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Surface Degradation of Polymer Insulator under Ultraviolet Stress

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***Abstract* —This paper talks about the negative impacts that ultraviolet light rays have on the polymeric insulators used in the electrical transmission lines. These effects are vividly discussed in details, furthermore, other environmental factors are also discussed in the paper. The fact that the polymeric insulators are generally organic materials, they are subject to several environmental dereliction effects which results to considerable gradual aging. The sources of ultraviolet rays are Sunlight and corona formation. Sunlight being the chief source of ultraviolet rays has weighty annihilation of composite insulators and mostly measurements reveal that it has a range of 270nm to 320nm. Furthermore, the paper has statistical facts collected from various towns in Libya indicating the Sunlight characteristics in these parts of the town. The conducted research has significant result supporting the possibilities of severe influences of Sunlight on the composite insulator.**

Keywords—Polymer/Composite insulator, Ultraviolet rays (UV), Corona effects, Environmental factors, Aging effects, Transmission lines

I. INTRODUCTION

Insulators are the fundamental unit in the electricity transmission and distribution. Ultraviolet rays from the sun have significant aging effects on polymeric insulators and that occurs mostly in arid areas [1]. The arid areas are mostly African countries bordering Sahara desert. A conducted research reveals severe sunlight intensity in these areas, thus, providing a basis why aging effect mostly happens there. A part from ultraviolet rays from the sun, there are other factors that affect polymeric insulators.

For instance, environmental factors have significant negative effects on the polymeric insulators. The reason is that they are made of organic materials, thus, subjecting them to gradual aging [2]. Their main purpose is to guard living things from shock of electricity through strong opposition of flow of electrons. There is a strong need to check out on the insulators to make sure they properly fit to guard human beings from the hazardous effect of electricity.

II. THE CONDUCTED RESEARCH ON EFFECTS OF UV RADIATION ON ELECTRICAL INSULATORS

The research conducted in some parts of Libya reveals the minimum, maximum, and monthly average value of the solar radiation incident on the horizontal surface of some regions of the country. Libya possesses a good study region given the fact that it is in arid areas of Africa where the intensity of Sun is high [3].

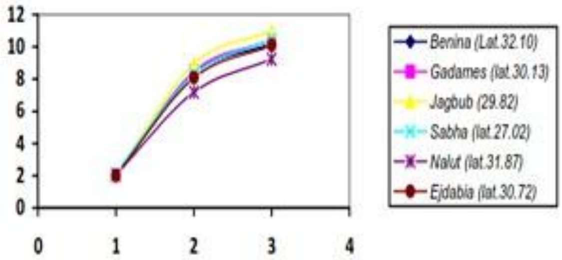

Figure.1 The Maximum Solar Radiation Incident on a Horizontal Surface by Units KW.H/M^2/day

In consideration of the global system wholly, specific outlines is identified for by discrepancies in features of the surface of the earth that influence insolation. The maximum isolations are established mostly in the subtropical and tropical regions of the globe. At this point, there are many inclination angles of the Sun, and also there is lack of clouds cover in regions of desert allowing abundant insolation on to the surface of the earth. The amount of solar reaching the earth's surface reduces to a minimal amount at the poles. At the poles there is low Sun inclination angle and due to the fact that the Sun does not directly rise above horizon for a period close to half a year, an aspect that decreases insolation annually.

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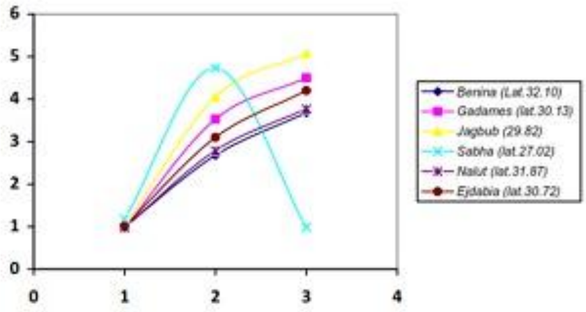

Figure. 2 The Minimum Solar Radiation Incident on a Horizontal Surface by Units KW.H/M^2/day

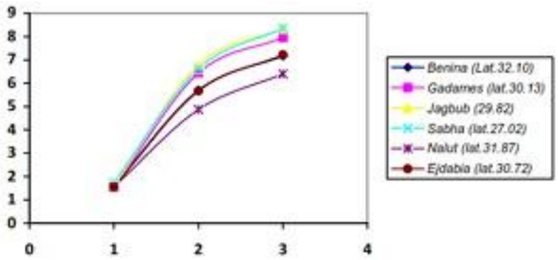

Figure.3 Monthly average of The Maximum and Minimum Solar Radiation Incident on a Horizontal Surface By Units KW.H/M^2/day

