Surface Degradation Analysis of Vacuum Composite Epoxy Resin Insulation Material Using Coastal Sand and Filler Containning Much Calsium

Moh Toni Prasetyo[1, a)]

[1]*Faculty of Engineering, Semarang Muhammadiyah University.*

[a)] Corresponding author: toniprast@gmail.com

Abstract. One of the insulating polymer in high voltage air insulation materials is epoxy resin because it has several advantages. However, has a degradation of the surface due to environmental pollution. Material that was used in this research was epoxy resin polymer isolation using of comparison values, material DGEBA : MPDA were 1:1, with the increase filler. Vacuum method to left out void. Research was done in laboratory according to standard IEC 587: 1984. High voltage electrodes were connected to high voltage AC generator 3.5 KV. The ground electrode was connected to oscilloscope for measuring the leakage current. The effect of variation were analyzed. From the results of the research, the composite are categorized as hydrophobic and partially wetted. The increase concentration of filler caused the increase in contact angle, slow down the aging on the surface of insulating material. Concentration value of filler that had the optimal performance was 40%.

INTRODUCTION

Moment happened by the rain, polutan in isolator surface will be dissolve in water and form the conductive band which continue so that can cause the leaky current [6]. Existence of this leaky current generate the heat to dry the polutan on isolator surface. This matter cause formed dry ribbon. Existence of dry ribbon trigger the happening of payload release into the air because of distribution electrics field compared to higher dry ribbon other area [2]. If dry ribbon progressively mount, hence longer will cause the happening of flashover representing failure an isolator. From leaky current phenomenon and impact generated, its important background conducted research concerning leaky current in laboratory [4] especially at material of epoxy resin by *silane* and coastal sand as filler.

In conducting research to leaky current at this isolator surface is used by method of Inclined-Plane Tracking (IPT) arranged in IEC 587:1984 [3]. In this method, certain sampel material of the size positioned with the angle 45° and given dilution polutan made in with the certain stream, so that this method is very suited for represent of external isolator situation in Indonesia owning high rainfall [7].

THEORY BASE

A. Insulation Material.

Insulation is the nature of functioning materials can dissociate electricly two or more nearby electrics voltage conductor, so that is not happened the current leakage, jumping movement fire (*flashover*), or fire sprinkling (*sparkover*). While isolator is appliance weared for the insulation of partitioning or ability of insulation. Materials to restrain the volage referred as a dielectric strength, dielectric strength excelsior of good insulation materials progressively weared, especially at equipments of high voltage electrics. Dielectric strength from insulation materials is vital importance in the case of determining the quality of isolator which later will support the overall of electric power system.

B. Epoxy Resin

Epoxy resin is faction of termoset polymer where mixture two component which finally in form of vitriform at room temperature having the nature of competent electrics insulation as well as having high waterproof. That has become the important shares from insulation material especially in the field of electrical because this polymer type

has been recognized more than 50 year. Epoxy resin is good electric isolator and protect the electrics component from short current, dirt and humidity.

Epoxy resin have the characteristic: nature of low viscosity, easy to formed, low decrease, mount the high hardness, nature of high mechanic, high electrics insulation and also good chemistry resistance.

Epoksi resin used in this research is result of maturation of epoksi resin *diglycidyl ether of bisphenol - A* (DGEBA) and *metaphenylenediamine* (MPDA) with the *silane* filler (stick on glass).

C. Materials of Filler Silane.

Silane so-called also *silicon rubber* is materials which hold up to high temperature which is usually used for the insulation of cable and materials of high voltage insulation. *Silicone Rubber* represent the polymeric synthetic which relative newly its use upon which insulation in the field of electrics technique compared to with the other polymer like epoxy resin or *polyethylene* [5]. Popularity this materials is compared to with the ceramic materials/porcelain and other polymer type because measuring up to high hidrofobik, thereby conductivity of isolator surface remain to lower, so that minimization leaky.current. Besides measuring up to good dielectric, as light as a feather, easy to handling and its installation. Nature of this material physical is repairable by mixing filler materials like silica or calsium sand.

