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"I hereby declare that I have read through this report entitle "Study On Tracking Performance For Pollution Insulators By Using Salt Fog Test" and found that it has comply the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Industrial Power)"

Signature :…………………………………………..

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

Supervisor Name :…………………………………………..

Date :…………………………………………..

STUDY ON TRACKING PERFORMANCE FOR POLLUTION INSULATORS BY USING SALT FOG TEST

MUHAMMAD SHAFFIQ IZWAN BIN ABDUL AZIZ

A thesis submitted in fulfillment of the requirement for the Bachelor in Electrical Engineering (Industrial Power)

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2014 / 2015

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Signature :

Name : Muhammad Shaffiq Izwan Bin Abdul Aziz

Date :

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To My Beloved Parent (Ibu & Ayah)

From Love With Love To Loved

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ABSTRACT

The pollution flashover performance of insulators is generally tested by the steam fog method. However, environmental temperature in tests differs greatly, so the dispensability of test results is high. Moreover, the influence of fog-water conductivity has been taken into recorded. Compared with the steam fog method, the cold-fog method simulating natural fog is more consistent with the actual operating conditions of transmission line insulators. This deals with the influence of salt deposit density (SDD) and fog-water conductivity on pollution flashover performance. The contaminant level is consideration of the ratio water with salt. The influence of the two factors is determined by analyzing the results of laboratory experiments where polluted insulators were tested by using the salt cold-fog method. The results show that the 50% AC pollution flashover voltage (U50) decreases as SDD and fog-water conductivity increase. The correction coefficient indicating the influence of fog-water conductivity on U50 can be expressed as an exponential function. *This is the technique for figuring out the condition of ageing occurs among the insulators on line or predicts their remaining life span has yet to be proposed. In addition, a study on diagnosis and monitoring of aged glass insulators is found lacking.* At the end, leakage current flow has been recorded. *The findings in this research suggest that under wet insulator surface condition of the transmission line glass insulator leakage current are good indicator of ageing. Furthermore this technique can be applied for online monitoring and diagnosing ageing transmission line glass insulator and it is very useful to the utility supplier.*

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ABSTRAK

Pencemaran prestasi sah penebat umumnya diuji dengan kaedah kabus wap. Walau bagaimanapun, suhu alam sekitar dalam ujian sangat berbeza, jadi kebarangkalian terhadap keputusan ujian adalah tinggi. Selain itu, pengaruh kekonduksian kabus air telah diambil direkodkan. Berbanding dengan kaedah kabus wap, kaedah sejuk kabus simulasi kabus semula jadi adalah lebih persis dengan keadaan operasi sebenar penebat talian penghantaran. Ini berkaitan dengan pengaruh kepadatan deposit garam (KDG) dan kekonduksian kabus air kepada prestasi pencemaran arka. Tahap pencemaran adalah pertimbangan air nisbah dengan garam. Pengaruh kedua-dua faktor ditentukan dengan menganalisis keputusan uji kaji makmal di mana penebat tercemar telah diuji dengan menggunakan garam kaedah sejuk kabus. Hasil kajian menunjukkan bahawa 50% AC flashover pencemaran voltan (U50) berkurangan apabila KDG dan kabus air peningkatan kekonduksian. Pekali pembetulan menunjukkan pengaruh kekonduksian kabus air di (U50) boleh dinyatakan sebagai fungsi eksponen. Ini adalah teknik untuk memikirkan keadaan penuaan berlaku antara penebat pada baris atau meramalkan jangka hayat mereka masih belum dicadangkan. Di samping itu, kajian mengenai diagnosis dan pemantauan penebat kaca berumur adalah didapati kurang. Pada akhirnya, aliran arus bocor telah direkodkan. Penemuan dalam kajian ini menunjukkan bahawa di bawah keadaan permukaan penebat basah daripada talian penghantaran kebocoran kaca penebat semasa adalah penunjuk yang baik penuaan. Tambahan pula teknik ini boleh digunakan untuk memantau talian dan mendiagnosis penuaan talian penghantaran kaca penebat dan sangat berguna kepada pembekal untuk aktiviti penyelenggaraan.

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LIST OF ABREVIATIONS

AC	-	Alternating Current
AEC	-	Artificial Environmental Chamber
C	-	Capacitor
cm	-	centimetre
CT	-	Current Transformer
DAQ	-	data acquisition device
DC	-	Direct Current
EPDM	-	Ethylene Propylene Diene Monomer
EPR	-	Ethylene Propylene Rubber
ESDD	-	Equivalent Salt Deposit Density
FOV	-	Flashover Voltage
FFT	-	Fast fourier transform
Hz	-	Hertz
IEC	-	International Electrotechnical Commision
kg	-	kilogram
kS/s	-	kilosamples per second
kV	-	kilovolts
LabVIEW	-	Laboratory Virtual Instrumentation Engineering Workbench
LC	-	Leakage Current

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LV	-	Low Voltage
m^3	-	cubic metre
mA	-	miliampere
ml	-	mililitre
mm	-	milimetre
min	-	minute
NSDD	-	Non-soluble Salt Deposit Density
PC	-	Personal Computer
R	-	Resistor
Rad	-	Radian
RH	-	Relative Humidity
rms	-	root- mean- square
SIR	-	Silicone Rubber
THD	-	Total Harmonic Distortion
TNB	-	Tenaga Nasional Berhad
V_z	-	Zener voltage

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CHAPTER 1

INTRODUCTION

1.1 Project Background

At present, by using salt fog method, the contamination of flashover performance of insulator can be tested. The test leads to a rather big difference between the temperature of the real environment and the high temperature of the test environment (more than 25°C). Moreover, the salt fog conductivity has influenced the test method. The real environment temperature is below 12°C (<12°C) when it is sprayed [1]. Fog-water conductivity is differs depending on the district, the season and environmental contamination. For example, fog-water conductivity is as high in seriously polluted districts, in suburbs, and in outer suburban districts [2]. Therefore compared with the traditional salt-fog method, the suitable method can be use for the research of the contamination flashover performance of insulators and fog-water conductivity is a fresh-fog method. It is more suitable for specific reasons.

Mainly, fog-water conductivity can be done into consideration of ratio water and salt. Because of that, the use of the cold-fog method can provide more reason references for the design and selection of the external insulators. After that, it is easier to make the temperature of the test similar to the temperature of the real environment. This influence makes the test of environment more consistent with real operating conditions. The contamination flashover of insulators is a complicated process with that process. The contamination of performance flashover voltage (PFV) can be influenced by numerous factors. The additional of salt deposit density (SDD) into the method has been referred in

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papers, and the results show that flashover performance is increases with the decreased the salt density [3]–[7]. It can be expressed by refer to the power function. The influence of non-soluble deposit density (NSDD) into the method also been studied [8]-[10]. For this additional, the result show that the flashover performance is increases with the decreased the non-soluble density. It is also can be expressed by the power function.

Scholars have discovered that the non-uniform contamination distribution between the top and bottom surfaces of insulators has great impact on the PFV. This finding has been studied further in papers [11][12]. The results show that the PFV increases with the increase of non-uniform contamination distribution degree. The influence of atmospheric pressure on PFV has been studied in papers, and the results indicate that PFV decreases with the decrease of atmospheric pressure, which can be expressed by a power function[13]–[18]. The research results of papers show that PFV decreases by 0.7–1.0% when the environmental temperature increases by 1°C within the range, from 5°C to 35°C [19][20]. The influence of contaminating ingredients on PFV has been analysed in papers, and the results of these studies indicate that under the same SDD, PFV varies with different contaminating ingredients [21]–[23]. The influence of acid rain on PFV has also been studied in papers [24][25], and the results show that PFV decreases with the increase of acidity. There are many other factors influencing PFV, such as the profile of the insulators, the materials, the arrangement of the insulators, string length and the environmental parameters [26]-[28]. It can be seen that several factors influencing PFV have been studied. However, the previous studies barely touched on the flashover performance of polluted insulators in cold fog and the influence of fog-water conductivity on the flashover performance of polluted insulators.

This paper attempts to address the said issue. The influence of SDD and fog-water conductivity on the AC contamination flashover performance of typical porcelain, glass and composite insulators under cold foggy conditions will be studied in this paper. The contamination flashover performance will be analysed under different fog-water conductivity conditions. The correction coefficient indicating the influence of fog-water conductivity on U50 will be proposed. The steam-fog method and the cold-fog method will be analysed and compared. This paper is expected to provide a basis for the selection and design of the external insulation of transmission lines.

1.2 Project Motivation

Many studies have been done to examine the effect of ceramic insulator design under various conditions of wetting. For example, in desert conditions, open profile or aerodynamic designs have been found to perform well when compared to designs having ribs [1]. On the other hand in salt fog conditions, a bell shape design or designs having deep ribs on the underside of the insulator, example of fog type insulators, perform better in coastal areas than open designs. The shed spacing to diameter ratio, shed inclination angle, and protected creepage distance are the various design parameters that have been studied and shown to be important in insulator performance [2,3].

The measurement of flashover voltage and the distribution of pollution density have been used to study the various aspects of insulator design in ceramic insulators [2]. With non-ceramic insulators, less attention has been given to weather shed design. Most of the research has concentrated on the material composition rather than on the design of the weather sheds. As a result, it is not yet entirely clear if insulator design affects the long-time performance of polymer insulators. Research conducted (by Ontario Hydrc) in clean fog concluded that insulator design has a negligible effect on insulator flashover [4]. However, it is believed that when insulators are contaminated and cleaned under natural conditions, their performance will be dependent on weather shed design. On the other hand, the research done at NGK indicated that alternating shed designs showed better contamination performance than straight sheds [5]. Znaidi studied the effect of weather shed design on accumulation of contamination for both ceramic and non-ceramic insulators in actual field and laboratory conditions [6].

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Non-ceramic insulators with open profiles (low slope) accumulated more pollution on the topside than on the bottom side. Also insulators with small shed diameters have been found to keep more pollution on their surfaces than insulators with longer shed diameters. The self-cleaning factor was effectively improved for insulators with large shed spacing but their cores were generally more polluted. Finally, insulators with alternate shed diameter showed better performance for both desert and coastal conditions than with straight shed design [6]. Gorur *et al.* [7] studied the effect of polymer insulator profile on the erosion and tracking performance in salt-fog. It was found that insulators with protected profiles maintained their initial surface hydrophobic for a much longer time than other designs. Also, the leakage current was much less for the protected profiles than for un-protected profiles.

Chemey and Stonkus studied the effect of the form factor (L/A where L is the leakage distance and A is the surface area) on the performance of polymer insulators [8].

The leakage current decreased with an increase in the form factor. Measurement of flashover voltage [4], distribution of pollution density [5,6], and leakage current [7,8] have been used to study the effect of insulator design in polymer insulators. Leakage current, during various types of tests, has been measured and analyzed by various researchers. It has been observed that by studying the various components of the leakage current more information on specific characteristics can be obtained. Suds studied the leakage current harmonic components for ceramic insulators in clean-fog. [9]. He noticed that the likelihood of flashover became higher when the peak leakage current and the magnitude of odd-order harmonic components exceeded a particular level. Karady *et al.* [10] also studied the correlation of the harmonic content of the leakage current to flashover in clean fog. The FFT analysis of the leakage current showed that the harmonic content increased suddenly before flashover. Fernando and Gubanski conducted a detailed leakage current analysis on non-ceramic insulators in clean fog [11-14]. The measured leakage currents were found deformed from sinusoidal shape. However, the measured levels were much lower than the level of leakage current that precede flashover. These deformed waveforms contained a significant third and fifth harmonic components and their content increased with the applied voltage.

