Performance of polymer concrete insulators under light pollution

K.L. Chrzan[1*], and M. Skoczylas[2]
[1]Wroclaw University of Technology, Institute I – 7, 50-370 Wroclaw, Poland
[2] NTI Pomiary, 67-200 Glogow, Poland
*Email: krystian.chrzan@pwr.wroc.pl

Abstract: This paper deals with polymer concrete, a highly filled composite material as a low cost alternative to porcelain outdoor insulators. A review of earlier laboratory and field tests of PC insulators was given. The insulators were produced according to the technology developed in the USA 30 years ago. The 20 kV support insulators were installed at a distribution power line and exposed to mechanical and electrical stress 8 years ago. The insulators made from polymer concrete are also investigated at Glogow pollution test station under 75 kV operating voltage. The highest leakage current of 27 mA was measured under the short specific leakage distance of 1,9 cm/kV (phase to ground voltage). Our tests confirm that these insulators can be apply under light pollution condition that means in nearly whole territory of Poland and neighbouring countries.

1 INTRODUCTION

Polymer concrete (PC) is a composite material consisting of a graded mixture of aggregates and fillers bound together by means of low-viscosity organic resin system. Polymer concretes were applied first in 1960s as corrosion-resistant, high strength material in civil engineering, e.g. saline water desalination or geothermal energy installations [1]. A higher attention was paint on less energy-intensive technology and materials during oil crisis in 1973. The most attractive features of polymer concrete is its room temperature processing (low energy technology) and its low cost. The polymer concrete is a material with a very high filler content, usually higher than 85%. Silica is chosen because of its low cost and its superior electrical properties, especially its arc resistance. Therefore, PC is few times cheaper than porcelain manufactured at very high temperatures. The formulation of polymer concrete called Polysil was given in [2].

The first electrical insulators made from PC were developed by Westinghouse under an EPRI sponsored contract. Many efforts has been done to design a disc insulator for dc lines [2] [3]. Polymer concrete insulators are used mainly for medium voltages in many countries. There is also a limited experience with 69 kV and even with 132 kV voltage level. Polymer concrete was also applied for bushings and housings of switchgears, surge arresters and fuses. The production is possible in very small companies. There are currently few producer in USA, Poland, South Africa and South Korea.

2 MATERIAL PROPERTIES

A very important property of polymer concrete is its high impact strength. These insulators are therefore more vandalism resistant than ceramic insulators. The high impact strength is also of great value in those parts of the world which are susceptible to seismic activity. 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.

The properties of polymer concretes given in few papers were listed in tab. 1. The filler content in polymer concrete manufactured in Poland was relatively low, of 75% [4]. Probably therefore, the dielectric permitivity of PC material made in Poland was 5,3 and that from Korea was 4,0 (tab. 1).

Tab. 1: Properties of polymer concretes with 75% filler content [4] or greater [5, 6]

Properties	Jednostka	According to	Before water bath	After water bath
Arc resistance	s	PN 74/E-04441 U = 14 kV	325	325
Resistance to tracking and erosion	kV/ h	PN 89/E-04442 IEC-587	2,5 / 6 3,5/6 [5] 4,5/8 [5]	
Breakdown voltage	kV/mm		21 [4]	
Electrical resistivity	Ω·cm	T = 20 °C	10^{14}	10^{10}
Dielectric loss factor tg δ	-	f = 50 Hz	0,06 (0,06)	0,6 (0,11)
Relative permitivity	-	f = 50 Hz	5,3 [3] 4,0 [4]	
Flexural strength	kg/cm^2	PN-72/C-04243	430 (990)	240 (910)
Impact strength	kJ/m^2	PN-68/C-89028	1,6 (3,3)	1,4 (2,9)
Water absorption	% weight	PN-89/E-06307	0,75 (0,15)	
Apparent porosity	% weight	PN-89/E-06307	1,48 (0,30)	

The data in parenthesis are given for PC with silane coupling agents. These agents influence positive the mechanical properties of products and decrease the moisture absorption. Some data in the tab. 1 were given for samples which were conditioned in water for 100 hours (the column “after water bath”).

Due to a very low polymer content the PC has a relatively high resistance to high voltage arc, the time to arc extinction is longer than 300 s. The resistance to surface discharges according to inclined plane test amounts 2,5 kV. The arc degradation products do not build a conductive path (non-tracking material). The PCs with higher filler content (e.g. 90%) have higher resistance to surface discharges and could be applied in medium polluted areas.

3 AGEING TESTS OF PC INSULATORS (REVIEW)

In this chapter the review of laboratory ageing tests and field tests conducted in different countries is given.

3.1. Tests in laboratory

The available literature on aging tests carried out in laboratory is very poor. The salt fog tests of medium voltage insulators with the salinity of 10 g/l and the wetting intensity of 0,4 $l/m^3/h$ were carried out in Poland [7] [8]. The specific leakage distance was 17 mm/kV and 35 mm/kV. The current up to 60 mA was measured, no flashover were noted and any tracking was found even after 1000 hours of testing. The surface roughness increased from 0,6 µm on new samples to 4,5 µm on the insulator tested for 1000 hours in salt fog. This value is similar to the roughness of samples stressed by ozone and UV radiation for 240 hours as reported in [9].

