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Using Newton's Divided Difference Method to Evaluate Dielectric Properties of H.V Polymer Blends

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***Abstract*—High voltage Insulators are essential for the reliable performance for electric power power systems. Polymeric inslators widely used outdoor H.V insulators. In the presence of heavy poluted and wet condition, resistance to vandalism and high dielectric strength decreases. Polymer insulators particularly those made of silicone rubber are increasingly being used today. Blending of rubber polymer and synthetic polymer is an attractive way to develop a new material combining the best properties of these two materials. Today silicone rubber is one of the most widely used materials to made weather sheds. Poly vinyl chloride (PVC) is widely used in high and medium voltage cables insulation due to its low dielectric losses and its ability to improve cables properties in high temperatures. This paper aims to improve PVC electrical properties (dielectric strength) for high voltage and medium voltage cables in respect of mechanical characteristics by adding silicone rubber (SiR). The dielectric strength of the blends was tested in several conditions, Then trying to find an appropriate weight percentage composition of such blend in order to enhance the dielectric strength and mechanical characteristics.**

Index Terms*— Polymers; PVC/SiR Blend, Newton's Divided Difference method, dielectric strength, mechanical properties.

I. INTRODUCTION.

Many ways have been used to prevent the high voltage electrical networks. The first way is to provide good insulation of the conducting parts subjected to high voltage. These materials used for this aim, must have special properties to function under all circumstances. These materials are called insulating materials or dielectrics. They are used for isolating conducting parts from each other or to separate conductors from the surroundings.

Electrical insulator must be used in electrical systems to prevent current flow to the earth so it play an important role in electrical system. Electrical insulator are a very high resistive path through which practically no current can flow. In transmission and distribution systems, the overhead conductors are generally supported by towers or poles. The two both are properly grounded, so there must be insulators between the grounded tower or pole and the current carrying conductors [1].

To determine the performance of any insulation material, it is necessary to investigate its weather resistance. Theweather factors include UV radiation, rain, salt fog and industrial pollutants and biological degradation etc.

Outdoor insulators have traditionally been made of porcelain or glass. The use and development of polymeric insulators began since 1960s [2,3].

The use of polymeric insulators has increased clearly in the last twenty five years.

Polymeric insulators offer many significant advantages over porcelain and glass insulators, especially for ultra HV transmission lines. The specific advantages of composite insulator, compared with ceramic insulators are light weight, lower construction costs, vandalism resistance, better contamination performance and insulator surface hydrophobicity. They also have other advantages such as greater handling safety high mechanical stregnth better voltage withstanding and easy backaging etc [4].

The typical components of of a polymeric insulator are core, end fitting, housing and weather sheds. The core made of fibre glass is empolyed for electrical stregnth under dry condition and for mechanical stregnth.Under wet condition fibre glass absorbs water moisture therefore it is not a good insulator. So polymeric housing is installed over the fibre glass core/rod to prevent this problem.

The weathersheds are insulating parts, projecting from the housing, intended to increase the leakage distance and to provide an interrupted path for water drainage. End fittings transmit the mechanical load to the core. They are usually made of metal [4].

Although polymeric insulators have many advantages, they can be degarded by environmental cases, such as chemical changes, heat, water moisture and contaminations which could cause surface discharge and traking that is due to some contaminats on insulator surface or electrical discharges heat.

They have also other disadvantages and like unexpectable life time, unknown reliability legnth and less experience in the field as more polymer products come out [4].

Many studies have been made on polymer insulators dielectric properties under contamination conditions[5-13].

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A polymer is a long-chain molecule composed of a large number of repeating units of identical structure.

Polymers classified according to source are natural polymers and synthetic polymers.

Polymers can be assigned to groups based on characteristics of processing or mechanism of polymerization. More specific classification is made on polymer structure basis. Grouping is very important as it facilitates properties analysis and discussion [14].

Material scientists try to combine advantages of different materials using composite materials .They are looking for Nano-composites to gain new advantages such as easy processing, low cost, stable properties.

Many investigations and researches have been made to improve polymers electrical properties by suitable doping [15-17].

