

AIR BREAKDOWN CHARACTERISTICS IN PLANE-PLANE AND SPHERE
GAP ELECTRODE CONFIGURATION UNDER LIGHTNING IMPULSE

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A project report submitted in partial
fulfillment of the requirement for the award of the
Master of Electrical Engineering

Faculty of Electrical and Electronic Engineering
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JULY 2014

ABSTRACT

This report describes the air breakdown characteristics in plane-plane and sphere gap electrode configuration under lightning impulse. The breakdown in air (spark breakdown) is the transition of a non-sustaining discharge into a self-sustaining discharge. In electrical power system, high voltage power equipments are mainly subjected with spark over voltage. This over voltage which may causes by the lightning strokes, switching action and so on. In this project, two different electrodes (plane-plane and sphere gap) are used to study the air breakdown characteristics. This two electrodes are tested by using different gap start with 0.5 cm, 1.0 cm until 2.5 cm. Refer to British Standard BS EN 60060 that explained detail about the general definitions and test requirements for high voltage test techniques to construct in this project. In addition, TERCO lightning impulse circuit are use to obtain the lightning impulse waveform. To estimate U_{50} during the experimental, up and down method are used with the value of $n \geq 20$. Finite element method magnetic software (FEMM) is use to shows the potential higher electric field occurs around the electrodes. Vector and contour around the electrodes also can be viewed. From this project can conclude that electric field distribution between two conductors (or electrodes) depends on applied voltage (U_{50}), gap between electrodes, types and surface of electrodes. In the end of this project, the relationship between voltage (U_{50}) and gap, electric field ($|E_{max}|$) and gap, field utilization factor (η) and gap, U_{50} and field utilization factor (η) and electric field ($|E_{max}|$) and field utilization factor (η) have been constructed with help of graph.

ABSTRAK

Laporan ini menerangkan ciri-ciri pecahan udara (air breakdown) dalam konfigurasi elektrod rata-rata (plane-plane) dan sfera dibawah denyutan kilat. Pecahan didalam udara (spark breakdown) adalah peralihan pelepasan tidak kekal ke dalam pelepasan kekal. Di dalam sistem kuasa elektrik, kebanyakan peralatan kuasa voltan tinggi sering dikaitkan dengan percikan lebihan voltan. Lebihan voltan ini disebabkan oleh panahan kilat, tindak balas suis dan sebagainya. Dalam projek ini, dua elektrod yang berbeza (elektrod rata-rata dan sfera) digunakan untuk mengkaji ciri-ciri pecah tebat udara. Kedua-dua elektrod ini diuji dengan jarak yang berbeza iaitu 0.5 cm, 1.0 cm sehingga 2.5 cm. Merujuk kepada piawai British BS EN 60060 yang menjelaskan secara terperinci mengenai definisi umum dan keperluan ujian untuk teknik ujian voltan tinggi dalam menjalankan projek ini. Di samping itu, litar denyut kilat TERCO yang digunakan untuk mendapatkan bentuk gelombang denyut kilat. Untuk menganggarkan U_{50} semasa eksperimen dijalankan, kaedah naik dan turun digunakan dengan nilai $n \geq 20$. Perisian magnet kaedah elemen terhingga (FEMM software) digunakan untuk menunjukkan medan elektrik yang lebih tinggi yang berpotensi berlaku di sekeliling elektrod. Vektor dan kontur di sekitar elektrod juga boleh dilihat. Daripada projek ini boleh disimpulkan bahawa taburan medan elektrik di antara dua konduktor (atau elektrod) bergantung kepada voltan yang dimasukkan (U_{50}), jarak antara elektrod, jenis dan juga permukaan elektrod. Di akhir projek ini, hubungan antara voltan (U_{50}) dan jarak, medan elektrik ($|E_{max}|$) dan jarak, faktor penggunaan medan (η) dan jarak, U_{50} dan faktor penggunaan medan (η), dan juga medan elektrik ($|E_{max}|$) dan faktor penggunaan medan (η) telah dibina dengan bantuan graf.

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LIST OF SYMBOLS AND ABBREVIATIONS

E_{max}	-	Maximum electric field
U_{50}	-	50% probability voltage to breakdown
η	-	Field utilisation factor
AC	-	Alternative current
DC	-	Direct current
<i>FEMM</i>	-	Finite element method magnetic
<i>HV</i>	-	High voltage
<i>UTHM</i>	-	Universiti Tun Hussein Onn Malaysia

CHAPTER 1

INTRODUCTION

1.1 Project background

In the wide of engineering's world, built a perfect and safe condition system to the consumer always be the main important aspect for an engineer. Every analysis result is highly important to achieve the mission and goal. For example, to design of overhead line, substation equipment and various air insulated high voltage equipment, the fundamental characteristics of the electrical breakdown have to understand. All the aspect for the electrical breakdown must be examined. British standard are use in this project as guidance for the high voltage test technique. This British Standard is the UK implementation of EN 60060-1:2010 [1]. It is identical to IEC 60060-1:2010. BS EN 60060-1:2010 explained detail about the general definitions and test requirements for high-voltage test techniques.

This project is study about the air breakdown characteristics in plane-plane and sphere gap electrode configuration under lightning impulse. Use two different electrodes which are sphere gap and plane to plane as the testing objects. The main aim for this project is to find the air breakdown voltage experimentally for different electrodes (plane-plane and sphere gap) by using lightning impulse test. From the theory, lightning impulse waveform has front time and tail time. The front time is 1.2 μs with the 93% from maximum voltage while tail time is 50 μs with the 50% from maximum voltage.

In addition, this project consists of experimental setup and software simulation. For the experimental setup, TERCO lightning impulse circuit is used to obtain the lightning impulse waveform. The lightning impulse waveform could be observed by using oscilloscope which is connected to the circuit. The most important thing before conducting the experiment is to make sure the experiment is to produce lightning impulse. Besides, during conducting the experiment, the safety aspects always come first.

In addition, this project also use up and down method. This method is use to determine the U_{50} during the experiment. U_{50} is 50% probability breakdown voltage. The data for voltage are taken until $n \geq 20$ to estimate $U_{50} \pm 3\%$ of voltage also consider in decrease or increase the voltage value during the experimental with the interval time for voltage is 60 second.

