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Leakage Current Phenomenon on Ceramics and Epoxy Resin as 20 kV Outdoor Insulator at Tropical Environment

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Abstract— **This paper explains the research results of leakage current, hydrophobicity and flashover voltage comparison on ceramics and epoxy resin 20 kV outdoor insulator in a chamber at tropical climate conditions. The waveform of leakage current (LC) was measured using a digital oscilloscope. The digital data was transferred to a personal computer using a RS-232 cable. The digital data was analyzed using Fast Fourier Transform. The result showed that LC was affected by various environment conditions like temperature, humidity and pollution. LC of ceramics insulator was higher than epoxy resin insulator in low temperature, high humidity and high pollution condition.**

Keywords— **outdoor insulator, epoxy resin, leakage current, hydrophobicity, flashover voltage.**

I. Introduction

Nowadays, ceramics and resin epoxy have been used in many sectors. In electrical engineering, ceramics and resin epoxy can be used for insulation.

Electrical characteristics which will be examined are leakage current. Based on leakage current data, it will be calculated the estimation of flashover voltage by using statistical methods on SPSS and MATLAB software. Physical characteristic which will be tested is hydrophobicity. Another phenomenon which will be tested is the effect of dry band arcing to insulator performance. Dry band is formed at insulator surface because of high pollution and environmental humidity. This incident can cause out of order of insulator. Beside that, comparison of other parameters are done which are gotten from insulator company.

In this research, ceramics and epoxy resin will be tested their characteristics in a chamber which its condition likes tropical climate. So, data about ceramics and epoxy resin will be gotten in all kinds of pollution, humidity, and temperature in tropical environment.

II. Experiment

The first type tested insulator used in this experiment is 20 kV pin type ceramics and 8.2 kg weight with composition 50% clay ($Al_2O_3.2SiO_2.2H_2O$), 25% silica dan 25% ceramics ($4K_2O.Al_2O_3.3SiO_2$) [1]. The second type tested insulator used in this experiment is 20 kV pin type epoxy resin and 1.8 kg weight. The curing agent of epoxy resin insulator is diamine.

Fig 1. Ceramics Insulator

Fig 2. Epoxy Resin Insulator

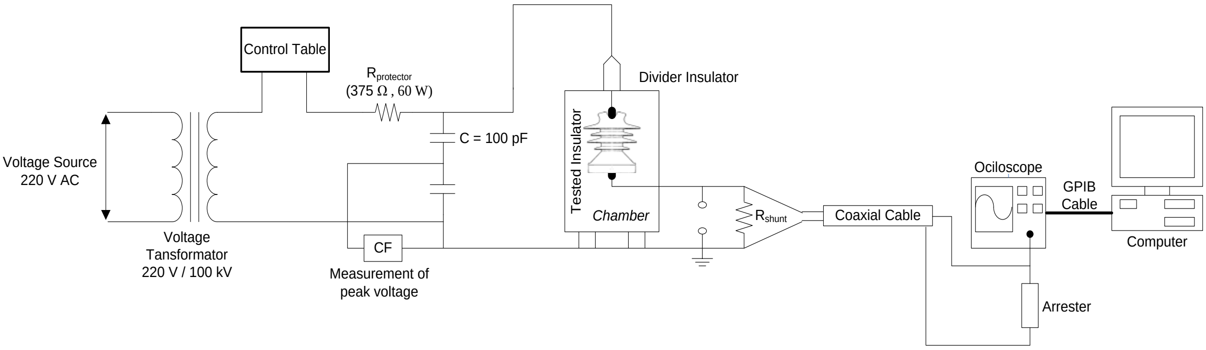


Fig 3. Leakage Current Measurement

The chamber dimensions are 90x90x120 cm^3 with 80x80 cm^2 transparent acrylic door. Chamber temperature and humidity are varied like in tropical environment. Chamber temperature is varied from 25°C to 35°C. Chamber humidity is varied in low (50-60%), medium (70-80%) and high humidity (85-98%).

Artificial pollutant used in this experiment was kaolin-salt with conductivity varied from 6 mS/cm to 36 mS/cm. IEC 507 standard was used in this artificial pollution arrangement. LC was measured using a digital oscilloscope Textronik TDS 220 with digitizer of 8 bit, 100 MHz bandwidth and 1 GS/s the maximum sampling rate. LC waveform was analyzed using Fast Fourier Transform (FFT) for getting Total Harmonic Distortion (THD). THD can be expressed as :

$$THD = \frac{\sqrt{\sum_{i=2}^{\infty} {I_n}^2}}{I_1} \qquad (1)$$

where

I_n : n^{th} harmonic for n = 2,3,4 ….

