COMPARATIVE STUDY OF LEAKAGE CURRENT PROPERTIES ON THE NEW-CLEAN PORCELAIN AND EPOXY RESIN OUTDOOR INSULATORS DUE TO VARIOUS PARAMETERS

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ABSTRACT

This manuscript presents the experimental results of leakage current waveform properties which produced on the new-clean porcelain and epoxy resin insulators due to various voltage, temperature, humidity and pressure parameters. The measurements have been done in the hermetically sealed chamber where the parameters could be regulated and monitored or recorded simultaneously. The examined leakage current parameters were wave amplitude, phase angle or power factor, first to thirteenth odd harmonics and THD. The analysis was done with some multivariate statistical tools, such as correlation matrix, pca and scree plot. The results indicated that leakage current amplitude and phase angle were influenced by humidity, indicated by correlation coefficients as 0.56 and -0.88 respectively on new-clean porcelain insulator. Otherwise, on the new-clean epoxy resin insulator, leakage current magnitude influenced to the phase angle as -0.75. These were supported by principal component analysis. Based on the scree plots, the extracted of information quality were higher than 80%.

Keywords: *humidity, leakage current, multivariate, phase angle, correlation coefficient*

INTISARI

Makalah ini memaparkan hasil eksperimen sifat-sifat bentuk gelombang arus bocor yang ditimbulkan pada isolator porselen dan epoxy resin baru-bersih akibat berbagai parameter tegangan, temperatur, kelembaban dan tekanan. Pengukuran telah dilakukan dalam kamar kabut terkunci kedap udara dimana parameter tersebut dapat diatur dan dipantau atau direkam secara simultan. Parameter arus bocor yang diamati adalah amplitudo, *sudut fasa atau faktor daya, harmonisa ganjil pertama sampai ketigabelas* dan THD. Analisis dilakukan dengan beberapa sarana statistik multivariate, seperti matriks korelasi, pca dan scree plot. Hasilnya menunjukkan bahwa amplitudo arus bocor dan sudut fasa dipengaruhi kelembaban, ditunjukkan oleh koefisien korelasi berturut-turut sebesar 0.56 dan -0.88 pada isolator porselen baru-bersih. Di sisi lain, pada isolator epoxy resin baru-bersih, besar arus bocor mempengaruhi sudut fasa sebesar -0.75. Hal demikian didukung oleh analisis komponen utama. Berdasarkan pada scree plot, kualitas informasi yang diserap di atas 80%.

Kata kunci: kelembaban, arus bocor, multivariate, *sudut fasa*, koefisien korelasi

INTRODUCTION

Overhead transmission or distribution lines are widely used in present power system to transmit electric power from generation stations to customer points. Their proper function depends to a large extent on the insulation system with the supporting structures (Fernando et al, 1999). The performance of outdoor insulators, as main insulating materials, is affected by many parameters. Those some of paramaters are voltage magnitude, temperature, humidity and pressure

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parameters, which three latest parameters are environmental parameters in real condition. On this research, such parameters employed on two kinds insulator, porcelain and epoxy resin, as representation of ceramic and non ceramic insulator respectively, which they were on new-clean condition. These two types of insulator have different properties [Vosloo, 2002; Vosloo et al, 2004].

To approach the real condition of parameter effects on the insulator performance, it has been conducted leakage current measurement of outdoor insulators with above various parameters experimentally at the high voltage laboratory.

The objective of research is to obtain the significance of correlation among parameters. However, the main parameters to be examined analyzed are leakage current amplitude, phase angle or power factor and waveform parameters, to the environmental parameters. The waveform parameters are presented by first to thirteenth odd harmonics and THD. The correlations among parameters were analyzed by using correlation coefficients and principal component analyzes.

The new-clean porcelain and epoxy resin insulator in dry condition was put in the hermetically sealed chamber, with the humidity, temperature and pressure parameters, and applied voltage could be regulated. The insulator was subjected to high voltage, where the voltage and leakage current waves were recorded by a 100 MHz digital storage oscilloscope. The recorded data were transferred to personal computer, in two forms, Bitmap and **csv** extention files. The Bitmaps for drawing forms, and **csv** extention files were opened by Excel for further analysis. They passed through USB (Universal Serial Bus) port. The schematic diagram of experimental setup is shown on Figure 1. The 220 V – 50 Hz low voltage source was supplied to the step-up transformer which the magnitude of output could be raised gradually.

The leakage current waveforms were analyzed using fast fourier transform and total harmonic distortion (THD). It defined as the total ratio of the harmonics components and the fundamental, or expressed mathematically as below and which has been used (Suwarno, 2006).

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

Thus, the leakage current frequency spectra of the measurement results were obtained. These implementations used the **Danielson-Lanczos** method (Origin Lab Co., 2003).

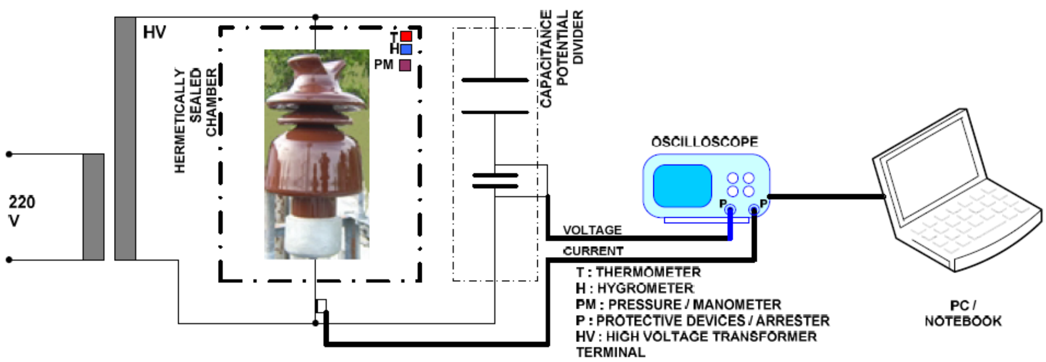

Figure 1. Schematic diagram of experimental setup

Physically, the necessary main tools for experimental researches are shown on Figure 2. The leakage current measurement tools were high voltage equipment (step-up high voltage transformer, resistor, power cable and capacitive voltage divider), a hermetically sealed chamber including controlling and monitoring devices (heater, water evaporator, air cooler, vacuum pump, compressor, temperature indicator, relative humidity (RH) indicator, positive-negative indicator manometer), the porcelain and epoxy resin insulators as equipment under tests, a two channel storage digital oscilloscope, computer and necessary software, suitable cables and wires. For pollutant chemical content and surface observation tests, it was used respectively EDAX and SEM in one instrument.


(a) High voltage equipment


(b) Hermetically sealed chamber and monitoring device


(c) Two channel storage digital oscilloscope and computer


(d) Vacuum pump and compressor


(e) Porcelain insulator sample


(f) Epoxy resin insulator sample


(g) SEM & EDAX instrument

Figure 2. Main experimental equipments

The relations among parameters, whether between leakage current and environmental parameters or their selves, were analyzed use correlation coefficient matrix of multivariate statistical tools. The correlation matrix is derivation of covariance matrix to understand how much level of correlation among parameters base on data. A covariance value is defined as below.

$$Cov(X,Y)=\frac{1}{n}\sum_{j=1}^{n}(x_j-\mu_x)(y_j-\mu_y) \quad \text{..........} \quad (2)$$

Where n is number of data, x_j and y_j are values of data on one and another variables, and μ_x and μ_y are corresponding mean or average of data for one and another variables respectively.

Furthermore, the components of coefficient correlation matrix is defined as below.

$$\rho_{x,y}=\frac{Cov(X,Y)}{\sigma_x.\sigma_y} \quad \text{...........................} \quad (3)$$

Where σ_x and σ_y are variances of data on one and another corresponding variables.

The values of coefficient correlation matrix components are between -1 until 1. If a value close to -1, it represents that one parameter highly influences to another, but it is reciprocal property. Otherwise, if a value close to 1, it represents that one parameter highly influences to another, in proportional property. Finally, if a value closes to zero, it is minor in dependency (Anderson, 1984; Whittaker, 1996).

It was also analyzed using principal component analysis (PCA). PCA shows a scatter plot, which nearness among variables indicate the correlation level one to another variables. If a set of data is presented in matrix X, which X consists of some variables and a number of data, the main algorithm of PCA involves some steps.

