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Experimental Investigation on Room Temperature Vulcanised Silicone rubber and Epoxy resin coated porcelain outdoor insulators located at highly polluted environment

M. Ravindran[a,*], S. Senthil Kumar[b], N. Karuppiah[c] and M. Asokan[d]
[a]*Associate Professor (S.G), Department of EEE, National Engineering College, Tamil Nadu, India*
[b]*Assistant Professor (S.G.), Department of EEE, National Engineering College, Tamil Nadu, India*
[c]*Professor, Department of EEE, Vardhaman College of Engineering, Telangana, India*
[d]*PG Scholar, National Engineering College, Tamilnadu, India*

Insulators flashover is one of the major problem that confronts all around the world, particularly in austere weather conditions and highly polluted areas. Any failure in the acceptable performance of high voltage insulators result in intrerruption of electrical power that leads to loss of capital. Flashover voltage (FOV) is directly related to the severity of pollution on the surface of insulator. Generally, anti-pollution flashover coating is considered as one of the most effective means to prevent and reduce flashover. This paper investigates and compares the results on application of Epoxy Resin and Room Temperature Vulcanized (RTV) Silicone Rubber for improving the performance of outdoor (near coastal thermal plant area) insulators of 12 KV rating. The flash over voltage of the insulators is optimized for a polluted environment by applying the protective coating and tested experimentally. The experimental results are compared with simulated results using Artificial Neural Network.

Key words –Artificial Neural Network, Epoxy Resin, Flashover voltage, Post Type Insulator

Introduction

The rapid development of modern society and industries, worldwide, made the power requirement to be more significant. The reliability of the electrical network and its setup is essential for the satisfactory performance of an electric power system [1, 2]. Insulators are one among the significant apparatus in the high voltage transmission line and switch yard, which are used for keeping apart the electrical supply irregularities [3].

In general, electric power system has exploited the usage of ceramic and non-ceramic insulators. In recently developed transmission systems, polymer insulators which offer several advantages over porcelain insulators are used. Polymer insulators have excellent hydrophobic surface property under wet conditions, eminent mechanical strength to weight ratio, saving on labour due to less weight and bringing down maintenance costs [4, 5]. Eventhough, polymer insulators have a number of advantages, it suffers from a significant drawback i.e, these insulators are more prone to chemical changes (weak bond compared to porcelain). Also, it suffers from erosion and tracking their life expectancy is difficult. Porcelain Insulators have some advantages over the polymer insulators as it is environmental friendly, higher electrical strength (25 kV/mm), high thermal resistance, stable against the effects of UV radiation and do not suffer from defects in the ceramics-to-metal interface. Porcelain is a sluggish and stable material and the surface does not easily degrade, because dry band arcing withstand capacity is high when compared to silicone rubber [6-8].

Pollution is a million dollar problem especially for outdoor insulation systems. Pollution severity and the contamination present on the surface of the insulators depend on the type of surface area of the insulator (marine, industrial, ice and fog, chemical, desert, bird segregation etc). There are several factors that are responsible for the flashover voltage on the surface of the insulator [9]. They are surface resistance of a material, surface condition and electric field intensity within the conductor and insulator. Electric Arcing is an outside disruption on the insulator surface. It is a cognitive process whose value is smaller than the puncture voltage of the insulator. Sometimes it exceeds the ceiling value and damages the insulator due to puncture which is one of the worst cases that must be avoided. This paper investigates a 12 kV Post type ceramic insulator which has been taken from near coastal coal based power plant, which is situated in a nearest coastline within 1 km. The combustion of coal at thermal power plants