Two polymers are blended by different weight percentages for enhancing a specific property, this method called "polymer blending" is very interesting.

Blending some polymers with PVC (poly vinyl chloride) can improve its properties as it has many merits such as high dielectric strength and good insulation resistance. It has also adequate resistance to water moisture, alkalis, alcohols, acids, and abrasion. Also, it has flame retardant properties as it is chlorinated and low water absorption [18].

The Silicon Rubber (SiR) insulator is a 3rd generation material among the polymers used for making outdoor insulators. It has good leakage current suppression capabilities under intense environment. Long term investigation of SiR insulator under conditions that simulate the service environment is of practical interest to effectively utilize It. The experience with SiR insulators is reported in many scientific papers [19].

This paper aims to enhance (poly vinyl chloride) PVC electrical properties specially dielectric strength for medium voltage and high voltage cables in respect of mechanical properties by adding (SiR) silicone rubber and measuring dielectric strength of the blends in several conditions, Then trying to find an suitable weight percentage composition of such blend to improve the dielectric strength and mechanical characteristics.

II. EXPERIMENTAL PROCEDURE

A. Blend Preparation.

Chemical ingredients of the materials used in the present investigation are as follows:

1. Polyvinyl chloride (PVC).

2.Silicne rubber (SiR).

Five blend samples shown in figure 1 have been prepared as: 100% PVC, 40% SiR with 60% PVC, 50% SiR with 50% PVC, 60% SiR with 40% PVC and 100% SiR. The mixing formulation are listed in table 1.

Table 1. Mixing formulation of SiR with different percentages of PVC.

Blend Number	SiR content wt. %	PVC content wt. %
1	100%	0%
2	60%	40%
3	50%	50%
4	40%	60%
5	0%	100%

B. Electrical test components.

The A.C high voltage obtained from a 1-ph tansformer (5 kVA-100kV). Its output voltage can be easily controlled with a (0-200 Volts) variac regulating panel.

The high voltage set is enclosed within an earthed cage.

0

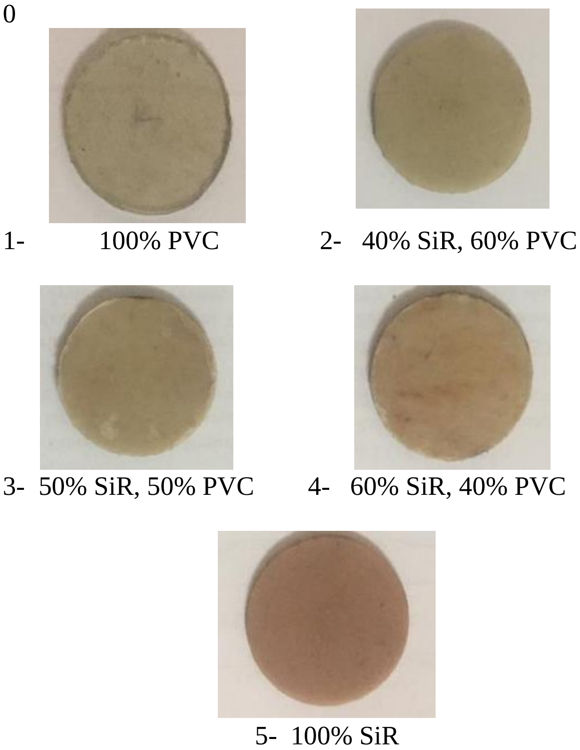

Fig. 1. Different percentages of SiR/PVC blend samples.

B. Dielectric Strength Test.

All insulators fail at a certain level of applied voltage for given operating conditions. The voltage that an insulator withstand before breakdown occurs is defined as breakdown voltage or dielectric stength. It is usually expressed in terms of voltage-gradient kilo volt per millimeter (kV/mm).

Insulating material failure can ne characterized dy an arc or excessive current flow and partial vandalism of the maerial.

Disc blend samples with 1 mm thickness and 5 cm diameter have been tested using high A.C voltage. Figure 2 represents dielectric breakdown strength test.

