ENVIRONMENTAL EFFECTS ON POLYMER INSULATORS

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ABSTRACT
This paper investigates the technical performance of polymeric insulators with specific reference to the environmental parameters such as humidity, dust, temperature, UV radiation and contamination and to finally assess the suitability of the insulators for practical applications on transmission lines in the Kingdom of Saudi Arabia. This has been done by conducting extensive literature survey and investigated the utility service experiences with polymeric insulators inside the Kingdom, and in surrounding countries as well as in other countries with similar environment as the Kingdom.

1. INTRODUCTION

Since the 1960s, composite insulators have been introduced internationally as the potential replacement of conventional porcelain and glass insulators. These insulators offer several advantages in terms of being light-weight, and having ease of handling, resistance to vandalism and relatively low-cost. In principle, composite insulators should provide the same service as conventional ceramic insulators, i.e., withstand electrical, mechanical and weather stresses. However, the behavior of composite insulators is usually time dependent and most of the tests must, therefore, be chosen to account for aging [1-3].

The search for a compact and efficient transmission system has risen in the last few years. The increased use of polymer insulators is a reality which has intensified in the recent decades worldwide. This increase is due to characteristics of theses insulators, and best performance under polluted environment when compared to the conventional insulators. Despite of these characteristics, there are some concerns related to polymer insulators. For example, the diversity of shapes and materials used in the manufacture of these insulators makes it difficult to standardize them, also the uncertainties related to their lifetime, the need of more adequate testing techniques, etc. Therefore, it is important to find ways to assess the insulator conditions, by means of laboratory experiments, computational simulations or using appropriate apparatus [4].

Aging and life expectancy are the greatest concerns of utilities while using polymer insulators. Although different laboratory techniques have been developed to assess weather aging of composite insulators, no method is available to accurately predict composite insulator service life. Many researchers investigated, in laboratories, the polymer insulators performance with respect to ageing factors. However, no single test can be considered as the best simulation of all the weather conditions and the effects of service and climatic stresses [7].

The main objective of this paper is to investigate the technical performance of polymeric insulators with specific reference to the environmental parameters such as humidity, dust, temperature, UV radiation and contamination and to assess the suitability of such insulators for practical applications on transmission lines in the Kingdom of Saudi Arabia.

2. INTERNATIONAL EXPERIENCES

Field experience has been gained through studies conducted at field test stations or by actual installations on high-voltage transmission lines. In recent years, many international surveys were initiated by research entities, utilities and manufacturers to collect service experience information on polymeric insulators, in addition to the reported individual country service experience. These surveys and service experience data provided a wealth of information for other utilities to assist them in their decision making in regard of polymeric insulators [5-6].

Both service experience and laboratory tests demonstrated better performance of polymeric insulators in contaminated environments, particularly the silicone rubber insulators. Generally, the polymer insulation materials have shown the following advantages compared to the non-organic insulation materials such as porcelain, or glass: Light weight (l5 %), mechanical strength (2 times in tensile strength and 5 times in impact strength), good vandalism resistance, easy to install, facilitate line compaction and excellent surface contamination characteristics [7].

3. KFUPM INVESTIGATIONS

Leading insulator manufacturers were approached to participate in this project from Europe, Asia and the USA. They provided insulator samples for laboratory pollution evaluation and laboratory accelerated aging, in addition to material samples for aging at the weathering chamber. The utility company in Saudi has also provided few different field-exposed samples to facilitate the research work with field-aged insulators.

The study dealt with both naturally and artificially contaminated insulators. Electrical performance was studied to offer comparison among different polymeric insulators and to compare it with conventional porcelain insulators. The electrical performance of the collected international insulators in terms of V_{min} was determined for three distinct pollution levels representing low, medium and high pollution severity. The V_{min} through this procedure is equivalent to V_{50}.

A typical example of generating V_{min} through Rapid Flashover Voltage Technique (RFVT) method is shown in Figure 1. To make comparison among different insulators, the data of V_{min} were converted into kV/m of leakage distance.

From the relative comparison of the acquired data through artificial means of testing, it has been possible to have broader ranking among the tested insulators. Generating field-performance data on these insulators in the future will facilitate insulator ranking more practicably. It is however, obvious from the acquired data that all types of insulators tested have shown excellent electrical performance in simulated pollution environments.

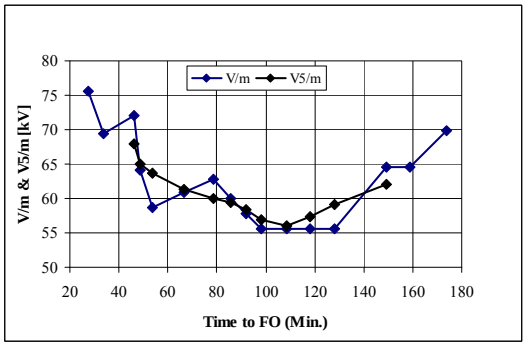

Figure 1. Sample of the electrical testing results.