I_1 : fundamental harmonic (n = 1)

Based on LC data, mathematical correlation between LC and testing voltage can be analyzed using non linear regression method. After that, estimation of flashover voltage can be gotten. The correlation of LC and testing voltage is :

$$I_{leakage} = \alpha {V_{testing}}^{\beta} \qquad (2)$$

where :

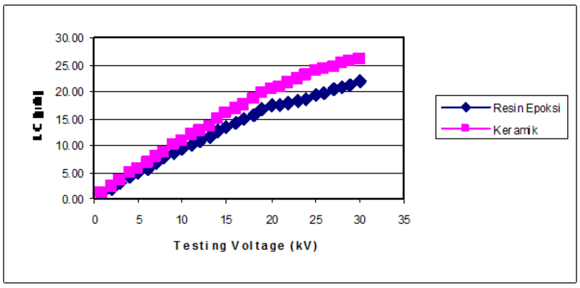
α is testing voltage coefficient

β is testing voltage degree.

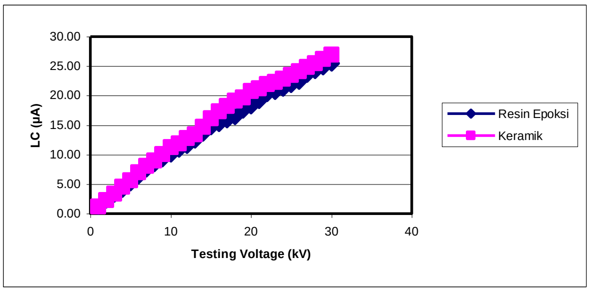
III. Results and Discussion

A. *Leakage Current as Function of Testing Voltage*

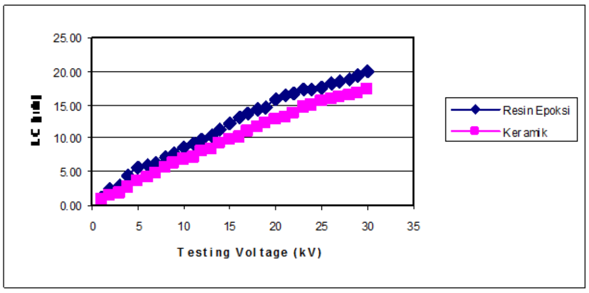
Fig. 4 show LC as function of testing voltage for clean insulators on low and high humidity. Fig.5 shows LC as function of testing voltage for 6 mS/cm polluted insulators on low and high humidity.



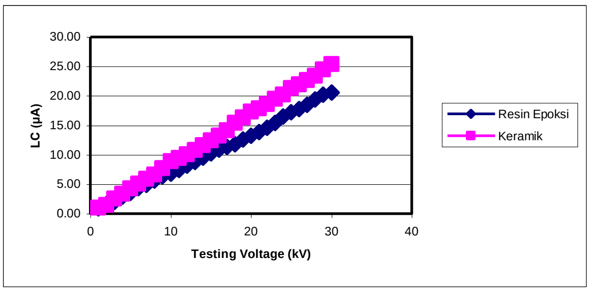
(a) Temperature 25°C and Humidity 70-80%



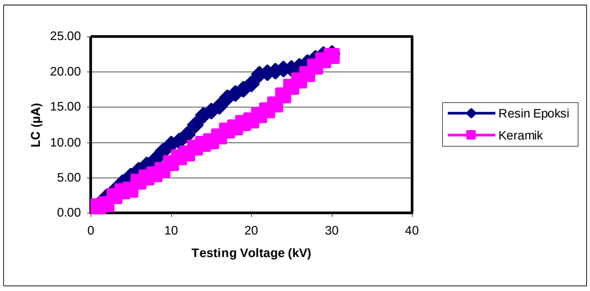
(b) Temperature 25°C and Humidity 85-98%



