High Voltage Technology Lab

Lab Manual

Student Name	
Registration #	

Department Of Electrical Engineering

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Lab Instructor: Engr. Muhammad Qamar ud Din

College of Engineering & Technology
University Of Sargodha

LIST OF EXPERIMENTS

Lab	Title
1	Generation and measurement of AC voltage.
2	Generation and measurement of AC voltage through oscilloscope.
3	Generation and measurement of AC voltage through sphere gaps.
4	Understand Generation and measurement of DC voltage through oscilloscope
5	Generation and measurement of DC voltage through oscilloscope
6	Voltage doubler circuit.
7	Polarity effect and insulation screen.
8	Generation and measurement of impulse voltage.
9	Generation and measurement of impulse voltage using trigger sphere gap.
10	Disruptive discharge voltage tests with alternating current.
11	Disruptive discharge voltage tests with direct current.
12	Lighting impulse disruptive discharge test.
13	Insulation test for transformer oil.

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab Manual
Safety Regulations and Introduction to Control Desk, And Associated <u>Apparatus</u>

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Introduction

Experiments with high voltages could become particularly hazardous for the participants should safety precautions be inadequate. To give an idea of the required safety measures, an example the safety regulations followed in several high voltage laboratories attached to the Technical University of Braunschweig shall be described below. These supplement the appropriate safety regulations and as far as possible prevent risks to persons. Strict observance is therefore the duty of everyone working in the laboratory. Here, any voltage greater than 250 V to earth potential is understood to be a high voltage (VDE 0100).

Fundamental Rule

Before entering a high-voltage setup area, participants must first ensure that all conductors which can assume high potential and lye in the contact zone are earthed and that all main leads are interrupted.

Fencing

All high-voltage setups must be protected against unintentional entry to the danger zone. This is appropriately done with the aid of metallic fences. When setting up the fences for voltages up to 1 MV the following minimum clearances to the components at high voltage should not be exceeded:

Alternating and direct voltages 50 cm for every 100 kV

Impulse voltages 20 cm for every 100 kV

A minimum clearance of 50 cm shall always be observed, independent of the value and type of voltage. For voltages over 1 MV, in particular for switching impulse voltages, the values quoted could be inadequate; special protective measures must then be introduced.

The fences should be reliably connected conductively, earthed and provided with warning boards inscribed: "High Voltage! Caution! Highly Dangerous!". It is forbidden to introduce conductive objects through the fence while the setup is in use.

Safety locking

In high-voltage setups each door must be provided with safety switches; these allow the door to be opened only when all main leads to the setup are interrupted. Instead of direct interruption, the safety switches may also operate the no-voltage relay of a power circuit breaker, which on opening the door, interrupts all the main leads to the setup.

These power circuit breakers may also be switched on again when the door is closed. For direct supply from a high-voltage network (e.g. 10 kV city network), the main leads must be interrupted visibly before entry to the setup by an additional open isolating switch. The switched condition of a setup must be indicated by a red lamp "Setup switched on" and by a green lamp "Setup switched off".

If the fence is interrupted for assembly and dismantling operations on the setup, or during large-scale modifications, all the prescribed precautions for entry to the setup shall be observed. Here, particular attention must be paid to the reliable interruption of the main leads. On isolating switches or other disconnecting points and on the control desk of the setup concerned, warning boards inscribed "Do not switch on! Danger!" must be displayed.

Earthing

A high-voltage setup may be entered only when all the parts which can assume high-voltage in the contact zone are earthed. Earthing may only be affected by a conductor earthed inside the fence. Fixing the earthing leads onto the parts to be earthed should be done with the aid of insulating rods. Earthing switches with a clearly visible operating position are also permissible. In high-power setups with direct supply from the high-voltage network, earthing is achieved by earthing isolators. Earthing may only follow switching the current source off and may be removed only when there is no longer anyone present within the fence or if the setup is vacated after removal of the earth. All metallic parts of the setup which do not carry potential during normal service must be earthed reliably and with adequate cross-section of at least 1.5 mn^2 Cu. In test setups with direct supply from the high-voltage network, the earth connections must be made with considerations of dynamic forces which can arise.