It is apparent from the preceding that the overall value of the global incident insolation on a horizontal surface in desert cities are intense during May, June, July, and August, while it significantly decreases during December and January in coastal cities[1]. So we can say that the annual rate changes from 4.44KW.H/M^2/day to 10.33KW.H/M^2/day within a year. It means that the average annual total for the amount of radiation that reaches Libya is 2.967MW.H/M^2/day, and the total annual diffuse radiation is 0.557MW.H/M^2/day.

The in-depth analysis of solar radiation reveals that these radiations instigates from events of solar wares solar wind. Constant Sun emission results to solar wind. The solar wind has particles composed of low energy having 91.3% protons which are doubly or solely charged. The ions contain negligible amount of electrons having energy below 500 eV. Owing to magnetic field of the earth, it is not possible for the particles to get near surface of the earth excluding via regions of polar. The radiation bursts intensely interrelated with Sun's spot activity cycles at the surface of the Sun. High Fluxes of flare cause the serious effects on transmission lines insulators.

The results of the linear fitting for some locations are listed in tables 1, 2, 3.

Table 1 Value of constants a, b and R^2 for whole year

City	Oct→Mar		
	a	b	R^2
Benina	0.70	0.31	0.80
Gadames	1.32	0.14	0.32
Jagbub	0.01	0.93	-
Sabha	1.04	0.12	0.50
Nalut	0.11	0.76	0.02
Ejdabia	0.44	0.46	0.28

Table 2 Value of constants a, b and R^2 form Apr to Sept

City	Whole Year		
	a	b	R^2
Benina	0.59	0.39	0.85
Gadames	0.49	0.51	0.28
Jagbub	0.16	0.80	0.14
Sabha	0.25	0.72	0.12
Nalut	0.45	0.39	0.33
Ejdabia	0.36	0.54	0.53

Table 3 Value of constants a, b and R^2 form Oct to Mar

City	Apr→Sept.		
	a	b	R^2
Benina	0.30	0.85	0.73
Gadames	0.46	0.53	0.60
Jagbub	0.14	0.84	0.16
Sabha	0.29	0.67	0.29
Nalut	0.31	0.52	0.42
Ejdabia	0.26	0.63	0.54

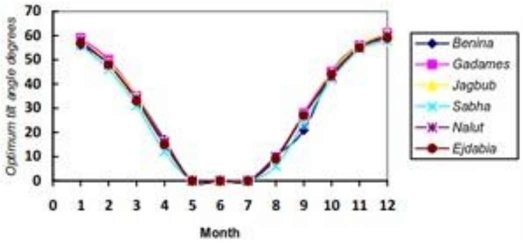

Figure. 4 Value of Optimum Angles Monthly Change During The Year

The above figure shows the optimum angles for incident solar radiation on an inclined surface in some areas of Libya with the method presented by Liu and Jordan. The annual optimum angles of incident solar radiation in any location in Libya can be obtained. The results can be used to find yearly angles in some locations of Libya as in the figures 5.

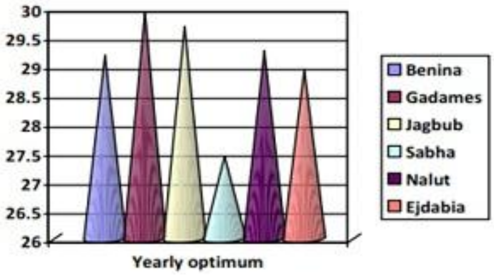

Figure.5 Yearly Optimum Angles For Some Areas of Libya

The results analysis attained show that the annual rate changes from 4.44KW.H/M^2/day to 10.33KW.H/M^2/day during the whole year, implying that the average annual total for the amount of radiation that reaches Libya is 2.967MW.H/M^2/day and the total annual diffused radiation is 0.557MW.H/M^2/day. It shows the high value of solar radiation over Libya [2]. Using the international standards (IEC standard) and its modified version for polymer insulators in coastal and desert areas, early collapse of insulators can be avoided.

Various regions recorded different values in the yearly optimal changes as a result ultraviolet light rays have varied effects as per every area. According to the chart indicated in figure 5, Gadames recorded the highest optimum angle while Sabha recorded the lowest optimum angle of 27.5 [4].