Furthermore, these projects use FEMM software to simulate electric field in electrostatic problem. The estimation of U_{50} from the experimental results are applied into the FEMM software. The actual dimensions for the electrodes are drawn in this software. The estimation value of U_{50} will be applied in this software to define the voltage for the electrodes. Means, the maximum or minimum electric field that occurs surrounding the electrodes could be seen. Electric field intensity shows the electric field strength in order to evaluate the electrical stress and breakdown characteristics between two different types of electrodes. In addition, vector and contour around the electrodes also can be viewed. From this project can conclude that electric field distribution between two conductors (or electrodes) depends on applied voltage (U_{50}), gap between electrodes, types and also the surface of electrodes.

In real life, sphere gaps are commonly used to measure the peak values of high voltage. IEC and IEEE also adopt the sphere gap as a calibration device. Besides, the standard sphere gaps are widely used for protective device in electrical power equipments. In Malaysia, the largest electricity utility is Tenaga Nasional Berhad (TNB). The gap overhead transmission lines in TNB are applied to reduce or restrain sag of an overhead transmission line. Higher gap is applied give less probability to breakdown and this will give more safety condition on the overhead transmission line. Another application that required use the suitable gap is in switch on burner. In power plant, to heat the boiler in order to generate electric, sparkover is

needed. This thesis is also important in application such as in power transformer, switch gear, overvoltage arrester, insulator, power cable and transformer.

1.2 Problem statement

Sparkover voltage is the mainly cause damage to high voltage power equipment in electrical power system. Usually, lightning strokes cause the overvoltage [2]. In order to avoid the overvoltage in high voltage power equipment, the study of air breakdown voltage with difference electrode configuration plane-plane and sphere gaps. This air breakdown will generated by using lightning impulse test. From this air breakdown, the different electrodes may determine which configuration of electrodes will more easily to breakdown.

1.3 Objective

The main aim in this project is to find the air breakdown voltage experimentally for different electrodes (plane-plane and sphere gap) by using lightning impulse test.

Objective for this project is:

- i. To find the electric field for different electrodes (plane-plane and sphere gap) for a given voltage by using FEMM software.
- ii. To construct relationship between voltage (U_{50}) versus gap, electric field ($|E|$) versus gap, field utilization factor (η) versus gap, U_{50} versus field utilization factor (η), and electric field ($|E|$) versus field utilization factor (η).

1.4 Project scope

In order to achieve the objectives of the project, several scopes have been outline.

The following are the scopes of the project:

- i. By using difference electrode plane-plane and sphere gaps in study of the air breakdown characteristic.

- ii. Generate the air breakdown voltage by using lightning impulse setup by refer to TERCO manual guide in UTHM High Voltage Laboratory.
- iii. The simulation of electric field between the electrodes will be simulating by using Finite Element Method Magnetic (FEMM) software.
- iv. The TERCO's single stage voltage impulse generator capable to produced lightning impulse at maximum 140 kV.
- v. Gap between electrodes start with 0.5 cm, 1.0 cm, 1.5 cm, 2.0 cm until 2.5 cm are used for measurement of air breakdown voltages and electric field of the high voltage equipments.
- vi. Use air = gas @ atmosphere $P = 1$ bar.
- vii. Temperature and humidity effect are not considered.

1.5 Organization of the project

This project divided into five chapters which are including the introduction, lightning and air breakdown: a review, lightning impulse test procedures and simulation models, breakdown properties of air under lightning impulse: effects of electrode geometry and gap lengths and lastly, general conclusion and future works. This thesis focused on the air breakdown characteristics in plane-plane and sphere gap electrode configuration under lightning impulse.

Firstly, chapter 1 describes on the project background and problem statement to explain in detail for this project. This project also elaborates the project objectives and several scopes or the limitation that had been outlined to achieve the objectives. Besides, the organization of the thesis also included as the outlines for this project.

Next, in chapter 2, it discussed more on theory and literature reviews that related to this project. In this chapter, the general knowledge about the lightning, air breakdown, and lightning impulse will be covered. Previous related works in this chapter helps a lot to guide and as references in this project.

In chapter 3, methodology discussed about the method and technical strategies to apply for this project. In addition, this project deals with the experiment set up for air breakdown characteristic in plane-plane and sphere gap electrodes configuration by using TERCO lightning impulse circuit. From FEMM software, the different result electric field are simulated for electrodes, plane-plane and sphere gap.

Then, chapter 4 described the result for the air breakdown characteristics in plane-plane and sphere gap electrodes configuration from the experimental and also in FEMM simulation. The main content of chapter 4 is the results from the simulations followed by comprehensive discussions on the findings. From the experiment, the reading of U_{50} obtained from up and down method. The data is used to view the electric field surrounding the electrodes configuration by using FEMM software. Comparison between two electrodes are shown with the helped of graph.

Finally, in Chapter 5 discussed for the overall accomplishments of the project and some recommendations for future improvement to this project.

CHAPTER 2

LIGHTNING AND AIR BREAKDOWN: A REVIEW

2.1 Introduction

Literature review is a process of collecting and analyzes data and information that are related to this study. By refer from variable source such journals, books, websites and articles, the data and information can be collected.

2.2 Lightning

Lightning can be defined as an electrical discharge between cloud and earth, of atmospheric origin, comprising one or more impulses of many kilo amps [3]. It can also be defined as a transient, high current discharge whose path length is measured in kilometers [3]. Lightning has an extremely high current, high voltage and transient electric discharge. It is transient discharge of static electricity that serves to re-establish electrostatic equilibrium within a storm environment [4]. Lightning is natural phenomena that are always happened in our country, Malaysia.

Typical Isokeraunic Level in Malaysia is approximately 200 Thunder Days per Year [5]. United State National Lightning Safety Institution reported that Malaysia has highest lightning activities in the world whilst the average-thunder day level for Malaysia's capital Kuala Lumpur within 180 - 260 days per annum [6, 7]. Figure 2.1 shows the lightning occurred. Figure 2.2 shows the top cities in Malaysia with highest lightning days per annum [5]. In Malaysia, the monthly trends for lightning are:

- High during inter-monsoon (April to May)
- Moderate during Southwest monsoon (May to Sept)
- Low during Northeast monsoon (Dec to March)



Figure 2.1 : Lightning [8]



Figure 2.2 : Top cities in Malaysia with highest lightning days per annum [5]

2.3 Sparkover

Sparkover defined as disruptive discharge that occurs in a gaseous or liquid dielectric [1]. Figure 2.3 shows the illustrated for spark over while for figure 2.4 shows the sparkover occurred in air.

