ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Website: www.ijareeie.com

Vol. 6, Issue 8, August 2017

Study of Nano Filler Effect on Electrical Behavior of Polymer Insulating Materials Using Artificial Intelligence

El-Said A. Othman[1], L. S. Nasrat[2], Abdelrahman A. Z. Saleh[3]

Professor, Department of Electrical Power and Machine, Faculty of Engineering, Alazhar University, Cairo, Egypt[1]

Professor, Department of Electrical Power and Machine, Faculty of Engineering, Aswan University, Aswan, Egypt[2]

Ph.D. Researcher, Qena, Egypt[3]

ABSTRACT: Flashover voltage of tour and outdoor insulators affects greatly the reliability of the power system that caused and depends on different parameters such as the environmental and weather conditions. Laboratory measurements have done on polymeric insulators with nanocomposites Silicon dioxide and Titanium (IV) oxide (polyester with Nano Tio2 and Nano Sio2 fillers) at different weather conditions , different sample lengths and different fillers concentrations. This research predicts the flashover voltage at any value of different inputs such as filler concentration using artificial neural network. Feed forward neural network (FNN) and Recurrent neural network (RNN) are trained and tested with wide range of samples data sets to confirm the principle of generalization and reach the optimum values of the output flashover voltage at the different inputs variables. RNN network achieved the best result and the minimum error compared to FNN network.

KEYWORDS: Flashover, High Voltage, Dielectric, Feed Forward, Recurrent, Neural Network, Nanocomposites, Polyester, Outdoor, Insulators, Titanium(IV) oxide, Silicon dioxide.

I.INTRODUCTION

Polymer nanocomposites technology is promising technology nowadays and in the future of power technologies to be used in many fields of electrical insulation of power cables, power apparatus and outdoor insulators because of their very high specific surface area. They are the 21st century engineering materials with wide range of markets such as transportation, electrical and electronics, food packaging and building industries [1]. Addition of those Nano fillers to polymer insulators has attractive improvement results on their electrical, mechanical, physical, dielectric and thermal properties in comparison to traditional composites [2,3]. Polyesters are widely popular and used in manufacturing of electrical components in many sectors because of their excellent insulating and mechanical properties, ease of use and their low cost [4]. Estimating of non-ceramic insulator with suitable filler percentage that takes long life time with high voltage values at different weather conditions and the relation between the leakage current and pollution conditions were predicted by Artificial Neural Network [5]. Experimental work on the electrical properties of different elastomer materials with variety of frequency range and temperatures were predicted using neural network and compared with traditional fitting methods [6]. Measurements of Epoxy insulators lifetime and the effect of adding fillers at variety of concentrations on the lifetime of each specimen were compared by two Artificial-Neural-Networks (ANN) methods; Feed-Forward-Neural-Network (FNN) and Recurrent-Neural-Network (RNN) for life time validation in terms of type , percentage of added fillers among different weather conditions[7]. Flashover voltage measurements of hydrophobic polymer insulator Ethylene propylene diene monomer (EPDM) rubber depending on the silicone rubber (SiR) content (%),water conductivity(μS/cm), volume of water droplet (ml) and number of water droplets on the surface of the polymer insulator. These different case studies were used to evaluate the electrical performance of polymer insulators, modeling and estimating the flashover voltage for different inputs with artificial neural network (ANN) [8].
Artificial neural network (ANN) with back propagation algorithm (BPA) is used for flashover voltage prediction of polymeric insulators as Laboratory measurements and experiments on polymeric insulators were carried out under AC voltage at different contamination levels and humidity [9].

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Website: www.ijareeie.com

Vol. 6, Issue 8, August 2017

Nano technology represented in Polymer nanocomposites are introduced, their advantages in comparison to classic and traditional fillers in terms of their electrical, mechanical and thermal properties with investigating of nanocomposites future applications were studied and reported [10,11].
Effects of Nano and Micro Mixture fillers by dispersing Nano-scale layered silicate fillers and micro-scale silica fillers in epoxy resin on the electrical insulation properties were demonstrated and summarized compared to traditional filled epoxy [12].

II.EXPERIMENTAL WORK

A single-phase high voltage transformer (100KV -5 KVA) is used to obtain the AC high voltage. (0-220V) variac regulating panel is used to smoothly control the output voltage of the transformer as shown in Fig.(1). The voltage applied to the transformer primary winding. The power supply was connected across two electrodes. Samples have been prepared from unsaturated polyester with nanocomposites Silicon dioxide and Titanium (IV) oxide (polyester with Nano Tio2 and Nano Sio2 fillers), and they were fabricated as cylindrical rods having 12 mm diameter. Fig.(2) shows nanocomposites Tio2 and Sio2 fillers that have been added to unsaturated polyester. Fig.(3) shows the unsaturated polyester product. Fig.(4) shows the final shapes of unsaturated polyester insulators with Nano fillers after being chemically prepared and during the lab testing.