D. Materials of Filler Coast Sand which is Many Containing Calcium.

Coastal sand of Kukup used as materials of addition filler representing type of coast sand which is many containing *calcium*. From result test at Analytic Chemical Laboratory of Gadjah Mada University, obstetrical *calcium kabonat* ($CaCO_3$) reach 55,98% from grand total sand, *oxide calcium* (CaO) 31,37%, *carbonate magnesium* ($MgCO_3$), and some other supporter element.

Addition of sand filler will improve, repair the nature of materials physical so that will be yielded a material which do not easy to flex and brittle.

E. Contact Angle Hidropobik.

Contact angle represent the angle formed by between materials surface test with the water dripped to materials surface test. Angle measurement contact at one particular insulation materials conducted to know the nature of materials surface, hidofobik or hidrofilik. Nature of hidrofobik good for external insulation because in a state of damp or wet will not be formed a continuely water coat at isolator surface, so that isolator surface remain to have the low conductivity, as a result leaky current very small [1].

Researcher classify the material surface with the amount of angle of contact that is material surface very wet (hidrophilik) when angle of contact dilution its surface smaller than 30°. If contact angle between 30° up to 89°, material surface referred as partially wetted contactangle more than 90° referred as hidrofobik or have the character of water-repelent.

F. Insulation of Leakage Current and Pollution.

Polutan which consisted in on the air can patch at isolator surface and gradually form a flimsy coat at isolator sumost having an effect on element. Most having an effect on element the isolator is salt brought by set breeze. In moment of wheater condition that way, will emit a stream of the leakage current from strand of metal of fasa to the ground through the conductive coat which patch at isolator surface and also at stanchion.

Leaky current surface of insulation materials from isolator of couple air-duct outside, depended from condition polutan causing surface contamination. Besides also depend on climate and wheater condition. Drenching of coat polutan by timid weather, item irrigate, the rain water drenching which moderate rain, resulting conductive electrolyte, so that resistansi surface will become small, and cause the leakage current surface.

Analyse the leakage current investigated by pursuant to waveform and duration of electrics sickening by signifikan influence the performance of insulation materials as a whole. Therefore, identify the nature of this leakage current applicable to detect early failure of high voltage isolator.

RESEARCH METHOD

A. Research Materials

Materials used in this research:

a. Polymer of epoxy resin by DGEBA (*Diglycidyl ether of Bisphenol A*) elementary upon which, MPDA (*Metaphenylenediamine*) upon which hardening.

b. *Silane* (Stick on the Glass), and coastal sand of Kukup which is many containing upon which filler.
c. Polutan in the form of NH_4CL (*Ammonium chloride*).
Sample composite produced by mixing resin epoxy and filler with vacuum method to left out void.

TabeI 1 Mixing composition of composite

No	Kode	Bahan Campuran (%)			
		DGEBA	MPDA	Silane	Pasir
1	RTV 10	45	45	5	5
2	RTV 20	40	40	10	10
3	RTV 30	35	35	15	15
4	RTV 40	30	30	20	20
5	RTV 50	25	25	25	25

B. *Research Equipments.*

Equipments used in this research cover:

a. A set appliance of materials printer test the (glass, mica paper, churn, place mingle the materials test).
b. A set appliance to measure the angle of contact (Lamp box with the lamp 1000W, pipette drop 50µl, place put the polutan, glass)
c. A set appliance for the examination of leaky current (upper electrode and under electrode made from alumunium (stainless steel), support, to put down the sampel which have been nipped by a electrode, paper filter the, pump peristaltik (peristaltik pump))
d. A set appliance for the vacuum system
e. Some equiptments for the measurement system: AC transformator, oscilloscope, digital camera and a computer

C. Measurement steps

C.1 Contact Angle Test

This angle of contact examination is mean to know the nature of materials surface test. Nature of such that is nature of hidrofobik. If angle got ever greater, its meaning the materials possibility measure up to the hidrofobik. Progressively hidrofobik a materials surface, hence ever greater also materials strength to arrest the water in order not to come into the materials [8]. Step the angle of contact examination that is as follows:

1. Putting down sampel and turn on the camera, both positioned in such a manner so that camera screen, rectilinear visible surface sampel.
2. Dripping water counted 50 µ l. Water dripped in the form of polutan to be used.
3. Turn on light source so thatwhen taken a photo, dot irrigate clear visible surface sampel.
4. Shooting, so that its result earn direct entered into computer to get big measured angle of contact.
Result angle of contact examination got in the form of data of value angle every each sampel.