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1.3 Problem Statement

A lot of research has been done on the electrical properties of high voltage insulation materials. Usually, there are two types of test can be conducted, the standard test used for product test and non-standard test for research work. On previous studies, the test has been conveyed to determine the dielectric strength of different type of polymer materials where, the breakdown tests are conducted for the analysis of the dielectric strength, performance of polymeric insulation material properties. Nowadays, this high voltage testing is going to be used to determine the voltage breakdown of the material using different shapes of electrode and analyze the characteristic of electrical breakdown. Since this experiment generates high voltages, compulsory handling steps and safety precaution need to be taken when handling the equipment. The safety precautions cover the laboratory safety, equipment, safety and user safety. Therefore, the standard test procedure accordingly to international standard is vital to be complied and must follow to get reliable results. And it's also referring to the British Standard Institution. Selection guide for polymeric materials for outdoor use under HV stress. PD IEC/TR 62039.2007 [6]. The minimum dielectric strength to be fulfilled for outdoor high voltage polymeric insulation shall not be less than 10kV/mm. In order to do testing on the dielectric strength of the polymer insulation, the international standard BS EN 60243-1:1998 is used. [7].

1.4 Objective of Study

The main objective of this project is:

1) To investigate the void around the insulator
2) To investigate the leakage current around the insulator
3) To analyze the condition of insulator when adjusted conductivity and maintain the HV or maintain the conductivity and adjusted HV.

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1.5 Scope of Study

The experiment has focused on the testing for flashover occurs among insulator when salt fog has been given. The specification of testing has followed the specification from ISO 9227 and ASTM B117. The insulator use is glass type LXY-160 and the contaminant is set by light, medium and heavy weight. The insulator has tested inside the chamber where the chamber is setup by referring standardize from ASTM B117.

CHAPTER 2

LITERATURE REVIEW

2.1 Review of Previous Related Works

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From the previous related research about salt fog test stated about the parameter and characteristic of salt fog test example of research of Farouk A. M. Rizk in April 1985 with research title Influence of AC Source Parameters on Flashover Characteristics of Polluted Insulators. This paper stated about systematic experimental investigation into the influence of AC test source parameters on the leakage current pulses, voltage fluctuations and flashover voltages of polluted insulators. The test techniques include both salt-and clean-fog methods, while the test insulators comprise long-rod and cap and pin strings of different lengths as well as support columns. Whenever possible the tests results are compared with the predictions of computer modeling of the phenomena involved.

Second of related research from Prof. Muhammad Amin and Dr. Mohammad Akhbar in 2006 with title Effect of UV Radiation, Temperature And Salt Fog On Polymeric Insulators. This research explained about the aging and estimate of useful life of polymer insulators installed in field is a major concern nowadays. In order, to find the extent of aging and useful life of polymer insulators, different laboratory methods are employed. This paper also analyzes the degradation caused by UV radiation, temperature, salt fog, electric stress and humidity; by exposing the HTV silicone rubber insulators to these parameters in laboratory. After these experiments, the samples were analyzed with material testing techniques and were visually observed to locate any noticeable change. Other than that, this paper also stated the polymeric insulators are gaining acceptability all over the world rapidly because of their advantages over ceramics. This paper is an effort towards introduction of polymeric insulators in Pakistan. In it, the behavior of polymeric insulators under the effect of UV radiation, temperature, electric stress and humidity with specific reference to Pakistani environment was observed and analyzed.

The last related works taken from A. H. El-Hag in 2001 with title research a Design Parameters of Weather sheds That Affect The Ageing of Polymer Insulators In Salt-Fog. This research mention the results of a study in which the third harmonic ti-equency component of leakage current is used to study various design parameters of weather sheds that affect the ageing of polymer insulators in salt-fog. Salt-fog was applied to model insulators for 120 hours at two different conductivity levels, i.e. 1000 pS/cm and 2000 pS/cm as an aging test. The effect of the number of sheds and shed inclination angle on the aging performance of polymer insulators was studied. Model insulators having 2-Sheds showed better performance than 4-Sheds. Also, the shed inclination angle improved the performance of the insulators in salt-fog.

2.2 Testing equipment

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The apparatus for testing consists of a closed testing chamber, where a salted is atom which is by means of a nozzle. This produces a corrosive environment of dense saline fog in the chamber so that parts exposed in it are subjected to severely corrosive conditions. Typical volumes of these chambers are because of the smallest volume accepted by International Standards (IEEE Standard) on Salt Spray Tests. Other than qualification of this chamber come from ASTM-B-117, ISO 9227 and now discontinued DIN 50021. It has been found very difficult to attain constancy of corrosively in different exposure regions within the test chambers, for sizes below 400 liters. Chambers are available from sizes as small as 4.3 cubic feet (120 L) up to 2,058 cubic feet (58,300 L). Most common machines range from 15 to 160 cubic feet (420–4,530 L).

Test has been performed with standardize of 5% solution of NaCl (Natrium Cloride) are known as NSS (neutral salt spray). Results are represented generally as testing hours in NSS without appearance of corrosion products (e.g. 720 h in NSS according to ISO 9227). Other solutions are acetic acid (ASS test) and acetic acid with copper chloride (CASS test), each one chosen for the evaluation of decorative coatings, such as electroplated copper-nickel-chromium, electroplated copper-nickel or anodized aluminum.

Some sources do not recommend to use ASS or CASS test cabinets interchangeably for NSS tests, as it is claimed that a thorough cleaning of the cabinet after ASS or CASS test is very difficult. ASTM does not address this issue, but ISO 9227 does not recommend it and if it is to be done, advocates a thorough cleaning.

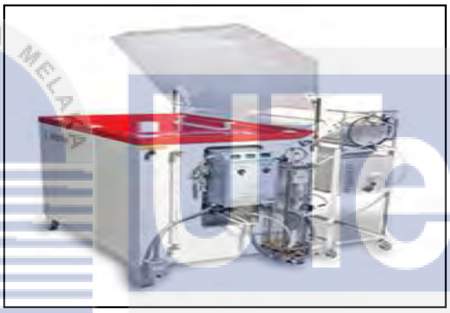

Figure 2.1 : Example of salt fog tested chamber[29]

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2.3 Standardization

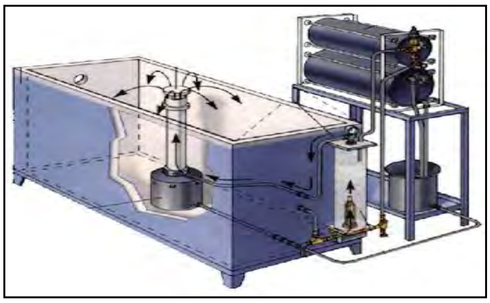

Figure 2.2 : Standardization of salt fog test chamber

The standard of chamber construction, testing procedure and testing parameters are standardized under national and international standards, such as ISO 9227 and ASTM B 117. These standards are describe the necessary information to carry out this test, example of testing parameters such as temperature, air pressure of the sprayed solution, preparation of the spraying solution, concentration, pH, and other else. Daily checking of testing parameters is necessary to show compliance with the standards, so records shall be maintained according the standard requirement. The standard requirement is produce by ISO 9227 and ASTM B 117 and it is widely used as reference standards.

Figure 2.3 : Corrosion in metal after Salt Fog Tested

Testing cabinets are manufactured according to the specified requirements here. However, these testing standards neither provide information of testing periods for the coatings to be evaluated, nor the appearance of corrosion products in form of salts. Requirements shall be agreed between customer and manufacturer. In the automotive industry requirements are specified under material specifications. Different coatings have different behavior in salt spray test and consequently, test duration will differ from one type of coating to another. For example, a typical electroplated zinc and yellow passivated steel part lasts 96 hours in salt spray test without white rust. Electroplated zinc-nickel steel parts can last more than 720 hours in NSS test without red rust (or 48 hours in CASS test without red rust) Requirements are established in test duration (hours) and coatings shall comply with minimum testing periods.

Artificial seawater which is used for Salt Spray Testing can be found at ASTM International. The standard for Artificial Seawater is ASTM D1141-98 which is the standard practice for the preparation of substitute ocean water.

2.4 Specifications

Salt spray tested chamber is referring the standard from ISO 9227 and ASTM B 117 for the specification in term of performance and parameter used. The some specification state in that standard are:

1. Temperature range Adjustable from ambient to +50°C/+122°F
2. Salt spray fall-out rates Adjustable from 0.5 to 2.5 ml per 80 cm2 per hour
3. Wetting mode (Premium chambers only) Adjustable from ambient to +50°C/+122°F
4. Drying mode (Premium chambers only) Adjustable from ambient to +50°C/+122°F
5. Cyclic corrosion test chamber performance
6. Wetting mode Temperature range Adjustable from ambient to +60°C/+140°F Humidity range Fixed at 95% - 100%
7. Salt spray mode Temperature range Adjustable from ambient to +50°C/+122°F Salt spray fall-out rates Adjustable from 0.5 to 2.5 ml per 80 cm2 per hour
8. Drying mode Temperature range Adjustable from ambient to +70°C/+158°F

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CHAPTER 3

METHODOLOGY

3.1 Test facilities and samples

The experiments were carried out in an artificial fog chamber (4.0 × 3.7 × 4.0 m) in the High Voltage Laboratory of Universiti Teknikal Malaysia Melaka (UTeM). The main power supply, consisting of a shifting coil voltage regulator (TDJY-1000 kVA/10 kV) and a test transformer (YDJ-900 kVA/150 kV) with the rated current of 6 A, the maximum short-circuit current of over 30 A, and the rated voltage of 150 kV, meets the requirements for the power source stipulated by the IEC Standards 60507 [29] and GB/T4585–2004 [30]. The applied voltage is recorded by an AC capacitive voltage divider (SGB-200 A, the divider ratio is 10000:1).

The leakage current is recorded by two serial non-inductive resistances, with the 50 Ω non-inductive resistance corresponding to the smaller leakage current, and the 2 Ω non-inductive resistance corresponding to the larger leakage current. The data acquisition system with sampling frequency of 5 kHz is composed of a personal computer, an NIUSB-6215 data acquisition card and Lab view Software. The samples are the porcelain insulator strings of seven units of XP-160, glass insulator strings of seven units of LXY4-160 and a composite insulator (FXBW4-35/70). The main dimensions and parameters of these insulators are shown in Table 3.1, and their configurations are shown in Figure 3.1, 3.2, 3.3.

3.2 Test method

3.2.1 Experimental Setup

The samples were polluted by the solid layer method, with sodium chloride of purity 99.5% simulating the soluble material, kieselguhr simulating the inert material and the ratio of SDD:NSDD was 1:6. Sodium chloride and kieselguhr were measured with a BT 224S electronic scale, and the measured deviation was ± 0.1 mg. Before contamination, all samples were carefully cleaned so that all the traces of dirt and grease were removed. The samples were then dried naturally. The surfaces of the composite insulators were coated with a very thin layer of dry kieselguhr to hinder hydrophobic it which would be at the degree of WC4 or WC5. Since the layer of kieselguhr was very thin, the effect of the kieselguhr on the NSDD could be neglected. In one hour after the aforementioned preparation, the solid layer method was applied to the contamination layer of the samples.

After 24 hours of natural drying, all the samples were suspended vertically in the chamber. The pressure in the artificial climate chamber was kept at 98.6 kPa, the ambient temperature at 10±2°C and the relative humidity (RH) was 100%. The atmospheric parameters were measured with the PTH200 (Pressure Temperature Humidity) measuring instrument, and the measured deviations of temperature, RH and pressure were ± 0.2°C, ± 1% RH and ± 0.03 kPa, respectively. The fog was produced by four ultrasonic fog generators. The fog water with different conductivities was prepared in deionising water by adding some sodium chloride. The fog-water conductivity was setup before the fogging inside the chamber given.

Table 3.1 : Type and characteristic of material used[32]

	Type	Material	h/mm	D/d/mm	L/mm	A/cm²	Contaminant (mS)
A	LXY-160	Glass	155	280	380	2098	5-14
B	LXY-160	Glass	155	280	380	2098	14-40
C	LXY-160	Glass	155	280	380	2098	40-112

The table shown where *h* is the dry arcing distance; *D* and d are the big and small disc diameter, respectively; *L* is the leakage distance; *A* is the surface area.