Firstly, determine the mean components of matrix X, those related by

$$\bar{x}_l=\frac{1}{n}\sum_{k=1}^{n}x_{1,k} \quad \text{..............................} \quad (4)$$

Furthermore, determine covariance matrix using equation of

$$C = X * X^T \quad \text{...............................} \quad (5)$$

Finally, determine eigen values and eigen vectors of covariance matrix use equation of

$$C\,Q = \lambda\,Q \quad \text{.............................} \quad (6)$$

Where λ are eigen values and Q are eigen vectors. Base on the eigen values, it is plotted their scatters in two dimensions, where the horizontal axis is first principal component and the vertical axis is second principal component. Finally, the nearness of parameters those plotted on PCA indicates the correlation level among parameters [Hannawati, et al, 2004; Mardia et al, 2000].

Using PCA, we can see which parameter influence dominantly each other. PCA describes correlations among parameters or variables statistically base on data. The data can not illustrate the correlations among parameters exactly in 100%. Nevertheless, PCA describes correlations among parameters in majority. By PCA, it is shown the closeness of parameters each other. If two parameters are very close, the first parameter influences significant proportionally to another one. If two parameters opposite very far, the first parameter influences significant reciprocally to another one. If two parameters are far in a same quadrant, it is minor dependency each other. Finally, if a parameter is close to central point of coordinate, it is minor to influence another one.

Based on coefficient correlation matrix and principal component analysis, as multivariate statistic tools, the experimental results were analyzed and discussed regarding the relation with the physical condition.

Beside leakage current measurements and analyses, it was also shown the test results of SEM (scanning electron microscope) for the new-clean porcelain and epoxy resin insulator specimens. Thus, it would be observed the insulator specimen surface conditions. It was also conducted EDAX (Energy Dispersive Analysis of X-rays) tests for both insulator specimens. Thus, it was obtained main chemical elements of insulator specimen surfaces.

RESULT DATA AND ANALYSIS

Actually, there were many data on these experiments, with various humidity, temperature, pressure and applied voltage amplitudes. However, in this manuscript it is revealed some typical waveforms of result data. Generally, the data could be obtained in two forms of file, bitmap drawing and spreadsheet data files.

In this manuscript, it is presented two significant conditions, dry and wet. These are indicated by high and low relative humidities, applied on both new-clean porcelain and epoxy resin insulators.

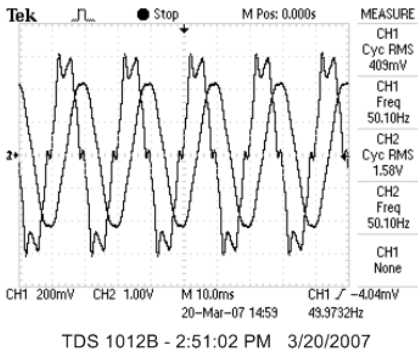

Figure 3. Bitmap form of applied voltage and leakage current waves of dry new-clean porcelain insulator

Figure 3 shows the bitmap drawing of leakage current and applied voltage waveforms of new-clean porcelain insulator. The environmental conditions and applied voltage were 67%, 26.7 centigrade, -0.8 kPa and 9.24 kV for relative humidity, temperature, pressure and maximum applied voltage respectively. This was as sample of dry condition. The pressure was compared to outside of chamber.

Whereas Figure 4 shows applied voltage and leakage current waveforms of Figure 2 condition those have been converted to real values in Excel graphical forms.

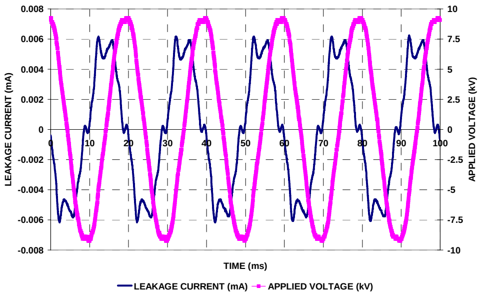

Figure 4. Excel graphical form of applied voltage and leakage current waves of dry new-clean porcelain insulator

On Figure 4, the pure sinusoidal waveform is the applied voltage, that the values are indicated on the right side of graphic. Otherwise, the values on left side indicate the actual leakage current, presented by the non-pure sinusoidal waveform.

The phase difference between leakage current and applied voltage waves was 81.3 degree. This meant that the porcelain insulator in new, clean and dry condition was very capacitive.

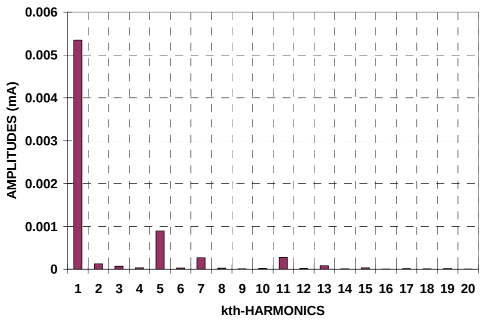

Figure 5. Frequency spectrum of leakage current waveforms of Figure 4

Figure 5 shows the frequency spectrum of the leakage current waveform that shown by Figure 4. In this condition, the amplitude of first (fundamental) to thirteenth odd harmonics were 87.87%, 1.28%, 14.93%, 4.26%, 0.19%, 4.87% and 1.13% compared to the amplitude of leakage current wave respectively. The third harmonic was very low of value compared to the amplitude actual leakage current waveform. As addition, the total harmonic distortion (THD) was 18.6%. The insulator was normal condition, very far from discharge phenomena.

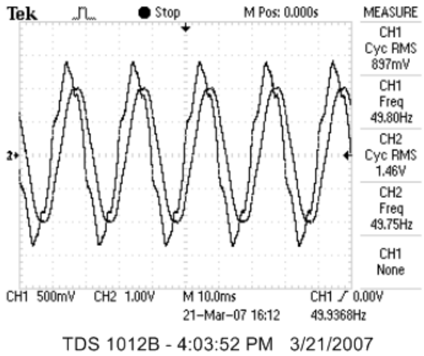

Figure 6. Bitmap form of applied voltage and leakage current waveforms of wet new-clean porcelain insulator

Figure 6 shows the bitmap of leakage current and applied voltage waveforms of new-clean porcelain insulator in 99% of relative humidity, 26.7 centigrade of temperature, no pressure and 8.6 kV maximum applied voltage conditions. Furthermore, it was as typical of wet condition. Whereas, Figure 7 shows the waves in Excel graphical form. The applied voltage is pure sinusoidal waveform, that the magnitude values are mentioned on the right side. Otherwise, the magnitude values of leakage current wave are indicated on the left side.

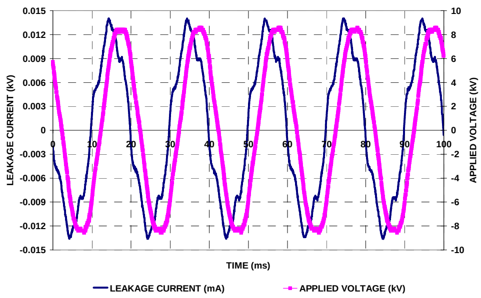

Figure 7. Excel graphical form of applied voltage and leakage current waveforms of wet new-clean porcelain insulator

From above figures, it is shown that the leakage current waveform was different from the previous dry new-clean condition. The peaks of wave become sharper. This indication tent to approach a pure sinusoidal wave. Otherwise, the phase difference between the leakage current and the applied voltage was 46.7 degree and the amplitude of leakage current wave became higher than the dry previous condition. This phenomenon was dominantly caused by wet high relative humidity. Thus, the high relative humidity made the new-clean porcelain insulator became little more resistive, rather than that dry condition. However, the leakage current wave was not up to pure sinusoidal wave, and the wave did not coincide to the applied voltage wave.

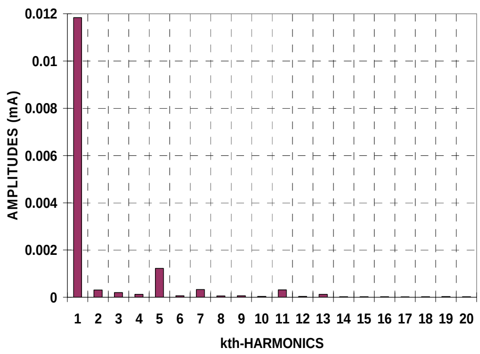

Figure 8. Frequency spectrum of leakage current waveforms of wet new-clean epoxy resin insulator

Figure 8 shows the frequency spectrum of leakage current waveform of Figure 7. On this condition, the maximum first to thirteenth odd harmonics were 85.8%, 1.43%, 8,.84%, 2.39%, 0.43%, 2.26% and 0.89% respectively compared to the maximum magnitude of leakage current wave. Whereas the total harmonic distortion (THD) was 11.2%, lower than that the previous dry condition. This meant that the leakage current wave tends to close a pure sinusoidal wave compared to the previous condition. However, this still worked normally.

