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INVESTIGATION OF LEAKAGE CURRENT OF INSULATOR USING ARTIFICIAL NEURAL NETWORK

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ABSTRACT

In order to improve the reliability of power transmission lines, one of the key issues is to reduce the hazard of contamination flashovers. At the present time, the most efficient way is to clean (or replace) the heavily polluted insulators. This study laboratory based tests were carried out on the model under ac voltage at different pollution levels. A new model based on artificial neural network has been developed to predict flashover from the analysis of leakage current. The input variable to the artificial neural network are mean (I_{mean}), maximum (I_{max}), and standard deviation (I_{σ}) of leakage current extracted along with the input voltage (V) and relative humidity (RH). The target obtained was used to evaluate the performance of the neural network model. The comparison of the simulated and actual (measured) results demonstrates that the ESDD prediction model from the stage characteristics.

KEYWORDS: Contamination Flashover, Leakage Current, Artificial Neural Network, Equivalent Salt Deposit Density (ESDD), Back Propagation, Stage Characteristics.

INTRODUCTION

In general obenaus model was the first propose for the contamination flashover of ceramic insulators [1]. During the wet weather conditions, contamination on the surface of the insulator has wet and leakage current flow through the surface. It will be generate the heat on surface of the insulator. The evaporation leads to the formation of “dry bands” [2].These process of dry band increases, due to decrease the properties of the mechanical strength, electrical strength, conductivity and so on. After that produce surface discharges in order to understanding the phenomena occurring on insulator surface [3].

For this case leakage currents are classified into the three stages are: security stage (<50mA), forecast stage (150mA) and dangerous stage (>150mA). The related study shows that the leakage currents during the forecast and dangerous stages are quite large and not easy to monitor [4].

The focus of this work is mostly on the leakage current RMS value during the security stage (<50mA). Three characteristics of the leakage current, namely the mean value, maximum value, maximum value and the standard deviation of the Root Means Square (RMS) value of leakage current are measured.

In this work artificial neural networks (ANNs) are used in order toestimate easily, costless, accurately and performance of the contamination level of insulators resulting in effective manner. The same three characteristics have been selected and supply voltage and relative humidity also used as the input of the neural network model.

EXPERIMENTAL SET UP AND DATA COLLECTION

Tests were performed in an artificial fog chamber in the high voltage laboratory. The test system is shown in Figure1.

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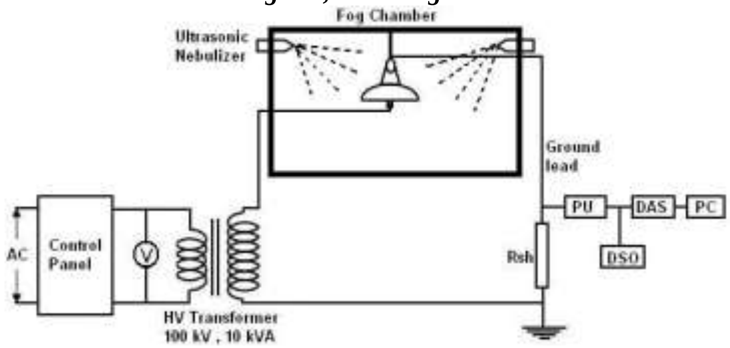
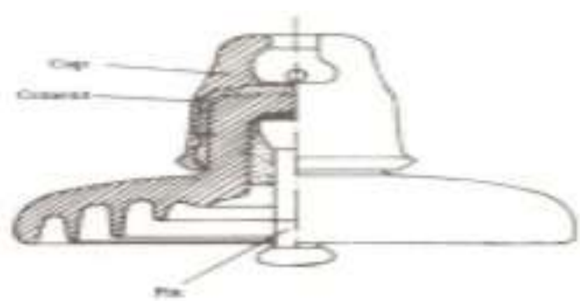
Figure 1: Fog chamber test circuit diagram, including the measurement and recording system.