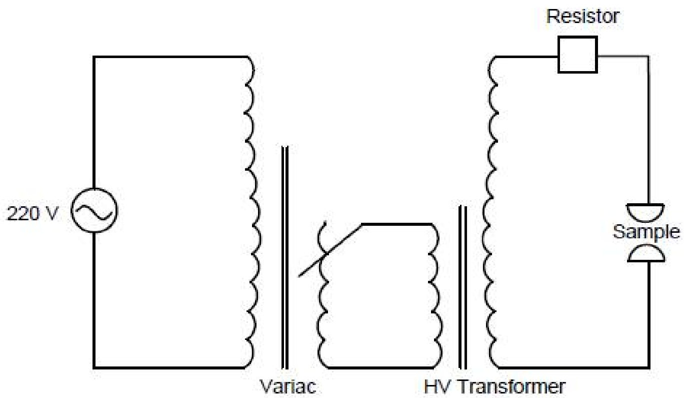

Fig.(1): Single-phase high voltage transformer

Fig.(2): Nanocomposites Silicon dioxide and Titanium (IV) oxide

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Website: www.ijareeie.com

Vol. 6, Issue 8, August 2017

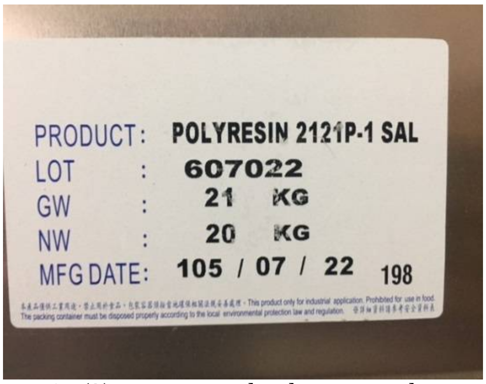

Fig.(3): Unsaturated Polyester product

Fig.(4): Unsaturated Polyester insulator with Nano fillers during test

III.RESULTS AND DISCUSSION

The flashover voltages experimental measurements have been recorded in laboratory for polyester polymer insulator with nanocomposites Silicon dioxide and Titanium (IV) oxide (polyester with Nano Tio2 and Nano Sio2 fillers) at different concentrations and conditions. Filler concentration affects greatly the flashover voltage as flashover voltage value increases when the Nano Tio2 or Sio2 fillers concentrations increase. Flashover voltage values of dry polyester nanocomposites 0.5 cm Sample length are 8.79, 9.04, 10.12 and 11.96 KV at 0 ,1,3 and 5 % Nano Tio2 filler concentrations respectively & 29.98, 32.08, 34.49 and 36.55 KV at 2.5 cm sample length with 0, 1, 3 and 5 % Nano Tio2 filler concentrations respectively as shown in Fig.(5). Flashover voltage values are reverse proportional to wet and salt weather conditions. Flashover voltage values of wet polyester nanocomposites with 0.5 cm Sample length are 5.83, 6.01, 7.22 and 8.93 KV at 0,1,3 and 5 % Nano Sio2 filler concentrations respectively & 24.62, 26.75, 27.63 and 29.99 KV with 2.5 cm sample length at 0, 1, 3 and 5 % Nano Sio2 filler concentrations respectively as shown in Fig.(6). Flashover voltage values of Salt polyester nanocomposites 0.5 cm Sample length are 4.66, 5.53, 6.71 and 7.62 KV at 0, 1, 3 and 5 % Nano Sio2 filler concentrations respectively & 22.72, 27.08, 28.62 and 30.66 KV with 2.5 cm sample length at 0, 1, 3 and 5 % Nano Tio2 filler concentrations respectively as shown in Fig.(7) and Fig.(8). Flashover voltage is directly proportional to sample length as measurements indicate that approximately 32.70 % increase in flashover voltage values of dry polyester nanocomposites Tio2 with 2.5 cm sample length in comparison to 0.5 cm sample length recordings of all used concentrations and 33.33 % with Nano Sio2 filler. Also measurements indicate that approximately 29.83% increase in flashover voltage values of wet polyester nanocomposites Tio2 with 2.5 cm sample length in comparison to 0.5 cm sample length recordings of all used concentrations and 29.77 % with Nano

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Website: www.ijareeie.com

Vol. 6, Issue 8, August 2017

Sio2 filler. Salt polyester nanocomposites Tio2 and Sio2 recorded 27.46 and 26.94 % increase in flashover voltage values with increase of sample length from 0.5 cm to 2.5 cm respectively.

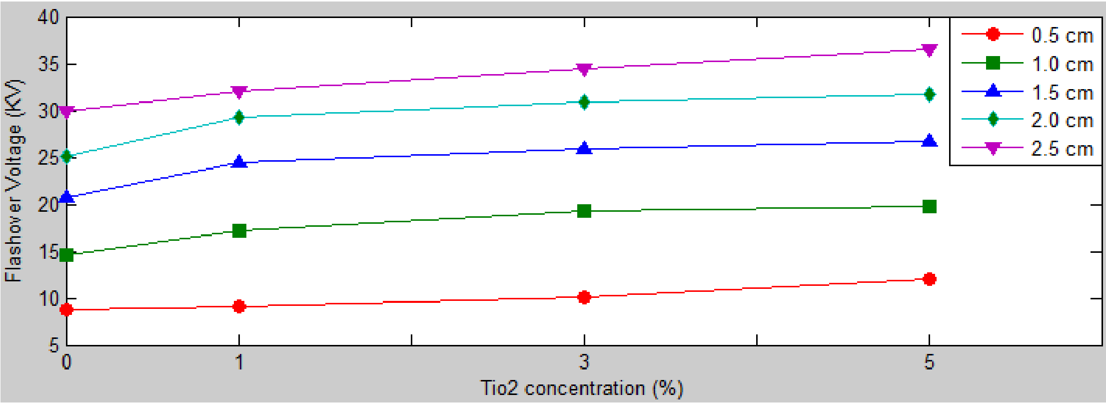

Fig. (5): Flashover voltage of nanocomposites Tio2 filler with Polyester at different concentrations and sample lengths in dry weather