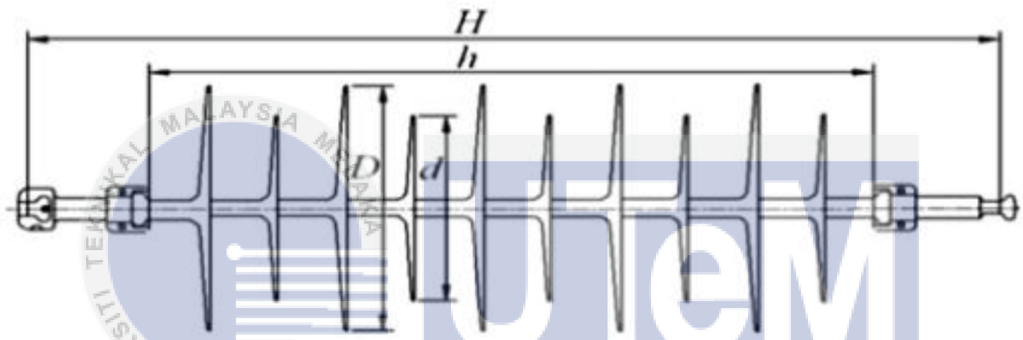

Figure 3.1 : Configuration of sample type A (SIR) [29]

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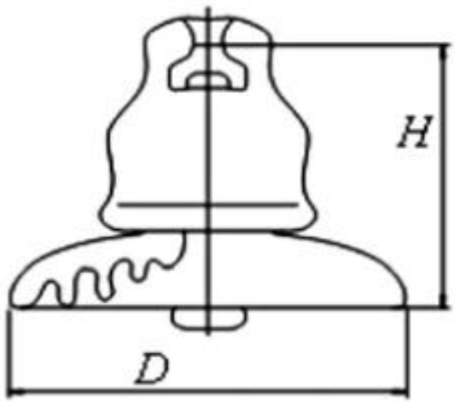

Figure 3.2 : Configuration of sample type B (Porcelain) [29]

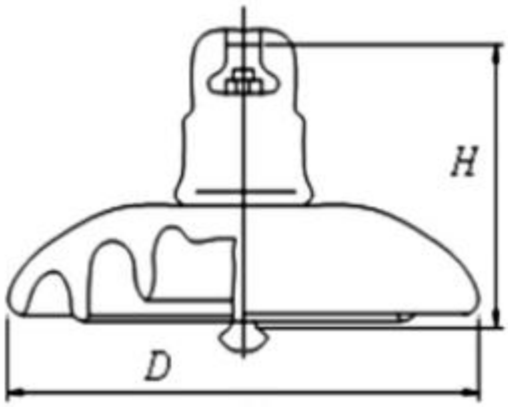

Figure 3.3 : Configuration of sample type C (Glass) [29]

Conductivity meter and the measured deviation was ± 1 µs/cm. The values of fog-water conductivity were translated to values of conductivity at 20°C. In order to distribute the fog evenly, four ultrasonic fog generators were placed at the four corners of the artificial fog chamber. Lastly, fog particles, with a diameter of 1–10 µm, were generated. The U50 of all the samples were obtained by adopting the up-and-down voltage method [29][30].

The main assumption in this method is that if the sample flashovers in the preceding test, the value of the applied voltage decreases by approximately 5% of the expected U50; and if the sample withstands in the preceding test, the value of the applied voltage increases by approximately 5% of the expected U50. Each test, ends when the flashover occurs; if no flashover occurs in 30 min, the applied test voltage would be maintained until the leakage current of the insulators' surface is reduced to about 70% of the peak value of the leakage current.

All samples in this study were subjected to at least ten valid individual tests at a specified degree of contamination. The value of U50 and the relative standard deviation (σ%) were calculated by analysing the results of the ten valid tests. The formulas used are the following

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$$U_{50} = \frac{\sum_{i=1}^{N} U_i}{N}$$

$$\sigma\% = \sqrt{\frac{\sum_{i=1}^{N} (U_i - U_{50})^2}{N-1}} \times \frac{100\%}{U_{50}} \quad \text{............(3.1)}$$

where U50 is the 50% AC PFV, kV; N is the total times of the valid test, N = 10; *Ui* is the PFV for the *ith* (current) test, kV; σ(%) is the relative standard deviation of the test data.

3.2.2 Salt fog test technique

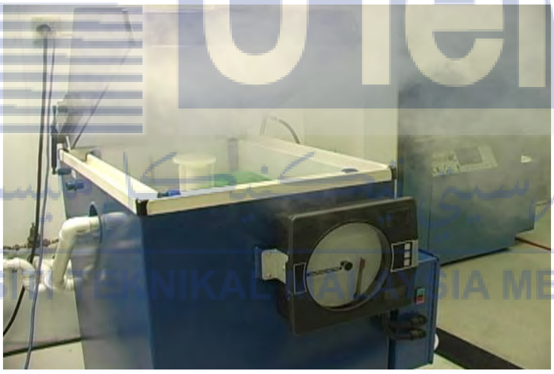

Figure 3.4 : Salt fog on the chamber [29]

Figure 3.5 presents a conventional test source while Figure 3.6 displays a simplified equivalent circuit of the source and test insulator. The 60 Hz test source consisted of a 4.8/200 kV, 1 MVA transformer having a short circuit impedance of 5.2% fed from a 1 MVA, 4.8 kV voltage regulator. For tests with a predominantly inductive source with reduced short-circuit current, air-cored reactors or an auxiliary transformer with short-circuited secondary were installed in series with the low voltage winding of the test transformer.

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A predominantly resistive source was achieved by connecting high ohmic resistors in series with the high voltage lead of the test transformer. A source with increased equivalent capacitance was realised, when needed, by loading the test transformer with one or two series connected 7.2 nF, 350 kV condensers, or a 6 nF, 200 kV capacitor. The test voltage was measured using a 200 pF, 200 kV damped capacitive divider while the current was measured by a 10 SI low inductance coaxial shunt. The voltage and current were recorded using a 10 bit programmable digitizer type Tektronix 390 AD. Furthermore the leakage current pulses were analysed statistically using a micro-processor-controlled analyser described elsewhere [3] and harmonic analyses of the pulse waveform was also conducted. The no-load test voltage wave-form was checked for all the sources involved to ensure that the peak to rms ratio lay within the range VW t 5% [4]. The salt fog tests were performed basically according to IEC Publication 507 [1], while the dust deposit clean fog tests were carried out as described in a recent IEEE Working Group paper [5].

However, two modes of voltage application were used which are referred to below as modes A and B. Mode A consisted of a conventional constant voltage test repeated according to the up-and-down method with constant voltage step in the range of 2.5 - 5 kV according to the nominal test voltage. Usually a test series consisted of 8 – 12 tests. Mode B, proposed to us by P.J. Lambeth [6], was used only with some salt-fog tests and while somewhat more complex, was much less time consuming. It basically consisted of a constant voltage application at 90% of the expected flashover voltage for 20 minutes, followed by 3-5 kV step increases of voltage of I minute duration until flashover. The stepped voltage procedure was repeated four times, each time starting at 90% of the preceding flashover voltage. The lowest value of the 4 flashover voltages was then treated as a more precise estimate for the flashover voltage. The voltage was then adjusted to 90% of that value and increased in voltage steps of 2.5% every 5 minutes until flashover occurred.

The test was repeated 12 times and the mean flashover voltage was calculated. In tests to investigate the effect of any of the supply parameters the same mode of voltage application was used throughout.

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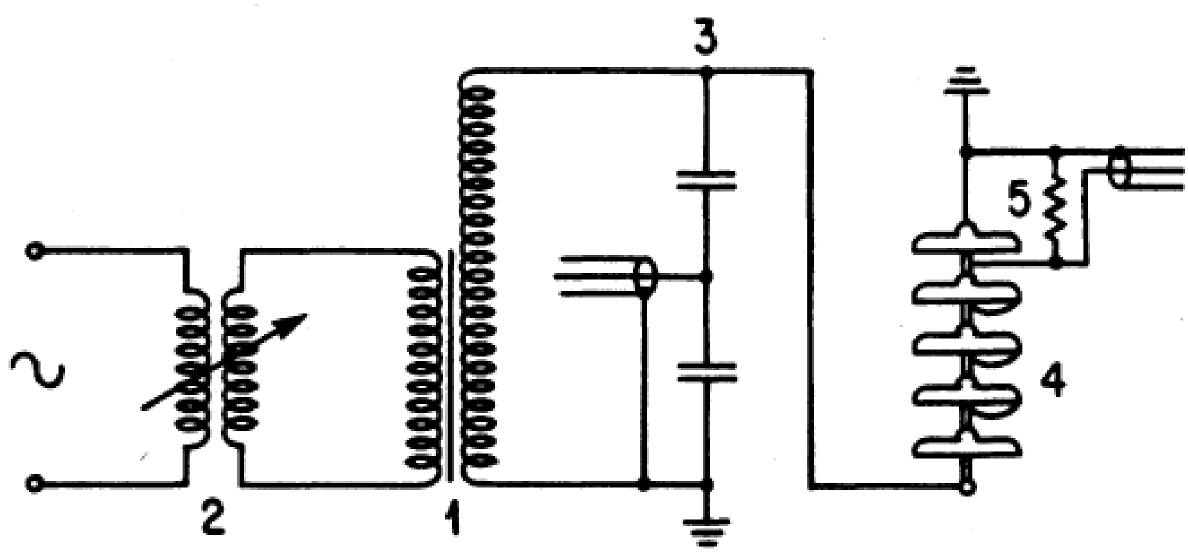

Figure 3.5 : Conventional of test circuit [29]

The circuit shown some has divided onto 5 part which is that part is :

1. Test transformer
2. Voltage regulator
3. Capacitive divide
4. Test string
5. Measuring shunt

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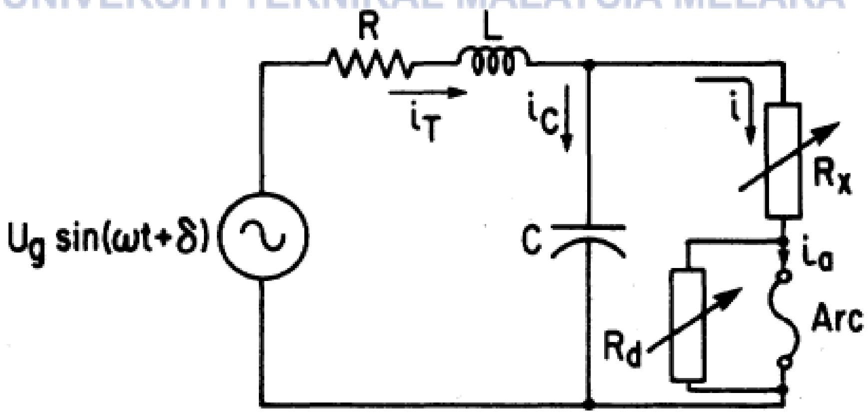

Figure 3.6 : Simplified of equivalent of conventional of test circuit [29]

The test insulators comprised suspension cap and pin, long rod and supporting column types. The suspension strings consisted of 5, 10 and 15 IEEE porcelain discs having 25.4 cm diameter, 14.6 cm unit spacing and 30.5 cm leakage distance. The long rod insulator consisted of a fibre glass core with 19 synthetic weather sheds. The insulator working length amounted to 84 cm, the leakage path 173 cm and the outer shed diameter 9.2 cm. Finally the insulator column consisted of one or two supports each having a working length of 77 cm, a leakage path of 204 cm and 18 sheds with an overall diameter of 18 cm.

3.2.3 Measuring Unit Box

In this research, the most common method of measuring LC is applied. Resistor is connected in series with the test object between its low voltage terminal and ground. The voltage across the resistor is proportional to the measured LC.