Table A, on Appendix, is the list of complete summary experimental result data on the measurements of new-clean porcelain insulator. First to last columns are maximum applied voltage (kV), maximum leakage current (micro ampere), relative humidity (%), temperature (centigrade), pressure (kPA), phase difference between leakage current and applied voltage waves (degree), cosine of phase difference, first to thirteenth odd harmonics (micro ampere), and total harmonic distortion

(THD) respectively. The positive pressure meant that the chamber was compressed, and the negative pressure meant that the chamber was sucked by the electric pumps. Generally, the phase difference between leakage current and applied voltage would reduce as the relative humidity increased. The leakage current amplitude would rise slightly as relative humidity increased. The levels of correlation among parameters are indicated by Table 1.

Based on the correlation matrix Table 1, the leakage current amplitude was influenced by applied voltage amplitude as 0.73. This indicated the leakage current was almost influenced by applied voltage. However, there was (were) other parameter(s) to influence the leakage current magnitude considerably. The main other parameter which influenced to the leakage current was relative humidity. This level of correlation was 0.56. This was significant. Otherwise, the phase difference between leakage current and applied voltage was also dominantly influenced by relative humidity. This correlation level was -0.88, which was very significant. The humidity increased cause the phase angle would reduce. Due to porcelain property, the water droplets of high humidity tended to stick and spread out on the insulator surface. This surface was hydrophilic. Therefore, the insulator performance was highly influenced by relative humidity. On a high humidity, the insulator property tended to be resistive.

Other phenomenon was total harmonic distortion (THD). The correlation level between THD and phase angle was very significant, namely 0.88. THD increased as the phase angle increased too. In other word, the leakage current would far away from pure sinusoidal wave as the phase angle increasesd, or porcelain insulator be capacitive. THD rose to cause be far away from pure sinusoidal wave.

Figure 9 shows the scatter plot of principal component analysis based on the data of Table A on Appendix. It is seen that the humidity close to the power factor (COS_PHA). The power factor would increase as the humidity rised considerably. On the contrary, the phase angle opposites very far from the humidity. This meant that the humidity rised, it would cause phase angle reduce, and vice versa. THD is fairly closed to phase angle, so that THD would increase as phase angle rise, or the porcelain insulator be more capacitive. Figure 10 shows the scree plot of experimental data. It is seen from the plot that to take two main components, the information quality could be extracted was more than 80%, or precisely was 81.4%.

As additional information, it is presented SEM and EDAX of new-clean porcelain insulator specimen. Figure 11 shows test result of SEM on the new-clean porcelain insulator specimen. It is seen that the porcelain surface was smooth, due to glazing. This picture was magnified by 2000 times. Whereas Table 2 shows the test result of EDAX, which indicates the chemical element contents on the insulator surface. The major contents were silicon, aluminium and kalium respectively. These elements were basic elements of porcelain insulator and glazing on insulator surface.

Like as porcelain insulator, there were many data on the new-clean epoxy resin insulator experiments, with various humidity, temperature, pressure and applied voltage amplitudes. However, in this manuscript it is revealed two typical waveforms of result data, wet and dry.

Table 1. The levels of correlation among parameters on the new-clean porcelain insulator

Variable	V_{max}	I_{max}	H	T	P	Θ	COS (Θ)	H1	H3	H5	H7	H9	H11	H13	THD
V_{max}	1.00	0.73	-0.07	-0.06	0.12	0.22	-0.21	0.76	0.59	0.93	0.88	0.39	0.92	0.88	0.44
I_{max}	0.73	1.00	0.56	-0.29	0.14	-0.47	0.47	1.00	0.94	0.92	0.91	0.80	0.74	0.81	-0.26
H	-0.07	0.56	1.00	-0.37	0.10	-0.88	0.87	0.54	0.59	0.24	0.24	0.54	0.00	0.19	-0.83
T	-0.06	-0.29	-0.37	1.00	0.08	0.24	-0.25	-0.28	-0.33	-0.20	-0.22	-0.37	-0.08	-0.09	0.31
P	0.12	0.14	0.10	0.08	1.00	-0.06	0.05	0.15	0.08	0.13	0.16	0.00	0.10	0.15	-0.03
Θ	0.22	-0.47	-0.88	0.24	-0.06	1.00	-1.00	-0.43	-0.55	-0.11	-0.12	-0.60	0.13	-0.05	0.88
COS(Θ)	-0.21	0.47	0.87	-0.25	0.05	-1.00	1.00	0.43	0.56	0.11	0.12	0.61	-0.13	0.05	-0.89
H1	0.76	1.00	0.54	-0.28	0.15	-0.43	0.43	1.00	0.92	0.94	0.92	0.78	0.76	0.83	-0.22
H3	0.59	0.94	0.59	-0.33	0.08	-0.55	0.56	0.92	1.00	0.82	0.81	0.93	0.53	0.62	-0.38
H5	0.93	0.92	0.24	-0.20	0.13	-0.11	0.11	0.94	0.82	1.00	0.98	0.65	0.89	0.89	0.12
H7	0.88	0.91	0.24	-0.22	0.16	-0.12	0.12	0.92	0.81	0.98	1.00	0.67	0.86	0.86	0.08
H9	0.39	0.80	0.54	-0.37	0.00	-0.60	0.61	0.78	0.93	0.65	0.67	1.00	0.36	0.43	-0.49
H11	0.92	0.74	0.00	-0.08	0.10	0.13	-0.13	0.76	0.53	0.89	0.86	0.36	1.00	0.94	0.38
H13	0.88	0.81	0.19	-0.09	0.15	-0.05	0.05	0.83	0.62	0.89	0.86	0.43	0.94	1.00	0.23
THD	0.44	-0.26	-0.83	0.31	-0.03	0.88	-0.89	-0.22	-0.38	0.12	0.08	-0.49	0.38	0.23	1.00

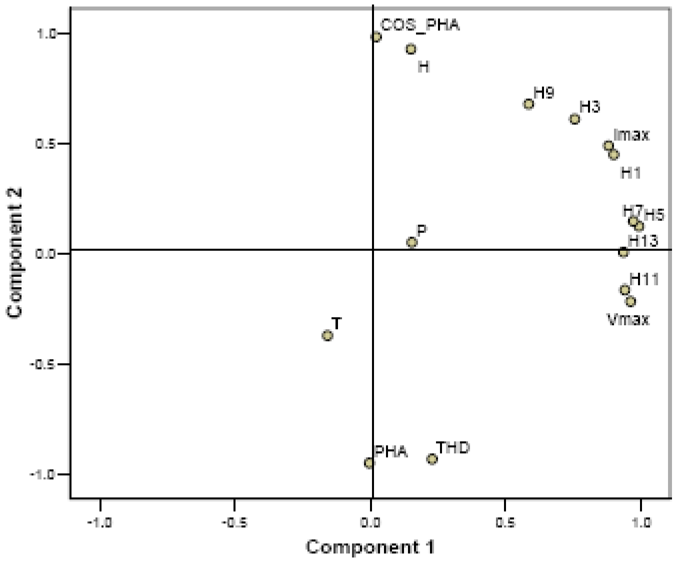

Figure 9. Scatter plot of principal component among parameters on the new-clean porcelain insulator

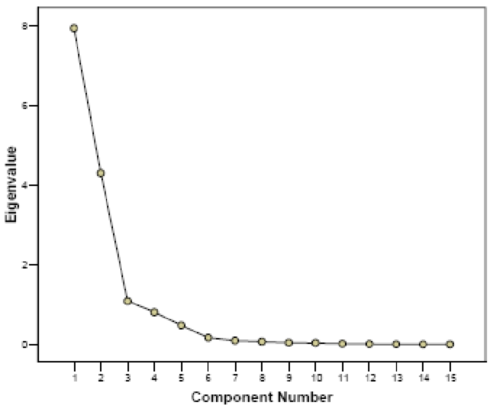

Figure 10. Scree plot of principal component among parameters on the new-clean porcelain insulator

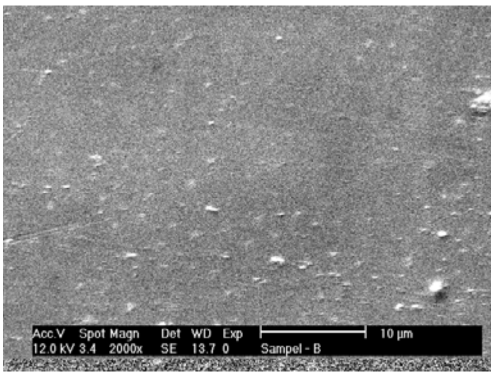

Figure 11. SEM test result of new-clean porcelain insulator specimen

Table 2. Test result of EDAX on the specimen of porcelain surface

No.	Elements	First Test (%)
1	Si	76.32
2	Al	15.02
3	K	8.62

These are indicated by high and low relative humidity respectively. The data could be obtained in two forms of file, bitmap drawing and spreadsheet data files.