Circuit and Test setup

In the case that the setup is not supplied from ready wired desks, clearly marked isolating switches must be provided in all leads to the low-voltages circuits of high-voltage transformers and arranged at an easily identifiable position outside the fence. These must be opened before earthing and before entering the setup.

All leads must be laid so that there are no loosely hanging ends. Low voltage leads which can assume high potentials during breakdown or flashovers and lead out of the fenced area, e.g. measuring cables, control cables and/or supply cables must be laid inside the setup in earthed sleeves. All components of the setup must be either rigidly fixed or suspended so that they cannot topple during operation or be pulled down by the leads. For all setups intended for research purposes, a circuit diagram shall be fixed outside the fence in a clearly visible position. A test setup may be put into operation only after the circuit has been checked and permission to begin work given by an authorized person.

Conducting the experiments

Everyone carrying out experiments in the laboratory is personally responsible for the setup placed at his disposal and for the experiments performed with it. For experiments during working hours one should try, in the interest of personal safety, to make sure that a second person is present in the testing room. If this is not possible, then at least at the times of the beginning and ending of an experiment should be communicated to a second person. When working with high voltages beyond working hours a second person familiar with the experimental setups must be present in the same room.

If several persons are working with the same setup, they must all know who is to perform the switching operations for a experiment. Before switching on high-voltage setups, warning should be given either by short horn signals or by the call “Attention! Switching-on!” . This is especially important during loud experiment can be announced when the equipment is de-energized either by a single long tone or by the call “Switched off”.

Explosion and fire risk, radiation protection

In experiments with oil and other highly flammable materials, special care is necessary owing to the danger of explosion and fire. In each room where work is carried out with these materials, suitable fire extinguishers must be close to hand and ready for use. Highly flammable waste products e.g. paper or used cotton waste, should always be disposed of immediately in metal bins.

Accident insurance

Everyone working in the institute must be insured against accidents.

Conduct during accidents

Mode of action in case of an electrical accident:

1. Switch off the setup on all poles. So long as this has not been done, the victim of the accident should not be touched under any circumstances.
2. If the victim is unconscious, notify the emergency service at once.

   Telephone Number: ……………………………………………
3. Make immediate attempts to restore respiration by artificial respiration or chest massage!
4. These measures must be continued, if necessary, up to the beginning of an operation. (Only 6 to 8 minutes time before direct heart massage!).
5. Even during accidents with no unconsciousness, it is recommended that the victim lies quietly, and a doctor’s advice is sought.

Introduction to Control Desk

Description – Function of Controls

The Table over the next pages gives a summary of the control and operating devices of the test equipment, as described in section 3.1, 3.2 and 3.3. Function of Controls refer to Drg.no.387060 "Keyboard" and Drg.no.386557 "Case (S2, R1)"

Control	Function	Back Signal	Remarks
1. Toggle Switch Black S1 " MAIN SWITCH"	Switches on: -Mains voltage 220V -Socket 220V -Control Voltage 24V -Control Voltage 220V -Auxiliary Voltage for measuring instruments 220V - Status " Ready for operation"	The following green lamps are illuminated H5 (mounted in S8)H5.1 (Lamps) on entrance of danger (zone) H7 (mounted in S10) H9	The signals are H5: Primary contactor OFF H5.1:Primary contactor OFF H7: Secondary contactor OFF H9: Grounding switch closed
2. Push-button, black S3 "HORN"	Signal horn H1 sounds		As a warning for instance before high voltage is applied
3. Key switch S6	Switches off the contactor control		Key prevents unauthorized operation of control. ATTENTION: Key can be removed in either positions
4. Emergency OFF Button S5 EMERGENCY	Switches off the entire control system – OFF		Press button catches when operated. It is released spring return.
5. Illuminated buttons 5.1 OFF" S7	Primary voltage on regulating transformer - OFF	Signal lamps Green H5, H5.1, H7, H9 (refer to part.1)	
5.2. "ON" S8	- On - Status " Ready for switching ON"	Red H4 (mounted in S7) Red H4.1 (warning lamps	Everybody shall have left the danger zone. The electrical