C.2 Leakage Current Test

Leaky current test yielding process of tracking and erosion from isolator of polymer resin epoxy with the filler of *silane*and coastal sandcontamined conducted to passthe steps following:

1. Putting down electrode upper and lower at sampel. At upper electrode, before attached, sampel given the paper filter counted 8 layer. Then put down the the sampel at support so that part of surface sampel face down wards with the angle 45° to tinder horizontal.
2. Arranging speed of stream polutan at 0,3 ml / minute, then emit a stream of into the sampel through the paper filter. Function from paper usage filter this is to be happened the stream contaminant which uniform from electrode to the until under electrode before application tension. Assess the this stream polutan relate to the voltage of break even and resistor application matching with IEC 587:1984.

Fig 1. Electrode location materials test.

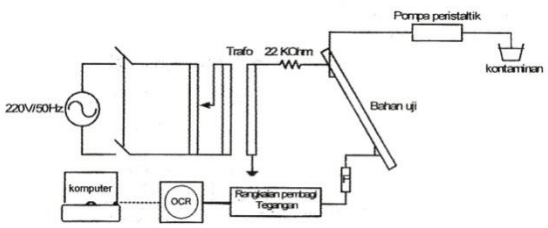


Fig 2. Leakage current test network

3. Applying 3,5 kV voltage at sampel, what is got from generating high voltage through the upper electrode while electrode of under attributed to a equipments measure.
4. Measuring leaky current use the oscilloscope. To over come the big voltage come into the oscilloscope, hence used the following voltage divider network.

C.3 Surface Degradation Test

Process the measurement of surface degradation of materials conducted by using macro photo which is on its essence represent the perception to change of structure of ageing materials test, with the the following working procedure.

Materials chaptured to use the macro photo shares the happening of conduction band by using ordinary photothen compared to each its concentration. Result of film record printed in the form of photo draw.

RESULT AND SOLUTION

A. Contact Angle Hidrophobic Test

Result of photograph processed using the *software Image Pro Plus to* get the angle of contact at right side and left side measured sample test.

From result data of test and fig 3 below, visible that resin epoxy composite wich used this research have the *partially wetted* character and *hidrofobik*. Angular value contact to range from 65° until 91.5° what can be categorized to have the partially wetted character (wet some of) until hidophobic

Tables 2. The test result of contact angle

Kode sampel	Konsentrasi pengisi, *nk* (%)	Sampel	Sudut kontak, θ (°)			
			kiri	kanan	rata-rata	terbaik
RTV 10	10	1	89	89	**89**	89
		2	77	75	76	
		3	79	79	79	
RTV 20	20	2	90	90	90	90,5
		3	91	90	**90,5**	
		4	88	90	89	
RTV 30	30	1	91,5	91	**91,25**	91,25
		2	90	90	90	
		3	91	89	90	
RTV 40	40	1	92	90	91	91,5
		2	93	90	**91,5**	
		3	90,5	86	88,25	
RTV 50	50	1	90	90	90	91,25
		2	92	90,5	**91,25**	
		3	92	90	91	

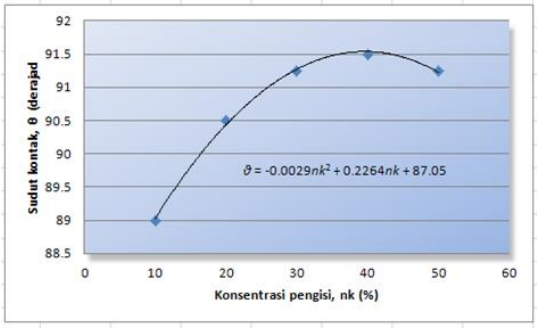


Fig 3. Graph, relation of contact angle and concentration

. The biggest contact angle is resin epoxy RTV40. Nature of hidrophobic at epoxy resin material got from its filler that is *silane* owning water-repelent characteristic.