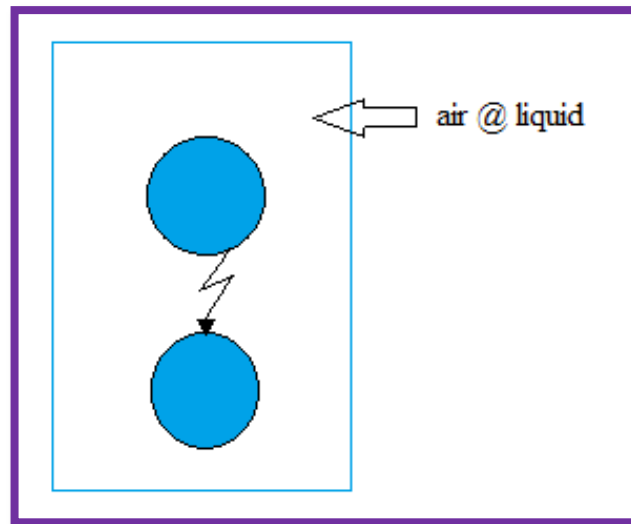


Figure 2.3 : Illustrate for sparkover (reproduced from [1])

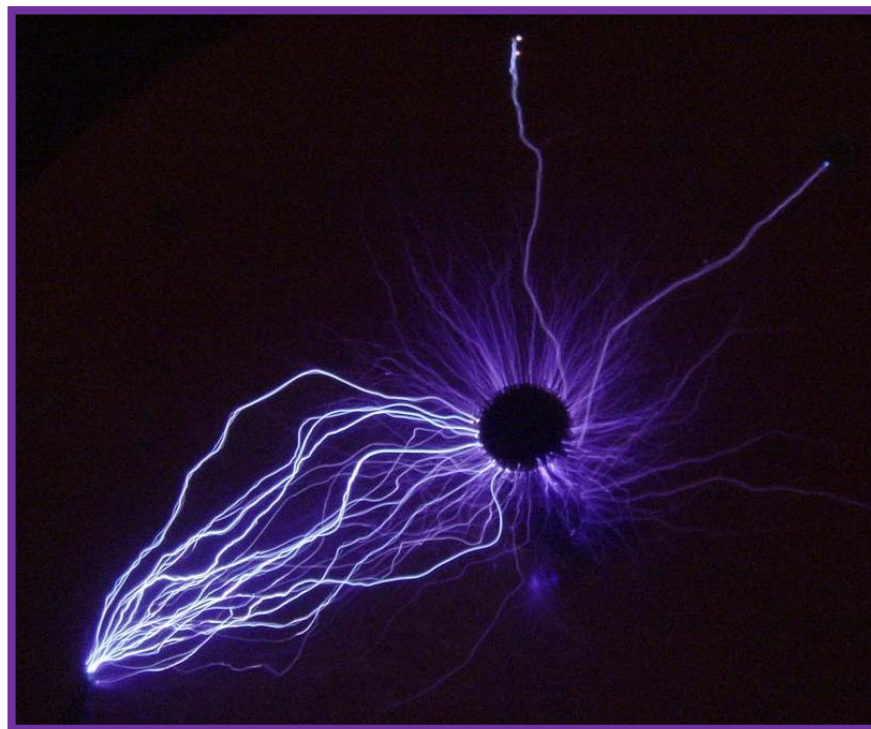


Figure 2.4: Sparkover occur in air [9]

2.4 Flashover

Flashover defined as disruptive discharge that occurs over the surface of a dielectric in a gaseous or liquid dielectric [1]. Figure 2.5 shows the illustrate for flashover while figure 2.6 shows the flashover occurred on surface of insulator .

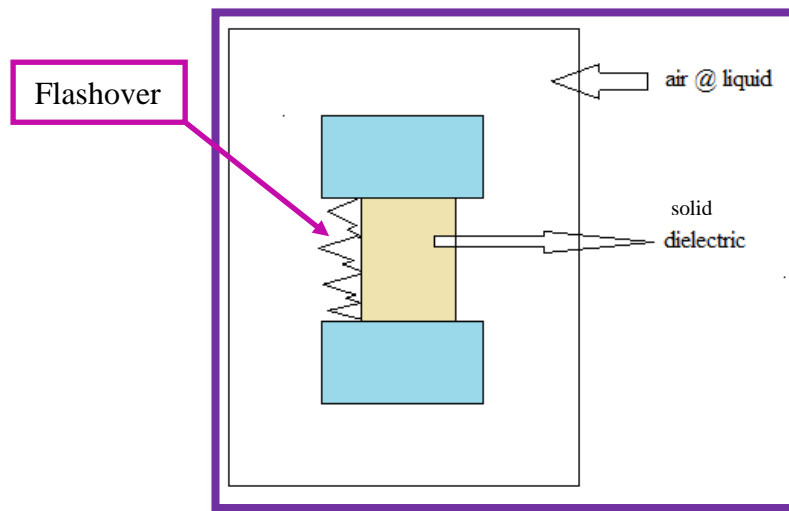


Figure 2.5 : Illustrate for flashover (reproduced from [1])



Figure 2.6 : Flashover occurred on surface of insulator [10]

2.5 Puncture

Puncture can be defined as disruptive discharge that occurs through a solid dielectric [1]. Figure 2.7 shows the illustration of puncture.

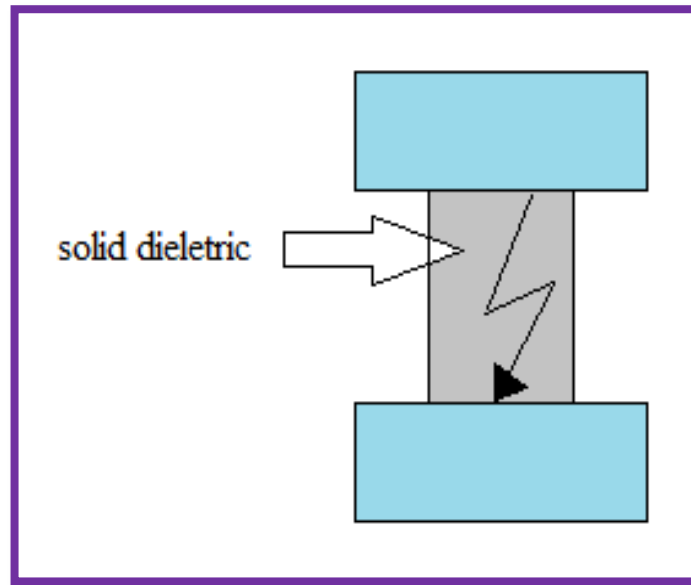


Figure 2.7 : Illustrate of puncture (reproduced from [1])

2.6 Lightning Impulse

Lightning impulse voltages are overvoltages due to lightning and are considered as external overvoltages and are dependent on the system voltages. Also known as fast-front overvoltages or FFO. This is due to very fast rise-time occurring on the waveform shape. The standard waveform used for testing is 1.2/50 μ s. 1.2 μ s represent the rise time T_1 while 50 μ s is a decay-time T_2 [2].