3.2. Field tests abroad

The first field tests of PC insulators were carried out in USA and Mexico [6], [10]. The performance of 69 kV insulators with 18 different designs in 25 locations was evaluated from 1980 to 1990. Insulators without additional coatings exposed in 22 places of USA were not damaged. However, the insulators installed in the Mexican test racks showed the worst performance. In heavy pollution conditions the erosion, tracking and puncture of sheds were registered.

The 11 kV insulators were assessed in Fawley, Hempshire, UK, 3 km from the sea since 1991. The facility for evaluation of 33 kV insulators was commissioned at Dungeness, Kent, about 100 m from the sea in 1994. The insulators made of silicone rubber, EPDM, cycloalipatic epoxy and polymer concrete were compared. Epoxy and PC insulators have shown the most significant deterioration. The silicone insulators offered the best resistance to environmental pollution.

3.3. Field tests in Poland

Few tens of prototype PC insulators manufactures by Wroclaw Division of Electrotechnical Institute were installed on 20 kV lines near Glogow in 1999 (fig. 2). The polymer insulator on the right hand side is exposed to bending load. The porcelain insulator on the left hand side insures the line in the case of hypothetical failure of polymer insulator. Simultaneously a string consisted of three such insulators was hung at Glogow test station under 75 kV. The specific leakage distance of insulators on overhead line amounted 2,2 cm/kV and only 1,0 cm/kV (phase to phase) of the test string. The overhead 20 kV lines are situated in clean rural areas and any traces of erosion were found on these insulators after 8 years of service. The erosion was found on the insulator string tested at the station after 2 years. A one from 18 sheds was punctured. The test station is situated in light polluted industrial area but the dust precipitation is higher than the dust precipitation in rural areas with 20 kV lines [12]. The mean dust precipitation at Glogow test station amounts 0,5 $g/m^2 \cdot day$. However, the leakage distance was 60% shorter than that recommended by IEC 60815 for porcelain insulators.

Fig. 2: Polymer concrete insulator (on the right) and porcelain insulator of 20 kV line.

ESDD measured on the damaged insulator showed a very non-linear pollution distribution along the string (fig. 3).

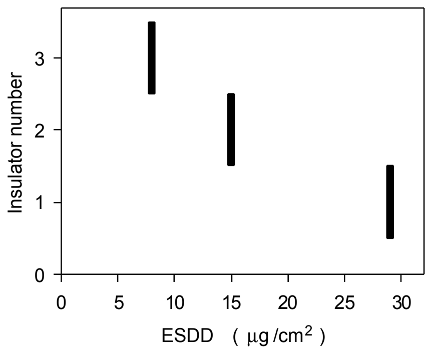

Fig. 3: ESDD on the damaged string consisted of three insulators.. The top insulator has the number 3.

The lowest ESDD value had the top insulator and the greatest value was measured on the bottom insulator. This distribution is caused by flowing the rain water from the top to the bottom of the string along its leakage distance. The droplets flow from the upper side of the sheds to the underside. The shed form should be improved. The drops should fall down from the rim of the sheds.

The new insulators manufactured in Poland were installed at the test station in April 2006. One string consisted of 3 medium voltage insulators had the leakage distance of 1,1 cm/kV. The second string of four insulators has the specific leakage distance of 1,4 cm/kV (phase to phase), (fig. 4).

Fig. 4: Medium voltage insulator chains tested at Glogow station. Hydrophobic epoxy insulator (on the left) and polymer concrete insulators (in the centre and on the left).

The highest currents recorded on May, 1, 2006 are shown in fig. 5. The current on polymer insulator with the leakage distance of 135 cm was 5 mA greater than the current on the hydrophobic cycloaliphatic epoxy (HCEP) insulator with the leakage distance of 154 cm. It should be underlined that HCEP insulator was installed in July 2005 and PC insulator in April 2006. The contamination of PC insulator did not reach the end state. The next interesting event was found on May, 16, 2006. This time the current on PC was smaller than 3 mA and the current on HCEP insulator reached 12 mA (fig. 6). This different performance of insulators made from different materials and having not identical profiles is not easy to explain. The flashover on PC string was noted in September 2006. The insulator was not damaged and no erosion was found. The string consisting of four medium voltage insulators withstand the environmental and electrical stress till today.

The experiment shows clearly that the string with the leakage distance of 135 cm was to short. The leakage distance of 180 cm seems to be long enough. Note that this longer leakage distance is shorter than that recommended by IEC for porcelain insulators. The specific leakage distance of longer PC insulator of 1, 4 cm/kV is smaller than 1,6 cm/kV.