B. Result of Leakage Current Test

Materials test placed with the inclination angle 45°. At this research, polutan NH_4Cl, with the speed 0,3 ml / minute emit a stream of on the surface of materials test to pass the paper filter 8 layer nipped among materials test and upper electrode going to under. Upper electrode applied by volgtage AC 3,5 kV

Result of this leakage current test shown by picture voltage waving at oscilloscope. Value waving this voltage represent the value of oscilloscope input from voltage divider network.

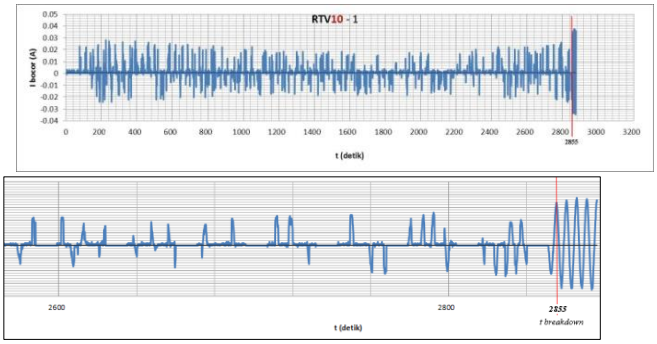


Fig 4. Result of composite leaky current test of resin epoksi RTV10 sampel 1

Fig 5. Result of magnification 10x range moment of before *breakdown*

Pursuant to fig 5, inferential that happened the payload discharge (*flashover*) at second 77. This payload deprival marked with the existence of leakage change magnitude current on the spur of the moment. This payload deprival happened till many times, then happened the insulation failure marked with the leaky wave sinusoidal current at second 2855. this sinusoidal wave indicate that have been happened the intact conduction band from electrode high voltage to ground electrode.

Matter which the same also happened in variation of assess the other concentration, but different at frequency and time the happening of flash over until the happening of breakdown.

Table 2. Tracking Surface Time.

% filler	Early flash over time (s)	Breakdown time (s)	Tacking time (s)
10%	77	2855	2778
	70	1585	1502
	187	1991	2018
20%	43	1190	1138
	351	1651	1300
	303	1925	1605
30%	452	2084	1701
	288	2800	2836
	68	1707	2067
40%	196	2467	2320
	628	2608	1980
	184	1940	1903
50%	49	1799	1750
	115	1235	1117
	49	2025	1976

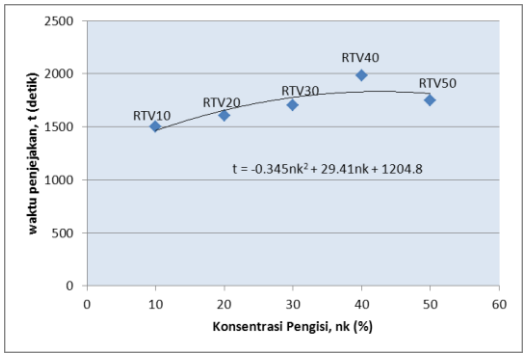


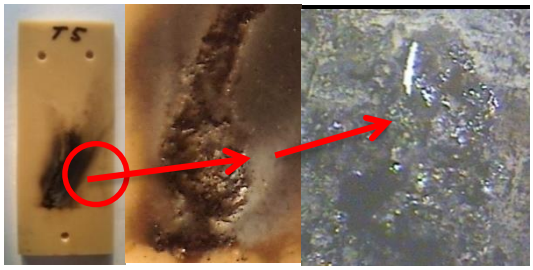
Fig 6. Graph of relation tracking time with the composite filler concentration.

From test result, earn also obtained time tracking of mean each concentration resin epoxy filler. Relation between tracking time and value the composite concentration visible epoxy resin shown at fig 6.

