

# Contamination Deposit and Model of Insulator

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Insulators are widely used in transmission lines as insulating elements. During operation, insulators are subjected to electric fields, mechanical stress loads, hot and cold alternations, chemical erosion, and other effects that lead to the degradation of their physical and chemical properties, such as shed rupture, insulation degradation, and internal conduction, resulting in insulator defects that can cause heat-related, corrosion, and other hazards. In principle, this it establishes a security risk for the line, potentially inducing a power outage accident. Simultaneously, various harsh environmental factors must be addressed, such as pollution, rainfall, lightning, and ultraviolet threats. Under certain conditions, these factors may lead to insulation performance degradation or even cause flashover, which in turn causes local failure of the power system or even a large area blackout. Although a lot of research has been conducted by domestic and foreign institutions, the problem has not been fundamentally solved, and insulator flashover accidents still occasionally occur, so further research on insulators is needed.

This Special Issue on “Contamination Deposit and Model of Insulator” comprises eight articles on different research aspects of insulator-related pollution accumulation modeling, flashover prediction models, and their related influencing factors. Thus, there are studies addressing the models of insulator dynamic contamination based on meteorological data [1]; a new model of SF<sub>6</sub> gas and insulator surface flashover [2]; a pollution flashover model for composite insulators using machine learning methods [3]; a pollution flashover voltage prediction model based on a response surface method with central composite design [4]; a mathematical model of insulator failure probability to determine an insulator replacement strategy [5]; surface electric field distribution and AC breakdown voltage of a new 10 kV lightning-protected composite insulator under pollution and icing conditions [6]; pollution flashover characteristics of composite crossarm insulator with a large diameter [7]; dynamic adjustment of the pollution level in a prescribed area [8].

A brief summary of the contents of the selected papers composing this Special Issue is provided in the next part.

Siyi Chen [1] considered meteorological data (PM<sub>2.5</sub>, PM<sub>10</sub>, total suspended particulate, and wind speed) to study the quantitative relationship between pollution and dynamic environmental parameters. The author developed a dynamic insulator pollution model based on atmospheric environmental parameters. This model was simulated with a finite element software, namely ANSYS, and an insulator natural accumulation test was conducted. Simultaneously, using an XP-160 non-soluble deposition density pollution amount as a reference, a structure coefficient was defined as the pollution ratio of U210BP/170 to XP-160. The calculated error of the insulator structure coefficient was shown to be dynamic, resulting in an acceptable calculated error. The proposed approach in this study is novel, and the insulator operating site environment and proposed model are practical.

Mohammed El Amine Slama and Abderrahmane Beroul [2] analyzed the relationship between flashover voltage and discharge heating characteristics based on the equivalent circuit discharge along the insulator surface, while considering the discharge resistance, insulator impedance, and gas interface impedance. As a result, a numerical analytical



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model was established. Moreover, the calculated and measured values of flashover voltage at different creepage distances under normal atmospheric conditions were compared. The proposed calculation model was verified using SF<sub>6</sub> as the medium, the flashover voltage model calculation, and the measured values of three types of insulators with varying pressure. The model produced values similar to the corresponding measurements. This study may set a reference for the design of SF<sub>6</sub>-filled insulators.

Arshad and Jawad Ahmad [3] took four variables, namely temperature, humidity, ESDD, and NSDD, and used a 10 cm × 4 cm × 0.6 cm silicone rubber sample as an object in a chamber. The inception voltage, surface resistance, and flashover voltage under different circumstances were obtained from their tests. The test results processed by a bootstrap method were simultaneously input into five methods, namely ANN, PSVM, GSVM, DT, and LSBE. The relevant theories and implementation approaches of these five methods are emphasized in this study to predict the flashover parameters of silicone rubber insulation. Four mathematical quantities, i.e., RMSE, NRMSE, MAPE, and R, were used as the criteria to assess the advantages and disadvantages of the proposed prediction method. The results show that PSVM outperforms the other four methods under different conditions and prediction target parameters. The results of this study can be used as a guidance for outdoor external insulation configuration of silicone rubber materials and prediction of flashover under pollution conditions.