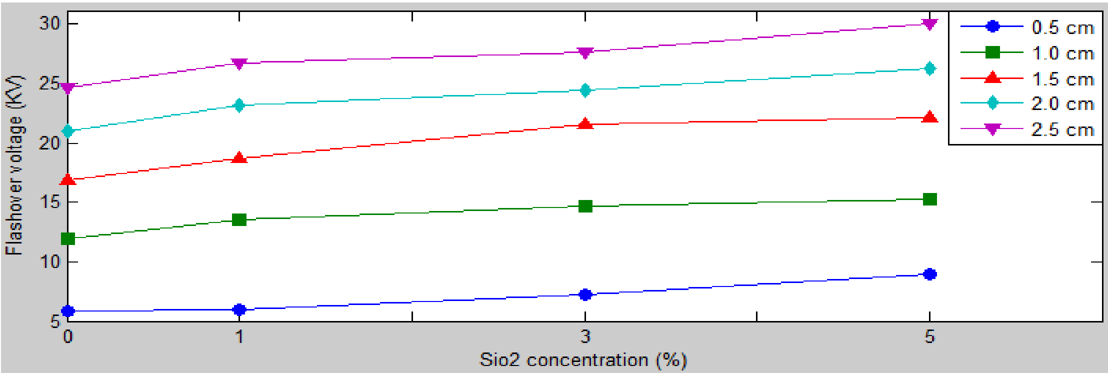

Fig. (6): Flashover voltage of nanocomposites Sio2 filler with Polyester at different concentrations and sample lengths in wet weather

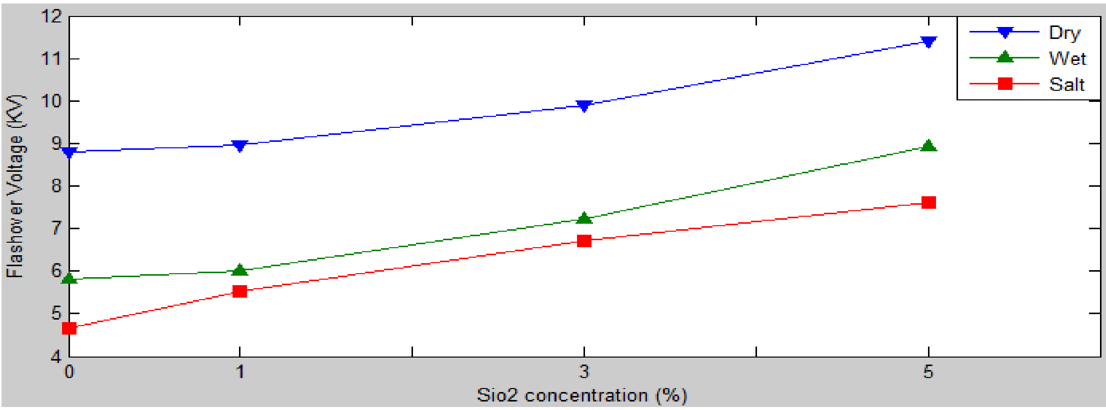

Fig. (7): Flashover voltage of nanocomposites Sio2 filler with Polyester at different weather conditions and concentrations with 0.5 cm sample length

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Website: www.ijareeie.com

Vol. 6, Issue 8, August 2017

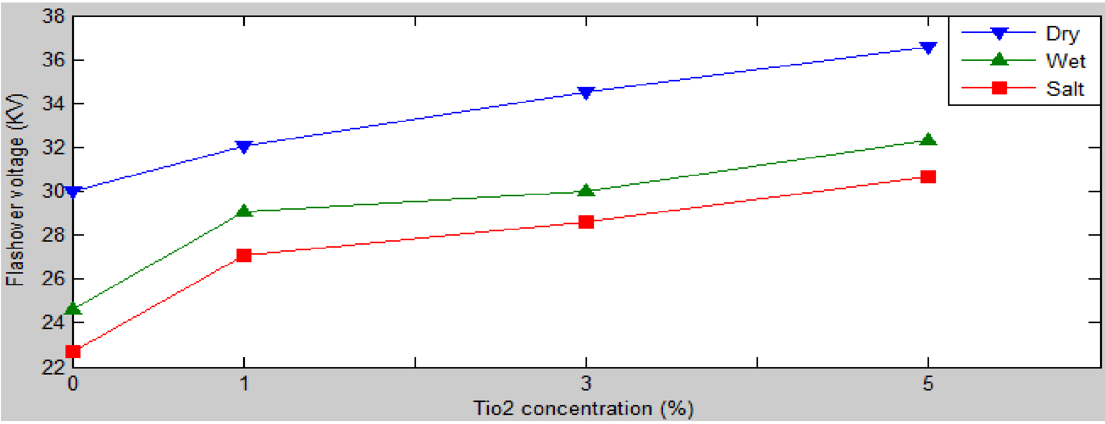

Fig. (8): Flashover voltage of nanocomposites Tio2 filler with Polyester at different weather conditions and concentrations with 2.5 cm sample length

The flashover voltage values of unsaturated Polyester and with different Nano fillers of Tio2 and Sio2 at different lengths of 0.5 cm, 1 cm, 1.5 cm, 2.0 cm and 2.5 cm with addition of Sodium Chloride were measured and are shown in Figures 9, 10.