(c) Temperature 30°C and Humidity 50-60%

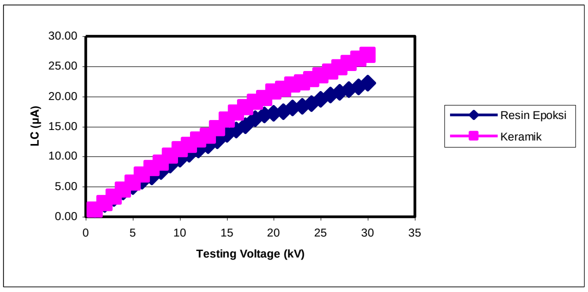


(d) Temperature 30°C and Humidity 70-80%

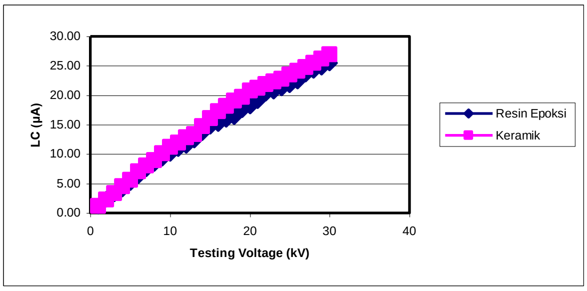


(e) Temperature 35°C and Humidity 50-60%

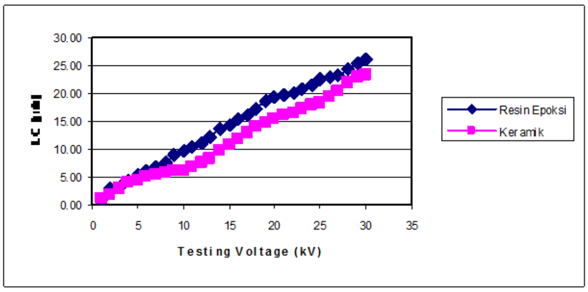
Fig 4. LC as Function of Testing Voltage in Various Environment Condition for Clean Insulators



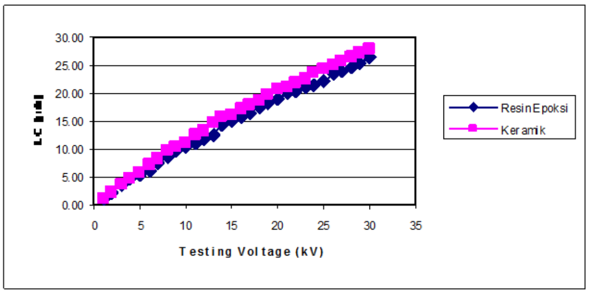
(a) Temperature 25°C and Humidity 70-80%



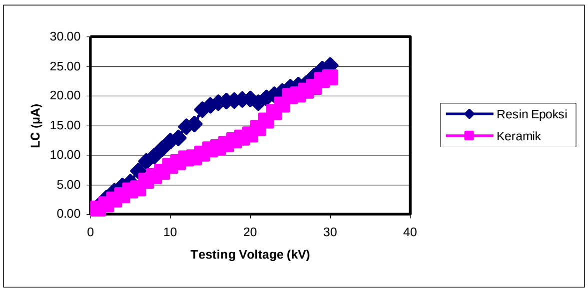
(b) Temperature 25°C and Humidity 85-98%



(c) Temperature 30°C and Humidity 50-60%



(d) Temperature 30°C and Humidity 70-80%



(e) Temperature 35°C and Humidity 50-60%

Fig 5. LC as Function of Testing Voltage in Various Environment Condition for Polluted Insulators

Leakage current of ceramics insulator in clean condition at temperature 25 °C and humidity 70-80 % be concerned with 1.15 to 22.90 µA whereas leakage current of epoxy resin insulator be concerned with 1.08 to 21.80 µA.

B. Estimation of Flashover Voltage

Based on lekage current data, it can be estimated the flashover voltage of insulator. It can be used statistical methods on software SPSS and MATLAB. SPSS is used to know the form of leakage current as the function of tested voltage. After that, we used MATLAB to know the value of tested voltage to get maximal value of leakage current. This tested voltage value is the estimation of flashover voltage. For example, it is shown below the estimation of flashover voltage of ceramics and epoxy resin insulator.

Insulator : Ceramics
Condition : Temperature 30°C ; Humidity 50-60%

By using SPSS :

```
Call: lm(formula = lnLC ~ lnTV^3 + lnTV^4, data =
PengolahanKF305060, na.action = na.exclude)

Residuals:
      Min        1Q    Median       3Q      Max
 -0.05803 -0.03298 -0.00884 0.03731 0.08382

Coefficients:
             Value   Std. Error  t value Pr(>|t|)
(Intercept)  2.1810   0.0223     97.5979   0.0000
I(lnTV^3)    0.0903   0.0059     15.2449   0.0000
I(lnTV^4)   -0.0147   0.0017     -8.6435   0.0000

Residual standard error: 0.04337 on 27 degrees of
freedom
Multiple R-Squared: 0.993
F-statistic: 1921 on 2 and 27 degrees of freedom,
the p-value is 0
```

