Artificial Neural Network Technique to Predict Lifetime For Polyester Insulators

Eman M. Eid [1], Loai S. Nasrat [2] and Abd Allah A. Ibrahim [3]
[1] Projects Department, New Urban Communities Authority, Aswan, Egypt
[2, 3] Elec. Power & Machine Department, Faculty of Engineering, Aswan University, Aswan, Egypt

Abstract
High voltage outdoor insulators used in transmission lines and substation are being subjected to various operating conditions and stresses, which lead to degradation of polymeric insulator, by different environmental and electrical effects.
Various environmental stresses such as, Ultraviolet, moisture, heat, light, atmospheric pressure and electrical stresses, which include corona, formation of dry bands, arcing over surface of insulators, roughness and erosion of surface, are effect clearly on insulator's lifetime.
In this study, under accelerated aging condition a new methodology based on Artificial-Neural-Networks (ANN) is developed to predict lifetime of polyester insulators by using their surface leakage current that obtained from laboratory measurements. And the effect of adding fillers such as; boric acid [H_3BO_3] and magnesium hydroxide [$Mg(OH)_2$] with various concentration rates on the lifetime of Unsaturated Polyester insulators which is compared with the base case (no filler and dry condition). Furthermore, the lifetime of each specimen under study is examined under various weather conditions such as dry, wet and salt wet
The feed-forward-neural-network (FNN) was trained to estimate the lifetime of polymeric insulators in terms of the surface leakage current, type and percentage concentration of filler and the results obtained from applying FNN show that it can be used to represent data with accuracy of 94%. Then a comparison between the laboratory measurements of aging of insulator and computational results are reported.

Keywords: *Polymeric Insulators, Polyester, Artificial-Neural-Networks (ANN), Feed-Forward-Neural-Network (FNN), Leakage Current.*

1. Introduction
The high voltage insulators have generally been made of ceramics or glass. These materials have outstanding insulating properties and weather resistance, but have the disadvantages of being heavy, easily Fractured, and subject to degradation of their withstand voltage properties when polluted. There was therefore a desire to develop insulators of a new structure using new materials that would overcome these drawbacks; Non-ceramic insulators, also referred to as composite insulators; polymer or polymeric insulators are used in power transmission lines.
However, composite polymeric insulators also possess some disadvantages, such as superficial chemical changes caused by some weathering and dry band arcing, erosion and tracking, which may ultimately lead to; failure of the insulators, difficult to evaluate service life, unknown reliability and difficult to detect faulty insulators [1- 4].
The advantages of polymer insulators have driven the utility people to prefer it over conventional porcelain or glass insulators. The polymeric materials, particularly silicon rubber, epoxy, ethylene propylene diene monomer (EPDM) and polyesters are used in many applications like transmission, distribution, termination of underground cables, bushings and surge arrester housings [5].
Neural networks have been trained to perform complex functions in various fields, including pattern recognition, identification, classification, speech, vision and control systems. Neural networks can also be trained to solve problems that are difficult for conventional computers or human beings. In the field of high voltage insulators, ANN can be used to estimate the pollution level [6], to forecast a flashover voltage [7-10], to analyze surface tracking on polluted insulators [11], to identify fault insulators using corona discharges [12], and to predict insulators lifetime which will be examined in this paper.
Back propagation learning algorithm is used successfully to train the network which is subsequently used to predict the lifetime of polyester insulator's without lost the insulators.

2. Experimental Procedure
2.1 Material Specimen

Electrical resistant unsaturated polyester resin can be prepared by using dibasic acids e.g. isophthalic acid, maleic anhydride and neopentyl glycol or tetrabromobisphenol-A in place of phthalic anhydride or propylene glycol [13].Electrical resistance of polyester resins can be further improved by blending with various additives such as boric acid and magnesium hydroxide .
Specimens have been prepared from polyester\styrene mixture with a ratio of 70\ 30% by weight in addition to MEK as an initiator peroxide and co-naph as an accelerator. Then the type of filler with the required

quantity has been added to the above mixture, two types of fillers have been used, namely boric acid [H_3BO_3] and magnesium hydroxide [$Mg(OH)_2$] with different concentrations, the composition of the specimens is given in Table 1.

Table 1: The specimens of unsaturated polyester resin with different Concentration of filler.