One of the apparatus in this experiment is a measuring box which acquires the LC flowing along the surface of the glass insulator. The fundamental design concept of LC measurement system hardware is truthful reflection of the basic features of LC, effective, protective for measurement system by using multiple layer of protective circuit to ensure the safety of measurement system. The protection unit as shown in is develop to prevent the entire acquisition system from over voltage sand over currents. A 50mA fuse connected in series with an insulator. There are two layer in the protection circuit of over voltages. The initial layer is a gas discharge tube that reduces any over voltage to 320V. The next layer, is zener diode with V_z = 10 V install to cut off any voltages that surpass the maximum voltage could across through data acquisition (DAQ) card. The maximum voltage allow across the DAQ system is 10V. The resistor for measuring LC is a 1k Ω placed after the protection layer. The schematic diagram in the measuring box is illustrated as in Figure 3.7 the physical of the measuring box as in Figure 3.8

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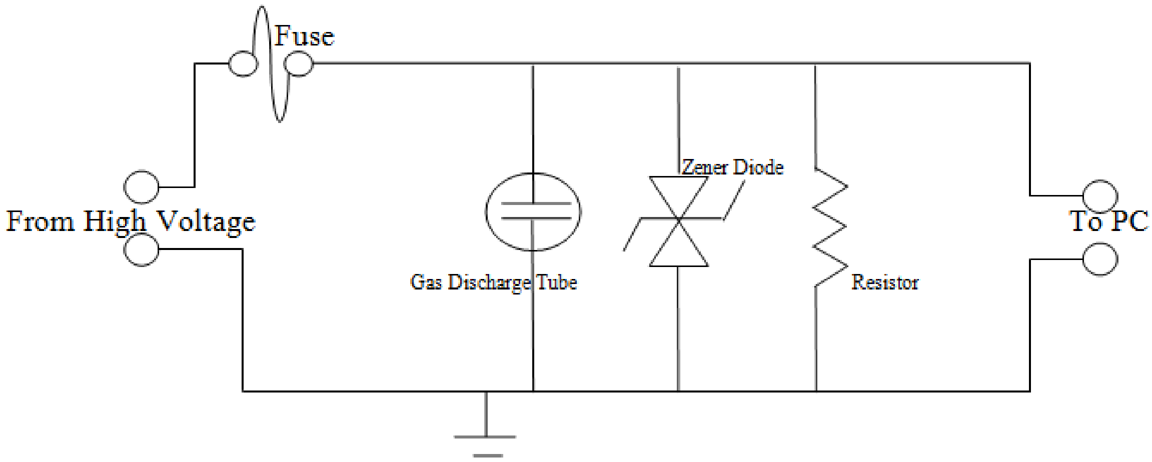

Figure 3.7 : Schematic Diagram Inside Measuring Box [32]

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Figure 3.8 : Measuring Unit Box [32]

3.3 Safety Procedure

In the high voltage lab, safety is most important before and after working in high voltage lab. This chapter will cover generally on testing setup. Safety is one of the most important requirements in a high voltage laboratory. The following procedures and regulations are intended to reduce the risk of injury to persons and damage to material during work in the laboratories.

3.3.1 Laboratory Procedures

The test area has to be equipped with an adequate security circuit the test area should be enclosed by a metal grid fence of at least 1.8 meters height with a maximum grid spacing of 50mm. all doors leading to the test room must be equipped with door contact, which close when the door is closed. All contacts should be connected in series to the interlock system provided by the control unit OT 276. This safety system will automatically turn of the high voltage if a door is opened while the test system is switched on. Red and green warning light should be installed at all door leading to the test room.

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3.3.2 Interlock System

All the door leading to the test room must be equipped with door contact which closed when the door is closed. All contacts should be connected in series to the interlock system. This safety system will automatically turn off the high voltages if door is opened while the test system is switch on. The indicator red and green warning light should be installed at the all doors leading to the test room.

3.3.3 User Safety

When using the lab high voltage, the rules below must be consider.

a) No student are allowed to work in the Laboratory in the absence of either the Lecturers or the Technician.

b) No student should be allowed to change the connection of the generator without the supervision of the lecturer or the technician.

c) Don't work alone - in the event of an emergency another person's presence may be essential.

d) Wear rubber bottom shoes or sneakers. An insulated floor is better than metal or bare concrete but this may be outside of your control. A rubber mat should be an acceptable substitute but a carpet, not matter how thick, may not be a particularly good insulator.

e) Set up our work area away from possible grounds that you may accidentally contact

f) Have a fire extinguisher rated for electrical fires readily accessible in a location that won't get blocked should something burst into flames.

g) Connect/disconnect any test leads with the equipment unpowered and unplugged. Use clip leads or solder temporary wires to reach cramped locations or difficult to access locations.

h) Don't attempt repair work when we are tired. Not only will be more careless, but our primary diagnostic tool - deductive reasoning - will not be operating at full capacity.

i) Before the high voltage is connected, the person responsible for the test must verify that:

   i. The test circuit is assemble correctly and the test object is connected correctly

   ii. All safety system are operable and the manual grounding rod has been removed

iii. If the operates in DC or impulse configuration, the short circuit cable from the capacitor has been removed.

j) Switch off all the supplies before leave the laboratory.

3.3.4 Equipment Safety

Safety procedure when using equipment for high voltage as shown below:

1. Testing procedure (OT276)

    i. Release emergency button

    ii. Push switch button (tap contact for motor ready)

    iii. Push ready button (earthing light)

    iv. Push green button (increase and decrease button)

    v. Red button (auto earthing)

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2. Precaution

    i. Do not increase the voltage too fast

    ii. Do not push the red button before decrease the voltage to zero

3. Setup procedure

    i. Select impulse display

ii. Select flash detection on/off

iii. Select trip detection on/off

iv. Choose the correct divider ratio

4. Procedure when flash/trip occurred

   i. Decrease the voltage to zero condition

   ii. Push setup button

   iii. Select display option

5. Reset procedure (DM 1551)

   i. Make sure in earthing/ grounding conditions

   ii. Push red button at OT276

   iii. Decrease the voltage to zero

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6. Precaution

   i. Choose the right divider ratio

   ii. Select AC, DC or IMPULSE based on the testing experiment

3.4 Supply Setup

The construction kit is build for test the object using high voltage. This construction is prepared at laboratories at FKE, UTeM is equipped with High Voltage Alternating Current (HVAC). The generation system for that configuration can generate up to 400 kV. The configuration kit is new equipment for T & L of high voltage subject as well as for R&D at the university. The basic procedure manual (user manual) has been provided by the manufacturer for user reference to operate the equipment. However, the steps on handling the equipment are not elaborated in experimental format. This construction kit is within the software simulation equipment to handle that of construction kit. The capture of waveform and the supply of generator are doing at that laboratory and the Figure 3.9 below shows the first stage diagram for HVAC generator circuit by using the High Voltage Configurations KIT.

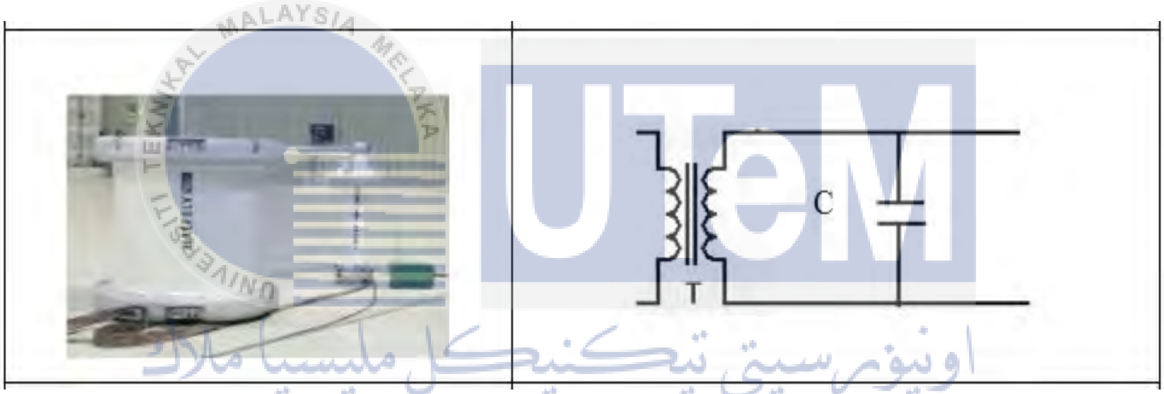

Figure 3.9 : HV structure for AC Configuration. [32]

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To generate high voltage requires several component part charging resistor, generator capacitor and spark gap, wave shaping-shaping resistor and triggering system, voltage divider and many more.

3.4.1 HV Supply

Test transformer which can be used for AC-Voltage generation and as High Voltage supply for DC and Impulse voltage generation. The output power can be extended by cascading the transformers. The combination of control unit as transformer regulator and transformer is capable to generate voltage up to 400kV for AC, DC and Impulse generation at either polarity. The Figure 3.10 shows the picture of transformer.

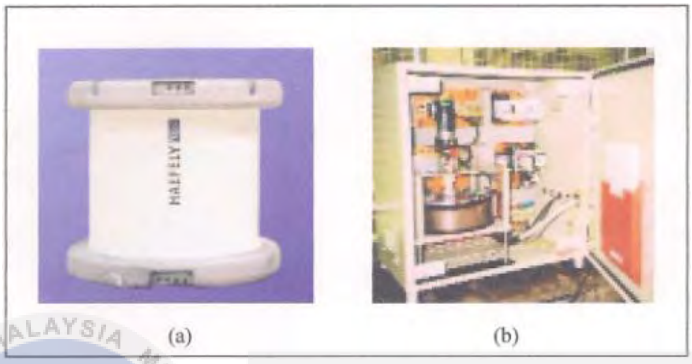

Figure 3.10 : HV supply (a) test transformer (b) regulating transformer [32]

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There are specification of test transformer and regulating transformer

i. *Transformer*

Rated voltage : 2 x 220V/100kV/220V

Rated power : 5kV

ii. *Regulator transformer*

Power supply : 230/22A (33A,43A)

Rated power : 5kV Frequency : 50/60 Hz

3.4.2 Capacitor

Capacitors are required for several charging and discharging operation which is it can be used as energy storage capacitor for generation of AC voltages or as smoothing capacitor for AC generation. Figure 3.11 shows one of the charging capacitor used in the high voltage generator circuit with the following specification:

Capacitance	:	100pF
Maximum Voltage	:	140kV
Weight	:	15kg

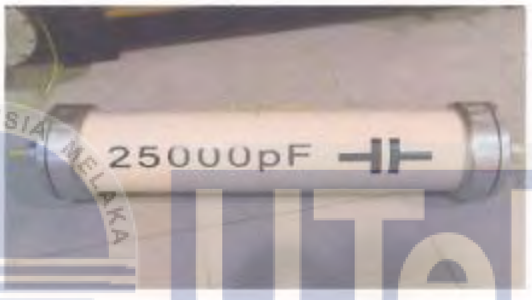

Figure 3.11 : Energy storage capacitor [32]

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3.4.3 Discharge Rod

Discharging of the remaining charge in a capacitor is an important process during the experiment to ensure the safety of the user. The discharging process has to be done every time after the experiment. This can be done manually using the grounding electrode as shown in Figure 3.12

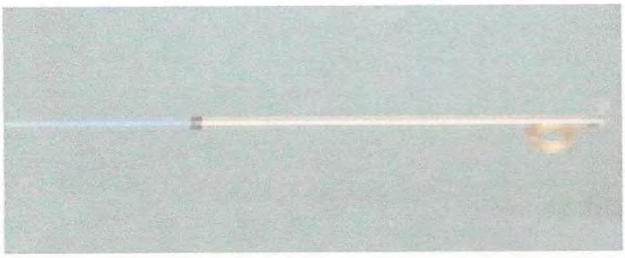

Figure 3.12 : Discharge Rod

3.4.4 Output Signal Displayed

The generated waveform from the High Voltage Generator should be displayed on the oscilloscope, so that the specification of the waveform can be determined. In order to display the waveform, special devices need to be used as experiment involve with the high voltage of few kilovolts.

Oscilloscope

The digital oscilloscope as shown in Figure 3.13 is used in the experiment to display the waveforms that capture from the breakdown voltage for high voltage testing.

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Figure 3.13 : Digital Phosphor Oscilloscope

The digital storage oscilloscope shown in the figure above has the following specification:

Type	:	DPO4000 series, Digital Phosphor Oscilloscope
Ability	:	1 GHz, 500 MHz, and 350 MHz bandwidths

3.4.5 Control and Triggering Unit

The high voltage KIT is supplied with two separate instruments. The OT 276 is used as a control unit and the DMI 551 AC, DC and impulse as trigger and measurement unit.

