Polymer Solutions to Contaminated Environments

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Introduction:

The purpose of this paper is to give a brief overview of some ways in which today's high voltage polymer materials are ideally suited for contaminated environments. Some of the polymer products that will be considered are distribution deadend insulators, distribution class surge arresters, and intermediate class surge arresters.

History:

Traditionally porcelain has been the material of choice for high voltage insulation. However, porcelain has several disadvantages including a low strength-to-weight ratio and a brittle nature. In the 1970's these issues were addressed by high strength fiberglass composite insulators with elastomeric coverings.

The use of "polymer" insulators has been steadily growing. In some applications, such as distribution class surge arresters, polymer products have virtually replaced porcelain.

Various materials were considered for use as the elastomeric covering. Three materials emerged as most suitable for high voltage applications. These are:

1. Ethylene Propylene Monomer (FPM)
2. Ethylene Propylene Diene Monomer (EPDM)
3. Silicone Rubber (SR)

EPM and EPDM (jointly referred to as EP) are known for their inherent resistance to tracking and erosion, as well as their physical properties. SR offers good contamination performance and UV resistance. Ultimately a hybrid has been developed by alloying silicone with EP rubber. This creates a product that achieves the hydrophobicity of silicone and the electrical and mechanical advantages of EP rubber.

A more detailed history of polymer insulation systems has been presented to the Southeastern Electric Exchange [1] therefore we will not spend more time on history of materials in this brief paper.

Distribution Voltages:

The original polymer application was at distribution voltages. However, some of the early materials had poor performance. The details of these are well known throughout the utility industry. It is unfortunate that the memory of these problems have showed the acceptance of the superior materials that are available today.

Distribution Deadend Insulators

Polymer distribution deadend insulators are in wide use today. They are especially suited to contaminated environments. When a contaminated insulator becomes wet, leakage currents begin to flow on the surface. If the leakage currents reach a high enough level, the insulator will experience an external flashover. The rate at which the insulator dries is critical to the performance of the product.

The relationship of the outer shed diameter and the core (shank) defines the form factor. Since the leakage current is the same along the length of the insulator, the current density must be higher at the shank. The leakage current generates heat along the surface of the insulator. The heat generated by the leakage current is calculated by I^2R. Since there is less conducting material at the shank, the resistance is highest at the shank.

Therefore, the greater the difference between the insulator's outside diameter and the shank the faster the insulator will dry. When the shank has dried out, the flow of leakage current ceases and the voltage is supported across the dry bands. This prevents the flashover of the insulator.

The high strength core of the polymer insulator allows for an extremely small shank. Also, the polymer coating can be molded with large, thin weathersheds. It is simply not possible to manufacture porcelain insulators with form factors approaching polymers.

Additionally, the active insulating segment in a porcelain insulator is small. Under lightning voltage stresses it is possible that this insulation may be punctured. During subsequent contaminated conditions the insulator may suffer a burndown. Polymer insulators with their continuous insulating core will not experience punctures.

Distribution Arresters

In contaminated environments extra leakage distance is usually required to allow the surge arrester to function property. For a porcelain arrester this extra leakage distance was usually achieved by adding housing length.

The ability of the polymer material to be molded with large diameter, thin weathersheds means that standard polymer arresters can be produced with “extra leakage distance”.

Table 1 summarizes the characteristics of porcelain and polymer distribution arresters.

Polymer arresters bring a major advantage in their resistance to moisture ingress and fault current withstand ability.

Studies [2] show the most common cause of porcelain distribution arrester failure is moisture ingress. In fact 86% of the failures of porcelain arresters are due to moisture ingress. Of the total installed population of porcelain arresters 1% fail each year.

Porcelain arresters do not usually have a means to relieve the internal pressure from a failure. This means that the arrester could fail violently and injure the general public or adjacent equipment.

Polymer arresters have fault current withstand ability. This means that if they should happen to fail from a system related event they will represent less of a safety hazard than their porcelain counterparts.

Intermediate Arresters

To meet the pressure relief requirements of today’s substations, the length of porcelain arrester housings must be limited. This is because it takes a longer time to vent a longer housing. Time allows for build up of internal pressure and a possible explosion of the housing.

One of the main advantages of the polymer arrester is that venting is almost immediate and is out the side of the arrester. This means that the housing length is no longer limited by the pressure relief capability. Therefore high voltage arresters can be one piece housings. The elimination of intermediate metal end fittings dramatically improves the contamination performance of the polymer arrester compared to porcelain. Concerns with uneven pollution problems are eliminated.

If only one of the housings of a multiple unit porcelain arrester is contaminated, the leakage currents flowing across its surface causes the same current to flow through the MOV discs in the other porcelain. It is possible that the leakage current could be sufficient to cause the MOV discs to go into thermal runaway.