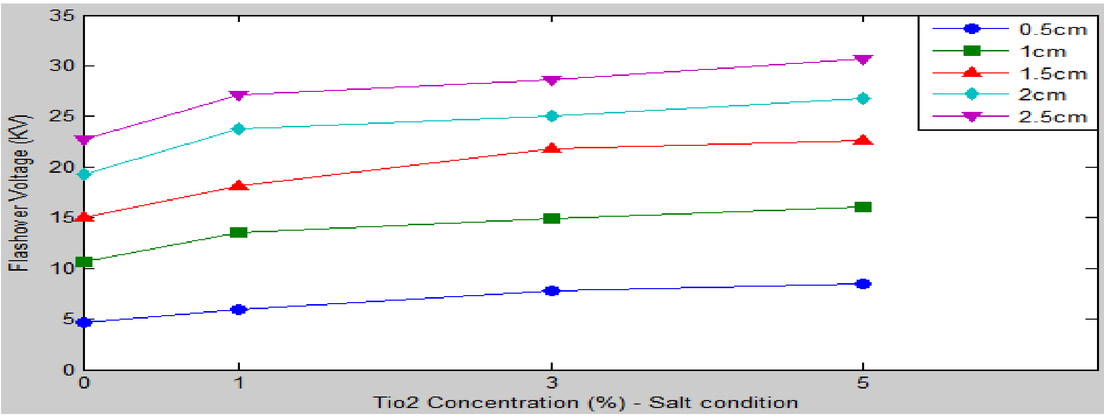

Fig. (9): Flashover voltage of nanocomposites Tio2 filler with Polyester at different concentrations and sample lengths in salt weather

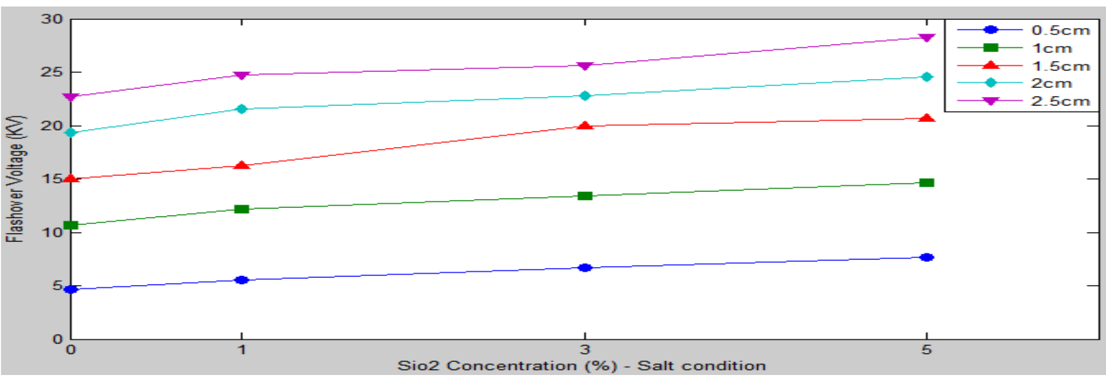

Fig. (10): Flashover voltage of nanocomposites Sio2 filler with Polyester at different concentrations and sample lengths in salt weather

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Website: www.ijareeie.com

Vol. 6, Issue 8, August 2017

Fig.(11) shows the flashover voltage values of unsaturated Polyester and with Tio2 Nano filler at different lengths of 0.5 cm, 1 cm, 1.5 cm, 2.0 cm and 2.5 cm that were measured in the lab at wet condition.

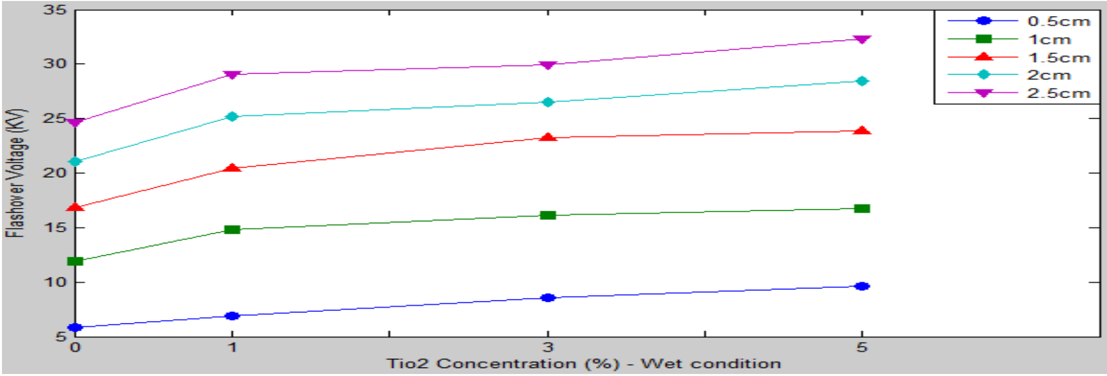

Fig. (11): Flashover voltage of nanocomposites Tio2 filler with Polyester at different concentrations and sample lengths in wet weather

Fig.(12) shows the flashover voltage values of unsaturated Polyester and with Sio2 Nano filler at different lengths of 0.5 cm, 1 cm, 1.5 cm, 2.0 cm and 2.5 cm that were measured in the lab at Dry condition.

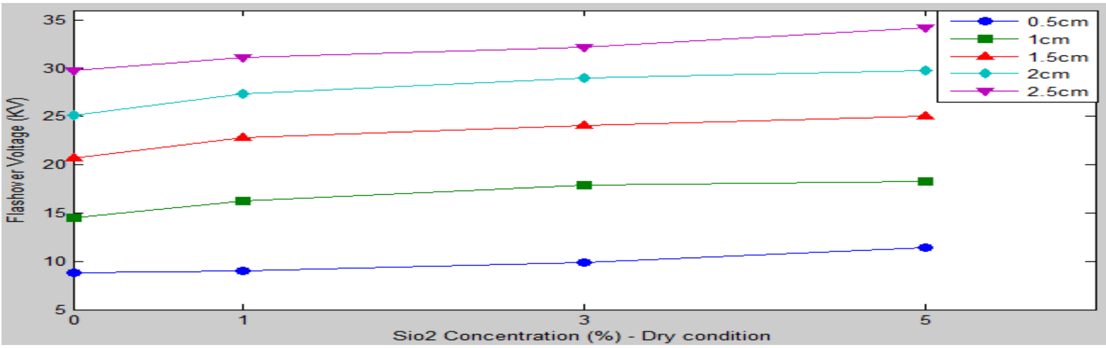

Fig. (12): Flashover voltage of nanocomposites Sio2 filler with Polyester at different concentrations and sample lengths in dry weather