Figure 12 shows the bitmap drawing of leakage current and applied voltage waveforms of new-clean epoxy resin insulator. The environmental conditions and applied voltage were 67%, 34.2 centigrade, -2.0 kPa and 13.6 kV for relative humidity, temperature, pressure and maximum applied voltage respectively.

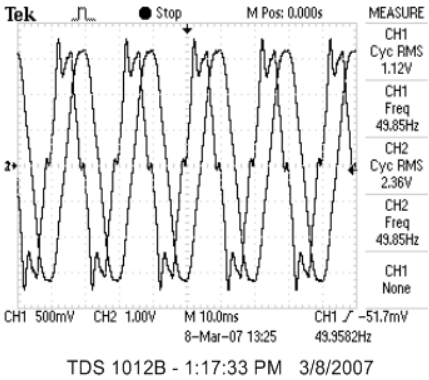

Figure 12. Bitmap form of applied voltage and leakage current waves of dry new-clean epoxy resin insulator

This is as sample of dry new-clean epoxy resin insulator. The pressure was compared to outside normal condition.

Whereas Figure 13 shows applied voltage and leakage current waveforms of Figure 12 condition those have been converted to real values in Excel graphical forms.

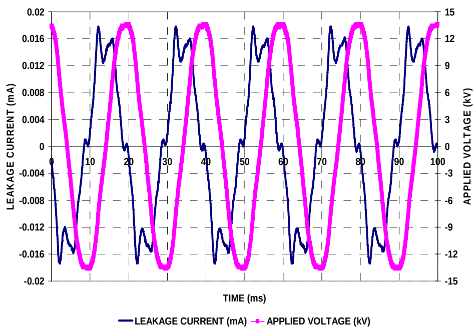

Figure 13. Excel graphical form of applied voltage and leakage current waves of dry new-clean epoxy resin insulator

On Figure 13, the pure sinusoidal waveform is the applied voltage, that the values are indicated on the right side of graphic. Otherwise, the values on left side indicate the actual leakage current, presented by the non-pure sinusoidal waveform.

The phase difference between leakage current and applied voltage waves was 82.8 degree. This mean the epoxy resin insulator in new, clean and dry condition was very capacitive, similar to the porcelain one.

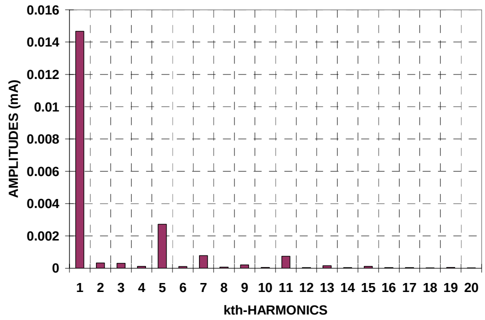

Figure 14. Frequency spectrum of leakage current waveforms of Figure 13

Figure 14 shows the frequency spectrum of leakage current waveform that indicated by Figure 13. In this condition, the amplitude of first (fundamental) to thirteenth odd harmonics were 82.6%, 1.6%, 15.2%, 4.3%, 1.1%, 4.1% and 0.9% compared to the maximum of leakage current wave respectively. The third harmonic was very low of value compared to the maximum actual leakage current waveform. As addition, the total harmonic distortion (THD) was 20%. The insulator was still normal condition, very far from a discharge phenomena.

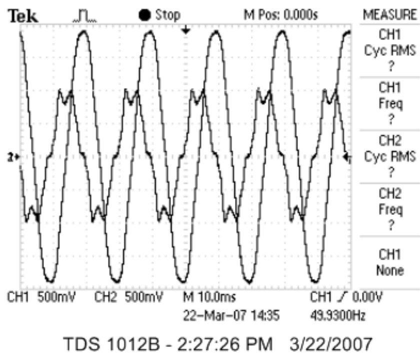

Figure 15. Bitmap form of applied voltage and leakage current waveforms of wet new-clean epoxy resin insulator

Figure 15 shows the bitmap of leakage current and applied voltage waveforms of new-clean epoxy resin insulator on 99% of relative humidity, 28.8 centigrade of temperature, -0.4 kPa of pressure and 8 kV maximum applied voltage conditions. Furthermore it was as typical of wet condition. Whereas, Figure 16 shows the waves in Excel graphical form. The applied voltage is pure sinusoidal waveform, that the magnitude values are mentioned on the right side. Otherwise, the magnitude values of leakage current wave are indicated on the left side.

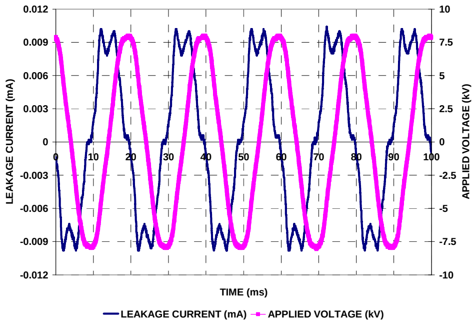

Figure 16. Excel graphical form of applied voltage and leakage current waveforms of wet new-clean epoxy resin insulator

From above figures, it is shown that the leakage current waveform is similar to or nearly same as the previous dry new-clean condition. Otherwise, the phase difference between the leakage current and the applied voltage was 84.7 degree and the amplitude of leakage current wave was similar too. Thus, the high relative humidity did not cause anything different from that dry condition considerably on the new-clean porcelain insulator. This was owned characteristics of new-clean epoxy resin insulator, that water droplets on its surface tent to be hydrophobic condition.

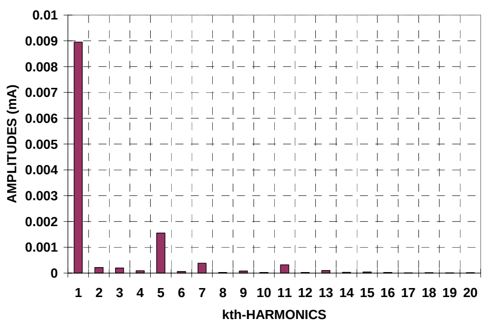

Figure 17. Frequency spectrum of leakage current waveforms of wet new-clean epoxy resin insulator

Figure 17 shows the frequency spectrum of leakage current waveform of Figure 15. On this condition, the maximum first to thirteenth odd harmonics were 87.1%, 1.7%, 14.9%, 3.9%, 0.7%, 3.2% and 1.0% respectively compared to the maximum magnitude of leakage current wave. Whereas the total harmonic distortion (THD) was 18.2%. This worked normally.

Table B, on Appendix, shows the complete summary experimental data on the measurements of new-clean epoxy resin insulator. First to last columns are maximum applied voltage (kV), maximum leakage current (micro ampere), relative humidity (%), temperature (centigrade), pressure (kPA), phase difference between leakage current and applied voltage waves (degree), cosine of phase difference, first to thirteenth odd harmonics (micro ampere), and total harmonic distortion (THD) respectively. The positive pressure meant the chamber was compressed, and the negative pressure meant the chamber was sucked by the electric pumps. Generally, the phase differences between leakage current and applied voltage reduced slightly as relative humidity increased. The levels of correlation among parameters are indicated by Table 3.

Based on the correlation coefficient matrix Table 3, the leakage current amplitude was influenced by applied voltage amplitude almost 100%. Whereas, the phase angle was influenced by leakage current amplitude as -0.75. This was considerable, the phase angle would reduce as the leakage current increased. Thus, the leakage current rose, as consequence of applied voltage, the new-clean epoxy resin would be more resistive. Otherwise, the humidity did not significant to influence leakage current, due to the property of insulator. The water droplets on insulator surface tended to be hydrophobic, so that the water did not spread out.

Other phenomenon was total harmonic distortion (THD). The correlation level between THD and phase angle was very significant, -0.84. THD rised as the phase angle reduced. This opposited with the porcelain one. In other word, the leakage current would far away from pure sinusoidal wave as the phase angle decreased. THD rises, it would be far away from pure sinusoidal wave.

Figure 18 shows the scatter plot of principal component analysis of above data. It seen that THD is close to power factor (COS_PHA) and it opposites with phase angle, nearer -1 than 0. That meant, THD would rise as the phase angle decreased considerably.