III. MECHANICAL AND CHEMICAL EFFECTS OF THE UV LIGHT

UV Radiation is characterized by very explicit and serious ecological settings for electrical insulators. The effects entail the influence of radiations of electromagnetic and the corpuscle charges. These factors typically cause physical features changes and degradation. UV Radiation changeover via a matter occurs due to its interface with substance atoms, transferring energy to the insulator. The excitation and ionization of the molecules and atoms consumes this energy. The mechanism of interaction of the radiations with other material depends on the internal structure of the material and types of bond. Outcome of the relations is: change in electron structure of the material; disorders of the interstitials; and the vacancy defect type formation. Bombardments of particles having high energy with atoms present in the grid results leads to the formation of grid opportunities. Atoms that are reflected habitually possess sufficient vigor to generate extra vacancies. The capture of atoms that are ejected to interstitial position in non-equilibrium, the result is a type known as interstitial defect.

The varied internal structure of the insulator materials substances makes them experience varied resistance to ionization. The interaction of UV radiations of high energy interacts with inorganic materials often causes distortions resulting to deformation of crystalline structure. This is replicated in deteriorating of physical - mechanical properties. Covalent bonds presence in the composite materials predisposes them to distortion. The most conspicuous changes in properties include; polymerization, cracking, and condensation. The resultant eccentric of vicissitudes are gauged by the composition in structure and chemical composition of the substance. Moreover, the external irradiation physically also determines the resultant changes of the polymers. Variations in the property of the polymers during irradiation ominously depend on structure of chemical composition.

The structure of the polymer changes due to continual radioactivity of the ultraviolet light radiations. The high irradiations on the polymers undergoes low rate of absorption though the effects are enormously high. Major radiation of ionization has commonly extra energy more than that needed to confiscate an electron from a single atom, nevertheless, the better portion of it is transformed into the dynamic/kinetic energy of the released free electrons, sufficient to fragment chemical bonds.

The irradiation period causes partial alterations in the structure of the matter during which, the original structure resumes its normal structure after the radioactivity. These variations results in generation of electrical conductivity, which disappear after irradiation. Irreparable chemical progressions are instigated by deviations in illuminated systems. The effects associated with the process include: crosslinking- the crosslink generation between the molecules, destruction- the main chain tearing of polymer molecules; oxidation; release of gases; polymerization; and generation of the intermolecular links [5].

The changes produced by radiations are replicated on exterior appearance of polymer, which entail the mechanical and physical conditions. The dimensions of the polymers changes due to effects emanating from radiation. There is possible emission of gases as a consequence of irradiation of polymeric materials. Polymers are vulnerable to emissions of the gases via property changes even at smaller radiations. Gas formation causes polymer swelling and reduction in density. During incessant polymers irradiation, the process of crosslinking would be successful and so do the formation of three dimensional cross-linked molecules with high firmness and stability.

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Demolition process advances opposing radiation effects. Radiation exposure has a significant effect on the polymers. The quarter value carbon atoms, which form polymer, have a predisposition for total destruction to the polymeric insulators. The composites having a minimum of an atom of hydrogen in a group of ethylene have a predisposition to crosslinking.

The variations in characteristics is influenced by ratio of speed beyond stated antiphons contingent on nature of chemical compositions of structure of polymer with conditions of the reaction and conditions of irradiation doses. In existence of oxygen, the oxidization still advances, resulting in significant impacts on certain polymers. Bigger sized weight of the molecular polymer quickens crosslinking of polymer and the lower the weight of molecular polymer, the lower the cross linking. In addition, entire course is dependent on the energy of irradiation [6]. The presence of mechanical strain in radiation, distresses the process of crosslinking and speed ratio of the degradation process. Additionally, it distresses the distribution of crosslinks and, thus, the structure of crosslinking. For instance, cited mechanisms of the degradation owed to irradiation are typical for systems of cables systems entrenched in reactor cores in atomic power stations [7].

IV. CORONA AND UV EFFECTS

When intensity of the electric field surpasses the breakdown strong point of air ranging in the region of 15 KV per CM, the result is the discharge of corona on the insulators surface. Corona production depends on particular atmospheric conditions such as humidity and the density of air. Furthermore, geometrical orientation of the polymeric insulator has significant role in instigating corona activity. Corona produces UV light, gas product such as nitrogen (IV) oxide and ozone gas, and the heat [8].