IV.FLASHOVER VOLTAGE PREDICTION WITH NEURAL NETWORK

Artificial neural network algorithm has been used successfully in many applications. It is useful because it acts as a model of real-world system or function. The model then stands for the system it represents, typically to predict or to control it. ANN can model a function even if the equation describing it is unknown. The neurons in the network can be divided into three layers: input layer, hidden layers and output layer [13]. Multilayer feed forward neural network FNN contains three layers they are input, hidden layers and output layer. The input layer contains variables of different inputs [14]. In this research, feed forward neural network FNN and recurrent neural network RNN are used to predict flashover voltage values at any inputs conditions. Inputs variables are weather conditions (dry, wet and salt), nanocomposites (Tio2, Sio2) concentrations varies from 0% to 5 % that added to polyester and sample lengths that varies from 0.5cm to 2.5cm. The output layer is the flashover voltage. Output results values depend on the number and neurons of the hidden layers and affected by them. The optimal size of the hidden layer is usually between the size of the input and size of the output layers. Fig. (13) Shows the mechanism of the flashover voltage computing and Fig.(14) shows the used neural network pattern. Many Neural network structures with different numbers of hidden layers are trained and tested as shown in Table (1) and Table (2), the structure that has given the least value of errors results has been selected in both FNN and RNN patterns as training and test errors have been calculated. [4×7×1] structure with one hidden layer is selected with FNN network (4×7×1 means four inputs, seven neurons in the hidden layer and one

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Website: www.ijareeie.com

Vol. 6, Issue 8, August 2017

output). [4×9×3×1] structure with two hidden layers is selected with RNN network (4×9×3×1 means four inputs, nine neurons in the first hidden layer , three neurons in the second hidden layer and one output). Fig.(15) and Fig.(16) show values of errors computed with inputs sets in training process of FNN and RNN patterns. RNN network achieved the best result and the minimum error compared to FNN network.

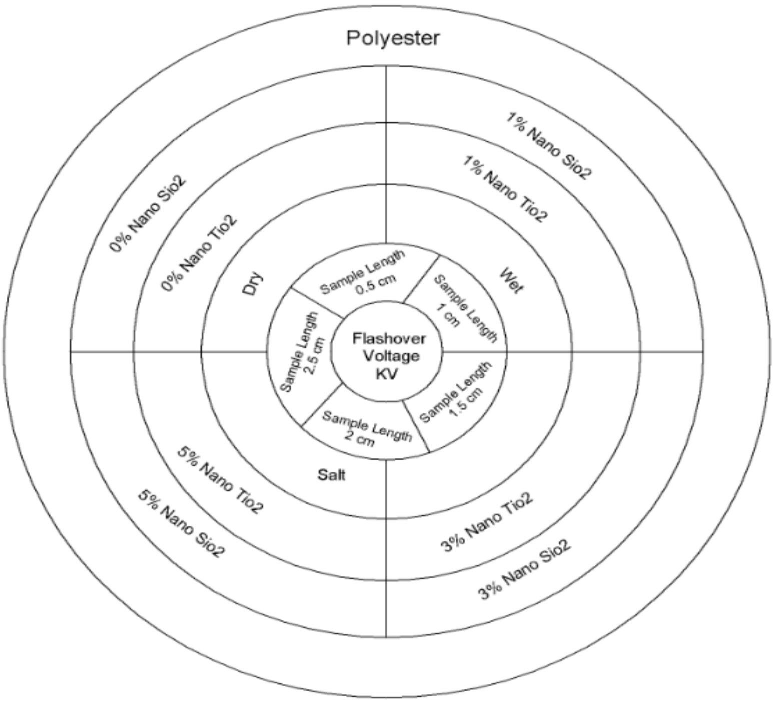

Fig.(13): Mechanism of Flashover Voltage Computing

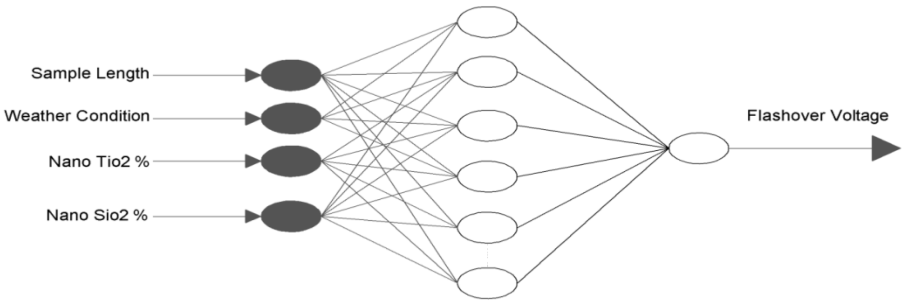

Fig.(14): The Neural Network Pattern

Table (1): Training and test Error for different FNN structures

FNN Network Structure	Training Error	Test Error
4×7×1	0.0172	0.2150
4×15×7×1	0.0145	0.2585
4×9×1	0.0096	0.3111
4×7×5×1	0.0270	0.2470
4×9×3×1	0.1010	0.4351