Figure 20 shows test result of scanning electron microscope (SEM) on new-clean epoxy resin insulator specimen. It is seen that the epoxy resin surface was rougher than porcelain one, due to its property and silicone coating. This picture is magnified by 2000 times.

Table 3. The levels of correlation among parameters on the new-clean epoxy resin insulator

Variables	V_{max}	I_{max}	H	T	P	θ	COS (θ)	H1	H3	H5	H7	H9	H11	H13	THD
V_{max}	1.00	1.00	-0.40	0.40	-0.22	-0.77	0.77	0.99	0.87	1.00	0.96	0.78	0.95	0.87	0.81
I_{max}	1.00	1.00	-0.37	0.44	-0.25	-0.75	0.75	1.00	0.89	1.00	0.96	0.80	0.95	0.87	0.80
H	-0.40	-0.37	1.00	-0.21	-0.02	0.40	-0.40	-0.36	-0.27	-0.38	-0.34	-0.29	-0.39	-0.18	-0.30
T	0.40	0.44	-0.21	1.00	-0.18	-0.26	0.26	0.46	0.55	0.45	0.30	0.27	0.43	0.23	0.25
P	-0.22	-0.25	-0.02	-0.18	1.00	-0.07	0.07	-0.27	-0.43	-0.23	-0.20	-0.15	-0.18	-0.07	0.05
θ	-0.77	-0.75	0.40	-0.26	-0.07	1.00	-1.00	-0.74	-0.57	-0.77	-0.65	-0.58	-0.84	-0.79	-0.84
COS(θ)	0.77	0.75	-0.40	0.26	0.07	-1.00	1.00	0.74	0.57	0.77	0.65	0.58	0.84	0.79	0.84
H1	0.99	1.00	-0.36	0.46	-0.27	-0.74	0.74	1.00	0.90	1.00	0.95	0.78	0.95	0.86	0.78
H3	0.87	0.89	-0.27	0.55	-0.43	-0.57	0.57	0.90	1.00	0.88	0.85	0.76	0.84	0.70	0.65
H5	1.00	1.00	-0.38	0.45	-0.23	-0.77	0.77	1.00	0.88	1.00	0.95	0.79	0.96	0.87	0.82
H7	0.96	0.96	-0.34	0.30	-0.20	-0.65	0.65	0.95	0.85	0.95	1.00	0.82	0.87	0.83	0.74
H9	0.78	0.80	-0.29	0.27	-0.15	-0.58	0.58	0.78	0.76	0.79	0.82	1.00	0.76	0.69	0.72
H11	0.95	0.95	-0.39	0.43	-0.18	-0.84	0.84	0.95	0.84	0.96	0.87	0.76	1.00	0.92	0.89
H13	0.87	0.87	-0.18	0.23	-0.07	-0.79	0.79	0.86	0.70	0.87	0.83	0.69	0.92	1.00	0.87
THD	0.81	0.80	-0.30	0.25	0.05	-0.84	0.84	0.78	0.65	0.82	0.74	0.72	0.89	0.87	1.00

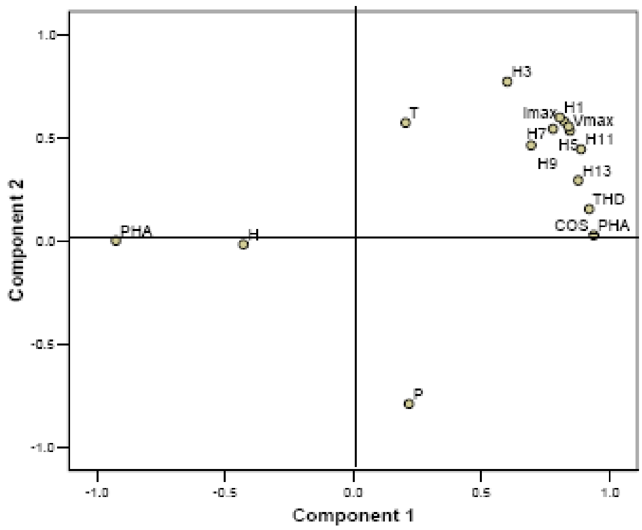

Figure 18. Scatter plot of principal component among parameters on the new-clean epoxy resin insulator

Figure 19 shows the scree plot of experimental data. It is seen from the plot that to take two main components, the information quality can be extracted as more than 80%, or preciselyis 80.1%.

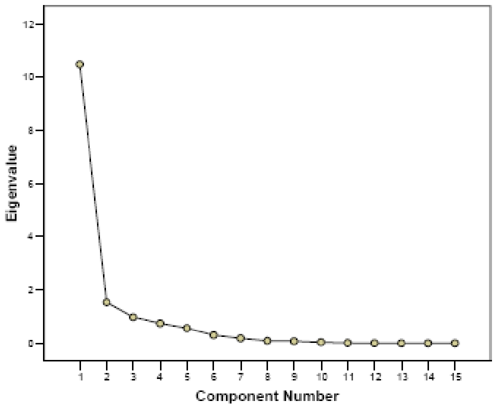

Figure 19. Scree plot of principal component among parameters on the new-clean epoxy resin insulator.

Whereas, Table 4 shows the test result of EDAX on new-clean epoxy resin insulator specimen, that indicated the chemical element contents on the insulator surface. The major contents were silicon, and magnesium respectively. These elements were basic elements of epoxy resin insulator and silicone coating on the surface.

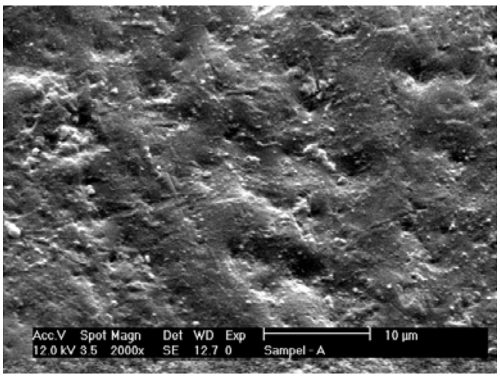

Figure 20. SEM test result of new-clean epoxy resin insulator specimen

Table 4. Test result of EDAX on the specimen of epoxy resin surface

No.	Elements	First Test (%)
1	Si	82.68
2	Mg	17.32

CONCLUSION

The new-clean porcelain and epoxy resin insulators have been examined using leakage current on some environmental conditions. On the porcelain one, the high humidity influenced to power factor or phase angle very significantly. The power factor rose as the humidity increased, with correlation level of 0.87, or the phase angle decreased with correlation level of -0.88. The humidity rose it also caused leakage current magnitude increased with correlation level 0.58. Furthermore, it also reduced THD as much as 0.83 of correlation level.

Otherwise, on the new-clean epoxy resin insulator, the leakage current was mostly influenced by applied voltage. The leakage current amplitude influenced to phase angle by -0.75 of correlation level. This meant, the phase angle reduced as leakage current increased. On other hand, the THD increased as leakage current increased too.

Base on SEM and EDAX, the new-clean epoxy resin insulator surface was rougher than porcelain one. The chemical element of silicon was main chemical elements for both porcelain and epoxy resin surfaces.