		(s) on entrance to danger zone) Red H8 grounding switch open	safety circuit must be closed.
6. Illuminated Buttons “SECONDARY” 6.1 OFF” S9	Secondary Voltage on regulating transformer -Primary voltage on test transformer. - OFF	Signal Lamps green H7 (mounted in S10)	
6.2. “ON” S10	- ON Status “Operating”	Red H6 (mounted in S9) and H4, H4.1 (refer to 5.2)	The secondary voltage of the regulating transformer must be on zero. Otherwise secondary contactor cannot be switched on. For exceptions, refer to par.10.
7. Toggle switches “ VOLATGE REGULATION” 7.1.“MAXIMUM” S15 (maximum speed) 7.2.”VARIABLE” S14(variable speed)	Setting primary voltage on test Transformer -With maximum speed - With variable speed Depending on setting of R1 (refer to par.8)		
8. Potentiometer1 “REGULATING SPEED”	Setting of regulating speed (refer to par.7)		Regulating time (0 to 100%) can be set in the range of APPROX 30-120 seconds
9. Push button Yellow S2 “I x 2 max 2 min. 50%”	Reducing the sensitivity of current indication and over current tripping.	50% deflection on Ammeter P2 with same current.	Short time duty 10KVA for maximum 2 min.
10. Push button Yellow S11 “UNLOCKING”	Compulsory zero reset is relinquished		Application of regulating transformer secondary voltage not reset to is admissible only up to 20% rated voltage and

			shall be limited to exceptional cases.
11. Push Button, black S4 " LIGHT OFF"	Switches off all lamps as long as the button is pressed.		For instance, to allow observation of glow discharges.
12. Toggle switch S12 "KF" (Sphere gap for impulse generator plant).	Increases (+) or reduces (-) the gap setting of KF.	The spheres of sphere gap KF are moved accordingly.	The control cable between plug KF (X13) and drive AKF shall be connected. AKF and KF must be inter connected over the drive shaft AS.
13. Toggle switch S13 "MF" (Measuring spark gap).	Increases (+) or reduces (-) the gap setting of MF.	The spheres of the measuring spark gap MF are moved accordingly.	The control cable between plug MF (X14) and MF shall be connected.

HV9159 Digital Oscilloscope

Technical specifications

The table below provides a summary of the main technical specifications of the HV9159 Digital oscilloscope. For further details please see the Rigol DS1052E Data Sheet.