*Corresponding author:
Tel : +9194870 80584
E-mail: ravinec99@gmail.com

lets out carbon dioxide (CO_2), sulphur oxides (SOx), nitrogen oxides (NOx), CFCs particulates such as fly ash and Suspended Particulate Matter (SPM) ranging from 0.5 to 100 micron in size. Because of these pollutants electrical equipments of coal based power plant are extremely affected [10, 11]. These coastal insulators often comes into contact with dust and humidity (seashore area) and thereby gets affected by the problem of corona. Generally anti-pollution flashover coating is considered to be one of the most effective means to prevent and reduce pollution flashover.The thickness of coating should also be improved to withstand the voltage of the insulator. Silicone oil and silicone grease are some of the existing coating methods that increases the life of the insulator. Protective polymer coatings greatly bring down the frequency of cleaning of insulators and periodic re-application of greases besides their drawbacks such as poor mechanical strength, thixotropic performance, tracking, erosion performance and flame retardancy [12, 13].

In literature discussed above, the strength of protective polymer coating of Epoxy Resin and Silicon rubber are compared. In recent literatures, the need for an optimization technique to improve the new design of insulator is discussed [14-16]. COMSOL is one of the advanced Finite Element methods and multi physics software package used to find out the optimized effect of electric field distribution of insulators. It is also used to minimize the electrical stress at the vicinity of the insulators [17, 18]. Also MATLAB is used in simulation and mathematical modelling of insulators. Critical flash over voltages of insulators are obtained through MATLAB simulation and these simulated values are compared with the experimental values.

Experimental Set Up

Post insulator specimens

Two test specimen sets (12 kV Post Type Ceramic Insulator) which are predominently used in high and extra high voltage substation switch yards are taken. These specimen insulators are used for supporting electrical equipment and bus conductors in switch yards. It is different from pin insulator in such a way that it has metal support on both sides. Firstly, the test specimens are measured in dimensions to find out the Insulation resistance values. These measured values for the test specimens are shown in Table 1. In this test, the insulators are cleaned and the measurement of breakdown voltages and leakage current are noted without pollution. The flasover voltages of the specimen insulators are tested experimentally and these values are shown in Table 2. Flash overvoltage test on insulator specimens should be conducted only a few times orelse the insulator may destroy permanently. The Insulator specimens should also be strong enough to withstand over voltages during the operation.

Table 1. Dimensions and Insulation Resistance values of Test specimens.

Test Specimens	Dimensions in mm	Insulation resistance in MΩ
Post Type Insulator 1	L (320), H (250), D (150)	250
Post Type Insulator 2	L (400), H (250), D (180)	230

Table 2. Flash over voltages of insulators before pollution test.

Types of Insulator	Condition	Flash over voltage in kV	Leakage current in mA
Post Type Insulator 1	Dry	74.9	37.1
	Wet	59.5	28.9
Post Type Insulator 2	Dry	72.2	36.5
	Wet	56.4	27.4

Experimental setup

Fig. 1 shows the experimental setup in high voltage laboratory. The setup has coupling capacitance and high voltage transformer. The voltage rating of transformer is 2×0.22/100/0.22 kV, current rating is 2×22.8/0.1A, with output rating as 10 kVA. The high voltage lab comprises of control panel with exact metering facilities.

Pollution test without protective coating

Before conducting the tests on the insulators, they are scavenged to get rid of dirt and greases. The type of pollutants which are accumulated near coastal thermal plants are coal and fly ash. These are taken at different ratios, and then mixed with distilled water and enforced over the surface of the insulators test specimens by brushing method. The artificial tests are carried out in high voltage laboratory and the test specimens are put on slowly from zero voltage until consummate flashover falls (occurring flashover as shown in Fig. 2) out on the insulator surface. The average flashover voltage and leakage current is precipitated when the quantity of dust is aroused. At flashover, the voltage and leakage current is put down.

Pollution test with protective coating

To improve the performance of porcelain insulator under polluted conditions, coatings are used to extenuate surface leakage current, surface discharge and bring down flashover occurrence. This practice is particularly desirable for insulators established at substations with pollution severity. This analysis looks into the performance of the proposed protective coating which increases the property of leakage current suppression and flashover voltage performance of the insulators in comparison with Epoxy Resin coatings and silicone rubber (RTV) coatings.The epoxy group, which is also addressed as the glycidyl group, has higher molecular group to commute Epoxy resin to plastic and this setting is called as a hardener. The hardener for the epoxy resins are primarily diamines and polyamines and chemical

Fig. 1. Experimental set up at High Voltage Research Laboratory in National Engineering College, Kovilpatti, Tamilnadu.