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APPENDIX

Table A. The summary of new-clean porcelain insulator experimental result data

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V_{max} (kV)	I_{max} (µA)	H (%)	T (°C)	P (kPA)	Θ (DEG	COS (Θ)	H1 (µA)	H3 (µA)	H5 (µA)	H7 (µA)	H9 (µA)	H11 (µA)	H13 (µA)	THD
8.1	8.2	78	24.5	0.0	74.4	0.27	7.16	0.110	0.914	0.287	0.041	0.205	0.058	0.138
10.2	10.6	79	24.4	0.0	73.4	0.29	9.19	0.144	1.200	0.361	0.062	0.263	0.072	0.141
12.6	13.2	79	24.4	0.0	72.3	0.30	11.34	0.187	1.590	0.466	0.066	0.369	0.112	0.151
14.8	15.6	79	24.3	0.0	70.6	0.33	13.51	0.190	1.960	0.617	0.101	0.567	0.138	0.159
18.1	19.2	79	24.3	0.0	69.8	0.34	16.49	0.235	2.440	0.811	0.108	0.618	0.157	0.161
18.5	22.4	79	24.3	0.0	69.8	0.35	19.41	0.331	2.960	1.050	0.216	0.678	0.170	0.167
25.2	26.0	80	24.2	0.0	70.3	0.34	22.60	0.419	3.580	1.450	0.275	0.703	0.204	0.175
4.5	4.5	79	24.1	0.0	71.9	0.31	3.91	0.073	0.472	0.137	0.020	0.085	0.023	0.129
7.3	10.6	80	24.0	0.0	57.2	0.54	8.75	0.216	1.050	0.324	0.136	0.206	0.069	0.131
1.7	1.6	79	24.0	0.0	73.2	0.29	1.46	0.036	0.159	0.049	0.006	0.022	0.008	0.118
8.6	8.6	74	24.4	0.0	74.0	0.28	7.37	0.098	1.040	0.337	0.039	0.353	0.108	0.157
8.6	8.2	71	25.6	0.0	75.0	0.26	7.17	0.094	0.995	0.339	0.054	0.367	0.113	0.157
6.9	10.2	87	26.8	0.0	53.4	0.60	8.43	0.159	1.040	0.273	0.060	0.172	0.074	0.131
6.9	10.2	88	26.6	0.0	54.5	0.58	8.17	0.143	1.010	0.234	0.062	0.164	0.058	0.130
8.6	14.0	97	26.5	0.0	46.7	0.69	11.85	0.202	1.220	0.312	0.072	0.289	0.117	0.111
8.6	13.8	99	26.7	0.0	46.7	0.69	11.84	0.197	1.220	0.330	0.059	0.312	0.124	0.112
7.4	10.6	85	23.7	0.0	57.3	0.54	8.85	0.192	1.080	0.328	0.103	0.205	0.083	0.132
7.3	10.6	84	23.9	0.0	57.1	0.54	8.75	0.216	1.050	0.324	0.136	0.206	0.069	0.131
7.3	11.0	81	24.7	0.0	56.2	0.56	9.06	0.216	1.080	0.351	0.146	0.227	0.068	0.131
7.3	10.2	80	25.3	0.0	57.9	0.53	8.51	0.170	1.050	0.311	0.107	0.214	0.072	0.133
7.2	10.0	79	25.6	0.2	58.6	0.52	8.25	0.181	0.978	0.279	0.120	0.198	0.054	0.128
7.3	9.8	78	25.8	0.2	59.8	0.50	8.08	0.144	1.010	0.324	0.086	0.216	0.075	0.136
7.3	9.6	77	26.5	0.2	60.1	0.50	7.96	0.128	1.020	0.356	0.052	0.216	0.077	0.140
7.3	9.6	76	26.8	0.2	60.5	0.49	7.91	0.112	1.010	0.309	0.060	0.216	0.077	0.138
7.2	9.4	75	27.3	0.2	60.6	0.49	7.74	0.162	0.966	0.216	0.100	0.212	0.059	0.133
7.2	9.2	74	27.8	0.2	60.2	0.50	7.63	0.142	0.944	0.326	0.079	0.211	0.066	0.136
7.2	9.2	73	28.1	0.0	60.6	0.49	7.50	0.162	0.941	0.304	0.095	0.206	0.060	0.137
7.3	8.8	73	28.3	-0.4	61.3	0.48	7.24	0.150	0.927	0.302	0.092	0.211	0.061	0.140
7.3	8.6	73	28.1	-0.8	64.7	0.43	7.10	0.151	0.907	0.282	0.104	0.213	0.059	0.140
7.2	8.4	74	27.4	-1.2	64.8	0.43	6.91	0.140	0.908	0.296	0.093	0.215	0.064	0.144
7.3	8.2	74	27.0	-1.4	65.4	0.42	6.84	0.138	0.903	0.296	0.091	0.207	0.062	0.144
7.3	8.2	75	26.6	-1.8	66.4	0.40	6.74	0.143	0.907	0.262	0.101	0.212	0.056	0.146
7.2	8.2	75	26.5	-1.6	66.2	0.40	6.77	0.140	0.909	0.282	0.091	0.196	0.063	0.146
7.3	8.0	75	26.3	-2.0	67.1	0.39	6.59	0.138	0.899	0.258	0.098	0.222	0.057	0.148
7.2	7.8	74	26.0	-2.4	68.5	0.37	6.51	0.134	0.861	0.242	0.089	0.212	0.058	0.144
7.3	8.0	74	25.9	-2.2	69.8	0.34	6.60	0.141	0.894	0.227	0.085	0.215	0.060	0.146
7.3	7.8	75	25.7	-2.8	70.0	0.34	6.47	0.145	0.865	0.209	0.100	0.192	0.052	0.144
7.4	7.8	75	25.6	-2.6	70.1	0.34	6.49	0.144	0.882	0.218	0.096	0.207	0.056	0.146
7.4	7.6	75	25.5	-3.4	71.4	0.32	6.36	0.139	0.871	0.215	0.089	0.203	0.061	0.147
7.3	7.4	75	25.3	-3.8	71.8	0.31	6.19	0.130	0.864	0.236	0.070	0.193	0.057	0.150
7.3	7.6	76	25.2	-3.0	73.3	0.29	6.26	0.132	0.877	0.235	0.074	0.203	0.060	0.151
7.3	7.8	72	26.9	-1.0	70.2	0.34	6.49	0.137	0.894	0.223	0.083	0.213	0.066	0.148
7.3	7.8	70	28.6	-0.4	70.6	0.33	6.49	0.133	0.903	0.223	0.086	0.210	0.064	0.149
7.4	8.0	69	29.6	0.0	70.4	0.34	6.52	0.138	0.875	0.185	0.097	0.195	0.045	0.143
9.2	6.1	68	26.7	3.0	80.8	0.16	5.34	0.076	0.898	0.257	0.008	0.260	0.074	0.183
9.2	6.1	68	26.8	2.2	80.6	0.16	5.34	0.076	0.894	0.247	0.009	0.270	0.075	0.182
9.2	6.1	68	26.7	1.8	81.4	0.15	5.34	0.076	0.899	0.254	0.008	0.267	0.077	0.183
9.2	6.1	68	26.6	1.4	80.1	0.17	5.35	0.075	0.912	0.272	0.011	0.293	0.070	0.187
9.2	6.1	68	26.6	1.0	79.9	0.18	5.34	0.074	0.915	0.270	0.004	0.314	0.071	0.189
9.2	6.1	67	26.6	0.6	80.8	0.16	5.35	0.077	0.912	0.266	0.011	0.287	0.068	0.187
9.2	6.1	67	26.6	0.4	80.3	0.17	5.35	0.076	0.907	0.264	0.015	0.283	0.074	0.185
9.2	6.1	67	26.6	0.2	80.3	0.17	5.34	0.069	0.883	0.268	0.014	0.274	0.080	0.181
9.2	6.1	67	26.7	0.0	80.5	0.17	5.35	0.071	0.896	0.269	0.012	0.278	0.084	0.184
9.2	6.1	67	26.7	-0.2	79.8	0.18	5.34	0.072	0.895	0.272	0.013	0.297	0.080	0.185
9.2	6.1	67	26.7	-0.6	80.5	0.17	5.35	0.076	0.883	0.268	0.015	0.289	0.078	0.182
9.2	6.1	67	26.7	-0.4	80.1	0.17	5.36	0.084	0.913	0.260	0.013	0.287	0.063	0.186
9.2	6.1	67	26.7	-1.0	80.1	0.17	5.35	0.079	0.905	0.260	0.011	0.297	0.071	0.186
9.2	6.1	67	26.7	-0.8	81.3	0.15	5.36	0.078	0.911	0.260	0.012	0.297	0.069	0.186
9.4	6.3	67	26.7	-1.4	79.9	0.18	5.43	0.084	0.940	0.242	0.012	0.294	0.067	0.188
9.4	6.2	67	26.7	-1.2	79.2	0.19	5.43	0.081	0.948	0.237	0.001	0.282	0.066	0.188
9.2	6.2	67	26.7	-1.8	79.4	0.18	5.43	0.083	0.947	0.240	0.004	0.269	0.074	0.188
9.2	6.1	67	26.7	-1.6	79.6	0.18	5.41	0.073	0.909	0.233	0.014	0.258	0.077	0.181
9.2	6.2	67	26.7	-2.2	80.6	0.16	5.43	0.079	0.938	0.241	0.010	0.288	0.075	0.187
9.2	6.2	67	26.7	-2.6	80.6	0.16	5.42	0.078	0.948	0.244	0.003	0.311	0.076	0.191
9.4	6.2	67	26.6	-3.0	79.4	0.18	5.43	0.081	0.944	0.232	0.007	0.294	0.069	0.188
9.2	6.2	67	26.7	-3.8	79.8	0.18	5.42	0.078	0.931	0.260	0.008	0.288	0.081	0.187
9.2	6.2	67	26.7	-4.2	80.3	0.17	5.41	0.078	0.917	0.248	0.006	0.287	0.080	0.185
9.2	6.2	66	26.7	-3.0	79.6	0.18	5.40	0.076	0.924	0.253	0.010	0.269	0.082	0.186
9.4	6.2	67	28.5	-1.2	80.5	0.17	5.42	0.080	0.927	0.235	0.013	0.247	0.079	0.183
9.2	6.2	67	30.0	-0.8	80.5	0.17	5.42	0.080	0.914	0.252	0.004	0.277	0.089	0.183
9.2	6.2	67	32.1	0.0	79.8	0.18	5.42	0.079	0.906	0.251	0.006	0.274	0.087	0.182
9.4	6.2	67	34.1	0.0	80.5	0.17	5.42	0.078	0.908	0.257	0.004	0.272	0.081	0.182
9.4	6.3	67	36.1	0.0	80.1	0.17	5.44	0.086	0.919	0.240	0.006	0.245	0.073	0.181
9.4	6.3	67	38.0	0.0	80.1	0.17	5.45	0.080	0.925	0.249	0.002	0.286	0.076	0.184
9.2	6.3	68	40.0	0.0	79.7	0.18	5.44	0.082	0.922	0.261	0.006	0.272	0.078	0.184
1.6	1.1	67	26.4	0	86.6	0.06	0.96	0.027	0.147	0.033	0.003	0.022	0.009	0.162
5.5	3.6	67	26.4	0	83.5	0.11	3.26	0.057	0.543	0.133	0.005	0.102	0.031	0.175
8.6	5.8	67	26.4	0	83.2	0.12	5.05	0.090	0.874	0.230	0.016	0.170	0.056	0.183
11.3	7.4	67	26.4	0	85.7	0.08	6.66	0.164	1.120	0.307	0.039	0.168	0.057	0.178
13.8	9.8	67	26.3	0	81.9	0.14	8.19	0.173	1.520	0.443	0.113	0.393	0.117	0.201
16.0	11.6	67	26.3	0	80.2	0.17	9.57	0.186	1.820	0.514	0.106	0.431	0.140	0.204
18.1	12.8	67	26.3	0	84.5	0.10	10.85	0.215	1.990	0.566	0.081	0.374	0.104	0.195