Filler added to unsaturated polyester resin		**Concentration of filler by weight (wt.%)**
H3BO3	Mg(OH)2	
B (0%)	Mg (0%)	0%
——	Mg(20%)	20%
B(30%)	Mg(30%)	30%
B(40%)	Mg(40%)	40%
B(50%)	——	50%

2.2 Test Arrangements

The high voltage arrangement for AC test consisted mainly of a single-phase high voltage-testing transformer (150kV-15kVA). The output voltage of the transformer is smoothly controlled by a variac regulating the voltage applied to its primary winding. A water-limiting resistor is connected between the high voltage electrode and high voltage transformer ,the electrodes that have been used are manufactured from copper and having a Bruce profile that were polished and cleaned just prior to the test.

2.3 Test Procedure

Before each measurement, sequence procedures that were required for all samples to obtain on the accuracy reading for each sample are as the following:

- The circuit is connected as shown in Fig. 1 and the samples are placed.
- Before each measurement sequence a preparation run which consisted of short-circuiting the sample.
- Ensure that all testing circuit links are correct to apply electrical safety rules.
- The applied voltage was gradually increased until 30kv then the leakage current and aging time for each sample have been measured every hour until the leakage current reaches 11mA.

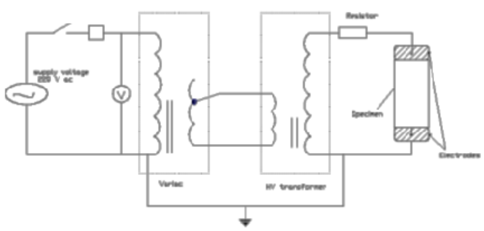

Fig. 1 Schematic diagram for the flashover testing circuit.

The leakage current has been measured for different sets of samples such as ; dry samples. Samples, which have been immersed in tap water for 24 hours in wet condition and another set, which has been, immersed in 5% NaCl solution for 24 hours in salt wet condition.

2.4 Surface Leakage Current Measurements

The aging degree of polymer insulator is estimated by (leakage current, measurement of hydrophobicity degree, damage conditions of insulator surface, withstand voltage test etc……), So the leakage current is a good indicator of the surface conditions.

The surface leakage current measurements were performed by means of a special system, which can register time variations of a voltage drop across a shunt resistor, supply voltage and phase shift between them. An oscilloscope recorded the data, then reported and analyzed, with a special circuit protects the instruments against both over voltage and over currents. The special circuit is 0.75 Amp-fuse enclosed in a glass tube, which melt in the event of flashover, and spark gap enclosed in a glass tube is connected shunt with the resistance and the oscilloscope.

2.5 Feed-Forward-Neural-Network (FNN*)*

Feed-forward ANN allow signals to travel one way only; from input to output without feedback (loops), i.e. the output of any layer does not affect that same layer. Feed-forward ANNs tend to be straightforward networks that associate inputs with outputs. They are extensively used in pattern recognition. This type of organization is also referred to as bottom-up or top-down. Since the input and output variables of the ANN have different ranges, the feeding of the original data to the network, leads to a convergence problem. It is obvious that the output of the ANN must fall within the interval of (0 to 1). In addition, input signals should be kept small in order to avoid a saturation effect of the sigmoid function. So, the input-output patterns are normalized before training the network. Normalization is done by dividing input-output variables to the maximum value of the input and output vector components. After the normalization, the input and output variables will be in the range of (0 to 1).

3. Results and Analysis

3.1 Experimental Results:

Under various testing conditions, the Ac (50 Hz) leakage current measurements have been measured for unsaturated polyester samples with different filler percentage.Fig.2, illustrates the relationship between the leakage current

International Journal of Scientific Engineering and Applied Science (IJSEAS) – Volume-3, Issue-6, June 2017
ISSN: 2395-3470
www.ijseas.com

against aging time for polyester insulators with various [H_3BO_3] filler percentage, under dry condition,
It can be noticed that, the values of aging time increase for samples B(30%), B(40%), B(50%),(43,50 and 54 hours) respectively, by increasing [H_3BO_3] filler percentage.