Fig. 2. Occurrence of flashover in Insulator test specimens

compounds with various molecular weights. These have high mechanical strength, chemical resistance, diffusion density, water tightness, electrical insulation capacity, shrinkage, Heat resistance etc., Silicone rubber compounds have characteristics of both inorganic and organic materials. Si-COAT 570 HVIC (High voltage Insulator Coating) is a one-part; room temperature vulcanizing (RTV) polysiloxane (silicone) coating. Its unique conceptualization furnishes a highly hydrophobic surface for its entire life. The coating is not impacted by UV light, corona discharge, chemical contaminants, salt, extreme temperatures or corrosive environments. Fig. 3 represents the structure of a RTV silicone rubber [19].

Coating the porcelain post type insulators with RTV coating is the only way to improve the water repellence of the surface. The coating is enforced on the insulator surface by spraying the liquid polymer, which then vulcanizes in presence of air into a flexible plastic layer and Epoxy Resin coating applied by brushing method as shown in Fig. 4.

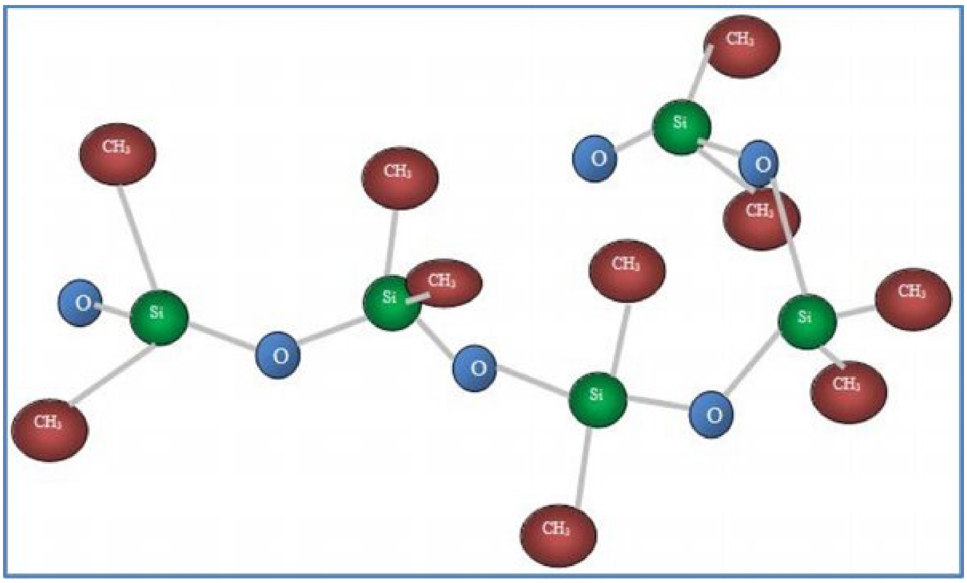

Fig. 3. Chemical structure of a linear silicon polymer

Fig. 4. RTV Silicone and Epoxy Resin Coating.

Flashover voltage vs Non Soluble Deposit Density value (NSDD) are compared for the test specimens without pollution test (dry and wet condition) and pollution test with RTV and Epoxy Resin coated 12 kV insulator through high voltage testing. Fig. 5 represents graphically the flash over voltage of insulator test specimens without pollution test and with pollution test coated with different resins (Epoxy Resin and RTV).