OT 276 controls the regulating transformer. it is based on conventional relay technology. The OT 276 is equipped with required safety functions by the laboratories large test and also those required by the standards Figure 3.14 show the picture of OT 276.

Figure 3.14 : OT 276

With the KIT it is often required to measure AC, DC and impulse voltages at the same time. Therefore the DMI 551 is equipped with three independent measuring channels (AC, DC and Impulse) and can display all three value simultaneously. The Digital Measuring Instrument DMI 551 is a microprocessor controlled instrument for measurement of AC, DC and impulse peak voltages. The instrument has also implemented a flash detector to store and display the last voltage measurement and its polarity before a breakdown or flashover occurred. Typical main applications of the unit include measurements of a voltage divider output or for automated product testing where the DMI 551 is integrated into a complete control and measuring platform. A DKD calibration certificate is optional available. Figure 3.15 shows the picture of DMI 551.

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Figure 3.15 : DMI 551

An interface (RS-232 or IEEE-488) is also available for connection to s host computer. The DMI 551 is designed in accordance with the international standard IEC 60.

Manual Setup DMI 551

1. Switch on DMI 551
2. Select 'setup' button and set data value:

Voltage divider	:	i) AC	:	708.266 v/v
		ii) DC	:	18735.1 v/v
		iii) Impulse	:	390.18 v/v
Polarity	:	i) AC	:	none
		ii) DC	:	positive/negative
		iii) Impulse	:	positive/negative

3. then select display button

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3.5 Testing Procedure

All experiment were conducted in the artificial environmental chamber. Atmospheric conditions such as temperature and relative humidity were setup manually and recorded using the temperature control and humidity meter. Wetting of insulator is controlled using the adjustable spray nozzle and water pump is controlled manually.

There are three stages of contamination level which is light, medium and heavy contamination level. To prepare the contamination slurry, NaCl was used. The NaCl weight is based on the ratio of water.

One unit glass insulator of standard profile and leakage distance of 290mm was used in this experiment. The glass ceramic insulator structure is cap and pin insulator hanging vertically in the middle of the chamber. Pin of the insulator was clipped using crocodile clip and high voltage AC was flowed direct through it and cap of insulator was clip and connected to the input of the measuring box . output of the measuring box is connect directly to oscilloscope. The diagram of connecting the apparatus is shown in Figure 3.16 below. Controlled parameter is the applied voltage which is 11kV rms and the voltage increased slightly by 2kVrms for every 15 minutes. The temperature in the chamber and humidity will setup first before that fogging given into the insulator. The humidity was 100 % and the temperature range is 20° C before the fogging started. Before the 11kV applied to the insulator, the insulator was 15 minute fully wetted on unenergized insulator sample in the chamber. Measurement of leakage current was recorded after 1 minute period of leakage current measurement. Leakage current data was recorded by oscilloscope and saved on the PC.

The test sample was wetted for 2 hours or until flashover occurred or which one comes first. There are 3 group consists of nine sample of insulator with different history services involved. After the entire artificial test is complete, the flashover voltage test was conducted. The flashover voltage is common which voltage will step up until a arcing occur on the insulator and disconnecting the supply of high voltage. The reading of flashover voltage is taken.

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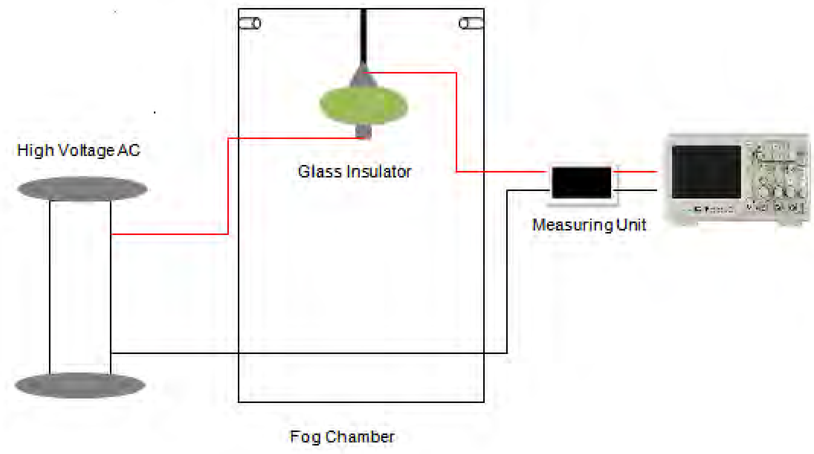

Figure 3.16 : Connection of Testing Setup [32]

3.6 Description of the work to be undertaken

3.6.1 Methodology Process

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In completing the project, the arrangement of the planning is very important. In this project, there are several step was determined and need to be follow to make sure the implementation of the project is on track. Basically, project methodology was defined in a process flow. With that, the project then will follow the process flow equally in order to make sure the project did not performed any misalignment process. In other word, the process flow will guide and conduct every process on each stage. However, to create and to define the process flow of the project is the critical part of the project. A proper studies and background research need to be done to make sure and to become fully understand on the project conducted. If the process flow doesn't actually representing the experiment procedure, it may cause a problem and difficulty to occurs when conducting the project.

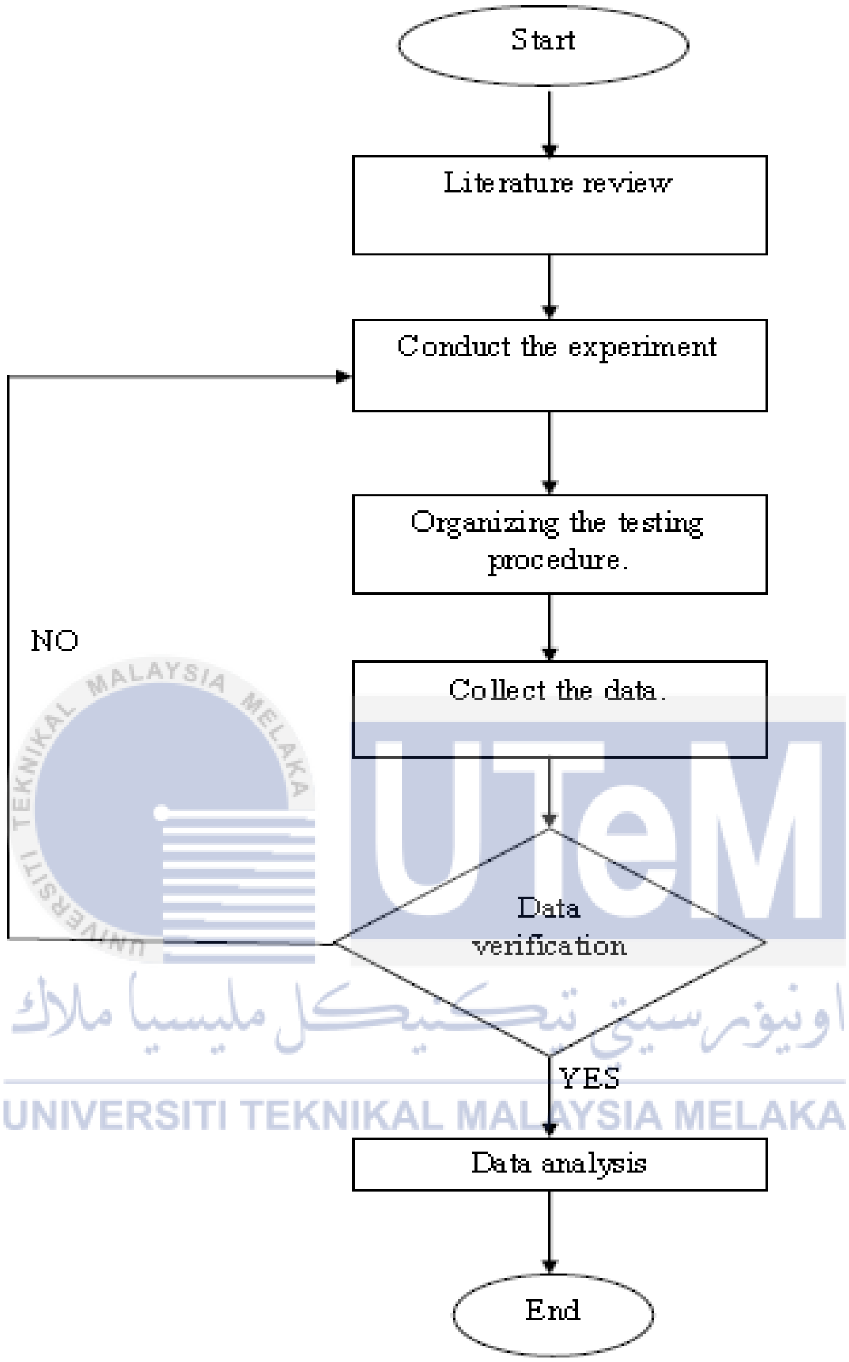

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Figure 3.17 : Methodology flow chart

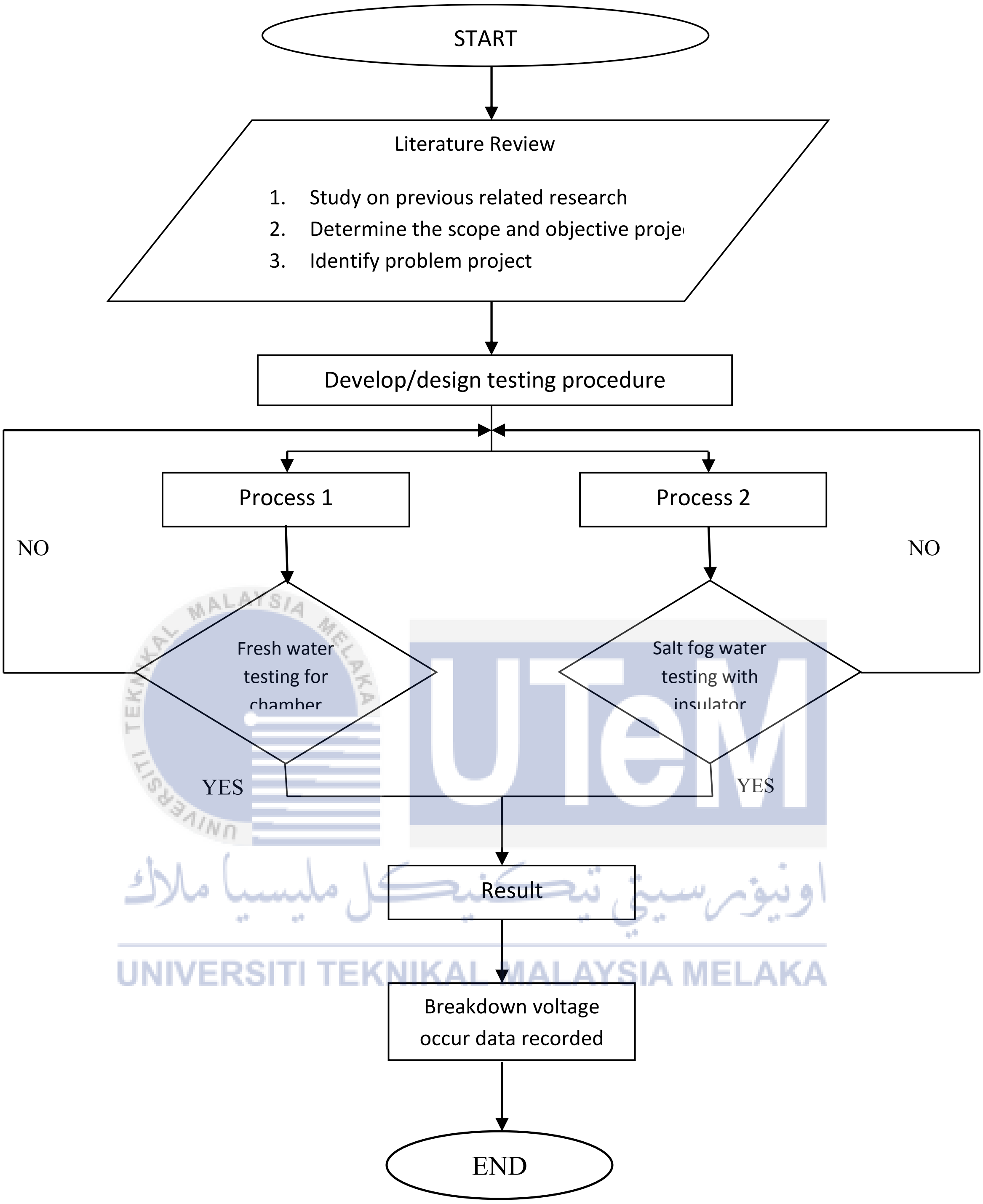

Figure 3.18 : Experiment procedure flow chart

3.6.2 Key Milestones

Table 3.2 : Project progress and duration for each step

Project Progress	Duration
Collection of Journal and Literature Review	September 2014
Study related journal and source involved	October 2014
Study on the related method	October 2014
Write report draft	October 2014
Submission report draft	November 2014
First seminar	November 2014
Doing salt fog testing and research	December 2014 – March 2015
Write thesis report	April 2015
Submission of thesis	May 2015
Final seminar	May 2015