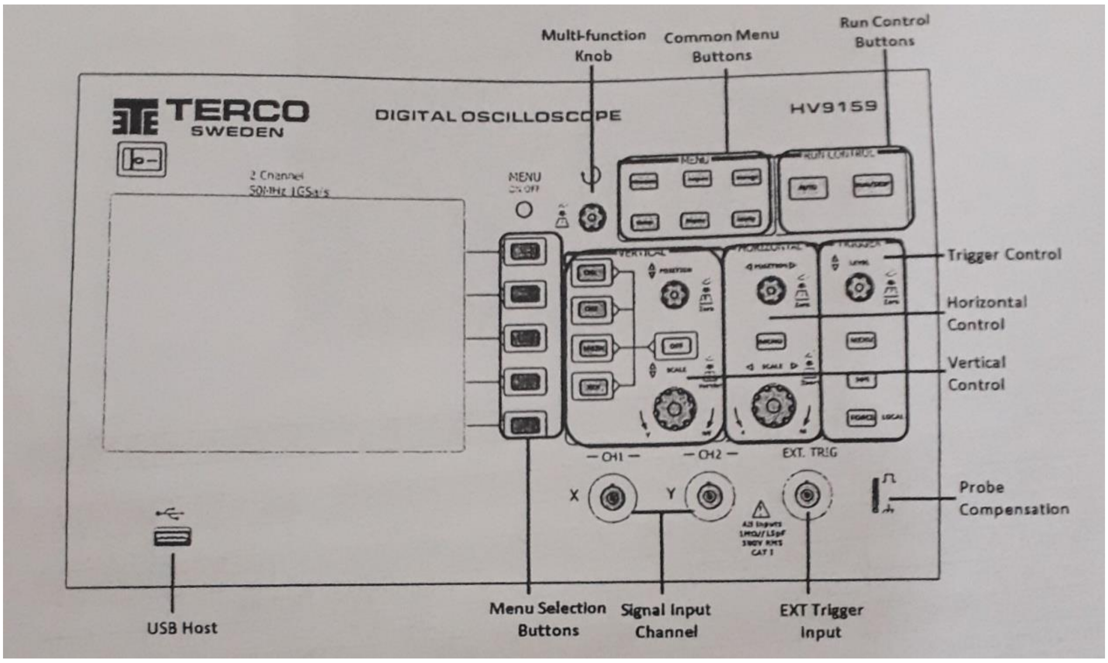
<table>
<tr><td>Name</td><td colspan="2">Oscilloscope</td></tr>
<tr><td>Brand</td><td colspan="2">Rigol DS1052E</td></tr>
<tr><td>Bandwidth</td><td colspan="2"></td></tr>
<tr><td>Analog Bandwidth</td><td colspan="2">50 MHz</td></tr>
<tr><td>Acquisition</td><td colspan="2"></td></tr>
<tr><td>Sample Modes</td><td>Real-Time Sample</td><td>Equivalent Sample</td></tr>
<tr><td>Sample Rate</td><td>1GSa/s</td><td>10GSa/s</td></tr>
<tr><td>Inputs</td><td colspan="2"></td></tr>
<tr><td>Input Impedance</td><td colspan="2">1MN I 2%, 18pF 3Pf</td></tr>
<tr><td>Maximum Input Voltage</td><td colspan="2">400V</td></tr>
<tr><td>Horizontal</td><td colspan="2"></td></tr>
<tr><td>Record length</td><td colspan="2">
<table>
<tr><td>Channel Mode</td><td>Sample Rate</td><td>Memory depth (normal)</td><td>Memory Depth (long memory)</td></tr>
<tr><td>Single channel</td><td>1GSa/s</td><td>16kpts</td><td>N.A</td></tr>
<tr><td>Single channel</td><td>500MSa/s</td><td>16kpts</td><td>1Mpts</td></tr>
<tr><td>Dual channel</td><td>500MSa/s</td><td>8kpts</td><td>N.A</td></tr>
<tr><td>Dual channel</td><td>250MSa/s</td><td>8kpts</td><td>512kpts</td></tr>
</table>
</td></tr>
<tr><td>Scanning Speed Range</td><td colspan="2">Sns/div-50s/div</td></tr>
<tr><td>Vertical</td><td colspan="2"></td></tr>
<tr><td>A/D Converter</td><td colspan="2">8-bit resolution, all channels sample simultaneously</td></tr>
<tr><td>Volts/div Range</td><td colspan="2">2mV/div10V/div</td></tr>
<tr><td>Single-shot Bandwidth</td><td colspan="2">50MHZ</td></tr>
<tr><td></td><td colspan="2"></td></tr>
</table>

Trigger	
Trigger Sensitivity	0.1div-1.Odiv (adjustable)
Trigger Modes	Edge, Video, Pulse Width, Slope, Alternate
Math	
Operations	+, -, X, FFT, Invert
Display	
Display Type	5.7inch. (145mm) diagonal TFT Liquid Crystal Display 64k color
Display Resolution	320 horizontal RGBX 234 vertical pixels

Front panel and user interface

This section provides an overview of the most important controls to operate the oscilloscope. For a more detailed look.