Fig. 6 represents the comparison of fly ash pollutants with Epoxy Resin and RTV coating and without flyash pollutant. Tests are conducted and flash over voltage is obtained in each case. In both the graphs referred, it is clear that when the NSDD values are increased for every ratio the flashover voltage has decreased. In wet conditions the flashover is atrociously departed along with the increase of pollution severity. In dry conditions the flash over voltage has slight variations. In dry flash over, the performance comparison between epoxy resin and silicone rubber are same, but in wet conditions silicone rubber coating has better performance when compared to epoxy resin.

Results and Discussion

The experimwntal results of the test specimen is compared with the simulation results and the outcomes are discussed.

Simulation result analysis using artificial neural network

In electrical power systems, to avoid insulator failure, flashover designing is one of the major constituents. ANN is an effective tool through MATLAB, which is used for insulator flashover. Training process of ANN require more values which are drew out by curve fitting method of experimental data. The TRAINLM (Leven berg-Marquardt algorithm) function is used in Feed-forward back propagation method. The Leven berg-Marquardt (LM) algorithm is a reiterative proficiency that locates the minimum of a function that is evinced as the sum of squares of nonlinear occasions and is mathematically calculated using TANSIG method [20-23].

Test results using ANN

In this experiment, test specimens without pollutants (coal) and RTV coating and with pollutant (coal) and RTV coating are compared using experiment setup and ANN. In ANN, it is trained with 80 inputs and outputs. The following comparison graph is drawn considering 19 values from initial and final of experimental data and from ANN training data sets. In coal with wet condition and without coating result in high experimental values when compared with ANN simulation values.

In above Fig. 8 graphical representation, coal with protective coating under wet conditions have percentage error values as oscillatory (both in positive and negative

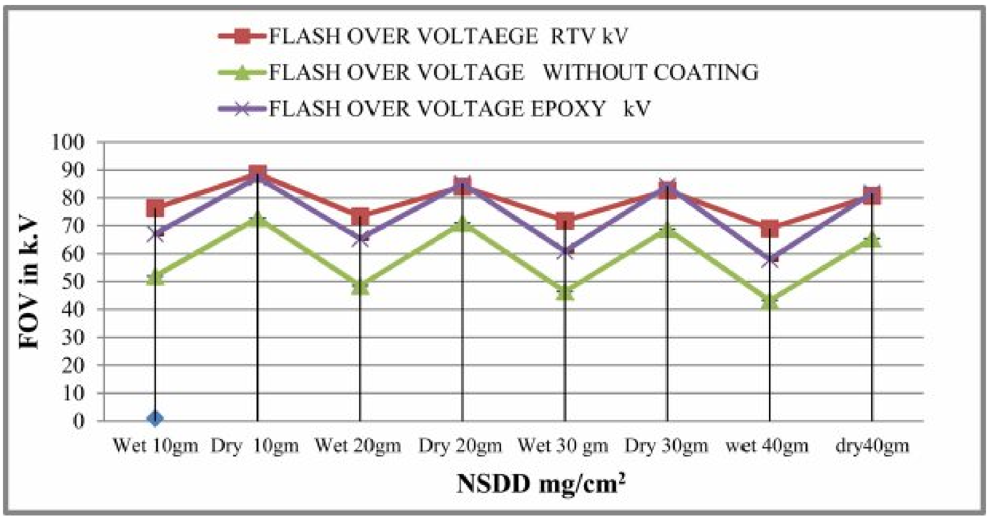

Fig. 5. Comparison of flash over voltages of insulator test specimens with Epoxy Resin and RTV Coating with coal pollutant and without pollutant test.