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CHAPTER 4

RESULT & DISCUSSIONS

4.1 Introduction

The results of laboratory experimental on the surface leakage current of naturally ageing ceramic glass insulator are presented in this chapter. The aims of this chapter was to determine the characteristic of the leakage current components of the ageing insulators by trace the voltage leak at the resistance designed in the measuring unit box before the signal shown in the oscilloscope. The laboratory tests were carried out on the insulator on the insulator samples to investigate the effect of varying contamination level in 3 stage of testing and every testing is varying the voltage for each testing in the chamber. The concentration of NaCl salt was varied to give equivalent salt deposit density (ESDD) in mg/cm^2 to 0.06 lightly polluted, 0.08 (moderately polluted) , 0.12 (heavily polluted) at a constant 100 % relative humidity conditions. The insulator samples were applied with AC voltages of 11 kVrms. Results and discussion of each investigation was presented in this chapter as a subsection.

Besides the results of the LC components measurement, the results of flashover voltage measurement also presented.

4.2 Leakage Current Acquisition & Measurement System

The parameter variable measured in the environmental chamber when testing insulator is the leakage current. Research on the field observation and laboratory result in the previous study prove that there are an existing relationship between insulator leakage current time and frequency component and insulator and its surface condition. Pollution, contamination, flashover and ageing on the insulator have a tight bond with the LC flowing on the outdoor insulator, making it a good indicator for monitoring on insulator condition.

Insulator samples were contaminated at varying level, from light, medium and heavy in the laboratory using salt as the contamination. After contamination was applied, insulators were energized at the operating voltage and the leakage current measured as voltage drop across the resistor (shunt) connected in series with the insulator sample. The voltage drop in the resistance designed in measuring unit box was measured using the oscilloscope. By constant the resistance value, leakage current has determined by calculation. The current (leakage current) through the insulator surface can be calculated by using equation below :

$$\boldsymbol{V = IR} \quad \text{...........} \quad (4.1)$$

$$\boldsymbol{I\ (Leakage\ Current) = \frac{Vdrop}{Rshunt}} \quad \text{...........} \quad (4.2)$$

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The resistance of the shunt is 1000 Ω. This value is suitable to captured the leakage current because the lower the resistance, the higher the current. Leakage current comes in a very small amount in mA to µA. This value is easy to show the waveform shape clearly to ease the analysis part. The procedure was repeated for different value of contaminant of testing. All the data and result were being recorded into the data table, graph, and chart.

4.3 Graphical Result

As the method by ASTM B-117, the testing has conduct by 3 stages which is the first testing conducted b y light contaminant, second testing conducted by medium contaminant and last testing conducted by heavy testing. The ratio of the contaminant has followed by standart from ASTM-B117.

4.3.1 Light Contaminant

For this testing, the contaminant has set into 7mS which is the range of standart requirement is set from 5mS to 14mS. The resistant designed has set constant into 1000Ω, the temperature for the chamber is 29°c before the chamber run and the temperature for the chamber has increase into 59°c when the testing running. The result for light contaminant has shown at Table 4.1.

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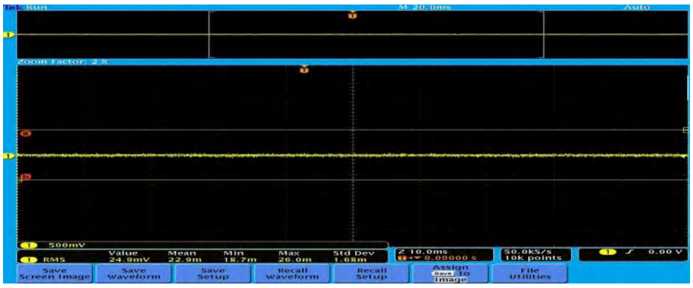
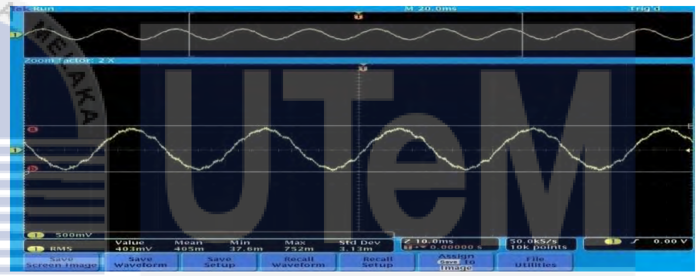
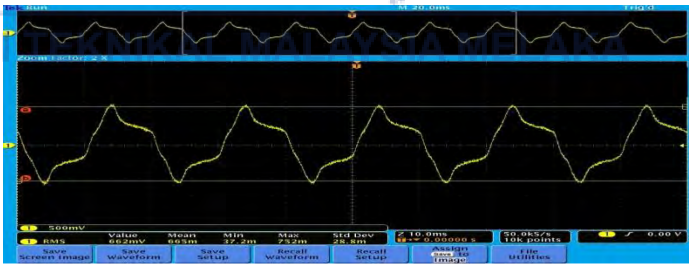
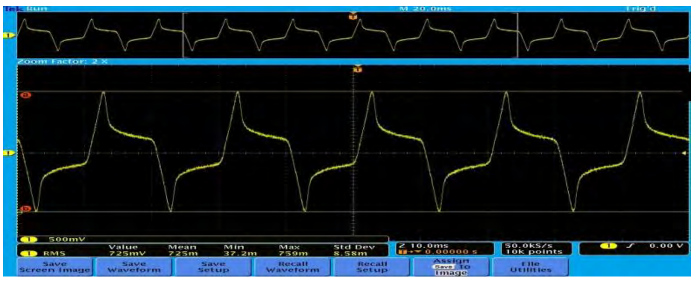
Table 4.1 : Result for Testing Insulator with Light Contaminant

Contaminant = 7mS , Ave Time = 15 min				
Vrms (kV)	**Vp-p (kV)**	**Vleak (V)**	[redacted]	**LC (mA)**
0	**0**	**0**		**0**
2.075	**2.936**	**710m**		**0.71**
4.045	**5.724**	**1.16**		**1.16**
6.030	**8.551**	**1.75**		**1.75**

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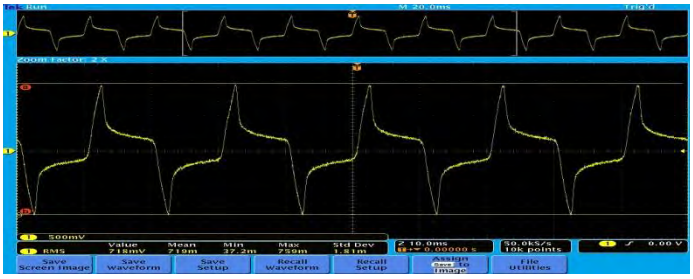
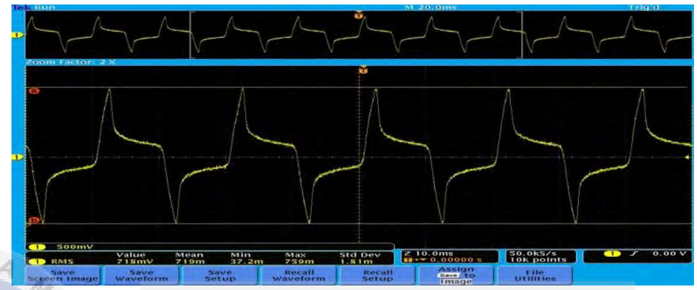
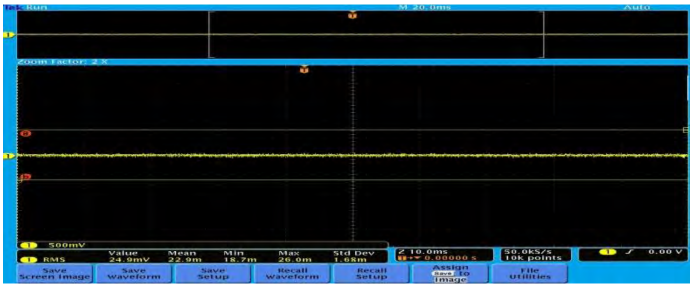
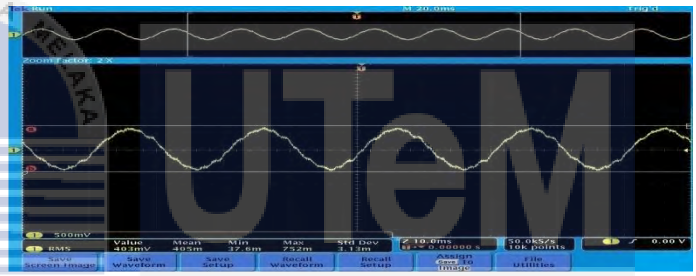
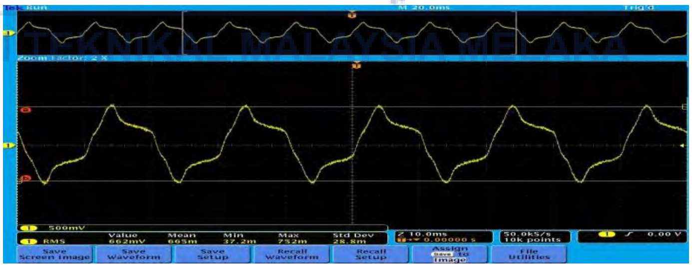
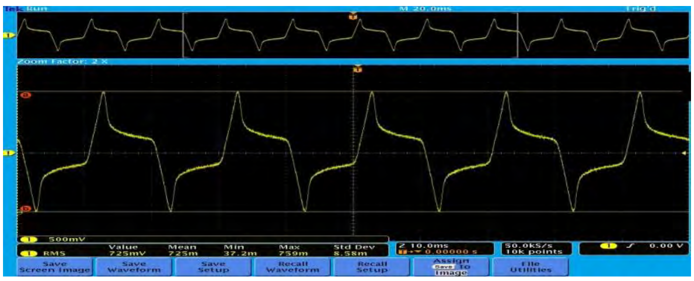
8.030	**11.35**	**1.92**		**1.92**
10.01	**14.15**	**1.92**		**1.92**
11.01	**15.56**	**1.29**		**1.29**

4.3.2 Medium Contaminant

For this testing, the contaminant has set into 25mS which is the range of standart requirement is set from 14mS to 40mS. The resistant designed has set constant into 1000Ω, the temperature for the chamber is 28°c before the chamber run and the temperature for the chamber has increase into 57°c when the testing running. The result for light contaminant has shown at Table 4.2.