The performance of naturally contaminated insulators, provided by Saudi utility, under artificial wetting in the laboratory environment was determined. From the acquired electrical data of naturally exposed insulators, it has become quite clear that for all insulators, V_{min}/kV of creepage distance is quite high and therefore, for conventional design creepage adopted by the Saudi utility, all these insulators gave outstanding performance for a long duration without maintenance.

For the purpose of comparison with conventional porcelain insulators, the electrical performance data of the KFUPM data on ceramic insulators from an earlier study was referenced, as presented in Figure 2. It is clear from this figure, that for the same level of contamination, all the international polymeric insulators investigated have given superior electrical performance compared with porcelain insulators of all the three main designs, i.e. aerodynamic, standard and antifog types. The factors which may be contributing here are the hydrophobicity as well as better field distribution of silicone rubber insulators incorporating less complex design compared with conventional porcelain insulators which have highly stressed regions due to shape complexity.

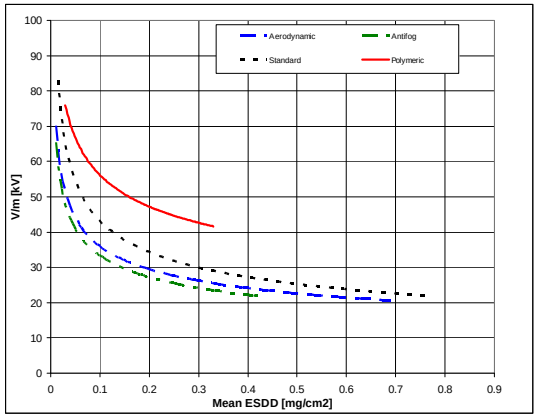

Figure 2. Relative pollution performance of polymeric and ceramic insulators

Normally, the laboratory artificial wetting system is considered to be more severe than natural wetting taking place due to high humidity or fog. Therefore, it is expected that these insulators which were brought from the field will give even better performance under actual field wetting.

Samples of the pollution deposit collected from field-used insulators of the Saudi utility were also analyzed at the chemical laboratory to identify the main components of the soluble and insoluble parts. The insoluble part does not contribute directly to the ESDD levels and subsequently to the leakage current, but it acts as a binder for the soluble parts which ultimately increase the severity of the pollution at the targeted insulator location. All insulators showed high values of silicate (SiO_2) deposit, which constitutes a high percentage of the soil. Few insulators showed high levels of iron deposits.

Samples of the polymeric insulators were exposed to accelerated aging using various techniques. Various measurements to identify the occurrences of aging were utilized to finally assess how polymeric insulators will perform in real life.

All insulator samples of the leading international manufacturers of polymeric insulators were subjected to 1,000 hours tracking and erosion test according to the aging test of IEC 61109 for aging the insulator samples. After the test was finally concluded, each insulator was carefully inspected for any obvious sign of aging and was photographed. The most encouraging output of this aging test is that in spite of very aggressive electrical activities on some insulator samples (involving heavy leakage current and flashover occurrences), none of the samples showed any sign of erosion or tracking.

4. CONCLUSIONS

Based on extensive review of literature pertaining to international, regional and Saudi Arabian utility experience and after performing a systematic study on use of polymeric insulators at KFUPM, the following are concluded.

- The international utility service experience of the polymeric insulators in the whole range of environment has proven that silicone rubber insulators are the best among the family of polymeric insulators. Therefore, in making any decision on use of polymeric insulators in the Kingdom of Saudi Arabia, the material considered should be silicone rubber.
- For the same degree of pollution, polymeric insulators gave superior performance as compared with conventional porcelain insulators. This aspect should be exploited either in reduction of insulation level or through savings achieved due to lower required maintenance frequency while using polymeric insulators.
- Most of the international insulator Companies declared that polymeric insulator have superior antipollution performance.
- The polymeric insulator is widely used in highly vandalized areas.
- There is an increasing trend internationally to use polymeric insulators, especially in highly polluted areas. However, some utility companies are still conservative and make limited use of these insulators.
- In the areas of insulation studies, due to the tremendous potential they offer, polymeric insulators are widely studied both by researchers as well as operating utility companies. The same level of study is recommended for Saudi Arabia.
- Most of the polymeric insulators are subjected to different levels of aging through the working life, which can be attributed to the electrical, mechanical and environmental working stresses. Some polymeric material proved better performance than others with respect to aging.

Acknowledgements

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