Table 2 summarizes the results of partial wetting and 5 hour slurry tests performed on two and three unit porcelain intermediate arresters and their polymer counterparts.

The tests were more severe than the contamination tests of ANSI C62.11-1987 because three (instead of two) slurry applications were used plus the length of time delay was decreased from 10 minutes to 3 minutes. The reduction in the time was to minimize the MOV disc cooling during the slurry application period.

The results of the testing shows the highest temperature reached was in the two unit 66 kV MCOV porcelain housed intermediate arrester.

Neither of the samples of the polymer arresters experienced any significant amount of heating during the partial wetting period.

After the conclusion of the partial wetting test the arresters were tested using the 5 hour uniform slurry test procedure. This test consists of applying a uniform coating of standard 400 ohm-cm slurry to the test arrester. Within 30 seconds, MCOV is applied for 15 minutes, during which time the surface leakage currents cause the surface to dry. Slurry applications are repeated for a total of 20 test cycles. After the 20th test cycle MCOV is applied to the arrester for 30-60 minutes to demonstrate thermal stability. Surface leakage currents were measured at the end of the 5th, 10th, 15th and 20th test cycles.

The results of the testing are summarized in Table 2 and demonstrate that the polymer housed surge arrester will be much more able to survive under contaminated conditions. More information on polymer housed intermediate arresters is contained in the IEEE Transactions [3].

Other Polymer Advantages

In addition to the benefits polymers offer specifically for contaminated environments, there are several general advantages.

Polymer products weigh significantly less than their porcelain counterparts. This is an advantage that can result in a cost savings for the utility in structure and installation costs.

In fact, the EPRI Blue Book [4] recognizes the construction cost savings of polymer insulators in its cost estimating section.

Table 3 shows the percent weight reduction of polymer compared to porcelain for several different applications.

Polymer insulators and surge arresters are resistant to damage resulting from installation and also to damage from vandals. The lack of flying porcelain when a polymer insulator is shot soon discourages the sportsman looking to bag himself an insulator for his trophy case.

Conclusions:

This paper has attempted to show that polymer insulators and surge arresters offer to the industry a large number of advantages in contaminated environments. Polymers can no longer be considered the material of the future. **Polymers are the material of today!**

References:

[1] A brief history of non-ceramic, polymer, composite insulators; R. Allen Bernstorf, Presented to the Southeastern Electric Exchange - May 28, 1992.

[2] CEA Contract Number 077-D-1 84A “Application Guide for Surge Arresters on Distribution Systems” Mike Lat Principal Investigator and Project Leader.

[3] “Utilization of polymer enclosed intermediate class arresters to improve the performance of modern power systems”; Dennis W. Lenk, Joseph L. Koepfinger and John D. Sakich, IEEE T&D Transactions - Dallas Meeting 1991.

[4] EPRI Blue Book “Transmission Line Reference Book” Section 8 Published 1978.

Table 1
Polymer Distribution Arrester Leakage Disadvantage

MCOV	Standard Porcelain Leakage Distance (in.)	Standard Porcelain Height (in.)	Special Porcelain Leakage Distance (in.)	Special Porcelain Height (in.)	Standard Polymer Leakage Distance (in.)	Standard Polymer Height (in.)
8.4	9.0	9.4	18.3	15.9	15.4	5.5
15.3	18.3	15.9	22.0	20.0	26.0	8.5
22.0	22.0	22.0	29.0	28.9	52.0	17.2

Table 2
Comparison of Contamination Performance of Polymer versus Porcelain Housed Intermediate Class Arrester

			Partial Wetting Test		5 Hour Slurry Test - Maximum Current After Slurry Number			
MCOV (kV)	Housing Material	Housing Leakage Distance (in.)	Max. Current (mA crest)	Max. Disc. Temp. (°C)	5	10	15	20
57	Polymer	81	<1	<38	35	42	44	44
66	Porcelain	54	68	>163	–	–	–	–
84	Polymer	109	<1	<38	50	52	60	60
98	Porcelain	122.4	18	<82	143	160	175	185

Table 3
Polymer Insulation Weight Advantage

Product	Type	Voltage (kV)	Porcelain Weight (lbs.)	Polymer Weight (lbs.)	Percent Weight Reduction
Insulator	Distribution	15	9.5	2.4	74.7
Arrester	Distribution	15	6.0	3.8	36.7
Post Insulator	Transmission	69	82.5	27.2	67.0
Suspension	Transmission	138	119.0	8.0	93.2
Intermediate Arrester	Substation	69	124.0	28.0	77.4
Station Arrester	Substation	138	280.0	98.9	64.7

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