These discharges causes considerable electro-mechanical strains in polymeric insulators, thus, resulting into chemical degradation. It is true beyond reasonable doubt that continual degradation may eventually render polymeric insulators useless and unusable [9]. However, it's also true that when the polymers possess the right chemistry, they are capable of withstanding these adverse effects throughout the time prescribed for service. Corona also causes energy losses, generation of ozone, noise generation, generation of TVI and RI.

Corona can take place on the moist surface, and this activity is termed as wetting corona. This leads to increase in intensity of electric field along the transmission lines. Wetting activity of corona is dependent on the magnitude and type of the wetting activity and electrical field intensity on the insulators surface. The characteristics of the surface of polymeric insulators affect the magnitude of corona wetting, that is, hydrophilic or hydrophobic. Moreover, wetting type such as those caused by mist, rain, condensation, and the fog has significant influence on the magnitude of the corona wetting. The electrical field surface magnitude depends on the grading ring dimension, position of grading ring, end fittings, and the hard wares fitted at the live-end [10].

Corona wetting is mostly experienced at the ground and live terminals. The discharge activity is more likely to occur due to presence of lower hydrophobicity [11]. Corona results in formation of nitric acid in the company of water ($H_2O + NO_2 \rightleftharpoons HNO_3$) which may lead to deterioration of the surface. Additionally, precipitation of salt, the rain, wind and dust particles may result in significant physical changes on the surface of the insulating material through cracks and roughening. The alteration of polymeric insulators occurs when salt, other soluble substances and acids react. [12]. Therefore, the polymeric insulator becomes hydrophilic and, consequently, water infiltrates the insulating material resulting into the failure of the material. The physical, electrical, and chemical properties of the polymer insulators are very basic in service lifetime of these insulators. Therefore, it is necessary to predict the effects well to analyze the aging effects.

V. SUMMARY

Insulators are one of the major electrical components in the electrical power systems. Their application ranges from the substation down to transmission and distribution levels. The negative effects caused by ultraviolet radiation are, therefore, necessary to find out ways to increase the efficiency. Insulators manufactured from composite of polymeric materials are known as composite or polymeric material. Attributable to the fact that they are organic materials, the materials are prone to environmental dilapidation effects. They experience plodding aging effects over certain period of time [13].

Environmental factors also contribute to degradation of insulators over period of time. These environmental factors include light, heat, and the moistness. Generally, light and heat cause significant erosion and cracking on the materials. Lights hastens oxidation rate through hydrophobic methyl scission resulting to manufacture of ketones, carbolic acids and aldehydes. Relatively, the cessation may be trifling distressing only the side groups or severe resulting into decrease in macromolecules size [14].

One of the major factors having a significant effect on the composite insulator is the ultraviolet light. The chief sources of UV light include sun, arcing activities of dry band on the surface of insulators and formation of corona. Statistical analysis of sunlight is responsible for significant destruction of polymers range from 270 nm to 320 nm. When the insulators absorb these sunlight radiations, the result is degradation in chemical and mechanical structure of the composite materials thus affecting weathering and dielectric properties of the polymers. The wavelength and intensity of radiation has significant consequence on the rate at which degradation of these materials occur. They vary with time of the day, latitude, elevation and season. Furthermore, factors such as presence of moisture on the surface of the polymers hasten rate of degradation. In points form, UV radiation leads to hydrophobicity loss, surface cracking/chalking, crazing, and discoloration.

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VI. CONCLUSION

Generally, insulators utilized in electricity transmission lines are very significant components portion in the transmission of electrical power systems. Detailed analysis and concrete expertise on the insulators is very fundamental for the Electrical Engineers. In simple terminology, insulator is a physical material or technique that constrains the transmission of either electricity or heat [15]. The insulators are utilized to guard human beings from the hazardous electricity effects while flowing in the conductors. They are resources constituting contradictory influence on the electrons flow system. They hardly permit the electrons to smoothly flow from one atom to the next [16]. This is because they have covalent bonds thus they are not permitted to wander around to the neighboring atoms.

The advancements have been gradually made to achieve the most modern type of insulators as in fig 6 below.