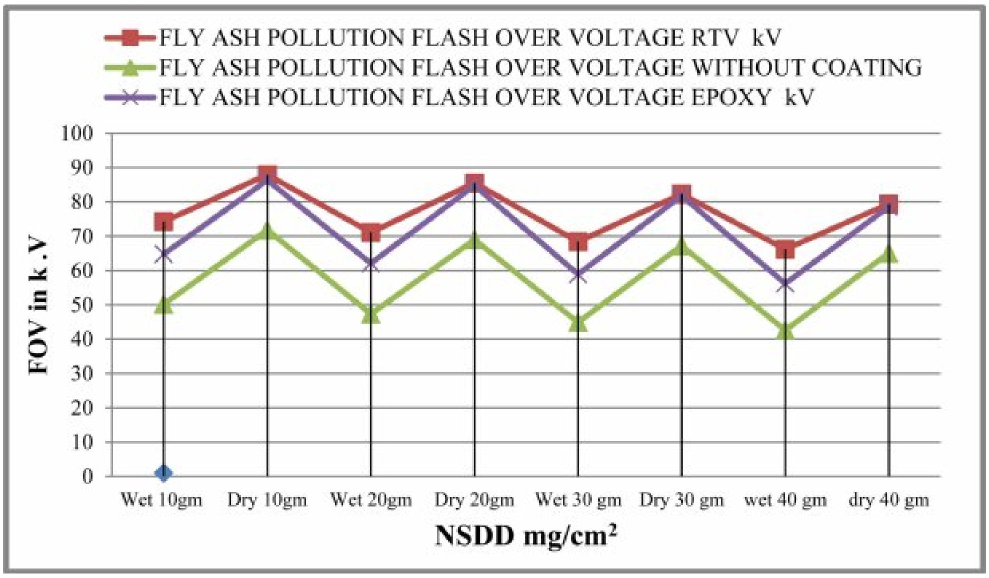

Fig. 6. Comparison of flash over voltages of insulator test specimens with Epoxy Resin and RTV Coating with fly ash pollutant and without pollutant test.

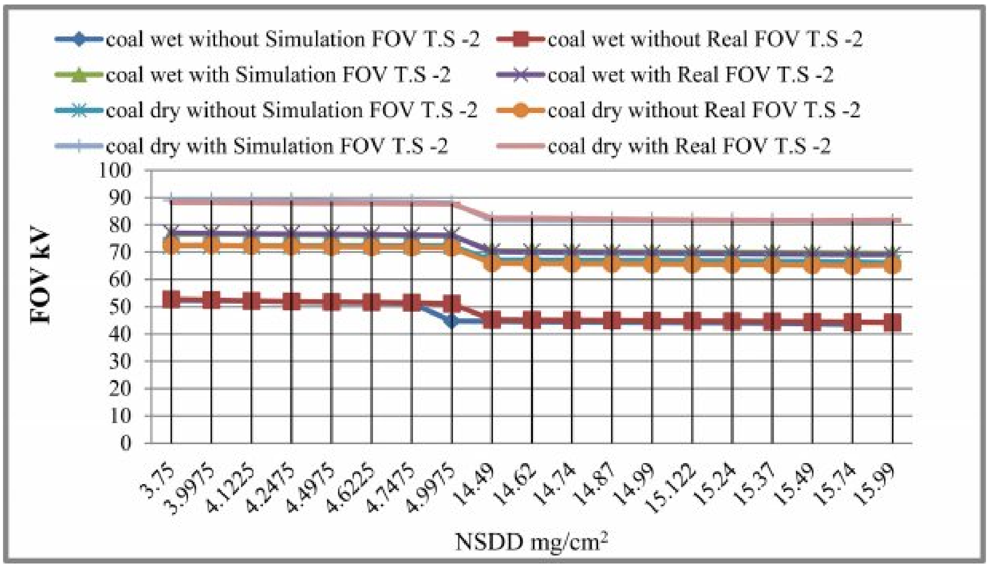

Fig. 7. Insulator without and with coal and RTV Coating for wet and dry conditionds under simulation and real test (experiment) on test specimen.

values). Coal without protective coating under wet conditions have an decreasing error percentage for starting values and increases upto 2 percentage. Coal with protective coating under dry conditions have percentage error values as oscillatory (both in positive and negative values). But the percentage error graph is opposite to that in wet condition. Coal without protective coating under dry conditions have an decreasing error percentage.

Secondly, comparison of graphical representation for Fly ash pollution under wet and dry conditions using ANN and experimental set up is shown in Fig. 9. The graph shows that the values are same even if the conditions are varied.