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Website: www.ijareeie.com

Vol. 6, Issue 8, August 2017

Table (2): Training and test Error for different RNN structures

RNN Network Structure	Training Error	Test Error
4×7×1	0.0031	0.2386
4×15×7×1	0.2658	0.7728
4×9×1	0.0155	0.7228
4×7×5×1	0.0096	0.5137
4×9×3×1	0.0081	0.0533

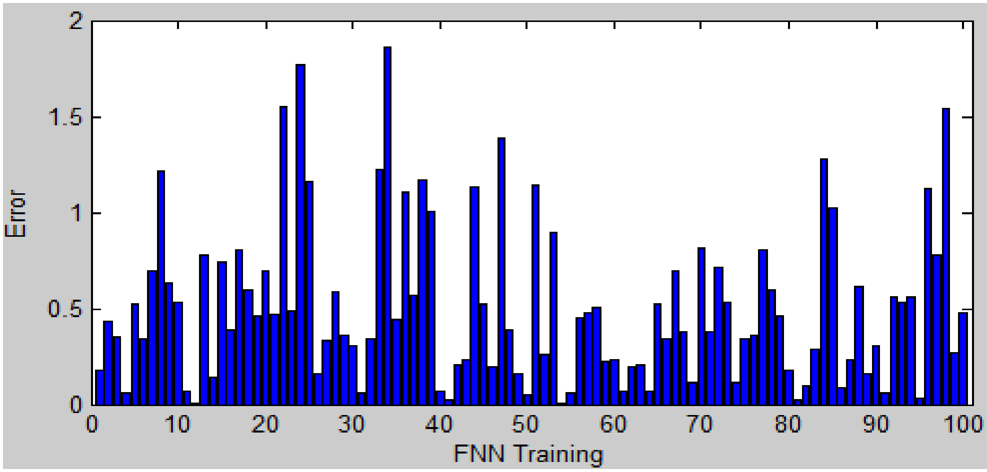

Fig.(15): FNN Training Error

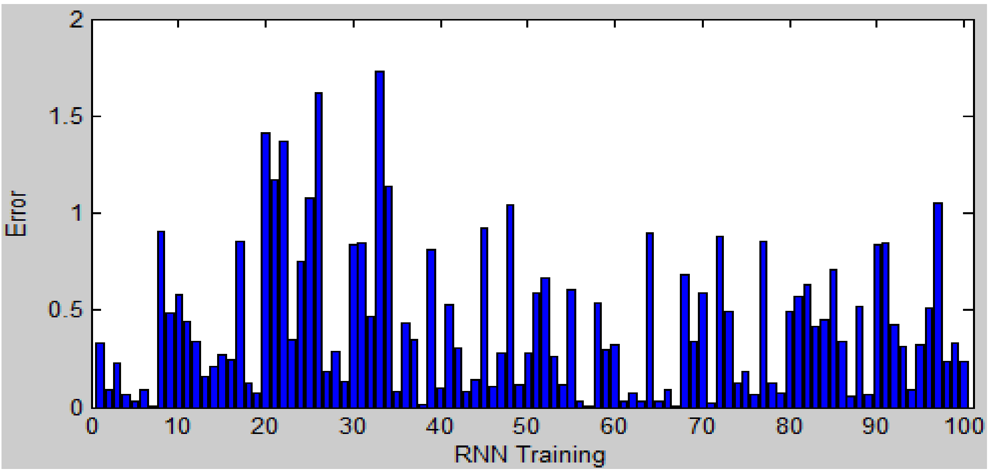

Fig.(16): RNN Training Error

Table (3) and Table (4) show such as a comparison between experimental values of the output flashover voltage and those estimated and predicted by using FNN and RNN pattern. It is noted that flashover voltage experimental values are similar and very close to values estimated by neural networks FNN and RNN. For example, at 0.5 cm sample length, dry condition and 1% Nano Tio2 filler concentration inputs, the flashover value measured in lab is 9.0385 KV and the flashover voltage estimated by FNN and RNN are 8.8790 and 9.9636 KV respectively.

FNN results are acceptable and satisfied. RNN results are better than those of FNN as RNN has the least error value and the best accuracy of 98%.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Website: www.ijareeie.com

Vol. 6, Issue 8, August 2017

Table (3): Experimental and FNN output test of the inputs sets

Tio2 FNN Test	FNN Output	Experimental Output
[0.5;0.9;0.01;0]	8.8790	9.0385
[0.5;0.9;0.03;0]	11.8922	10.1196
[1;0.9;0;0]	15.1114	14.5587
[1;0.5;0.03;0]	16.6195	16.1404

Table (4): Experimental and RNN output test of the inputs sets

Tio2 RNN Test	RNN Output	Experimental Output
[0.5;0.9;0.01;0]	9.9636	9.0385
[0.5;0.9;0.03;0]	11.8029	10.1196
[1;0.9;0;0]	15.0025	14.5587
[1;0.5;0.03;0]	15.8211	16.1404

The main advantage of using neural networks in this research is making generalization to predict the output at any inputs variables values, so new samples data are set to measure generalization range of neural networks introduced as shown in Table(5) and Table(6) . For instance, at 2.5 cm sample length, dry condition and 4% Nano Tio2 filler concentration inputs, the flashover voltage estimated by FNN and RNN were 34.8405 and 34.5652 KV respectively.