In the standard lightning waveform, T_1 is determined at about 93% level (0.93) just about to reach the peak voltage/current magnitude and T_2 is measured at 50% off the peak magnitude [2]. Figure 2.8 shows the standard lightning impulse voltage waveform.

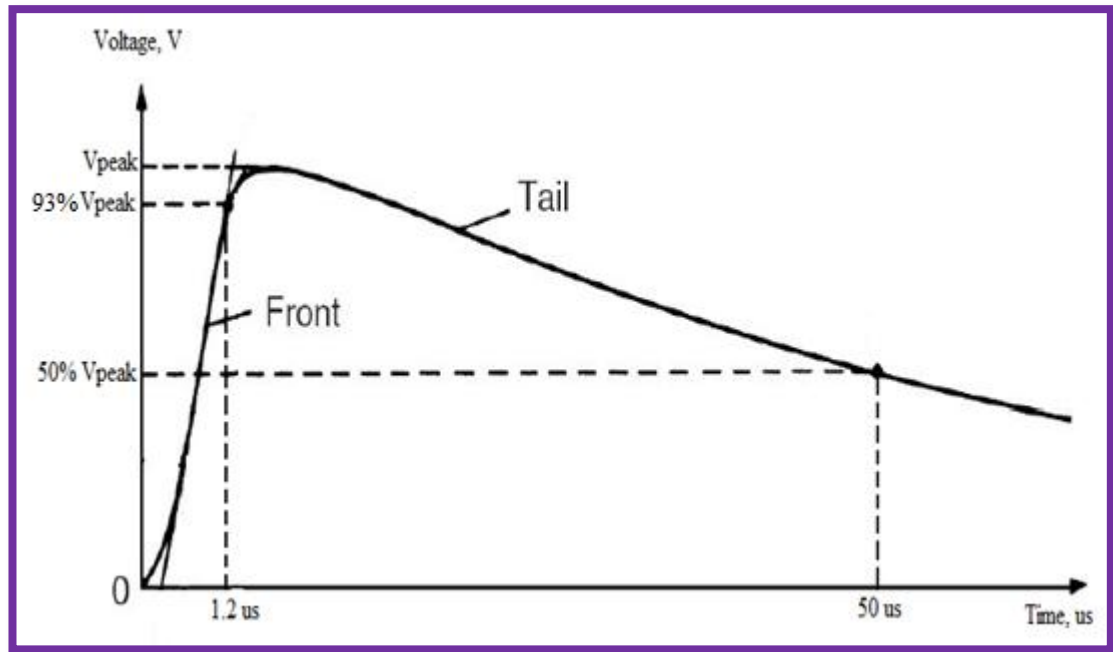


Figure 2.8 : The standard lightning impulse voltage waveform [11]

Due to many reasons such as equipments accuracy / aging, weather condition, humidity and extra, it may be difficult to generate an accurate impulse waveforms in the laboratory that can follow exactly the specific standard 1.2/50 μ s of FFO. Table 2.1 shows the tolerance for lightning impulse.

Table 2.1 : The tolerance for lightning impulse

Lightning Impulse	Front Time (T1)	Tail Time (T2)
Tolerances	$\pm 30\%$	$\pm 20\%$
Standard time, us	1.2	50
Voltage	$0.93V_{peak}$	$0.5V_{peak}$

Lightning impulse waveform will chopped when air breakdown occurred which a disruptive discharge causes a rapid collapse of the voltage, practically to zero value. The standard impulse chopped by an external gap with a time to chopping value between 2 μ s to 5 μ s [1]. There are two time chopping occur:

- i. Lightning impulse voltage chopped on the front between 0.5 μ s to 2 μ s [1].
- ii. Lightning impulse voltage chopped on the tail between 2 μ s to 5 μ s [1].

Figure 2.9 shows the lightning impulse voltage chopped on the front while figure 2.10 shows lightning impulse voltage chopped on the tail. The different between this waveform is the time chopping that occurs whether on the front time or tail time.

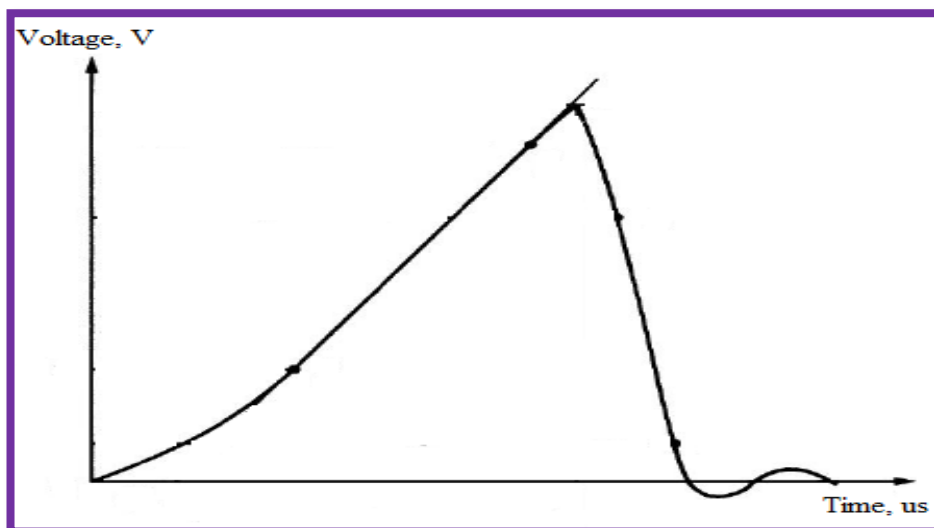


Figure 2.9 : Lightning impulse voltage chopped on the front [11]