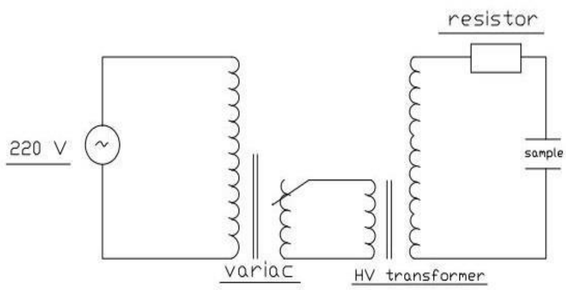

Fig. 2. Dielectric breakdon strength testing circuit.

Dielectric properties have been studied at three conditions; dry condition, wet condition and salty wet condition.

Blend samples were tested many times for accurate results and low error. Results were recorded in tables and then plotted for easy analysis and understanding.

Fig. 3. Two cylindrical electrode with a diameter of 25mm used in dielectric strength test in high voltage laboratory.

Test samples of the blend are put between the two cylindrical electrods shown in figure 3 and they are fixed into the middle of sample one at the top and the other on the bottom end when the test is carried out.

When the brekdown occurs, arc is seen on the specimen between them.

The relation between dielectric breakdown strength values and PVC content percentage in the blends was interpreted by newton's divided difference interpolating polynomial method.

III. NEWTON'S DIVIDED DIFFERENCE INTERPOLATING POLYNOMIAL METHOD

You will frequently have occasion to estimate intermediate values between precise data points. The most common method used for this purpose is polynomial interpolation. For n + 1 data points, there is one and only one polynomial of order n that passes through all the points. For example, there is only one straight line (that is, a first-order polynomial) that connects two points. Similarly, only one parabola connects a set of three points. Polynomial interpolation consists of determining the unique nth-order polynomial that fits n + 1 data points. This polynomial then provides a formula to compute intermediate values. Although there is one and only one nth-order polynomial that fits n + 1 points, there are a variety of mathematical formats in which this polynomial can be expressed. Newton's divided-difference interpolating polynomial is among the most popular and useful forms[20].

IV. RESULTS AND DISSCUSION.

A. Dielectric Strength Results.

1.Dry Condition Test.

Figure 4 shows dielectric strength (kV/mm) of blend samples in dry condition.

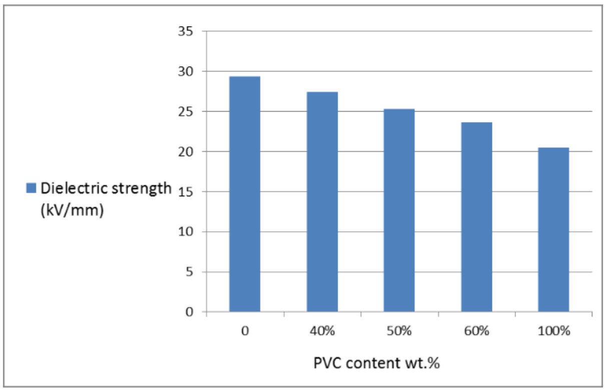

Fig. 4. Dielectric strength (kV/mm) of blend samples in dry condition.

It can be noted that, pure PVC (sample no.5) has the minimum value of dielectric strength 20.51 kV/mm. While pure SiR (sample no.1) has the maximum value of dielectric strength 29.33 kV/mm. The blend samples have values in between.

It can also be noted as the amount of PVC increases, the dielectric strength decreases.

Applying newton's divided difference interpolating polynomial criterion, the curve for the obtained results from the test is shown in figure (5.2) Representing the data by a 4th degree polynomial equation to minimize the error as possible we get:

$$Y = 29.33 - 4.725\,x - 33.750\,x\,(x - 0.4) + 99.853\,x\,(x - 0.4)(x - 0.5) - 114.333\,x\,(x - 0.4)(x - 0.5)(x - 0.6) \quad (1)$$

Where:

y is the dielectric strength under dry condition value,
x is the percentage of PVC in the blend,
b_0 is a constant = 29.33,
b_1 is a constant = – 4.725,
b_2 is a constant = – 33.750,
b_3 is a constant = 99.853,
b_4 is a constant = – 114.333,
and $R_{0.7}$ is the error at 70% PVC = – 0.48019.