Table (5): FNN output test for new samples sets

FNN Test	FNN Output
Tio2 [2.5;0.9;0.02;0]	32.9522
Tio2 [2.5;0.9;0.04;0]	34.8405
Sio2 [2.5;0.9;0;0.02]	31.8840
Sio2 [2.5;0.9;0;0.04]	33.6012
Tio2 [2.5;0.5; 0.04;0]	31.4830

Table (6): RNN output test for new samples sets

RNN Test	RNN Output
Tio2 [2.5;0.9;0.02;0]	33.9269
Tio2 [2.5;0.9;0.04;0]	34.5652
Sio2 [2.5;0.9;0;0.02]	31.6627
Sio2 [2.5;0.9;0;0.04]	32.8191
Tio2 [2.5;0.5; 0.04;0]	30.8388

V.CONCLUSION

Experimental measurements have recorded that Polyester with Nano Tio2 filler has the best results into comparison with Nano Sio2 filler at all sample lengths, all weather conditions and all concentrations as the maximum flashover voltage of Nano Tio2 was 36.55 KV at 5% concentration, dry condition and 2.5 cm sample length. The maximum flashover voltage estimated with neural networks were 36.5631, 36.0857 KV using FNN, RNN respectively; the insulator is Nano Tio2 5 % concentration at dry condition and 2.5 cm sample length.

FNN results are acceptable and satisfied. RNN results are better than those of FNN as RNN has the least error value and the best accuracy of 98%.

Polyester with Nano Tio2 filler at 5% concentration has the best and the highest flashover voltage values into comparison with all considered concentrations and other fillers at all input variables sets. So Polyester with Nano Tio2 filler at 5% concentration is recommended as outdoor insulator as it has the maximum flashover voltage in almost weather conditions.

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Website: www.ijareeie.com

Vol. 6, Issue 8, August 2017

Flashover voltages of unsaturated Polyester with Tio2 and Sio2 Nano fillers that have been measured in the lab at different weather conditions are shown in figures 17- 19.

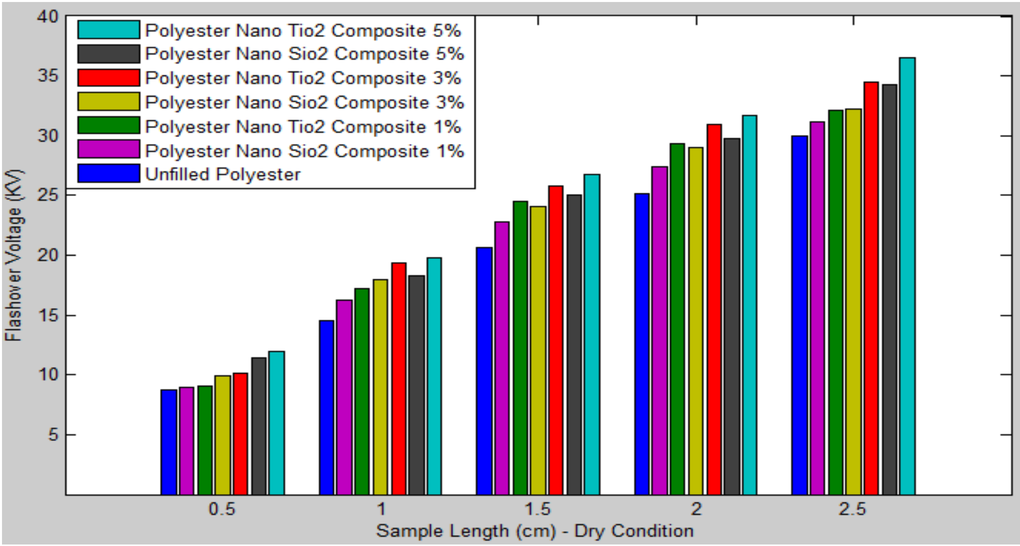

Fig. (17):Flashover voltage of nanocomposites Tio2 & Sio2 fillers with Polyester at different concentrations and sample lengths in dry weather

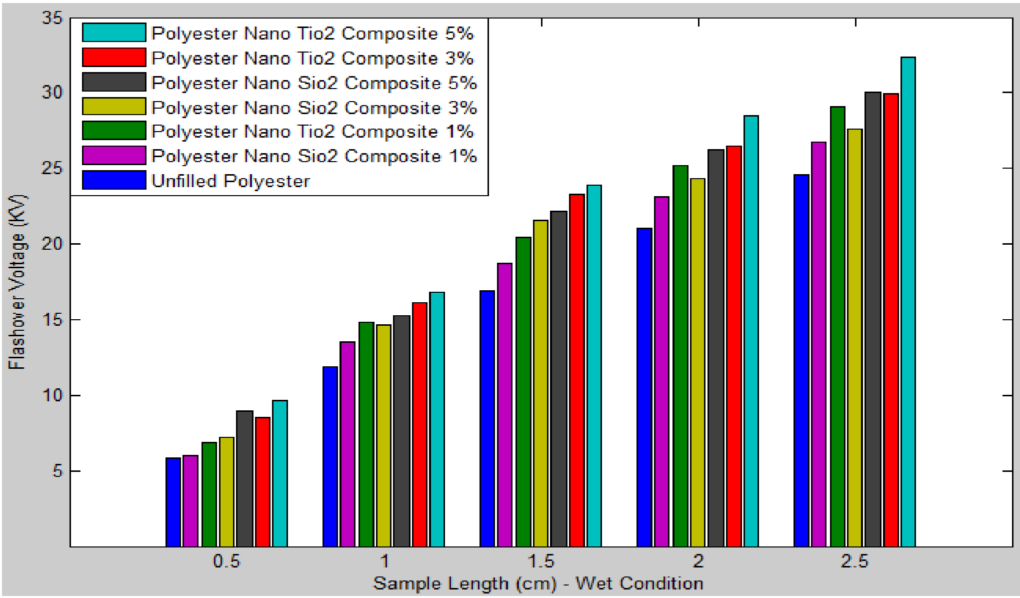

Fig. (18): Flashover voltage of nanocomposites Tio2 & Sio2 fillers with Polyester at different concentrations and sample lengths in wet weather