An 11kV high voltage insulator is used for the contamination experiment. The test insulator is suspended vertically inside the fog chamber (80X80X80cm).The source components are a voltage regulator (TDJY-1000/10) and test transformer ratio of 2X200kV/100kV/220kV. The rated current is 6 A, and the maximum short-circuit current is over 30A. The high voltage end is connected to an AC capacitive voltage divider (SGB-200A) with the divider ratio of 1:1000 which records the applied voltage in real time. The insulator is connected between the top and bottom of the high voltage electrode.Normally Ultrasonic nebulizer is used to generate fog inside the chamber. But in this work the ultrasonic nebulizer is replaced by the normal nozzle. Relative humidity inside the fog chamber was measured by using the wall-mount hydrothermal instrument.

Table 1: Insulator design parameterFigure 2: Sketch of the test insulator

Shed diameter (D) in mm	Unit spacing (H) in mm	Leakage distance (L) in mm	ESDD, mg/cm^2				
165	145	245	0.02	0.04	0.05	0.06	0.07



Based on the IEC-60507 standard, the five kinds of ESDD levels were applied to simulate five contamination levels, respectively also shown in Table 1. The ultimate test results are their average values. The energizing voltage was 11÷√3=6.35kV RMS (phase to ground voltage), applied to simulate the 11 kV transmission line voltage.

Test Procedure

The test procedure has been designed as follows: Before entering the test the test material has been wash and clean by distilled water and clean cloth.The experiment carried out in High Voltage Laboratory was solid layer method, based on IEC 60507 standards.The artificial pollution was prepared by mixing keisulghur and silicon dioxide in the ratio of 10:1.This mixture was coated on the insulator surface and allowed to dry for 24 hrs. In the testing setup, the polluted insulator was hung to a testing support.To measure the flashover voltage, the cap of the insulator is connected to ground and other terminal was connected to high voltage. The fogging procedure was carried out in a fog chamber by means of spraying sodium chloride with distilled water.

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MEASUREMENT OF LEAKAGE CURRENT

The main purpose of test was to measure and record in which compare the leakage currents under different contamination levels. After that it should be calculated the mean and maximum value and standard deviation.

Figure 3: Overview and magnified leakage current (RMS value) plots sample for the contamination process

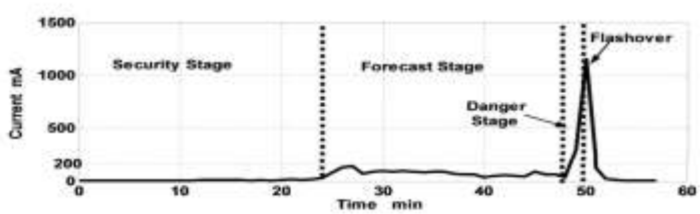


Table 2: Leakage current of insulator features.

ESDD (mg/cm^2) [o/p of the model]	Mean value (I_{em},mA)	Maximum value (I_{emax},mA)	Standard Deviation (σ)
0.02	8.81	10.97	1.65
0.04	11.72	13.83	1.54
0.05	13.99	17.20	1.99
0.06	17.14	21.91	2.81
0.07	19.38	26.73	4.31

The leakage current is expressed as I_e in equation (1)

$I_e=(1/T\int_0^T i(t)^2 dt)^{½}=\sqrt[2]{(I*I')/N}$ (1)

Where i(t) is the instantaneous value of the leakage current in the time domain; I is the sample value of the leakage current; N is the number of sampling points; T is the sampling period; t is the sampling time; I' is the transpose of measured currents.

The three characteristics, i.e., the mean value, maximum value and standard deviation of the leakage current, are proposed as follows:

$I_{em}=(\sum_{i=1}^{N} Ie(i))/N$(2)

I_{emax}=max (Ie (i)) (3)

$\sigma=\sqrt{\sum_{i=1}^{N}(Ie(i)-Iem)^2/N}$(4)

Where N is the total number of sampling points in the test time; I_e(i) is the leakage current value in one sampling period; I_{em} is the mean value of the leakage current; I_{emax} is the maximum value of leakage current; σ is the standard deviation of leakage current.