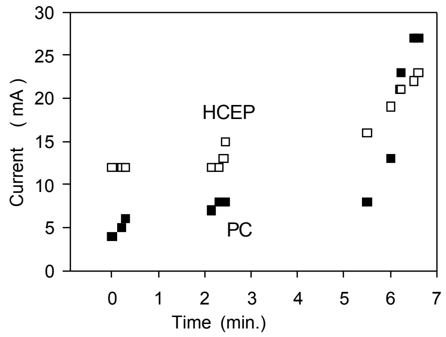

Fig. 5: Currents on PC insulators and on hydrophobic cycloaliphatic epoxy insulators (HCEP) recorded on 1.05.2006

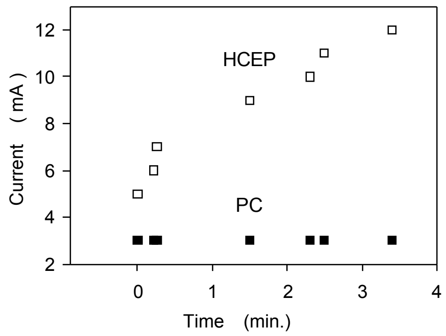

Fig. 6: Currents on PC insulators and on hydrophobic cycloaliphatic epoxy insulators (HCEP) recorded on 16.05.2006

4 CONCLUSIONS

Polymer concrete with a relatively small filler amount of 75% has the resistance to tracking and erosion of 2,5 kV. This material could be applied for clean pollution areas. The polymer concrete with higher filler amount of 90% (like American Polysil) has higher resistance to erosion of 3,5 kV or even 4,5 kV.

The erosion of PC insulators was found in high polluted areas in Mexico and Great Britain. The PC insulators perform well in many countries in light or medium polluted areas. The eight years field trial in Poland confirms that polymer concrete insulators with 75% filler amount can be used in clean areas.

The environment improvement in Europe last 25 years allows the selection of PC insulators in nearly whole European interior.

The geometrical shape of some PC insulator types is not optimal. The profile improvement should results in a better field performance.

5 ACKNOWLEDGMENT

The field test was carried out at Glogow Pollution Test Station. Author thanks the Advisory Board of Glogow Copper Smelting Plant, especially Mr. Andrzej Szydlo and Mr. Jacek Rzepecki for their help in test station maintenance.

6 REFERENCES

[1] M. Gunasekaran , Polymer concrete high voltage insulator: a versatile material for the 90' s and beyond. Electrical Electronic Insulation Conference and Electrical Manufacturing and Coil Winding Coneence, Chicago 1993, pp. 649-653

[2] J.E. Schroeder, Y. Zletin, T.C. Cheng, C.T. Wu, J.H. Dunlup, design of a Polysil dc insulator. IEEE Trans. On Electrical Insulation, Vol. 16, No. 3, June 1981, pp. 235-241

[3] J.E. Schroeder, T.C. Cheng, C.T. Wu, E.R. Perry, Y. Zlotin, An evaluation of Polysil as an insulating material. IEEE Trans. On Electrical Insulation, Vol. 16, No. 5, October 1981, pp. 446-452

[4] A. Gasperowicz, J. Stankiewicz, Nowy materiał elektroizolacyjno-konstrukcyjny dla izolacji napowietrznej średnich napięć. Konferencja Nowe Materiały i Technologie w Elektrotechnice MATEL, Łódź-Dobieszków 1995, s. 38-41

[5] J. Seulng-Ik, Accelerated outdoor degradation characteristics of polymer concrete insulator. Proceedings of the 4th Int. Conf. on Properties and Applications of Dielectric Materials, Brisbane, Australia 1994, pp. 511-514

[6] E.R. Perry, Field evaluation of polysil outdoor post-type insulators. 7th IEEE/PES Transmission and Distribution Conference, 1979, pp. 89-94

[7] A. Gasperowicz, A. Traczewski, J. Stankiewicz, Odpornosc elektroizolacyjnego betonu polimerowego na narazenia napowietrzne. Konferencja Postepy w Elektrotechnologii, Szklarska poreba 1996, pp. 90-93

[8] J. Stankiewicz, Z. Swierzyna, M. Kapuscinski, Prady uplywu izolatorow kompozytowych w toku badan starzeniowych w komorze mgly solnej. Konferencja Napowietrzna Izolacja Wysokonapieciowa w Energetyce NIWE, Szklarska Poreba 2003, pp. 113-115

[9] J.L. Fierro-Chavez, T.P. Duguid, Diagnostics techniques for the field evaluation of polymer concrete insulators. Int. Conf. On Dielectric Materials Measurements and Application, 1992, pp. 146-149

[10] J.L. Fierro, J.F. Hall, A.G. Reichenbacher, Field evaluation of 69 kV outdoor Polysil insulatorsin the USA and Mexico. Conf. On Electrical and Dielectrical Phenomena CEIDP, Pacono Manor, USA, 1999, pp. 551-556

[11] S. Stocks, Performance assessment of non-ceramic overhead line insulators. IEEE/KTH Power Tech Conference, Stockholm 1995, pp. 316-321

[12] K.L. Chrzan, A. Haddad, Behaviour of insulators and surge arresters at Glogow pollution test station. 39th Int. Universities Power Engineering Conference UPEC, Bristol 2004, pp. 193-196, Available: http://ieeexplore.ieee.org/iel5/9986/32065/01491990.pdf