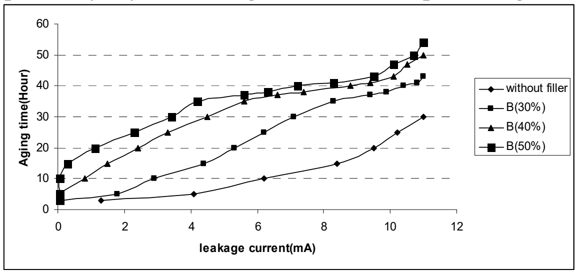

Fig.2 Aging time against the leakage current for polyester insulators with boric acid [H3BO3], under dry condition.

Using different type of filler under dry condition is shown in Fig.3. This figure shows that, the values of aging time increase with increasing [$Mg(OH)_2$] filler percentage for polyester samples Mg(20%), Mg(30%), Mg(40%),(36,41and 47hours) respectively.

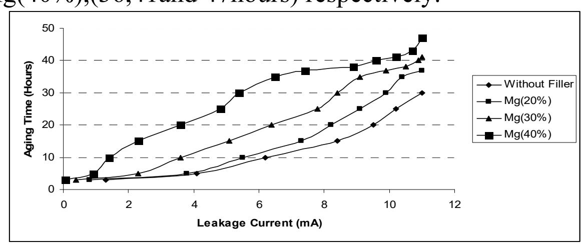

Fig.3 Aging time against the leakage current for polyester insulators with magnesium hydroxide [$Mg(OH)_2$], under dry condition.

The leakage current against aging time for Polyester samples with various [H_3BO_3] filler percentage under wet condition is shown in Fig.4 , It can be seen from this figure that, the leakage current trend against aging time for each sample (B(30%) to B(50%)) is sharply increased, compared to the same trend at dry condition. It can be observed from these curves that, wet condition reduces the aging times for all polyester samples.

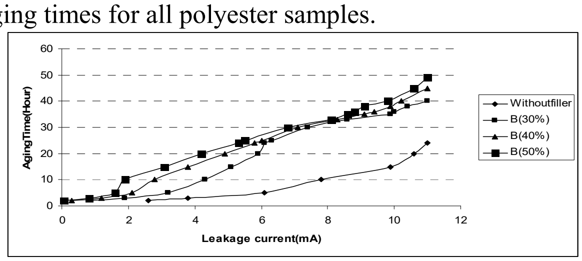

Fig.4 Aging time against the leakage current for polyester insulators with boric acid [H_3BO_3], under wet condition.

The lowest value of aging time is equal to 40 hours for sample B(50%), while the highest value of aging time is equal to 49 hours for sample B(50%),at the same value of withdrawal leakage Current . But Under the same condition, the values of aging time for [$Mg(OH)_2$] filler percentage for polyester samples Mg(20%), Mg(30%), Mg(40%),(29,32 and 35 hours) respectively, to reached the value of withdrawal leakage current 11mA which is shown in Fig.5.

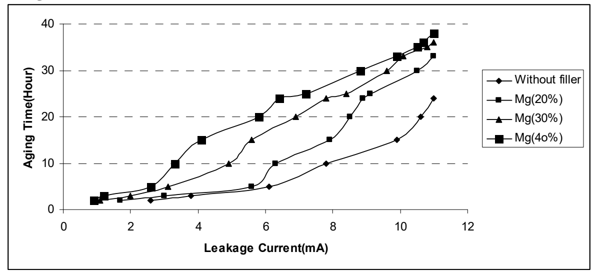

Fig.5 Aging time against the leakage current for polyester insulators with magnesium hydroxide [$Mg(OH)_2$], under wet condition.

Fig.6, illustrates the relationship between the leakage current against aging time for polyester samples with various [H_3BO_3] filler percentage , under salt wet condition , It can be noticed that, the values of aging time increase for samples B(30%), B(40%), B(50%),(36,39 and 43 hours) respectively, by increasing [H_3BO_3] filler percentage. It can be seen from the Fig.7 that, the values of aging time increase with increasing Mg(OH)2 filler percentage for polyester samples Mg(20%), Mg(30%), Mg(40%),(29,32 and 35hours)) respectively under the same condition. A comparison between the two types of in organic fillers [H_3BO_3] and [$Mg(OH)_2$] with different concentrations. in polyester specimens under dry , wet and salt wet conditions is illustrated in Fig.8. Polyester sample give the highest value of aging time was 50 hours, at 40% of [H_3BO_3] filler, while polyester sample with the same percentage of [$Mg(OH)_2$] samples give aging time of 47 hours under dry condition