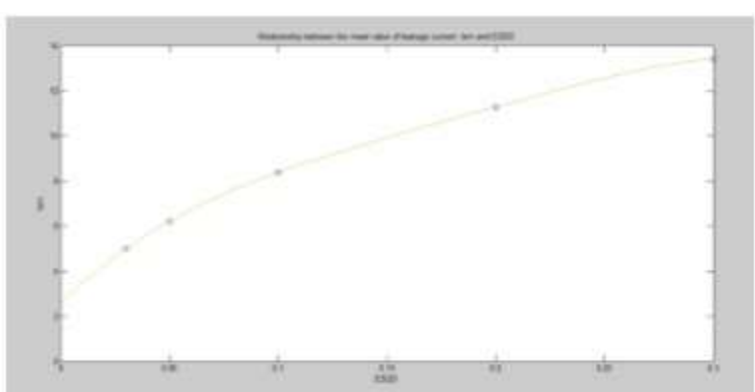
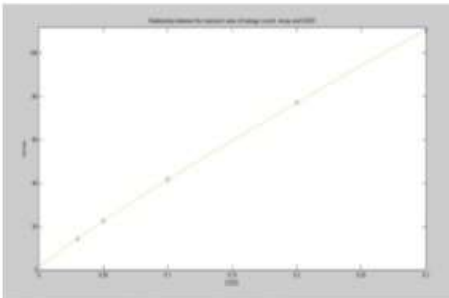
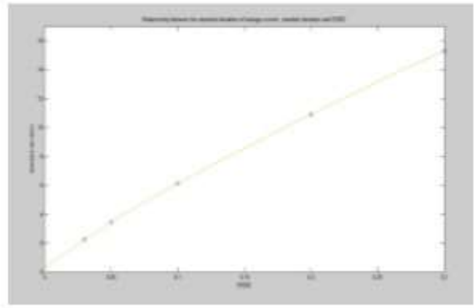


Figure 4 (a): Relationship between the mean value of the leakage current, I_{em} and ESDD.

Figure 4(b): Relationship between the maximum value of the leakage current, I_{emax} and ESDD.
Figure 4(c): Relationship between the standard deviation, σ and ESDD.

4(b) ***4(c)***





According to the experimental results, the regression relationship between I_{em} and ESDD are shown as follows:

I_{em}=-6.8083×e^6×S^4+1.1995×e^6×S^3-72719×S^2+1967.1×S-9.95 (mA/Insulator) (5)

Where S represents ESDD. The R-squared values, i.e., goodness of fit, are 1.

The fitting regression equations between $I_{e\,max}$ and ESDD are as follows:

I_{emax}=-4.217×e^6×S^4+7.227×e^5×S^3-3.803×e^4×S^2+907.2×S+2.93 (mA/Insulator) (6)

Where S represents ESDD. The R-squared values are 1.

The regression equations between σ and ESDD are shown in (7)

σ= 9.5×e^5×S^4-1.573×e^5×S^3+1.11×e^4×S^2-345.3×S+5.22 (mA/Insulator) (7)

Here the R-squared values are 1. Among all the prediction methods related to the insulator contamination of leakage current is most dynamic parameter, it can be measured in easy. The regression equation of the three characteristics and ESDD has been based on large number of the results. From the comparison of insulator leakage distance is the one of the important factor for the leakage current. Also, a reasonable insulator design can prevent the flashover effectively.