Table 4.2 : Result for Testing Insulator with Medium Contaminant

Contaminant = 25mS , Ave Time = 15 min				
Vrms (kV)	**Vp-p (kV)**	**Vleak (V)**	[redacted]	**LC (mA)**
0	**0**	**0**		**0**
2.075	**2.936**	**875m**		**0.875**
4.045	**5.724**	**1.83**		**1.83**
6.030	**8.551**	**2.81**		**2.81**

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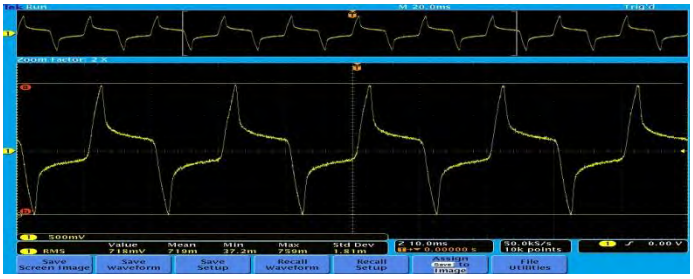
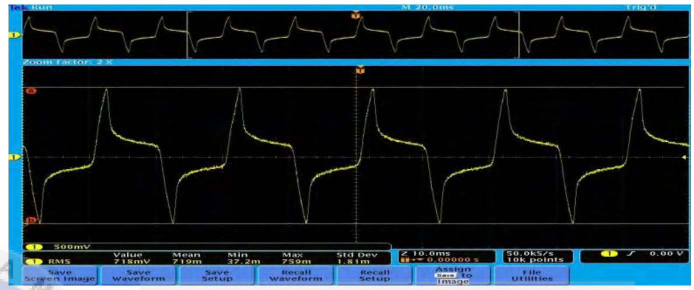
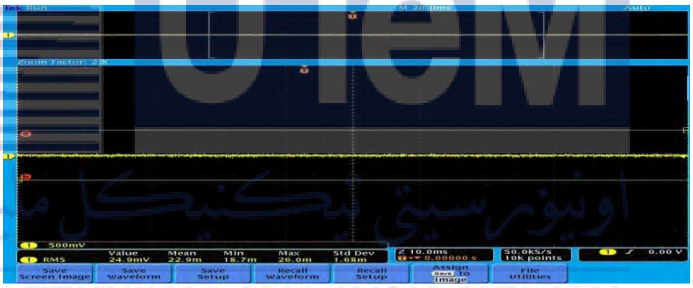
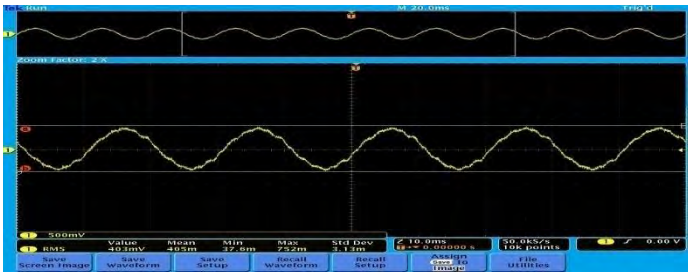
8.030	**11.35**	**4.21**		**4.21**
10.01	**14.15**	**4.73**		**4.73**
11.01	**15.56**	**5.42**		**5.42**

4.3.3 Heavy Contaminant

For this testing, the contaminant has set into 78mS which is the range of standart requirement is set from 40mS to 112mS. The resistant designed has set constant into 1000Ω, the temperature for the chamber is 30°c before the chamber run and the temperature for the chamber has increase into 74°c when the testing running. The result for light contaminant has shown at Table 4.3.

Table 4.3 : Result for Testing Insulator with Heavy Contaminant

Contaminant = 78mS , Ave Time = 15 min				
Vrms (kV)	**Vp-p (kV)**	**Vleak (V)**		**LC (mA)**
0	**0**	**0**		**0**
2.075	**2.936**	**1.23**		**1.23**

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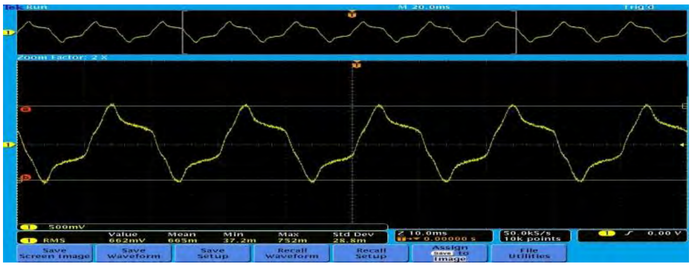
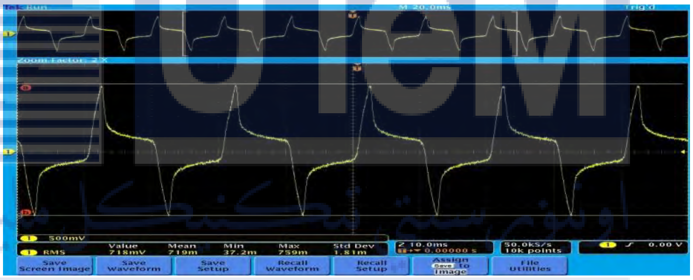
4.045	**5.724**	**2.48**		**2.48**
6.030	**8.551**	**4.42**		**4.42**
8.030	**11.35**	**7.21**		**7.21**
10.01	**14.15**	**7.30**		**7.30**

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11.01	**15.56**	**8.98**		**8.98**

4.3.4 Analysis Data

The graphs show the voltage drop around the resistance. Voltages drop in the resistance produced by tracking which occurred on the glass. The tracking occurred by the contaminant fogging inside the chamber and the wet of fogging will produce the track for the conductor paths. By the tracking occurs, the path will allow a leakage current flow through the tracking. The tracking also produces the resistive condition among the insulator. The insulator capacitances will decreases when the resistive produce.

With careful observation of the shapes of the LC's under salt fog test, the currents were classified into four groups namely capacitive, resistive, non linear, and discharge. The LCs were initially capacitive and then became resistive with increasing LC level. Later they became non linear shape due to content and due to arcing LC spikes appeared on the crest of the waveform showing further increase of harmonic content in addition to the increase of LC level. Each category has separates signature in LC level and in shape in frequency and time frequency domain.

When the insulators are wetting, resistive LC current flows on their surfaces. As shown at Table 4.1, insulator which is in light contamination level show capacitive type of LC. In general, the LC waveform was sinusoidal in shape. The separation of LCs between resistive and capacitive can be made easily from its level. When the cap of glass insulators become severely corroded, the rust deposits runs down to the dielectric thereby creating a continuous conducting path resulting in the flow of LC. The continuous conducting path makes the insulator behave like a linear load thus having a sinusoidal LC waveform. In figure 4.1 with Vs of 4kVrms, the LCs deformed from the resistive patterns and the signal started show the pattern of symmetrical graph. The levels were around 1.16 mA as the resistive type. The waveforms deformed from sinusoidal shape indicating higher content of harmonics. This behavior was clearly visible in FFT plots. In some LCs, one or two LC spikes occurred in the crest of the non linear waveforms. The same observed in light and medium contamination level. In that contamination of group, the magnitude of LC waveform was about 4kVrms and same as the started level of non-linear type. In addition to the fundamental frequency component, odd and even harmonics of fundamental frequency was seen clearly in FFT waveform and their content were less compared to the fundamental component. This was result of continuous spot arcing activities were evident in the corresponding amplitude spectrum.

During the development of LC, initially the waveform were sinusoidal in shapes. Then they deformed and increased the discharge activity which proceeds towards the flashover event. If the LC waveforms are sinusoidal, they could be either resistive or capacitive. The classification could be made from LC level. Once the waveforms deformed, the harmonic content will increase. With the increase of discharge activity, the LC level may further increase. At the same time, the harmonic content also increase and it showing in graph. From the result, it can be see that the LC magnitudes of the insulator samples increased proportionally with increasing the voltages level. Figure 4.3 show that insulator samples in the heavy contamination condition had the highest LC magnitude. This could be attributed to the conductive nature of the naturally aged ageing of the insulator surface.

4.4 MEASURING UNIT SIMULATION

4.4.1 Laboratory Simulation

Measuring unit actually is a one of protection for the equipment. The component assist in the box is a resistor (1kΩ), SPD (MOV 320V), zener diode (10V) and fuse (100mA). The fuse protect the circuit from over current occur in the circuit. As knowledge, the current flow in the circuit is a small current and usually it occur in µA. Fuse will broken or blow once the current occurred greater than maximum fuse current limited.

The Metal Oxide Varistor or MOV is a voltage dependent, nonlinear device that provides excellent transient voltage suppression. The Metal Oxide Varistor is designed to protect various types of electronic devices and semiconductor elements from switching and induced lightning surges. When exposed to high transient voltage, the MOV clamps voltage to a safe level. A metal oxide varistor absorbs potentially destructive energy and dissipated it as heat, thus protecting vulnerable circuit components and preventing system damage. Varistors can absorb part of surge. A MOV contains a ceramic mass of zinc oxide grains, in a matrix of other metal oxides (such as small amounts of bismuth, cobalt, manganese) sandwiched between two metal plates (the electrodes). They can be connected in parallel for increased energy-handling capabilities.

MOVs can also be connected in series to provide higher voltage ratings or to provide voltage rating between the standard increments. A Metal Oxide Varistor remains non-conductive as a shunt mode device during normal operation when voltage remains well below its “clamping voltage”. If a transient pulse (often measured in joules) is too high, the device may melt, burn, vaporize, or otherwise be damaged or destroyed. A Metal oxide varistor should be used to protect the circuit from HV spike. It has become mandatory and can be seen in all power supplies that work off directly from mains.

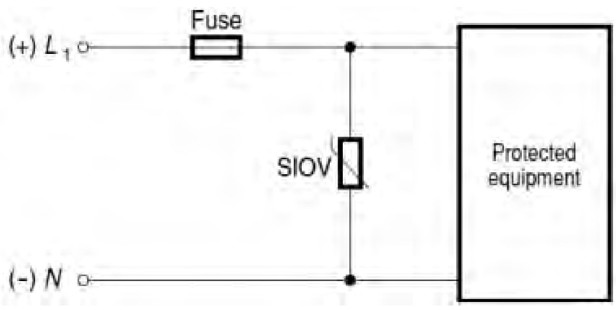

Figure 4.1 : MOV and Fuse placement in the circuit

In other hand, zener diode is use regulate or set the voltage output to 10V. The voltage set actually is the voltage output setting for the diode. Zener diodes are widely used as Shunt Voltage Regulators to regulate voltage across small loads. Zener diodes have a sharp reverse breakdown voltage and breakdown voltage will be constant for a wide range of currents. Thus we will connect the zener diode parallel to the load such that the applied voltage will reverse bias it. Thus if the reverse bias voltage across the zener diode exceeds the knee voltage, the voltage across the load will be constant.

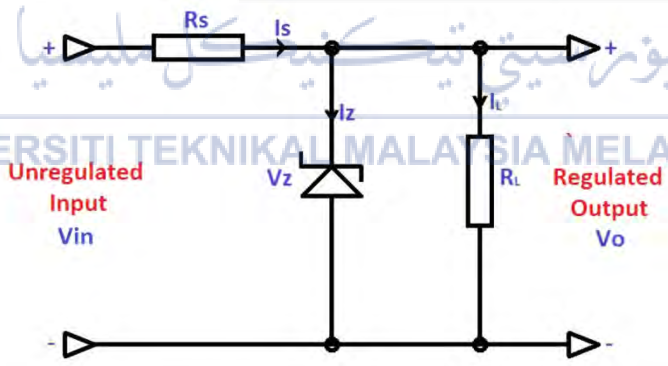

Figure 4.2 : Zener diode and resistor placement in the Measuring Unit circuit

The back to back connected zener diodes can be used as an AC regulator producing what is jokingly called a “poor man’s square wave generator”. Using this arrangement we can clip the waveform between a positive value of +10V and a negative value of -10V.

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In this research, the value wanted to clip an output waveform between two different minimum and maximum values of say, +10V and -10V, we would simply use two same value of zener diodes. Note that the output will actually clip the AC waveform between +10.7V and -10.7V due to the addition of the forward biasing diode voltage. In other words a peak-to-peak voltage of 11.4 volts instead of expected 10 volts, as the forward bias volt drop across the diode adds another 0.7 volts in each direction.

This type of clipper configuration is fairly common for protecting an electronic circuit from over voltage. The two zener's are generally placed across the power supply input terminals and during normal operation, one of the zener diodes is "OFF" and the diodes have little or no affect. However, if the input voltage waveform exceeds its limit, then the zener's turn "ON" and clip the input to protect the circuit.