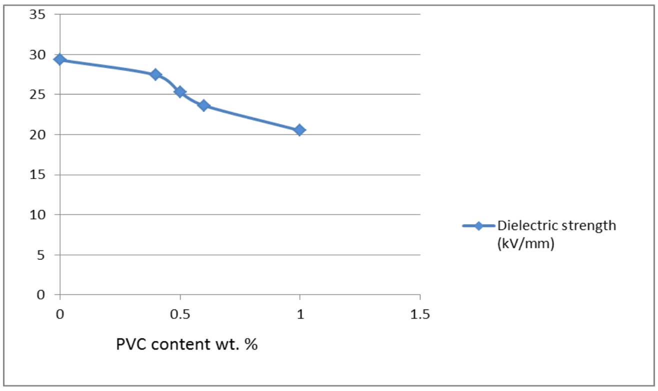

Fig. 5. Curve fitting for the dielectric strength of blend samples in dry condition.

2. Wet Condition Test.

For a simulation of rains and wet weather condition, samples are submerged into a distilled water container for a complete day (24 h) and tested for dielectric strength.

These studies are carried out in this work to know the effect of water on dielectric strength of blend samples. Results are shown in figure 4.

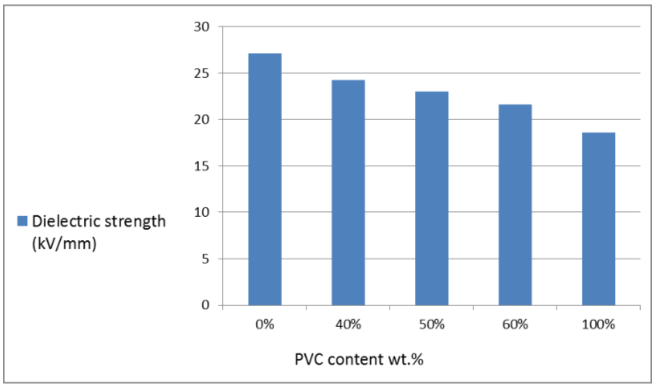

Fig. 6. Dielectric strength (kV/mm) of blend samples in wet condition.

It can be noted that, pure PVC (sample no.5) has the minimum value of dielectric strength (18.60 kV/mm). While pure SiR (sample no.1) has the minimum value of dielectric strength (27.16 kV/mm). The blend samples have values in between.

It can also be noted as the amount of PVC increases, the dielectric strength decreases.

Applying newton's divided difference interpolating polynomial criterion, the curve for the obtained results from the test is shown in Figure 5. After calculations the curve for the data obtained can be represented by 4^{th} degree polynomial equation as follows:

$$Y = b_0 + b_1 x + b_2 x(x - 0.4) + b_3 x(x - 0.4)(x - 0.5) + b_4 x(x - 0.4)(x - 0.5)(x - 0.6) \qquad (2)$$

Where:
y is the dielectric strength under wet condition value,
x is the percentage of PVC in the blend,
b0 is a constant = 27.16,
b1 is a constant = – 7.175,
b2 is a constant = – 10.85,
b3 is a constant = 4.75,
b4 is a constant = 34.333,
and $R_{0.7}$ is the error at 70% PVC = 0.1441986.

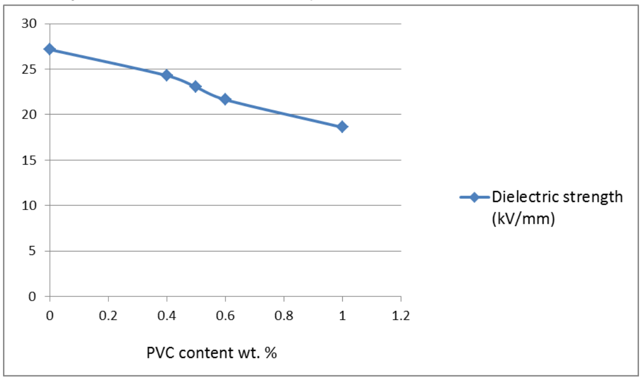

Fig. 7. Curve fitting for the dielectric strength of blend samples in wet condition.