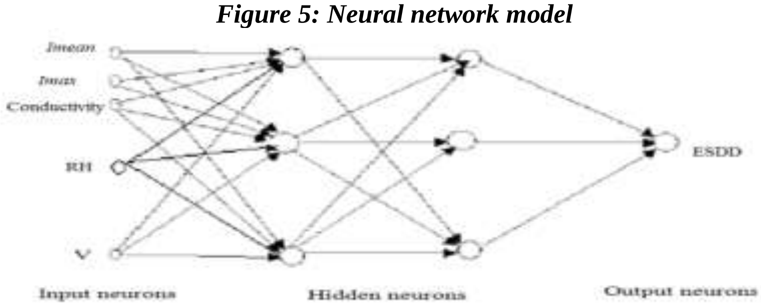
NEURAL NETWORK MODEL FOR PREDICTING ESDD ON THREE STAGE CHARACTERISTICS

An artificial neural network is a system based on the operation of biological neural networks, in other words, is an emulation of biological neural system. Artificial neural network (ANN), which has a high degree of self-learning, self-organization and adaptive capacity, can be used in many problems requiring function approximation, modeling, pattern recognition and classification, estimation and prediction, etc.[6-8].In order to predict the contamination level of insulator, the most widely used for feed forward back propagation (FFBP) neural network model (NNM) has been selected to construct the model for the insulator.

The neurons of the input layer include the three characteristics, I_{em} , I_{emax} and σ , the relativehumidity*RH*,andtheappliedvoltage *U*.Thehidden layerhasthreeneuralunits.Theoutputis *ESDD*,namelythe contamination level.ThesimulatorofBPNNM usesthe back propagation algorithmwithsupervised learning.

The multilayer feed forward neural network model with back propagation algorithm for training shown in Figure 5. Illustrates our implemented neural network.

Figure 5: Neural network model



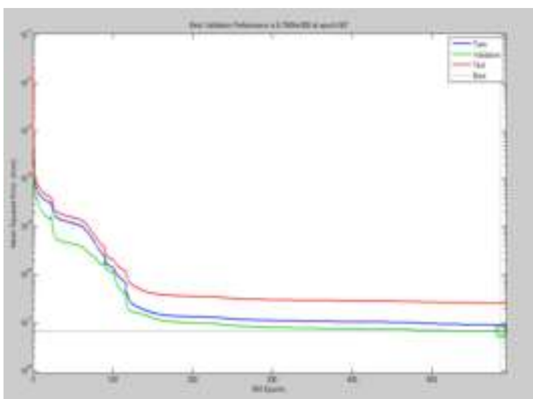
The normalized training patterns are fed to the model. Leven-marquardt algorithm is used for training as it coverage fast and the function 'trainlm' is invoked. Using trial and error the numbers of nodes in the hidden layer are determined.

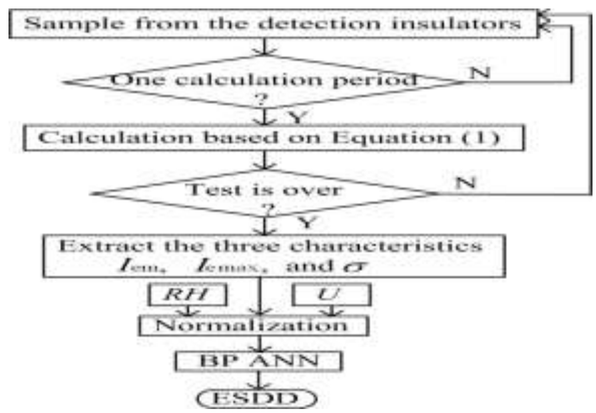
Table 3: Comparison of test and simulation results

SI.NO	T, Test results (mg/cm^2)	S,Simulation results (mg/cm^2)	D, Difference (mg/cm^2)
1	0.02	0.020234	0.000233
2	0.04	0.040186	0.000186
3	0.05	0.050395	0.000395
4	0.06	0.060032	0.000032
5	0.07	0.069606	0.019606

Where D is the difference (i.e., absolute error), S is the simulation result and T is the test result.

Figure 6:Performance graphFigure 7: Flow chart of the entire prediction process





CONCLUSIONS

In this study, three stages of the leakage current during the entire process of contamination flashover are classified: the security stage, forecast stage and danger stage. But the security stage appears to be the optimal one for contamination flashover pre-warning. It can be verified that the flashover probability of porcelain insulators with longer leakage distance is lower than that of the ordinary insulators at the same contamination severity.

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