In dry condition the percentage error without coating and flyash carried out using simulation and experimental values are oscillatory between positive and negative values. In dry condition the percentage error with coating and flyash carried out using simulation and experimental values is constant. In wet condition the percentage error without coating and flyash carried out using simulation and experimental values are oscillatory between positive and negative values in the beginning and settles down at a constant negative value. In wet condition the percentage error with coating and flyash carried out using simulation and experimental values are negative mostly with a steep negative surge at the end.

In Fig. 10 graphical representations for all error values

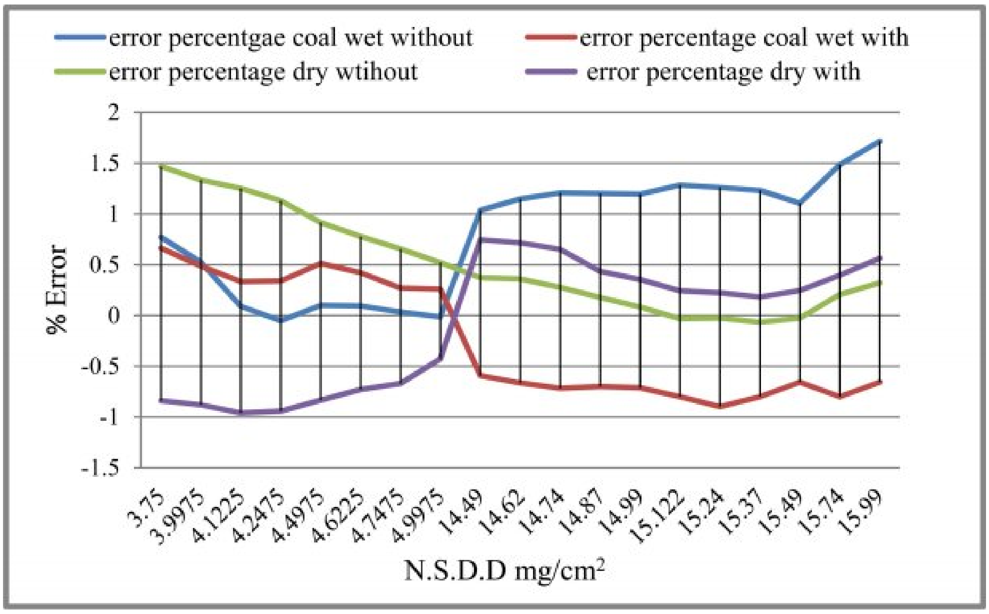

Fig. 8. Percentage error of test specimen with and without Coal and coating under wet and dry conditions.