3.Salty wet Condition Test.

For a simulation of areas near to seas or coast cities, samples are submerged into a NaCl solution container for a complete day (24 h) and tested for dielectric strength.Results are shown in figure 8.

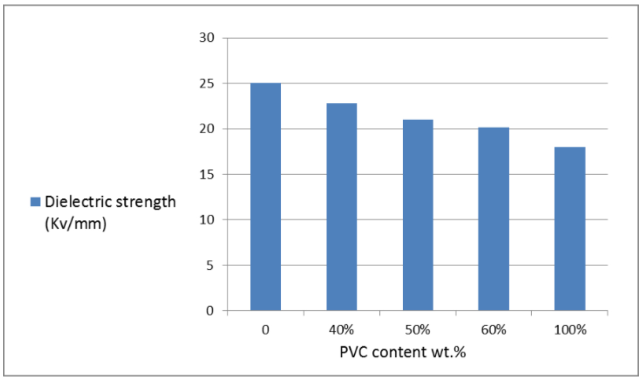

Fig. 8. Dielectric strength (kV/mm) of blend samples in salty wet condition.

It can be noted that, pure PVC (sample no.5) has the minimum value of dielectric strength 18.00 kV/mm. While pure SiR (sample no.1) has the maximum value of dielectric strength 25.02kV/mm. The blend samples have values in between.

It can also be noted as the amount of PVC increases, the dielectric strength decreases.

Applying newton's divided difference interpolating polynomial criterion the best curve fitting for the obtained results from the test is shown in Figure 9.

After calculations the curve for the data obtained can be represented by 4th degree polynomial equation as follows:

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$Y = b_0 + b_1 x + b_2 x(x - 0.4) + b_3 x(x - 0.4)(x - 0.5) + b_4 x(x - 0.4)(x - 0.5)(x - 0.6)$ (3)

Where:

y is the dielectric strength under salty wet condition value,
x is the percentage of PVC in the blend,
b0 is a constant = 25.02,
b1 is a constant = – 5.5,
b2 is a constant = – 25.6,
b3 is a constant = 126.833,
b4 is a constant = – 201.749,
and $R_{0.7}$ is the error at 70% PVC = – 0.8473458.

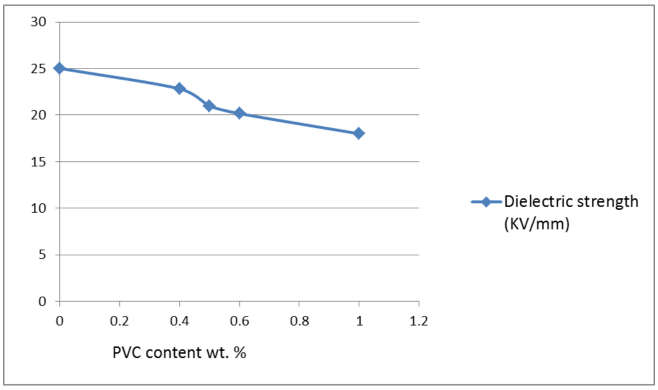

Fig. 9. Curve fitting for the dielectric strength of blend samples in salty wet condition.

B. Mechanical Results.

From the data recorded in table 2. It can be seen that, the tensile strength of the blend samples increases from 10.5 MPa for sample 1 to 16.67 MPa for sample 5. When amount of PVC is increased gradually from 0 to 40, 50, 60 and 100 in samples1, 2, 3, 4 and 5 respectively, the increasing percentage of tensile strength is almost 13.39%, 9.83%, 3.77% and 15.66% respectively.

Table 2. Tensile strength (M Pa) of blend samples.