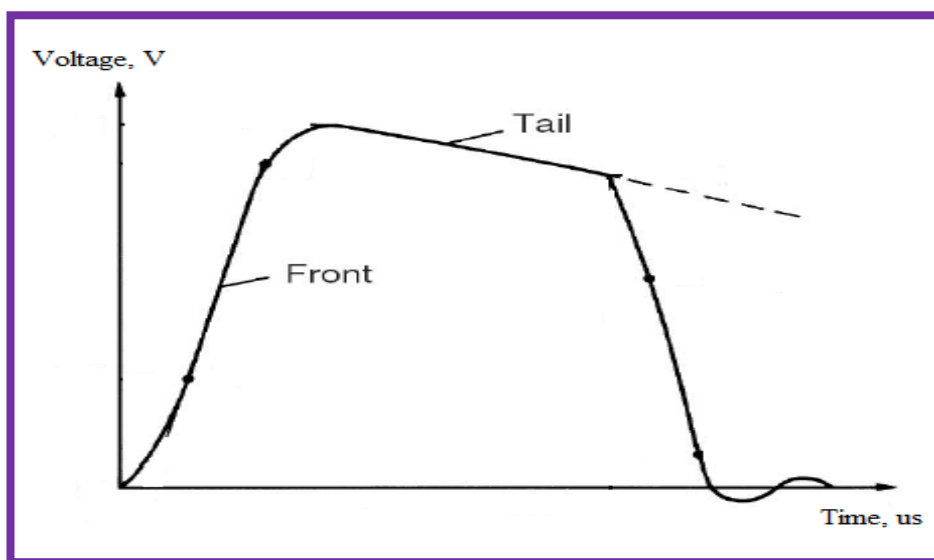


Figure 2.10 : Lightning impulse voltage chopped on the tail [11]

2.7 Air Breakdown

The breakdown in air (spark breakdown) is the transition of a non-sustaining discharge into a self-sustaining discharge. The buildup of high currents in a

breakdown is due to the ionization in which electrons and ions are created from neutral atoms or molecules, and their migration to the anode and cathode respectively leads to high currents. Townsend theory and Streamer theory are the present two types of theories which explain the mechanism of breakdown under different conditions as temperature, pressure, nature of electrode surfaces, electrode field configuration and availability of initial conducting particles. Normally air medium is widely use as an insulating medium in different electrical power equipments and over head lines as its breakdown strength is 30 kV/cm.

2.7.1 Townsend's Mechanism

The townsend discharge is named after John Sealy Townsend, who discovered the fundamental ionization mechanism by his work between 1897 and 1901 [3]. It is also known as a "Townsend avalanche". Townsend's mechanism is based upon, ionisation collision in the gas, ionisation collision on the surface of the cathode and photo-ionisation [11]. Basically, anode is positive polarity (+ve), cathode is negative polarity (-ve). Positively charge ions (cations) moves towards cathode while negatively charged ions (anions) moves toward anode [11]. Figure 2.11 shows townsend's mechanism process.

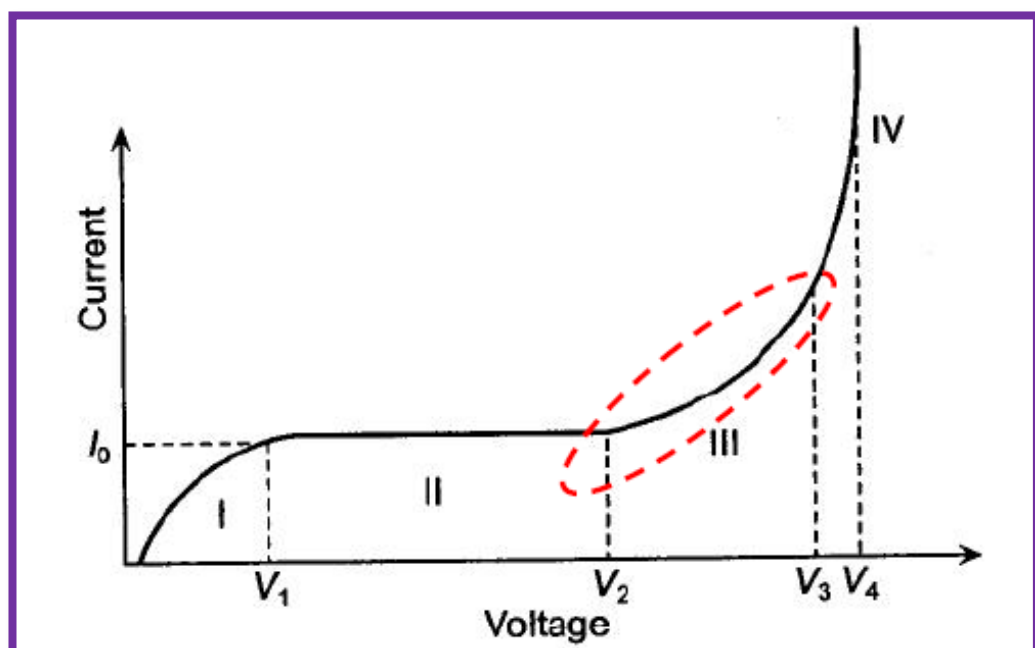


Figure 2.11 : Townsend's mechanism [11]

In region i, starting with low voltages, then current increase linearly with voltage up to saturation level (i_0) when all electron conduct. For region ii, current i_0 remains constant between V_1 and V_2 . At region iii, after V_2 , current growth exponentially. Exponential current to ionisation of gas by electron collision. Rapid increase of ionisation processes in the gap region are called avalanches process. Region iv, anod current increase very sharply. Current magnitude reach infinity and the value is limited only by the external resistance. Now, the gas is to be breakdown.

2.7.2 Streamer Mechanism

Streamer breakdown of gases developed by Loeb, Meek and Roether [3], streamer propagation is due to the appearance of secondary electrons ahead of the streamer because of photoionization of the gas by radiation from streamer itself [11]. This type of breakdown mainly arises due to the added effect of the space-charge field of an avalanche and photo-electric ionization in the gas volume [11].