From fig 6, visible that increase value the composite filler concentration epoxy resin tend to cause the increase of tracking time. This matter indicate that the composite filler concentration excelsior resin epoxy hence process the happening of band of conduction and carbon band at surface of insulation materials will tend to tardy progressively, so that can slow down the happening of degradation surface.

C. Result of Degradasi SurfaceTest

To know the degradation surface in the form of erosion, cart and calcify needed by an way for the characterize of surface. One of the methodused for macro photo technique.



(a) (b) (c)

Fig 7. Chapture result (a) without magnification (b) macro10x and (c) macro 30x from composite surface sampel resin epoxy RTV10

Result of macro photo composite surface sampel epoxy resin used at this test isobtained that have been happened the structure change at composite surface of resin epoksi isolator.

CONCLUTION

Pursuant to data obtained and result of data analysis which have processed, hence inferential:

1. Increase value the sand concentration have high calcium and *silane* as composite filler of resin epoxy tend to cause:
   a) Angle of contact tend to increase, biggest contact angle of epoxy resin RTV40 with the filler concentration 20% sand and 20% silane and comparison of materials of ossifying of *metaphenylene diamine* (elementary MPDA) Basic naterials, *diglycidyl ether of bisphenol A* (DGEBA) is 1:1.
   b) Lowing down the happening of insulation failure or complicate the happening of leakage current surface of materials insulation resin epoxy. Increase value the sand concentration have high calcium and *silane* as filler cause the increase contact angle meaning increase of resistansi of surface of insulation materials, so that leakage current do not easy to emit a stream of on the surface of insulation materials. Increase value the filler concentration of sand wich have calcium and *silane* will not water down the happening of jumping movement electrics (*flashover*) to trigger the happening of insulation failure.
   c) Slowing down process the happening of carbon band at surface of insulation materials.
   d) Degrading damage (degradation) at surface of materials insulation epoxy resin. Tracking pattern happened from low voltage electrode to high voltage. This matter caused by direction of electron stream actually from negative electrode to positive electrode.
2. Value the sand concentration have high calcium and *silane* as composite filler will compare diametrical to tracking time and level of contact angle will influence the tracking time, comparing diametrical to tracking time.
3. Value the sand concentration have high calcium and *silane* as composite filler of resin epoxy having optimal performance to tracking process and erosion is 40%.

REFERENCES

[1] Amin, M. et.al., 2007, *Hidrophobicity of Silicone Rubber Used For Outdoor Insulation (An Overview)* Advanced Study Center CO.Ltd.

[2] Berahim, Hamzah, "Metodologi Untuk Mengkaji Kinerja Isolasi Polimer Resin Epoksi Silane Sebagai Material Isolator Tegangan Tinggi di Daerah Tropis", Disertasi Fakultas Ilmu Teknik Jurusan Teknik Elektro Universitas Gadjah Mada, 2005

[3] British Standard, BSi., 1986, *Metode for Evaluating Resistance to Tracking and Erosion of Electrical insulating materials used under severe ambient conditions*, IEC 587 :1982

[4] Chandrasekar, S. et.al., 2007, *Analysis of Surface Degradation of Silicone Rubber Insulation Due To Tracking under Different Voltage Profiles*, Elecr.Eug (2007) 89 : 489-50 L

[5] Eklund, A. et.al., 1995, *Conditioning of Silicone Rubber Insulatiors : Loss and Recovery of Hydrophobicity*, 9th ISH, Graz, Austria.
[6] Jauhari, E., 2005, *Isolator Saluran Udara*. Eri Jauhari-EnJ's Blog
[7] Moh Toni, Efektifitas Pemanfaatan Pasir Pantai Berkalsium Tinggi Sebagai Material Pengisi Bahan Isolasi Resin Epoksi untuk Isolator Listrik (Media Elektrika,Vol.7 No.2, 2014, Semarang)
[8] Shaowu, W. et.al., 2002, *Hydrophobicity Changing of Silicone Rubber Insulators in Service*, 21,rue d'artois F-5008, Paris.