Blend number	PVC Percentage	Tensile strength (M Pa)			
		Test 1	Test 2	Test 3	Average
1	0	10.5	10.6	10.4	10.5
2	40	12.2	12.1	12.3	12.2
3	50	13.4	13.6	13.6	13.53
4	60	14.1	13.9	14.2	14.06
5	100	16.7	16.4	16.9	16.67

Figure 10 shows the tensile strength results of the samples. It can be observed that the tensile strength increase with the increasing percentage of PVC.

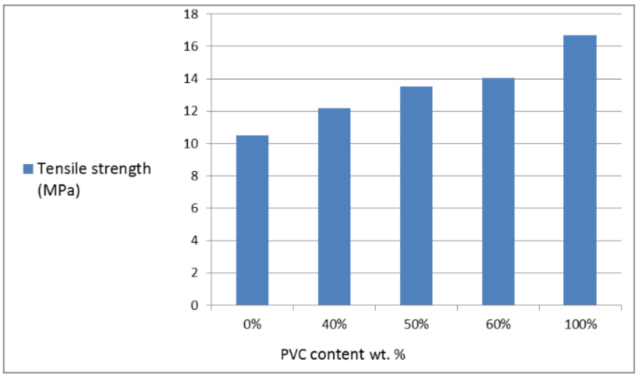

Fig. 10. Tensile strength (M Pa) of blend samples.

The best curve fitting for the data obtained can be represented by 4th degree polynomial growth equation as follow:

$Y = b_0 + b_1 x + b_2 x(x - 0.4) + b_3 x(x - 0.4)(x - 0.5) + b_4 x(x - 0.4)(x - 0.5)(x - 0.6)$ (4)

Where:

y is the dielectric strength value,
x is the percentage of PVC in blend,
b0 is a constant = 10.5,
b1 is a constant = 4.25,
b2 is a constant =18.1,
b3 is a constant = – 96.833,
b4 is a constant = 232.833,
and $R_{0.7}$ is the error at 70% PVC = 0.9778986.

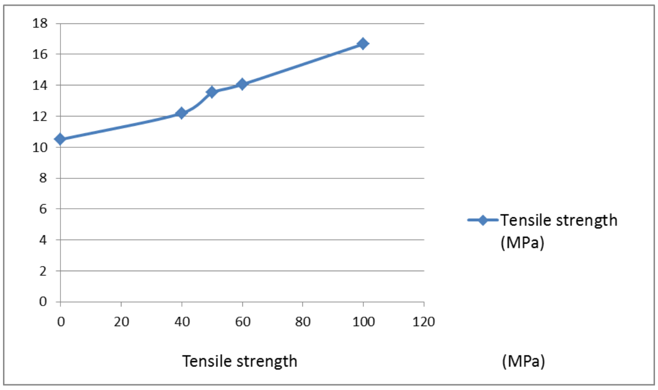

Fig. 11. Curve fitting for tensile strength (MPa) of blend samples.

V. CONCLUSION

The main conclusions drawn from the present investigations will be summarized as follow:

1. In the dry condition the dielectric strength of the blend decreases as the amount of PVC increases.
2. Also in the wet and salty wet condition the dielectric strength of the blend decreases as the amount of PVC increases.
3. The dielectric strength of PVC is lower than SiR.
4. Pure SiR (sample 5) has the maximum value of dielectric strength (29.33.25 kV/mm), While pure PVC (sample 1) has the minimum value of dielectric strength

(20.51kV/mm).It can be seen that, the dielectric strength was improved by increasing of SiR percentage in the blend.

5. The exposure to salt water solution drastically affected the dielectric strength.

6. It can be observed that the tensile strength increases as the percentage of PVC increases.

7. As a result of previous points, the suitable percentage can be used for blend sample is 50% SiR and 50% PVC (Sample 3) for good dielectric strength and mechanical poroperties.

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REFERENCES.