Ionization process by collision cause negative charges to anode and positive charge to cathode [11]. Ionization process will create avalanches of electron that must lighter and higher mobility compare to positive ion. Therefore the electron will fill the head and the positive ion occupied the tail. Figure 2.12 shows ionization process.

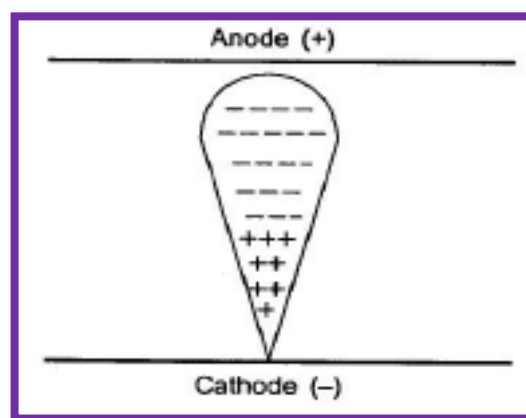


Figure 2.12: Ionization process [11]

Then, space charges cause by ionization will distort the uniform field. Spherical volumes concentrate at negative charges at the head and positive charge at

the tail. The field behind and a head of avalanches is increase by the space charge, ϵ_r . The field between the electron and the cloud is reduced. α_d increase, field distortion increase. When α_d at critical value, space charges field is comparable to ϵ_0 . 'α' is an average number ionising collision made by one electron per unit drift in the direction of the field [11]. This condition will create an intense ionisation and excitation of the gas partical in front of the avalanches head. Excited atoms return to normal. The process will release of photon, which turn generate secondary electron by the photo ionisation process. Figure 2.13 shows the distortion of electric field by space charge.

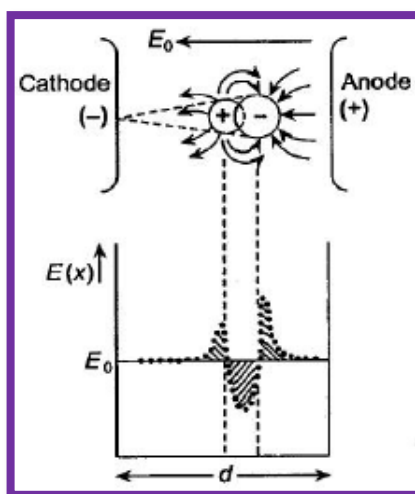


Figure 2.13 : Distortion of electric field by space charge [11]

Photo ionisation will generate further auxiliary avalanches. Photon travel with the speed of light. The process rapidly develop conduction channel and develop propagation streamer. Streamer proceed across the gap and to form a conducting filament of high ionised gas between electrodes. The gap therefore breakdown. Figure 2.14 shows the secondary avalanches formation by photo electrons.

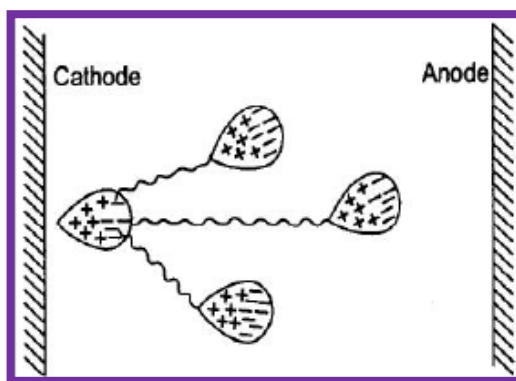


Figure 2.14 : Secondary avalanches formation by photo electrons [11]

2.8 Capacitive divider

A capacitive divider consists of two capacitors in series. It is commonly used to create a reference voltage, or to get a low voltage signal proportional to the voltage to be measured, and may also be used as a signal attenuator at low frequencies. For direct current and relatively low frequencies, a capacitive divider may be sufficiently accurate if made only of capacitors, where frequency response over a wide range is required, (such as in an oscilloscope probe), the voltage divider may have capacitive elements added to allow compensation for load capacitance. In electric power transmission, a capacitive voltage divider is used for measurement of high voltage. Figure 2.15 shows the capacitive divider that is connected in series.

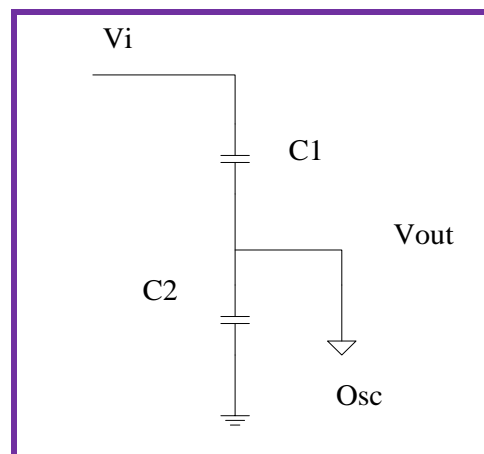


Figure 2.15 : The capacitive divider that are connected in series.

Formula for capacitive divider

$$V_{out} = \frac{C_2}{C_1 + C_2} * V_i$$

Capacitive dividers do not pass DC input. Any leakage current in the capacitive elements requires use of the generalized expression with two impedances. By selection of parallel R and C elements in the proper proportions, the same division ratio can be maintained over a useful range of frequencies. This is the principle applied in compensated oscilloscope probes to increase measurement bandwidth.

2.9 Previous related works

The thesis entitled “Measurement of air breakdown voltage and electric field using standard sphere gap method” is a project to simulate the air breakdown voltage experimentally in high voltage laboratory, standard diameter of 25 cm sphere are used for measurement of air breakdown voltage and electric field of high voltage equipment. This project is a work from Paraselli Bheema Sankar. From the referred thesis, it shows that the author has find the sphere gaps are commonly used for measurements of peak values of high voltages and have been adopted by IEC and IEEE as a calibration device. The sphere gaps are filled up with insulating medium such as liquid insulation (transformer oil), solid insulation (polyester, paper) and gas insulation (SF_6 , N_2 , CO_2 , CCl_2F_2 etc). Normally air medium is widely used as an insulating medium in different electrical power equipment as its breakdown strength is 30kV/cm. Therefore electrical breakdown characteristic of small air gap under the different applied voltage has its great significance for the design consideration of various air insulated HV equipment. In the author’s work to simulate the air breakdown voltage experimentally in high voltage laboratory, standard diameter of 25 cm spheres are used for measurement of air breakdown voltages and electric field of the high voltage equipment. Finite element method is also used for finding the electric field between standard sphere electrodes. The relative air density factor and maximum electric field are measured in MATLAB environment for different temperature and pressure. The electric field distribution for sphere gap arrangements is also calculated with the help of COMSOL [12].

