozova, G.Y. Shneider, V.V. Sokolov, V.M. Chornogodsky, “Internal insulation failure mechanism of HV equipment under service conditions”. CIGRE Session, paper 15-201, 2002

[8] M. Farzaneh, W.A. Chisholm, “Insulators for icing and polluted environment”. IEEE Press, page 376, 2009

[9] M. Poljak, B. Bojanic, “Method for the reduction of in-service instrument transformer explosions”. European Transactions on Electrical Power ETEP, Vol. 20, pp. 927-937, 2010

[10]H.M. Schneider, J.F. Hall, C.L. Nellis, S.S. Low, D.J. Lorden, “Rain and contamination tests on HVDC wall bushings with and without RTV coatings”. IEEE Transactions on Power Delivery, Vol. 6, No. 3, pp. 1289-1300, 1991
[11]A. Shinoda, H. Okada, M. Nakagami, Y. Suzuki, S Ito, M. Akizuki, “Development of high resistance semi-conducting glaze insulators”. Annual Power Meeting of IEEE Power Engineering Society, Toronto, paper 0-7803-9156-X, 2005
[12]K.L. Chrzan, “Lightning impulse performance of polluted medium voltage insulators”. 16th Int. symposium on High Voltage Engineering, Cape Town, paper E-29, 2009