ISSN (Print) : 2320 – 3765
ISSN (Online): 2278 – 8875

International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering

(An UGC Approved Journal)

Website: www.ijareeie.com

Vol. 6, Issue 8, August 2017

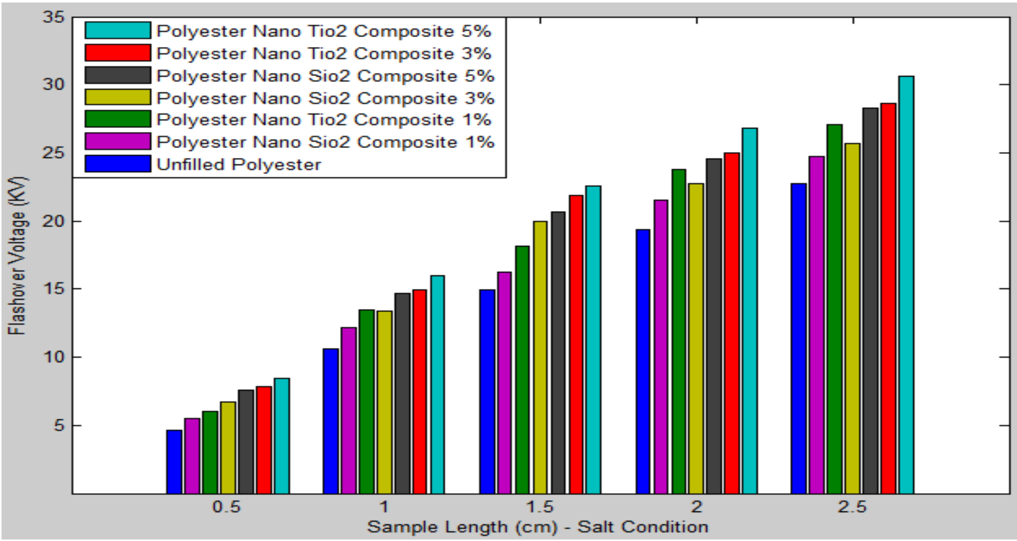

Fig. (19): Flashover voltage of nanocomposites Tio2 & Sio2 fillers with Polyester at different concentrations and sample lengths in salt weather

REFERENCES

[1] Pleşa, Ilona, et al. "Properties of Polymer Composites Used in High-Voltage Applications." Polymers 8.5 (2016): 173.

[2] Ding, H-Z., and B. R. Varlow. "Effect of nano-fillers on electrical treeing in epoxy resin subjected to AC voltage." Electrical Insulation and Dielectric Phenomena, 2004. CEIDP'04. 2004 Annual Report Conference on. IEEE, 2004.

[3] Q. Wang and G. Chen. "Effect of Nano fillers on the Dielectric Properties of Epoxy Nanocomposites", Advances in Materials Research, An International Journal, Vol. 1, pp. 93-107, 2012.

[4] Ersoy, Aysel, YasinÖzcelep, and AytenKuntman. "A study on the reliability of polyester insulators blended with borax." Turkish Journal of Electrical Engineering & Computer Sciences 16.3 (2008): 257-266.

[5] Elkhodary, Salem M., and L. S. Nasrat. "The use of experimental and artificial neural network technique to estimate age against surface leakage current for non-ceramic insulators." Power Engineering, 2006 Large Engineering Systems Conference on. IEEE, 2006.

[6] Nasrat, L., and R. M. Sharkawy. "On the measurements of the dielectric constant and dissipation factor of various elastomers." Power Modulator and High Voltage Conference (IPMHVC), 2012 IEEE International. IEEE, 2012.

[7] Ghamry, N., and L. S. Nasrat. "Fuzzy logic approach for the prediction of the lifetime of epoxy insulators." Fuzzy Systems and Knowledge Discovery (FSKD), 2015 12th International Conference on. IEEE, 2015.

[8] Nasrat, L. S., and SalehAly. "Evaluation of Flashover Voltage Mechanisms on Hydrophobic Polymer Insulators with Artificial Neural Network Approach." International Journal of Electrical and Computer Engineering 2.4 (2012): 487.

[9] Narayanan, V. Jayaprakash, B. Karthik, and S. Chandrasekar. "Flashover Prediction of Polymeric Insulators Using PD Signal Time-Frequency Analysis and BPA Neural Network Technique." Journal of Electrical Engineering & Technology 9.4 (2014): 1375-1384.

[10] Tanaka, Toshikatsu. "Dielectric nanocomposites with insulating properties." IEEE Transactions on Dielectrics and Electrical Insulation 12.5 (2005): 914-928.

[11] Tanaka, Toshikatsu, G. C. Montanari, and R. Mulhaupt. "Polymer nanocomposites as dielectrics and electrical insulation-perspectives for processing technologies, material characterization and future applications." IEEE Transactions on Dielectrics and Electrical Insulation 11.5 (2004): 763-784.

[12] Imai, Takahiro, et al. "Effects of nano-and micro-filler mixture on electrical insulation properties of epoxy based composites." IEEE Transactions on Dielectrics and Electrical Insulation 13.2 (2006): 319-326.

[13] Ahmad, Ahmad S., et al. "Artificial neural network for contamination severity assessment of high voltage insulators under various meteorological conditions." Aupec, Perth (2001).

[14] Teella, Sreedhar Kumar. Modeling of Breakdown voltage of Solid Insulating Materials Using Soft Computing Techniques. Diss. 2013.