[1] http://www.electrical4u.com/electrical-insulator insulating /material-porcelain-glass-polymer-insulator.
[2] Muhsin Tunay Gençoğlu," The comparison of ceramic and non-ceramic insulators", e-Journal of New World Sciences Academy IEEE Trans. Volume: 2, No: 4, 2007.
[3] Gubanski, S.M, " Modern outdoor insulation concerns and challenges," IEEE Electrical Insulation Magazine. Vol. 21, No. 6, pp. 5-11,2005.
[4] http://www.composite-insulator.com.
[5] CIGRE TF33.04.07, "Natural and Artificial Ageing and Pollution Testing of Polymer Insulators," CIGRE Pub. 142, June 1999.
[6] G. G. Karady, H. M. Schneider and F. A. M. Rizk, "Review of CIGRE and IEEE Research into Pollution Performance of Non Ceramic Insulators: Field Ageing Effects and Laboratory Test Techniques," CIGRE 1994 Session Paper No. 33 – 103, August/September 1994.
[7] I. Gutman, R. Harting, R. Matsuoka and K. Kondo, "Experience with IEC 1109 1000h Salt Fog Ageing Test for Composite Insulators," IEEE Electrical Insulation Magazine, Vol. 13, No. 3, pp. 36 – 39, May/June 1997.
[8] T. Zhao and R. A. Bernstorf, "Ageing Tests of Polymeric Housing Materials for Non – ceramic Insulators," IEEE Electrical Insulation Magazine, Vol. 14, No. 2, pp. 26 – 33, March/April 1998.
[9] R. S. Gorur, E. A. Cherney and R. Hackam, "A Comparative Study of Polymer Insulating Materials under Salt Fog Test," IEEE Trans. On Electrical Insulation, Vol. EI – 21, No. 2, pp. 175 – 182, April 1986.
[10] M. C. Arklove and J. C. G. Wheeler, "Salt – Fog Testing of Composite Insulators," 7th Int. Conf. on Dielctric Material, Measurements and Applications, Conf. Pub. No. 430, pp. 296 – 302, September 1996.
[11] S. H. Kim, R. Hackam, "Influence of Multiple Insulator Rods on Potential and Electric Field Distributions at Their Surface," Int. Conf. on Electrical Insulation and Dielectric Phenomena 1994, pp. 663 – 668, October 1994.
[12] J. P Suwarno, " Investigation on Leakage Current Waveforms and Flashover Characteristics of Ceramics for Outdoor Insulators under Clean and Salt Fogs," The WSEAS Transaction on POWER SYSTEMS, Vol. 3, No. 6, pp. 456 – 465, June 2008.
[13] Zulkifli Ahmad (2012). Polymer Dielectric Materials, Dielectric Material, Dr. Marius Alexandru Silaghi (Ed.), InTech, DOI: 10.5772/50638.
[14] http : // www.intechopen.com / books / dielectric material / polymer-dielectric-materials.
[15] Fried, Joel R., "Polymer Science and Technology, Third Edition," 2014.
[16] Ray, S., Easteal, A.J., Cooney, R.P. and Edmonds, N.R., "Structure and Properties of Melt-Processed PVDF/ PMMA/Polyaniline Blends," Materials Chemistry and Physics,113,829-838,2009. http://dx.doi.org/10.1016/j.matchemphys.2008.08.034.
[17] Blom, P. W. M., H. F. M. Schoo, and M. Matters, "Electrical characterization of electroluminescent polymer/nanoparticle composite devices," Applied physics letters 73.26 : 3914-3916, 1998.
[18] http://dx.doi.org/10.1063/1.122934.
[19] A. Kiesow, J.E. Morris, C. Radehaus, A. Heilmann, J., "Switching Behavior of Plasma Polymer Films Containing silver Nanoparticles," Journal of Applied Physics,94,6988,2003. http://dx.doi.org/10.1063/1.1622990.
[20] Abu-Gurain and Ali Muhammad Ali, "Investigation and analysis of thermal aging of XLPE and PVC cable insulation materials manufactured in Saudi Arabia," Diss. King Fahd University of Petroleum and Minerals, 2003.
[21] Muhammad Amin and Salman Amin, "Aging research on SiR and TPE insulators," Rev. Adv. Mater. Sci. 36 (2014) 29-39.
[22] Chapra, Steven C., and Raymond P. Canale, "Numerical methods for engineers." Seventh edition.