Front panel



The Multi-Function knob is used for a number of things, especially to scroll and select settings in the submenus, adjusting the brightness and selecting/moving the measuring cursors.

(1). The Common Menu buttons group consists of:

(a). The Measure button activates the automatic measurement function. The oscilloscopes provide 20 auto measurements: Vpp, Vmax, Vmin, Vtop, Vbase, Vamp, Vavg, Vrms, Overshoot, Preshoot, Freq, Period, Rise Time, Fall Time, Delay1-2, Delay1-2, +Width, -Width, +Duty, -Duty.

(b).The Cursor button displays the menu for the different cursor measurement modes. The cursor measurement has three modes: Manual, Track and Auto Measure.

(c).The Acquire button is used to set up the sampling system. Sampling modes, memory depth and acquisition modes can be adjusted in the Acquire menu.

(d).The Display button activates the menu for the setting of the display system. Among other things display type, intensity, brightness and grid settings can be adjusted.

(e).The storage button shows the menu for the settings of the storage system. Waveforms and setup can be stored in and recalled from, both internal memory and external memory.

(f).Utility button is used for setting up the utility system. Such as IO settings, sound, language, Printer settings and system information.

(2). Run Control Buttons include

(a). The AUTO button features automatic adjustments to produce a usable display of the input signal.

(b). The RUN/STOP button starts and terminates the acquiring of a waveform.

(3). The Menu Selection buttons is used to make selections in the menus.

(4). The Vertical Control buttons group consist of:

(a). The CH1/CH2 buttons activates each channels operation menu. The type of coupling,bandwidth limits, probe attenuation filters and scale resolution can be adjusted in the operation menu.

(b). The Math button displays the menu for the oscilloscopes different mathematical Operations. The mathematic functions include "add", "subtract”, “multiply" and "FFT" For Channel 1 and Channel 2.

(c). The REF button displays the reference waveform menu. Reference Waveforms are Saved waveforms to be selected for display.

(d). The vertical Position knob is used to change the vertical display position of each channel. Pressing the vertical Position knob moves the signal back to its original position in the middle of the screen.

(e). The vertical Scale knobis used to change the vertical scale. Vertical Sensitivity is 2mV/div - 10V/div

(5). The horizontal control group includes

(a). The horizontal Position knob moves displayed signal horizontally. Pressing the knob sets the horizontal offset to its zero position.

(b). The horizontal Scale knob changes the sweep speed in a 1-2-5 step sequence, and displays the value in the status bar. The time base ranges of the oscilloscope is from Ins/div to 50s/div.

(6). The Trigger control group includes

(a). The Level knob sets the trigger level; press the knob and the level will reset to zero.

(b). The trigger MENU button activates the trigger controls menu where the type of mode, source and sweep can be selected.

(c). The 50% button sets the trigger level to the vertical midpoint between the peaks of thetrigger signal.

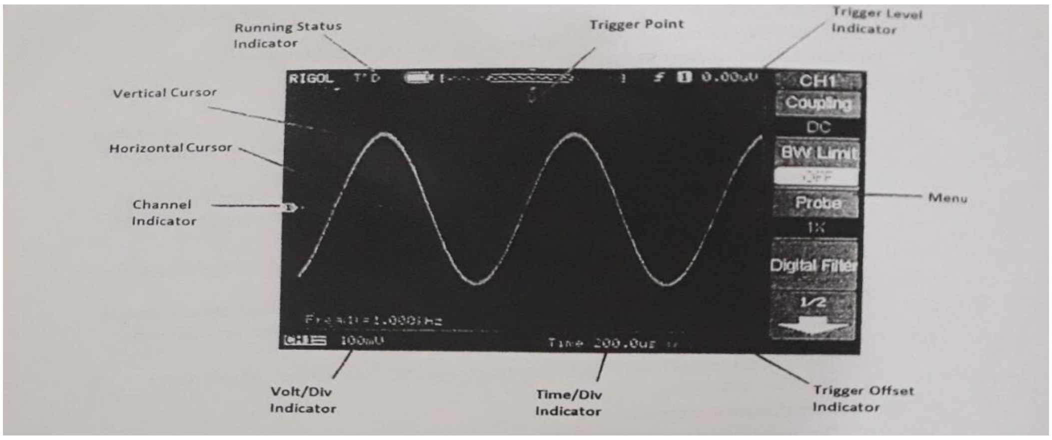
(d). The FORCE button is used to force create a trigger signal and the function is mainly usedin Normal and Single mode.