By using MATLAB :

```
syms logTV
clc;
a = 2.1810;
b = 0.0903;
c = -0.0147;
LC = exp(a + b*logTV^3 + c*logTV^4);
```

```
dLC = diff(LC);
FV = exp(solve(dLC));
double(FV)
```

Insulator : Ceramics
Condition : Temperature 25ºC ; Humidity 70-80%

By using SPSS :

```
Call: lm(formula = lnLC ~ lnTV + lnTV^6, data =
PengolahanK257080, na.action = na.exclude)

Residuals:
      Min       1Q    Median       3Q     Max
 -0.04615 -0.0134 -0.003323 0.01624 0.06382

Coefficients:
             Value  Std. Error  t value  Pr(>|t|)
(Intercept)  0.1591   0.0202     7.8880   0.0000
lnTV         0.9248   0.0107    86.1133   0.0000
I(lnTV^6)   -0.0001   0.0000    -6.2486   0.0000

Residual standard error: 0.02854 on 27 degrees of
freedom
Multiple R-Squared: 0.9986
F-statistic: 9768 on 2 and 27 degrees of freedom,
the p-value is 0
```

By using MATLAB :

```
syms logTV
clc;
a = 0.1591;
b = 0.9248;
c = -0.0001;
LC = exp(a + b*logTV + c*logTV^6);
dIbocor = diff(LC);
FV = exp(solve(dLC));
double(FV)
```

Insulator : Epoxy Resin
Condition : Temperature 35ºC ; Humidity 50-60%

By using SPSS :

```
Call: lm(formula = lnLC ~ lnTV + lnTV^6, data =
PengolahanD355060, na.action = na.exclude)
Residuals:
     Min       1Q    Median      3Q     Max
 -0.0639 -0.01503 -0.005401 0.0185 0.08715

Coefficients:
             Value  Std. Error  t value  Pr(>|t|)
(Intercept)  0.8828   0.0233    37.8505   0.0000
lnTV         0.9992   0.0124    71.1382   0.0000
I(lnTV^6)   -0.0001   0.0000    -2.5974   0.0150

Residual standard error: 0.033 on 27 degrees of
freedom
Multiple R-Squared: 0.9981
F-statistic: 7078 on 2 and 27 degrees of freedom,
the p-value is 0
```

By using MATLAB :

```
syms logTV
clc;
a = 0.8828;
b = 0.9992;
c = -0.0001;
LC = exp(a + b*logTV + c*logTV^6);
dLC = diff(LC);
FV = exp(solve(dLC));
double(FV)
```

Insulator : Epoxy Resin
Condition : Temperature 25ºC ; Humidity 85-98%

```
Call: lm(formula = LC ~ TV + TV^3, data =
PengolahanB258598, na.action = na.exclude)
Residuals:
     Min      1Q  Median     3Q   Max
 -0.4151 -0.1874 -0.0355 0.1587 0.391

Coefficients:
             Value  Std. Error  t value  Pr(>|t|)
(Intercept)  0.5526   0.1267     4.3605   0.0002
TV           0.9481   0.0133    71.2497   0.0000
I(TV^3)     -0.0001   0.0000    -9.6149   0.0000

Residual standard error: 0.2471 on 27 degrees of
freedom
Multiple R-Squared: 0.9989
F-statistic: 12740 on 2 and 27 degrees of freedom,
the p-value is 0
```

By using MATLAB :

```
syms TV
clc;
a = 0.5526;
b = 0.9481;
c = -0.0001;
LC = a + b*TV + c*TV^3;
dLC = diff(LC);
FV = solve(dLC);
double(FV)
```

Note :
TV : Testing Voltage
LC : Leakage Current
FV : Flashover Voltage

Based on these simulations, estimation of flashover voltage per creepage distance of ceramics insulator in low and high humidity condition are 0.20 kV/mm and 0.15 kV/mm. Estimation of flashover voltage per creepage distance of epoxy resin insulator in low and high humidity condition are 0.20 kV/mm and 0.14 kV/mm. These estimation values are not too different with data from the producer of theses insulators.

C. Contact Angle

Contact angle of ceramics insulator before leakage current measurement is 25 degree whereas for epoxy resin insulator is 88 degree. Contact angle of ceramics insulator after leakage current measurement is 13 degree whereas for epoxy resin insulator is 81 degree. It means that epoxy resin insulator is more hydrophobic than ceramics insulator.

IV. CONCLUSIONS

After characteristics of these materials have been gotten, leakage current characteristics and forecast of flashover voltage are compared. Based on data analysis which have been done, ceramics insulator is suitably used in low humidity area and epoxy resin insulator is suitably used in high humidity area.

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