The thesis entitled “An experimental study of air breakdown voltage and its effects on solid insulation” is a project to protect such equipments different types of conducting electrodes having protective gap are used widely throughout the world. This project is a work from Subrata Karmakar. The author describes the standard sphere electrodes are commonly used for this purpose among those all electrodes configuration. In the author study to simulate the air breakdown voltage experimentally in high voltage laboratory, standard diameter of 25 cm spheres are used for measurement of air breakdown voltages at NTP [13]. In addition, the air breakdown voltage with insulation barrier and without insulation barrier is investigated inside the high voltage test laboratory. The effects of the breakdown voltage on paper insulation have been investigated in this work for quality

assessment. The comparison of microstructure before and after the breakdown test reveals the information about the effects of electrical stress on the insulating paper.

The thesis entitled “Impulse breakdown voltages of ester-based transformer oils determined by using different test methods” use three different testing methods including rising-voltage method (refer to ASTM and IEC Standards), up-and-down method and multiple-level method, were employed to determine the lightning impulse breakdown voltage of two ester-based oils, Midel 7131 as synthetic ester and FR3 as natural ester [14]. This project is a work from Q. Liu, Z.D. Wang and F. Perrot. From the author’s results clearly indicated that test methods have significant influence on breakdown voltage measurement values.

The thesis entitled “Simulation of air breakdown mechanism using different electrodes” that observe the effect on insulation due to breakdown mechanism, the insulation samples are collected both before and after breakdown voltage test and analysis by using Scanning electron microscope (SEM) [15]. This project is a work from A Srikant and Shekar Chandra Pradhan. From the author’s results clearly indicated that the SEM analysis showed the level of deterioration in three different insulation papers and it observed from the SEM analysis that the deterioration of such insulation is minimum for lamiflex paper.

The thesis entitled “Air breakdown characteristics in rod-plane gaps due to repetitive nanosecond-pulses” that investigated breakdown characteristics of an atmospheric air for parallel-plate gaps by repetitive burst conditions. This project is a work from Shao Tao, Sun Guangsheng, Yan Ping, Wang Jue and Zhang Shichang. This paper focuses on the pulse breakdown characteristics of non-uniform field using rod-plane gaps due to repetitive pulses at different pressures. From the author’s experimental results show the polarity dependence is not very distinct. Relations among applied voltage, observational breakdown time lag, number of applied pulses to breakdown, and repetition rates are presented [16]. Excited particles and residual charges formed during the consecutive nanosecond-pulses would present an accumulation effect and affect the development of gas breakdown. Table 2.2 shows the summary for the previous work that are related to this project.

Table 2.2 : The summary for the previous work

Title	Author	Project Description
Measurement of air breakdown voltage and electric field using standard sphere gap method	Paraselli Bheema Sankar	Simulate the air breakdown voltage experimentally in high voltage laboratory, standard diameter of 25cm sphere is used for measurement of air breakdown voltage and electric field of high voltage equipment.
An experimental study of air breakdown voltage and its effects on solid insulation	Subrata Karmakar	Protect such equipments different types of conducting electrodes having protective gap are used widely throughout the world.
Impulse breakdown voltages of ester-based transformer oils determined by using different test methods	Q. Liu, Z.D. Wang and F. Perrot	Determine the lightning impulse breakdown voltage of two ester-based oils, Midel 7131 as synthetic ester and FR3 as natural ester.
Simulation of air breakdown mechanism using different electrodes	A Srikant and Shekar Chandra Pradhan	Observe the effect on insulation due to breakdown mechanism, the insulation samples are collected both before and after breakdown voltage test and analysis by using Scanning electron microscope (SEM).
Air breakdown characteristics in rod-plane gaps due to repetitive nanosecond-pulses	Shao Tao, Sun Guangsheng, Yan Ping, Wang Jue and Zhang Shichang	Focuses on the pulse breakdown characteristics of non-uniform field using rod-plane gaps due to repetitive pulses at different pressures

From the above summary, the previous works very useful to at some investigation in air breakdown research. By refer to the previous work, mind map for this project created to define the methods in the air breakdown. From the reading conclude that air breakdown characteristics can breakdown under different conditions as temperature, pressure, nature of electrode surfaces, electrode field configuration and availability of initial conducting particles. Higher probabilities to breakdown occur if the distance between electrodes is small. Normally air medium is widely used as an insulating medium in different electrical power equipment as its breakdown strength is 30kV/cm.

CHAPTER 3

LIGHTNING IMPULSE TEST PROCEDURES AND SIMULATION MODEL

3.1 Introduction

This project deals with the experiment set up for air breakdown characteristic in plane-plane and sphere gap electrode configuration by using TERCO circuit. From FEMM software, the different result electric fields are simulating for plane-plane and sphere gap electrodes. The method and technical strategies implied are the most important disciplines.

3.2 Methods to obtain lightning impulse

Obtain the lightning impulse is the important thing before start this project. Firstly, research and study about the literature review that related from journal, relevant paper and publication. Then, from the study, plan and select the suitable method for the projects. To prove the right circuit are use for this project, the circuit are test and observe the result waveform whether it is the lightning waveform or not. If no, try to find and test others circuit but if yes, save the data from oscilloscope and then draw the waveform by using MS excel. Figure 3.1 shows the flow for method to obtain lightning impulse.