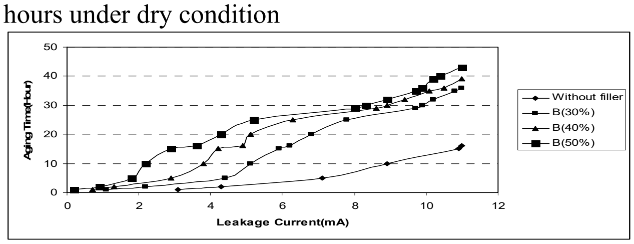

Fig.6 Aging time against the leakage current for polyester insulators with boric acid [H_3BO_3], under salt wet condition.

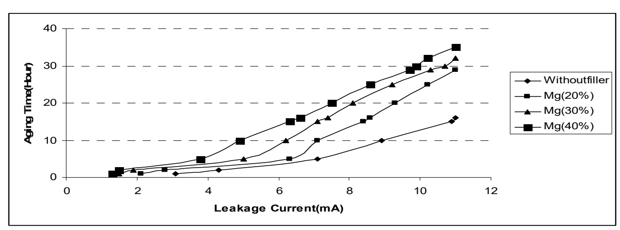

Fig.7 Aging time against the leakage current for polyester insulators with magnesium hydroxide [$Mg(OH)_2$], under salt wet condition.

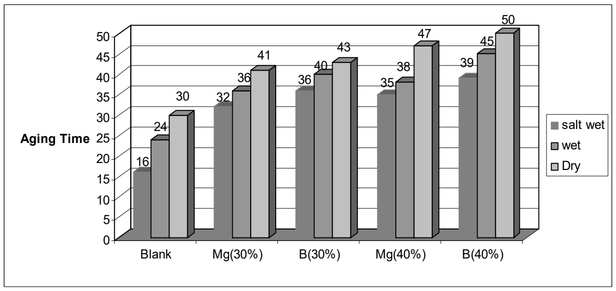

Fig. 8 Comparison of the seven polyester samples with and without filler under dry, wet and salt wet conditions.

3.2 Results of the ANN Analysis:

Neural networks, as used in artificial intelligence, have traditionally been viewed as simplified models of neural processing in the brain The supervised learning is widely used to train the ANN with a set of different input output examples by adjusting weights between layers.
The ANN used is the multi-layer feed-forward type, with one or more hidden layers represented in Fig. 9.

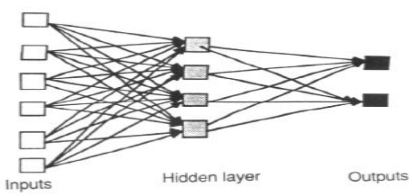

Fig. 9: the Feed-forward networks

The number of units in each hidden layer is determined experimentally, from studying the network behavior during the training process taking into consideration some factors like convergence rate and error criteria.
Different experimental measurement for leakage current and aging time were performed on seven different polymer samples. These experimental measurements were used for the training of two neural networks. Each neural network has 4 inputs (type of inorganic filler material, the percentage of filler in polyester (0, 30, 40, and 50%), the test conditions (dry , wet or salt wet), and the corresponding leakage current.
Training neural network by gradient descent algorithm with tan-sigmoid transfer function using neural network toolbox of MATLAB software.
The network with one hidden layer and 4 hidden neurons is selected in our simulation which gives minimum errors for both training and test data. In order to measure the generalization capability of the neural network, the output of the neural network is compared with the actual measured outputs.

4. Conclusions

The following conclusions may be drawn from the present investigation:

1. Under different weather condition at using Blank polyester samples' aging time was 30 hours at dry , 24 hours at wet, 16 hours at salt wet condition.
2. Type and percentage of filler in polyester samples effect to aging time range.
3. A trained ANN can be used successfully for predicting aging time of insulators without lost the insulator and it can be used for triggering washing devices in substations.
4. The proposed technique in this paper predicts the best non-ceramic insulator with the exact filler percentage that withstands higher voltage with longer lifetime under contaminated weather and polluted condition.