Table B. The summary of new-clean epoxy resin insulator experimental result data

V_{max} (kV)	I_{max} (μA)	H (%)	T (°C)	P (kPA)	θ (DEG)	COS (θ)	H1 (μA)	H3 (μA)	H5 (μA)	H7 (μA)	H9 (μA)	H11 (μA)	H13 (μA)	THD
13.8	18.2	70	44.5	0.0	83.0	0.12	15.12	0.284	2.98	0.800	0.162	0.712	0.147	0.211
13.8	18.0	69	43.2	-0.4	81.4	0.15	15.10	0.272	2.95	0.759	0.182	0.751	0.153	0.209
13.6	18.2	69	41.7	-0.8	82.6	0.13	15.02	0.251	2.86	0.740	0.162	0.702	0.145	0.203
13.6	17.8	67	40.5	-1.0	83.2	0.12	14.98	0.262	2.82	0.760	0.157	0.679	0.154	0.201
13.8	17.8	67	39.2	-1.2	81.1	0.16	15.03	0.235	2.82	0.660	0.069	0.677	0.136	0.199
13.8	18.0	67	38.2	-1.4	81.2	0.15	14.95	0.262	2.89	0.763	0.156	0.781	0.150	0.208
13.6	18.2	67	36.4	-1.6	81.6	0.15	14.89	0.316	2.85	0.753	0.170	0.662	0.122	0.204
13.6	17.8	67	35.0	-1.8	83.0	0.12	14.75	0.298	2.78	0.783	0.221	0.740	0.146	0.204
13.6	17.8	67	34.2	-2.0	82.8	0.13	14.70	0.281	2.71	0.770	0.198	0.725	0.152	0.200
13.6	17.8	67	33.6	-2.2	84.1	0.10	14.67	0.304	2.72	0.783	0.203	0.738	0.159	0.201
13.6	17.8	67	33.0	-2.4	83.5	0.11	14.62	0.289	2.74	0.806	0.189	0.724	0.155	0.203
13.6	18.2	67	32.6	-2.6	82.6	0.13	14.62	0.335	2.77	0.806	0.253	0.759	0.155	0.206
13.6	17.8	67	32.0	-2.8	81.9	0.14	14.55	0.315	2.80	0.841	0.233	0.764	0.160	0.210
13.6	17.6	67	31.5	-3.0	80.0	0.17	14.51	0.328	2.78	0.785	0.231	0.694	0.144	0.207
13.6	17.8	67	31.1	-3.2	82.7	0.13	14.45	0.300	2.77	0.860	0.051	0.749	0.174	0.209
13.6	17.4	67	30.8	-3.4	84.6	0.09	14.41	0.290	2.67	0.827	0.208	0.714	0.164	0.202
13.8	17.8	68	30.5	-3.6	80.8	0.16	14.60	0.279	2.81	0.743	0.190	0.721	0.155	0.207
13.9	17.6	68	30.2	-3.8	81.2	0.15	14.53	0.289	2.83	0.594	0.117	0.883	0.163	0.209
13.8	17.8	68	29.8	-4.0	83.7	0.11	14.59	0.313	2.79	0.768	0.198	0.791	0.132	0.207
16.1	20.4	68	26.0	0.0	79.6	0.18	16.57	0.299	3.28	0.987	0.167	0.943	0.241	0.216
16.1	20.0	68	25.4	-4.2	79.4	0.18	16.65	0.230	3.19	0.811	0.089	0.916	0.228	0.206
12.1	15.2	68	25.8	-2.6	81.0	0.16	12.37	0.247	2.44	0.716	0.143	0.754	0.164	0.216
7.4	8.6	68	25.9	-2.0	87.6	0.04	7.51	0.197	1.29	0.328	0.035	0.198	0.067	0.181
7.4	9.0	68	25.9	-2.6	82.6	0.13	7.55	0.163	1.32	0.308	0.016	0.237	0.075	0.184
4.0	4.5	68	25.8	-1.6	87.2	0.05	3.96	0.058	0.60	0.084	0.013	0.094	0.040	0.156
4.0	4.5	68	25.7	-2.6	88.7	0.02	3.96	0.094	0.63	0.121	0.049	0.117	0.025	0.166
2.8	3.1	68	25.7	-1.6	89.8	0.00	2.74	0.080	0.38	0.076	0.039	0.066	0.017	0.146
16.1	20.8	68	25.8	-0.6	78.6	0.20	16.73	0.273	3.35	0.966	0.166	1.090	0.272	0.220
25.5	33.2	68	25.6	-0.2	80.3	0.17	26.73	0.410	5.33	2.090	0.369	1.160	0.278	0.220
8.7	10.8	68	23.3	0.0	86.3	0.07	8.58	0.088	1.64	0.390	0.086	0.436	0.130	0.204
8.6	10.2	68	23.4	0.6	82.4	0.13	8.56	0.139	1.56	0.389	0.102	0.345	0.089	0.193
8.6	10.2	68	23.5	1.0	84.0	0.11	8.57	0.137	1.55	0.399	0.108	0.366	0.098	0.193
8.4	10.2	68	23.5	1.4	83.0	0.12	8.49	0.140	1.54	0.418	0.117	0.377	0.097	0.195
8.4	10.2	68	23.6	1.8	82.8	0.13	8.53	0.127	1.59	0.430	0.120	0.373	0.118	0.200
8.6	10.2	69	23.6	2.2	82.4	0.13	8.53	0.123	1.60	0.433	0.126	0.391	0.119	0.201
8.4	10.2	69	23.8	2.6	83.7	0.11	8.51	0.124	1.57	0.401	0.110	0.392	0.094	0.197
8.6	10.2	68	23.8	3.0	82.8	0.13	8.54	0.123	1.57	0.407	0.113	0.393	0.099	0.197
8.6	10.4	68	24.1	3.4	80.8	0.16	8.56	0.120	1.59	0.383	0.115	0.418	0.097	0.198
8.6	10.2	68	24.0	3.8	81.0	0.16	8.61	0.103	1.60	0.379	0.089	0.392	0.120	0.197
8.6	10.2	68	24.1	4.2	83.2	0.12	8.60	0.101	1.57	0.376	0.094	0.374	0.117	0.194
8.6	10.4	68	24.1	4.6	84.3	0.10	8.63	0.100	1.62	0.394	0.089	0.384	0.116	0.199
13.6	16.4	68	28.3	0.2	81.5	0.15	13.67	0.215	2.63	0.718	0.047	0.710	0.157	0.207
13.6	16.4	69	27.3	0.4	81.4	0.15	13.61	0.263	2.67	0.731	0.127	0.779	0.181	0.213
13.7	17.0	69	30.2	0.8	81.8	0.14	13.82	0.301	2.75	0.818	0.200	0.718	0.119	0.216
13.6	16.8	70	32.4	0.6	78.6	0.20	14.11	0.205	2.75	0.729	0.021	0.767	0.144	0.210
13.6	17.2	70	33.5	0.6	80.2	0.17	14.24	0.257	2.86	0.703	0.170	0.869	0.172	0.217
13.6	17.6	70	35.0	0.6	80.7	0.16	14.61	0.272	2.92	0.674	0.126	0.837	0.172	0.214
13.8	18.0	69	36.5	0.4	80.4	0.17	14.93	0.275	2.99	0.724	0.168	0.798	0.160	0.214
13.8	18.2	69	38.1	0.0	81.2	0.15	14.88	0.280	2.96	0.673	0.168	0.874	0.178	0.214