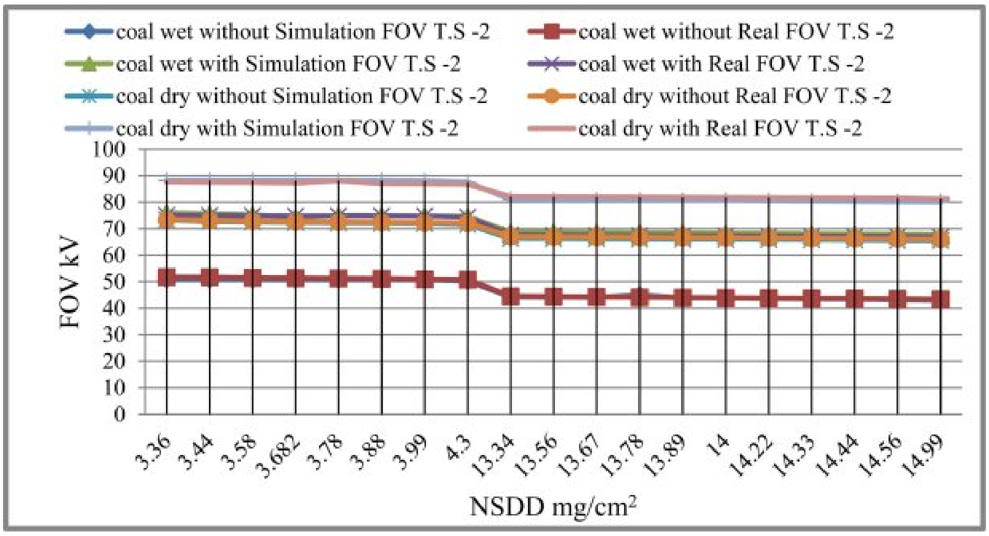

Fig. 9. Insulator without and with Fly ash and RTV Coating for wet and dry conditions under simulation and real value (experimental) comparison on test specimen.

are oscillatory in positive and negative value except wet without coating. Its function is to estimate the model relationship between critical flashover voltage, creepage distance and Non Soluble Deposit Density for predicting the flashover voltage of non-soluble polluted insulator. Simulation results are foretelling and basically logical and agree with the experimental results.

Conclusion

This paper analyses the comparison in high voltage Post Type insulators. The artificial pollution testing insulator flashover voltage performance is directly proportional to the quantity of pollution severity. Non-soluble Deposit Density (NSDD) values in coal is little higher when compared with NSDD of fly ash and combination of coal and ash. These results indicate that Silicone Rubber-RTV coating increases the performance of ceramic outdoor insulator to overcome pollution effect. The coated insulator maintains it hydrophobicity under various polluted conditions. The flashover voltage is approximately increased up to 25% after coated with Silicone Rubber coating. When comparing with Epoxy resin and silicone rubber coating, RTV coated insulator has high flashover voltage at wet and dry conditions. Silicone rubber coated insulator is suitable for seashore and tropical climate.

Pollution performance model of investigating samples under artificial pollution condition has been done using Artificial Neural Network. Its function is to estimate

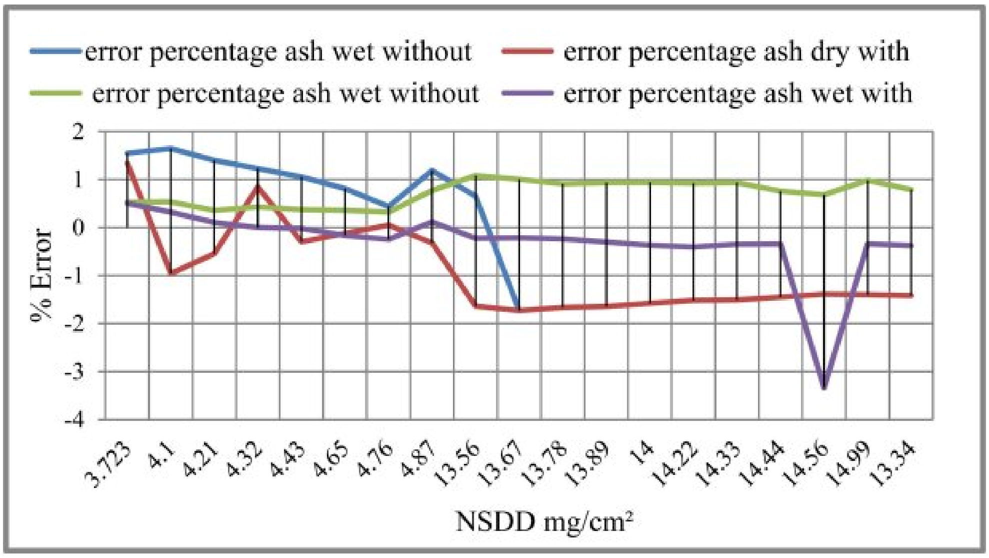

Fig. 10. Percentage error values for test specimen with and without Fly ash and coating under wet and dry condition.

the model relationship between critical flashover voltage, creepage distance and Non-soluble Deposit Density for predicting the flashover voltage of non-soluble polluted insulator. Simulation results are promising and are basically consistent with the experimental results.

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