References

[1] M. T. Gençoğlu, "The Comparison of Ceramic And Non Ceramic Insulators", Journal of New World Sciences Academy, Vol.2, No.3, 2007.
[2] H.M. Schneider, J.F. Hall, G. Karady and J. Rendowden, "Non Ceramic Insulators for Transmission Lines", IEEE Transactions on Power Delivery, Vol. 4, No. 4, 1989.
[3] E.A. Cherney, " Non Ceramic Insulators - A simple Design That Requires Careful Analysis", IEEE Electrical Insulation Magazine, Vol. 12, No.3, 1996, PP. 7-15.
[4] J. Mackev, M. Shah, "Polymer Outdoor Insulating Materials Part I: Comparison of Porcelain and Polymer Electrical Insulation", Raychem Corporation, USA, Vol. 13, No. 3, 1979.
[5] L.S. Nasrat, A.F. Hamed, M.A. Hamid and S.H. Mansour, "Study the Flashover Voltage For Outdoor Polymer Insulators Under Desert Climatic Conditions", Egyptian Journal of Petroleum, 2013.
[6] A.S. Ahmad, P.S. Ghosh, S.S. Ahmad and S.A.K. Aljunid, "Assessment of ESDD on High Voltage Insulators Using Artificial Neural Network", Electric Power Systems Research, Vol. 72, 2004, PP. 131-136.
[7] V.T. Kontargyri, A.A. Gialketsi, G.J. Tsekouras, I.F. Gonos and I.A. Stathopulos, "Design of An Artificial Neural Network for The estimation of The Flashover Voltage on Insulators", Electric Power Systems Research 77, 2007, PP.1532–1540.
[8] M.T. Gencog˘lu, M. Cebeci, "Investigation of Pollution Flashover on High Voltage Insulators Using Artificial Neural Network", Expert Systems with Applications 36, 2009, PP. 7338–7345.
[9] L. S. Nasrat, Saleh Aly, "Evaluation of Flashover Voltage on Hydrophobic Polymer Insulators with Artificial Neural Network", International Journal of Electrical and Computer Engineering (IJECE), Vol.2, No.4, August 2012, PP. 487-494.

[10] A. Gialketsi, V.T. Kontargyri, I.F. Gonos, I.A. Stathopulos, "Comparison between Artificial Neural Networks Algorithms for the Estimation of the Flashover Voltage on Insulators", 9th WSEAS International Conference on NEURAL NETWORKS (NN'08), Sofia, Bulgaria, 2008.

[11] M. Ugur, W. Auckland, B. R. Varlow and Z.Emin, "Neural Networks to Analyze Surface Tracking on Solid Insulators", IEEE Transactions on Dielectrics and Electrical Insulation, Vol. 4, No. 6, PP. 763-767, December 1997.

[12] C.R. Li, Q. Shi, Y. C. Cheng, C. Yu andY. Yiehao, "Identification of Faulty Insulators by Using Corona Discharge Analysis Based on Artificial Neural Network", Conference Record of the 1998 IEEE International Symposium on Electrical Insulation, June 7-10, 1998.

[13] Bharat Dholakiya, "Unsaturated Polyester Resin for Specialty Applications", sardar Vallabhbhai National Institute of Technology (SVNIT),Gujarat, IndiaGujarat, India,2012.

[14] S. Haykin, "Neural Networks – A Comprehensive Foundation", IEEE Press, Addision- Wesley, 1992.

First Author: Eng. Eman Mahmoud Ahmed Eid received the B.Sc of Electrical Engineering degree in 2012 from Faculty of Engineering, Aswan University, Aswan, Egypt and currently pursuing “Master of Electrical Engineering” from the same University, She works as an electrical engineer in the Projects Department of the New Aswan city, New Urban Communities Authority, Aswan, Egypt from 2014 till now.

Second Author Dr. Loai Nasrat is a professor at Elec. Power & Machine Department, Faculty of Engineering, Aswan University, Aswan, Egypt.

He has been actively involved in both basic and applied research in the area of HV engineering. His research interests include HV insulators, polymeric materials, HV cables insulations and environmental studies.Author and co-author of more than 60 papers on HV polymeric insulating materials, published in technical journals and proceedings of national and international conferences.

Third Author: Dr. Abd Allah Ahmed Ibrahim, is a professor at Elec. Power & Machine Department, Faculty of Engineering, Aswan University, Aswan, Egypt.