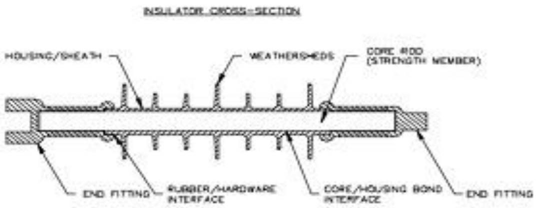

Figure.6 Cross Section of Insulators

Image retrieved from
http://www.appstate.edu/~clementsjs/surfaceflashover/insulatortesting.pdf

Polymeric insulators have several advantages, such as, performance contamination, reduction in the costs of setting up, the weight is light, resistance to vandalism, no or very low maintenance and it has a design which is compact [17]. UV radiation is the part of electromagnetic spectrum found between the visible light and the x-rays. It is 40 to 400 nm translating to energy between 30 to 3 eV. The Sun is the principal source of the ultraviolet light rays. The UV rays have significant hazardous effect on materials contingent to the wavelength of emission.

Apart from UV radiations there are other several factors that may hinder the performance of the polymer insulators [13]. They include chemical pollutants, temperature, leakage currents, and rainfall effects on flash over the voltage, humidity, effects caused by the prolonged contamination and conductivity flow on the HDPE, service deterioration appearance, other parameters such as contact angle and roughness of the surface, mishandling of the insulators and erosion.

REFERENCES

[1] Barry, Roger G, and Richard J. Chorley. *Atmosphere, Weather, and Climate*. London: Routledge, 2010. Internet resource.

[2] Hassan, Y.M, M.A Dakhil, and O.M Furawi. "Optimum Slope for Solar Insolation on a Surface Tilted Toward the Equator in Libya." *Research Journal of Applied Sciences*. 8.1 (2013): 22-26. Print.

[3] Aldali, Yasser. *Solar Thermal and Photovoltaic Electrical Generation in Libya*. Edinburgh Napier University, 2012. Internet resource.

[4] Naser, A D. "Estimation of Monthly Average Daily Global Solar Radiation on Horizontal Surfaces Over Libya." *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*. 32.18 (2015): 1720-1726. Print.

[5] Lean, Judith L. "Cycles and Trends in Solar Irradiance and Climate." *Wiley Interdisciplinary Reviews: Climate Change*. 1.1 (2010): 111-122. Print.

[6] Dipl.-Chem. Umme Habiba Hossain *Swift Heavy Ion Induced Modification of Aliphatic Polymers* aus Munshiganj (Bangladesh) Januar 2015-Darmstadt-D17.

[7] Chudnovsky, Bella H. *Electrical Power Transmission and Distribution: Aging and Life Extension Techniques*. Boca Raton, FL: Taylor & Francis, 2013. Print.

[8] Abd, el-wahed M. H, and Richard L. Snyder. "Calculating Sunshine Hours and Reference Evapotranspiration in Arid Regions When Solar Radiation Data Are Limited." *Irrigation and Drainage*. 64.3 (2015): 419-425. Print.

[9] Chen, Wai-Kai. *The Electrical Engineering Handbook*. Boston: Elsevier Academic Press, 2005. Print.

[10] Brezina, Tomas, and Ryszard Jabłoński. *Mechatronics 2013 Recent Technological and Scientific Advances*. , 2013. Internet resource.

[11] Kempe, Michael D. *Overview of Scientific Issues Involved in Selection of Polymers for Pv Applications: Preprint*. Golden, Colo.: National Renewable Energy Laboratory, 2011. Internet resource.

[12] Manos, D, S.R Kasi, and W.E Mlynko. *Oxide Degradation Effects in Dry Patterning of Resist Using Neutral Oxygen Beams*. Washington, D.C: United States. Dept. of Energy, 1992. Internet resource.

[13] Drobny, Jiri G. *Polymers for Electricity and Electronics: Materials, Properties, and Applications*. Hoboken: John Wiley & Sons, 2012. Internet resource.

[14] Kempe, Michael D. *Overview of Scientific Issues Involved in Selection of Polymers for Pv Applications : Preprint*. Golden, Colo.: National Renewable Energy Laboratory, 2011. Internet resource.

[15] Chudnovsky, Bella H. *Electrical Power Transmission and Distribution: Aging and Life Extension Techniques*. Boca Raton, FL: Taylor & Francis, 2013. Print.

[16] Wagner, Paul. *Long-term Aging of Systems Techniques*. Utica, N.Y: Reliability Information Analysis Center, 2011. Print.

[17] Heeger, Alan J, Niyazi S. Sariciftci, and Ebinazar B. Namdas. *Semiconducting and Metallic Polymers*. Oxford: Oxford University Press, 2010. Print.