13.8	18.0	69	39.2	0.0	79.9	0.18	15.14	0.276	2.96	0.655	0.151	0.907	0.181	0.210
13.8	18.2	69	40.0	0.0	80.1	0.17	15.08	0.273	2.95	0.656	0.146	0.879	0.189	0.210
13.8	17.8	69	41.5	0.0	79.8	0.18	15.02	0.274	2.96	0.674	0.126	0.869	0.200	0.212
13.9	18.2	70	43.0	0.0	77.4	0.22	15.04	0.279	2.96	0.632	0.116	0.925	0.191	0.212
13.8	18.2	70	45.0	0.0	82.1	0.14	15.14	0.291	2.97	0.763	0.157	0.777	0.158	0.210
7.3	8.4	67	29.2	0.0	84.1	0.10	7.50	0.166	1.12	0.297	0.034	0.245	0.067	0.160
6.2	7.0	68	26.9	0.0	88.9	0.02	6.54	0.162	1.01	0.287	0.030	0.155	0.045	0.164
6.3	7.1	67	27.3	0.2	88.9	0.02	6.57	0.153	1.04	0.292	0.026	0.171	0.046	0.168
6.3	7.1	67	30.8	0.8	89.8	0.00	6.51	0.134	1.04	0.289	0.021	0.169	0.043	0.169
6.2	7.2	68	35.3	0.4	89.5	0.01	6.62	0.167	1.06	0.280	0.033	0.156	0.035	0.169
6.3	7.2	68	38.1	0.2	88.0	0.03	6.69	0.146	1.06	0.296	0.030	0.172	0.052	0.168
6.3	7.3	68	40.3	0.0	88.2	0.03	6.75	0.147	1.04	0.288	0.025	0.160	0.046	0.163
9.7	12.0	69	23.9	0.0	85.5	0.08	10.49	0.190	1.62	0.534	0.039	0.327	0.104	0.167
7.1	9.6	67	35.0	0.0	84.6	0.09	7.98	0.190	1.39	0.354	0.105	0.360	0.097	0.188
7.8	9.8	97	31.2	0.4	86.4	0.06	8.70	0.189	1.45	0.375	0.074	0.298	0.087	0.177
7.9	10.2	87	30.7	0.2	85.9	0.07	8.78	0.205	1.47	0.414	0.080	0.358	0.093	0.181
8.0	10.2	74	30.5	0.0	86.7	0.06	8.86	0.210	1.51	0.376	0.077	0.316	0.089	0.181
8.0	10.2	72	30.5	0.0	83.7	0.11	8.87	0.203	1.51	0.392	0.082	0.359	0.085	0.182
8.0	10.2	70	30.4	0.0	84.7	0.09	8.86	0.196	1.55	0.407	0.069	0.364	0.102	0.187
8.0	10.2	68	30.3	0.0	83.9	0.11	8.88	0.197	1.54	0.398	0.083	0.344	0.102	0.185
7.7	9.8	93	29.4	0.0	86.7	0.06	8.58	0.200	1.37	0.286	0.079	0.243	0.085	0.168
7.8	9.8	87	29.2	0.0	85.9	0.07	8.72	0.161	1.46	0.343	0.054	0.307	0.096	0.177
8.0	10.0	88	29.1	0.0	84.9	0.09	8.84	0.154	1.48	0.372	0.046	0.315	0.101	0.178
8.0	10.2	94	29.1	0.0	88.7	0.02	8.86	0.180	1.50	0.359	0.077	0.325	0.086	0.180
8.0	10.2	98	29.0	0.0	86.3	0.07	8.86	0.174	1.49	0.395	0.069	0.335	0.104	0.180
8.0	10.2	99	28.9	0.0	85.0	0.09	8.88	0.177	1.52	0.395	0.080	0.341	0.104	0.183
8.0	10.2	99	28.8	-0.4	84.7	0.09	8.88	0.178	1.52	0.399	0.074	0.330	0.104	0.182
8.0	10.2	99	28.7	-0.2	86.5	0.06	8.88	0.178	1.52	0.400	0.073	0.333	0.105	0.183
8.0	10.0	99	28.6	-0.8	86.6	0.06	8.86	0.183	1.52	0.382	0.066	0.303	0.113	0.182
8.0	10.2	99	28.6	-0.6	87.7	0.04	8.87	0.167	1.51	0.401	0.068	0.324	0.117	0.182
8.0	10.2	99	28.5	-1.2	86.9	0.05	8.89	0.180	1.52	0.379	0.078	0.320	0.098	0.182
8.1	10.4	99	28.5	-1.0	85.1	0.09	8.95	0.194	1.55	0.380	0.076	0.318	0.100	0.184
8.1	10.4	98	28.3	-2.1	85.0	0.09	8.99	0.200	1.56	0.375	0.093	0.291	0.094	0.183
8.1	10.4	98	28.3	-1.4	85.8	0.07	8.95	0.171	1.54	0.389	0.077	0.337	0.105	0.183
8.1	10.6	94	28.1	-2.4	84.6	0.09	8.96	0.175	1.57	0.403	0.083	0.352	0.099	0.187
8.1	10.4	94	28.1	-2.0	86.4	0.06	8.95	0.166	1.60	0.427	0.092	0.354	0.121	0.191
8.1	10.2	93	28.0	-2.8	87.0	0.05	8.96	0.167	1.56	0.391	0.079	0.340	0.110	0.185
8.1	10.4	90	27.9	-3.4	86.0	0.07	8.97	0.169	1.58	0.385	0.082	0.352	0.111	0.187
8.1	10.4	90	27.9	-3.0	85.5	0.08	8.93	0.172	1.56	0.416	0.071	0.366	0.105	0.187
8.1	10.6	87	27.8	-4.2	87.5	0.04	8.95	0.183	1.59	0.421	0.093	0.372	0.106	0.190
8.1	10.4	86	27.7	-4.0	87.1	0.05	8.92	0.175	1.56	0.411	0.075	0.328	0.114	0.186
8.4	10.8	98	27.9	0.0	83.4	0.12	8.95	0.194	1.62	0.454	0.120	0.483	0.130	0.198
8.4	10.6	89	27.9	1.0	82.8	0.13	8.65	0.189	1.60	0.479	0.121	0.466	0.147	0.203
8.4	10.6	87	27.9	0.8	84.8	0.09	8.63	0.185	1.60	0.472	0.127	0.459	0.142	0.203
8.5	10.4	87	27.8	0.4	83.9	0.11	8.61	0.181	1.60	0.459	0.104	0.420	0.147	0.202
8.6	10.6	87	27.8	1.8	84.6	0.09	8.65	0.184	1.58	0.459	0.103	0.470	0.128	0.200
8.6	10.4	87	27.8	1.4	83.7	0.11	8.64	0.166	1.57	0.458	0.087	0.473	0.148	0.199
8.6	10.4	87	27.8	2.6	83.0	0.12	8.62	0.174	1.58	0.430	0.110	0.444	0.123	0.199
8.6	10.4	87	27.8	2.2	84.1	0.10	8.59	0.166	1.57	0.462	0.095	0.459	0.140	0.200
8.6	10.6	83	27.7	3.4	83.7	0.11	8.58	0.156	1.59	0.456	0.106	0.469	0.143	0.202
8.6	10.2	81	27.7	3.0	83.4	0.12	8.57	0.149	1.58	0.458	0.097	0.442	0.153	0.201
8.6	10.2	78	27.6	4.2	85.2	0.08	8.54	0.154	1.57	0.453	0.080	0.432	0.135	0.200
8.6	10.4	77	27.6	3.8	84.6	0.09	8.57	0.159	1.57	0.455	0.102	0.433	0.139	0.199