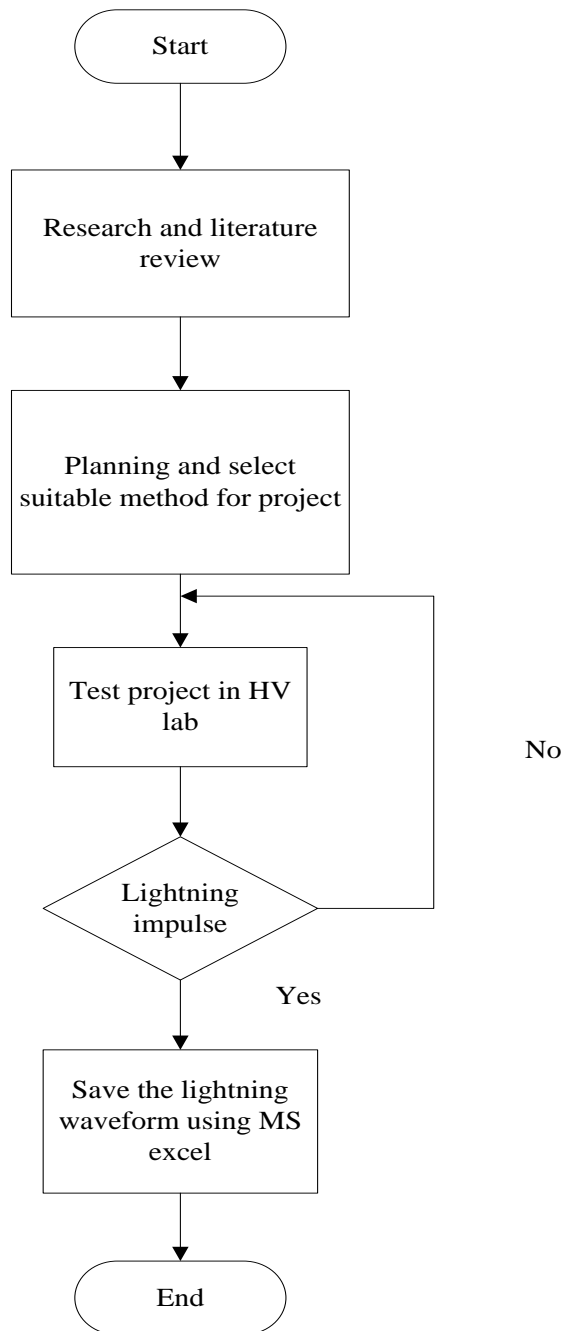


Figure 3.1 : Methods to obtain lightning impulse

3.3 TERCO lightning impulse circuit

TERCO lightning impulse circuit is main circuit that are used to obtain lightning impulse in this project. This TERCO experiment setup is available at UTHM's High Voltage Laboratory (HV lab). Figure 3.2 shows the experimental setup of lightning impulse waveform in the HV lab while figure 3.3 shows the experimental setup of lightning impulse waveform in TERCO manual guide.

Component description for the experimental setup of lightning impulse waveform shown in table 3.1. Figure 3.4 shows the block diagram for the lightning impulse circuit to make it easier to refer.



Figure 3.2 : The experimental setup of lightning impulse waveform in the HV laboratory

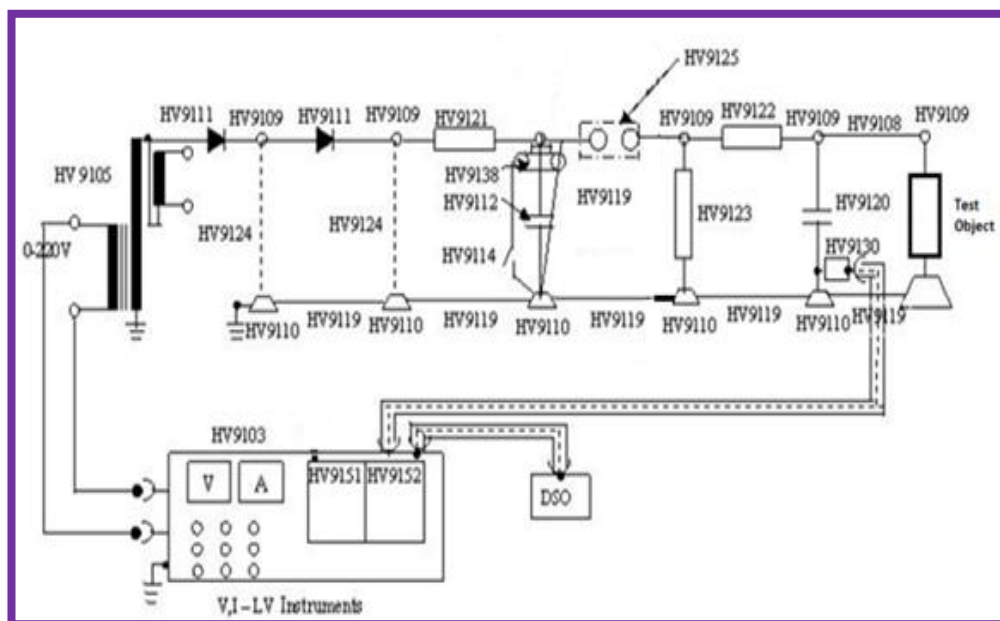













Figure 3.3: The experimental setup of lightning impulse waveform in TERCO manual guide [20]

Table 3.1 : Component description for the experimental setup lightning impulse waveform (reproduced from [20])

NO.	COMPONENT DESCRIPTION	COMPONENT	TERCO TYPE	QUANTITY
1	<p>HV Test Transformer</p> <ul style="list-style-type: none"> Produce AC high voltage (140kV) 		HV9105	1
2	<p>Control Desk</p> <ul style="list-style-type: none"> Control and operate high voltage AC/ DC/ Impulse test equipment 		HV9103	1
3	<p>Impulse capacitor (Smoothing Capacitor)</p> <ul style="list-style-type: none"> generation of impulse voltages Used as smoothing capacitor in DC voltage generation. 		HV9112	1
4	<p>Load Capacitor</p> <ul style="list-style-type: none"> Measurement of impulse voltages. 		HV9120	1
5	<p>Silicon Rectifier</p> <ul style="list-style-type: none"> Use in impulse voltage and DC voltage generation. 		HV9111	2

6	<p>Charging Resistor</p> <ul style="list-style-type: none"> For multi stage impulse voltage test equipment and current limiting resistor in DC voltage generation. 		HV9121	1
7	<p>Wavefront Resistor</p> <ul style="list-style-type: none"> For generation of impulse voltages. Determine the rise time of the impulse voltage 		HV9122	1
8	<p>Wavetail Resistor</p> <ul style="list-style-type: none"> For generation of impulse voltages. Determine the time to half value of the impulse voltage 		HV9123	1
9	<p>Sphere Gap</p> <ul style="list-style-type: none"> Pre-settings of Impulse voltage peak. 		HV9125	1
10	<p>Insulating Rod</p> <ul style="list-style-type: none"> Insulating component. 		HV9124	2
11	<p>Connecting Rod</p> <ul style="list-style-type: none"> Conductive connection element. 		HV9108	2

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