Oussama Ghermoul [4] used a second-degree quadratic equation to establish a pollution flashover voltage prediction model using a response surface method with a central composite design, including pollution and conductivity as influencing factors. In this study, three conductivity levels were studied, and eight pollution levels were established for each conductivity value. Each conductivity was paired with two, five, and eight pollution levels for the insulator flashover tests, and a total of nine datasets were obtained. The correlation coefficients of the prediction model were calculated by analyzing and processing test data, and finally, the model was validated. The resulting prediction model is simple and accurate, and after obtaining the pollution and conductivity of a certain area, the insulator flashover voltage in that area can be accurately determined, and a cleaning cycle can be planned.

Simpy Sanyal and Taeyong Kim [5] used 10 insulators of 154 kV and (M+E) 25,000 lbs that have been operating for 10, 30, and 50 years in South Korea as experimental research objects. The authors propose an insulator replacement strategy with an insulator failure probability based on the Weibull distribution. First, different parts of each insulator were photographed using light and scanning electron microscopes, and different mechanical failure modes were studied, as well as the relationship between mechanical strength and microstructure change after failure. Then, the probability of mechanical failure P(F) was analyzed, and a mathematical relation between P(F) and failure load was established. The P(F) of healthy insulators was ≤4.42%. This paper describes an accurate judgment method for assessing the condition of the insulator from an effective mathematical point of view.

Jiazheng Lu and Jianping Hu [6] studied the surface electric field distribution and AC breakdown voltage of a new type of 10 kV lightning-resistant composite insulator under pollution and icing conditions. The proposed law is different from that of traditional insulators. A finite element simulation showed that ice affects the electric-field size and distribution, and the electric field mainly covers the insulation part. An ice sheet with different conductivities and an insulator with an icicle attached were tested by a field test method. The corresponding flashover voltage and three discharge paths were thus obtained. The authors suggest to use quadratic or negative power functions with a constant term as the empirical formula for the flashover voltage of the sample insulator under icing conditions. The results presented in this study can provide guidance for the structural optimization of this type of lightning protection composite insulator.

Jing Nan and Hua Li [7] conducted artificial pollution tests on four types of AC composite crossarm insulators with diameters in the range of 100–450 mm, corresponding to 66–1000 kV. They also conducted simultaneous tests on the same insulation height and core diameter, but different creepage distances, umbrella structures, and umbrella

distances of the insulators. The influence of the pollution degree, hydrophobic state of silicone rubber surface, core diameter, umbrella structure, and arrangement mode on the pollution flashover voltage (U<sub>50</sub>) of composite crossarm insulator was analyzed, as well as the relationship between insulation distance and flashover voltage. The surface of a composite insulator silicone rubber was coated with kaolin to reduce its hydrophobicity. Two states, namely hydrophilic and weak hydrophobic ones, were simulated on the insulator surface in an actual operating environment. The weak hydrophobic flashover voltage was higher than that of the hydrophilic one. Under the same conditions, a core diameter of 300 mm with 500 kV insulators achieved the maximum creepage ratio distance. It is concluded that the development trend of experimental methods, leakage current, and point method of large-diameter composite insulators will be further explored to evaluate their flashover characteristics.

Issouf Fofana and Janvier Sylvestre N'cho [8] selected seven 13.2 kV distribution network porcelain insulators at different locations near the Rio Tinto plant in Saguenet, Canada. Different electrical parameters of insulators were compared, with dry and wet surfaces being the main analysis point. The leakage current and current density of the wet insulators were higher than those of the dry insulators, and the surface resistance was lower than that of the dry insulators. By measuring the phase difference between the applied voltage and leakage current of the insulator, it was found that the dry insulator was almost capacitive, and the wet insulator was resistive and capacitive. The authors also found that the content of the fifth harmonic in the leakage current was higher than that of the third harmonic. In addition, seven insulators were classified into pollution levels, and the pollution components in the surrounding air were analyzed. This study suggests that pollution should be considered as dynamic and needs to be reassessed in case of environmental changes around the insulator.

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