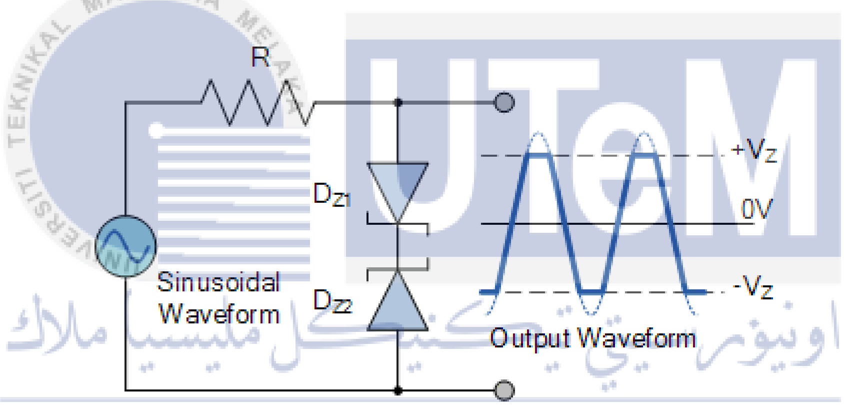

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Figure 4.3 : Zener diode back to back graphical capping signal

For the maximum current flowing through the zener diode :

$$Max\ Current = \frac{Power\ (watt)}{Diode\ Voltage\ (volt)} \qquad \ldots\ldots\ldots\ldots (4.3)$$

$$= \frac{1watt}{10volt} = 100mA$$

For protect the circuit, fuse with max current 100mA has placed at the main part of the circuit. For the value of the series resistor in the circuit before the zener diode is calculate by :

$$Rs = \frac{Vs - Vz}{Iz} \qquad \ldots\ldots\ldots\ldots (4.4)$$

$$= \frac{12v - 10v}{100mA} = 20\Omega$$

The parallel resistor has set constant into 1000Ω, and the load current through the parallel resistor calculate by :

$$I_L = \frac{Vz}{R_L} \qquad \text{........... (4.5)}$$

$$= \frac{10v}{1000\Omega} = 10mA$$

For the diode current at full load is calculate by :

$$I_Z = I_S - I_L \qquad \text{........... (4.6)}$$

$$= 100mA - 10mA = 90mA$$

By the calculation, the graph for output voltage should be in capping at 10V. It's because the zener diode will cut the over voltage flow through the diode. The result for the simulation on the measuring unit box has show the capping voltage.

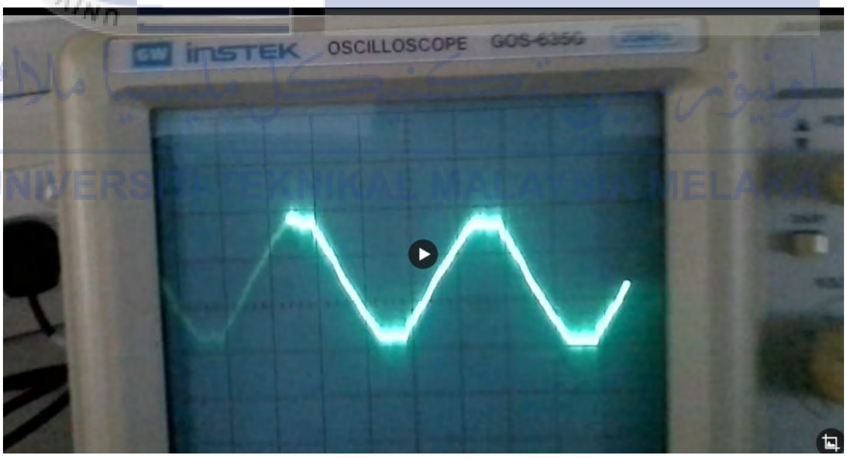

Figure 4.4 : Simulation output voltage signal capping by zener diode

The circuit has injected by 12V alternating current (AC) and the supply through the fuse (100mA) as a main part in the circuit. A 100mA fuse connected in series with an insulator. There are two layer in the protection circuit of over voltages. The initial layer is a Surge Protection Device (SPD) which is use a Metal Oxide Varistor (MOV) that operate

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when over voltage occur at the circuit. MOV will operated when the overvoltage occur mor than 320V. The next layer, is zener diode with $V_z = 10$ V install to cut off any voltages that surpass the maximum voltage could across through the equipment. The maximum voltage allow across the equipment is 10V. The resistor for measuring LC is a 1k Ω placed after the protection layer. When the graph show the capping signal, its shown that measuring unit in good condition and ready to use.

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CHAPTER 5

CONCLUSION

5.1 Summary of Project

Based on the result, there are some conclusion can be deduced for that insulator testing under different contaminant level. By referred of previous related works about the transmission line insulators, it was found that many of studies has been carried out for that pollution among the insulators. For example in Malaysia, lot of insulator has been use on overhead transmission. However, there are shortages of study in ageing condition on the transmission line insulator with surface leakage current. In this work, it was found out that insulator have effect by the contaminant level which is salt fog used. The contamination has produce the tracking among the insulator and the conductor path has occur by the tracking produced. This experiment had investigate the relationship between leakage current component and ageing of insulator for overhead transmission line. By giving the salt fog when the voltage injected on the insulator, it will produce electrical field among the insulator. The electrical field called as tracking and it will occur conductor paths and it will allow current flowing. The current flowing by that tracking called as leakage current and the leakage produce a small leakage current.

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5.2 Achievement of Project

Objective of the experiment achieved by diagnosis the leakage current occur among the insulator. This research has shown the tracking occur the conductor path to allow current flowing. The conductor path shown by referred to signal waveform on the ageing insulator. The best insulator must produce pure capacitance without affected by resistive. Salt fog given in the testing will help to produce the tracking and allow the conductor path. This condition will reduce a capacitance and raise the resistive component. The graph shown when the flashover occurs is symmetrical signal.

5.3 Achievement of Research

The prime objective of this research is to diagnosis the correlation between component in the leakage current of insulator with ageing of glass insulator. This research has shown there were tracking activities in the waveform on the ageing insulator. The tracking happen when the fogging has given into the insulator. This data can be used to predict the flashover activities and to help in maintenance of the high voltage insulator on the transmission system.

5.4 Recommendation for Research

This research actually has focused on glass as a insulator material. In Malaysia example have lot of insulator such as porcelain, ceramic, wooden, polymer and etc. For future study, the student can develop and request for many sample of insulator and not only focused on glass. Other than that, student also can use the pure contaminant such as sea water or dust from industry to develop the contaminant type. To applied a real situation into lab testing application, it’s more suitable for gained the student knowledge.

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Student also can being a intermediary between UTeM and industry. By using the FYP title, student can absorb input and gain the technical skill when they do the work or testing with industry. TNB is the one of the best company to develop student skill for this insulator testing. TNB is the largest user use the insulator for their transmission line. By working together with TNB, student can improve their skill and gain knowledge manifestly.

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APPENDICES

1. Insulator Sample

Glass Insulator

2. High Voltage Equipment

High Voltage Arrangment

3. Environmental Chamber

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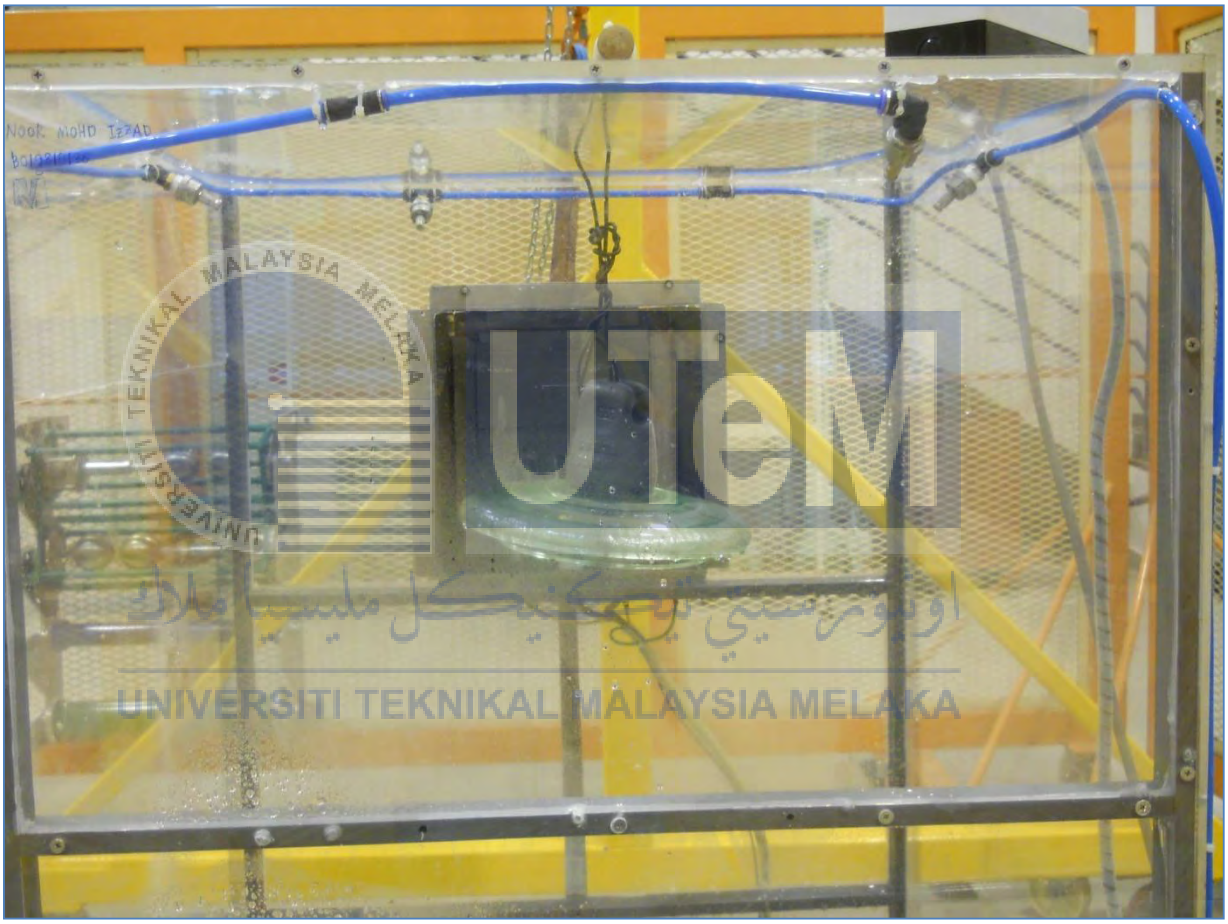
4. Insulator Sample Hanging in Environmental Chamber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5. A Flashover Incident During the Test

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Gantt Chart for PSM1

	2014/2015																	
Project Activities	**Sept**				**Oct**				**Nov**				**Dec**		**Semester Break**			
PSM 1	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**	**X**	**X**	**X**	**X**
1. Find Project Title and Supervisor																		
2. Identify the PSM project																		
3. Determine the project title																		
4. Discuss and understanding the project overview, objective and scope																		
5. Study the previous project and research to make comparison																		
6. Search the information regarding high voltage insulation specifications																		
7. Study on the tracking occurred around insulator and testing method																		
8. Discuss the expected results with the supervisor																		
9. Make the draft for the proposal																		
10. Prepare the proposal																		
11. Preparation for seminar																		

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Gantt Chart for PSM2

	2014/2015																	
Project Activities	**Feb**				**March**				**April**				**May**		**Semester Break**			
PSM 2	**W1**	**W2**	**W3**	**W4**	**W5**	**W6**	**W7**	**W8**	**W9**	**W10**	**W11**	**W12**	**W13**	**W14**	**X**	**X**	**X**	**X**
12. Find the Material																		
13. Identify the PSM project method																		
14. Determine the Material																		
15. Repair the Chamber																		
16. Do the Fogging by Using Fresh Water																		
17. Determine the Water Leakage around the Chamber																		
18. Do the Salt Fog into the Material																		
19. Take the Result of Testing																		
20. Make the draft for the Report																		
21. Prepare the Final Report																		
22. Preparation for seminar																		

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