(7). The USB Host is a USB interface used to save and load waveforms, setups, bitmaps and CSV files.

(8). The Signal Input Channels are BNC connectors for channel 1 and 2.

(9). The EXT Trigger input is a BNC connector for an external trigger signal. External trigger source uses the signal directly; it has a trigger level range of -1.2V to +1.2v.

(10). The Probe Compensation connector is used to match the characteristics of the probe and the channel input. It has an amplitude of ~3Vp-p and a frequency of 1 kHz.



User interface

(1). The running status indicator shows the current status of the oscilloscope. The status may be RUN, STOP, T' D, WAIT or AUTO.

(2). Trigger point shows the trigger point offset.

(3). The Trigger Level indicator shows the trigger level, the trigger source and the current trigger mode. The trigger level is adjusted with the Level knob in Trigger Control group whilst the source and mode is selected in the trigger menu.

(4). The Trigger Offset indicator shows the trigger offset, the trigger position will be changes horizontally by turning the Position knob in the Horizontal Control group.

(5). The Time/Div indicator shows the horizontal time base it is adjusted by turning the horizontal Scale knob in the Horizontal Control group.

(6). The Volt/Div indicator shows the vertical volts per division, the affected channel and the type of coupling. The volt per division can be adjusted by turning the vertical Scale knob in the vertical control group. The type of coupling, AC, DC or GND, can be selected under the specific channels operational menu.

(7). The Channel indicator displays the number of the channel and is a indicator of the signals value with respect to the ground reference located at the center of the screen. It can be moved vertically by turning the vertical Position knob in the Vertical Control group.

(8). Vertical and Horizontal cursors are used to measure voltage and time respectively. The positions of the cursors can be adjusted with the Multi-Function knob.

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UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 1 Manual
Generation and Measurement of AC Voltage

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!

It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the Safety Regulations for High Voltage Experiments section before commencing experiments.

Objective

Alternating voltages are required for most high-voltage tests. The investigations are performed either directly with this type of voltage or used in circuits for the generation of high DC voltage and impulse voltages. This experiment examines the generation of High AC Voltage using a TERCO test transformer.

Reference

Terco HV 9150 Digital AC Voltmeter Manual.
Terco HV 9103 Control Desk Manual.

Equipment to be used

COMPONENT DESCRIPTION	TERCO TYPE No.	QUANTITY
HV Test Transformer	HV9105	1
Control Desk	HV9103	1
Measuring Capacitor	HV9141	1
AC Peak Voltmeter	HV9150	1
Connecting Rod	HV9108	1
Connecting Cup	HV9109	1
Floor pedestal	HV9110	1
Earthing Rod	HV9107	1

Test setup

The test setup consists of the transformer, a measuring capacitor, a connecting cup and a floor pedestal, the electrical relationship of which is presented below:

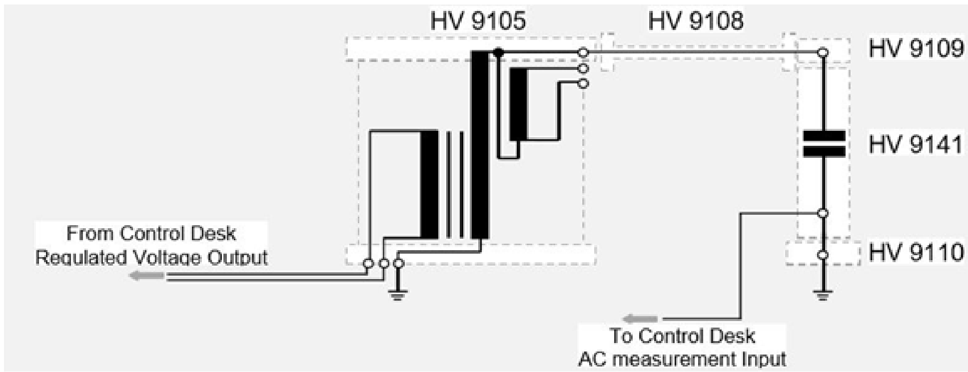

Fig. 1.1 Circuit for AC Voltage measurement

Introduction

Setting up the HV experiment

High Voltage AC is generated in the Laboratory using the 220V/100kV Test Transformer (HV9105). This is fed and controlled from the Control Desk. The high voltage experiments must be carried out in dedicated HV experimental areas enclosed with metal barriers. Control desks with power supply installations, safety circuits and the measuring instruments constitute the standard equipment. For voltage measurement, one instrument for measuring the primary voltage of the transformer and one AC peak voltmeter (HV9150) are provided at each desk. Participants should study the circuit of the Control Desk (HV9103) and familiarize themselves with its operation before commencing the experiment. This experiment assumes that power is supplied to the control desk and the door contact has been connected.

Methods of Measuring High Alternating Voltages

High AC Voltages can be measured by different methods: Measurement of Urms using primary input voltage and Transformer Ratio .Measurement of Û with the peak voltmeter (HV9150) via an AC Measuring Capacitor (HV9141) .Determination by using the breakdown voltage Ûd of a sphere gap .Determination of Û using a circuit after Chubb and Fortes cue. (Not covered here)

This experiment focuses on the first two methods of measurements, the results of which are then used for comparison.

Transformer Ratio to calculate Urms from the transformer primary input voltage and the transformer ratio, these values must first be established.

The HV 9103 Control Desk provides a user-regulated output voltage of 0 - 220/230 VAC. This is fed to the primary side of the HV 9105 transformer.

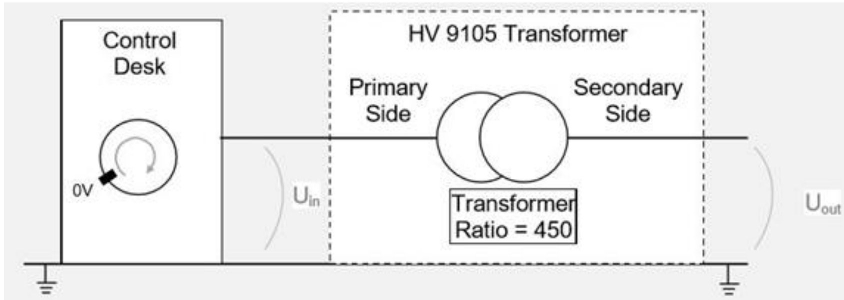

Fig. 1.2 Simplified Transformer Circuit

Uout is found by simply multiplying Uin by the transformer ratio:

Uout = 450 x Uin

Measuring Capacitor, The simplest and most common way of finding the AC voltage value in the Terco HV setup is by way of a measuring capacitor. High-voltage capacitors are well-suited for the reduction of high alternating voltages to values easily measurable with instruments. Loading To keep loading on the voltage source as low as possible, the HV capacitor C1 should be kept as small as possible. (In our case, 100pF for the HV 9141) Accuracy of high-voltage measurement with capacitors is then limited only by the environment that can affect the capacitor, C1. This is represented by the earth capacitance depicted as CE in circuit (a) below.

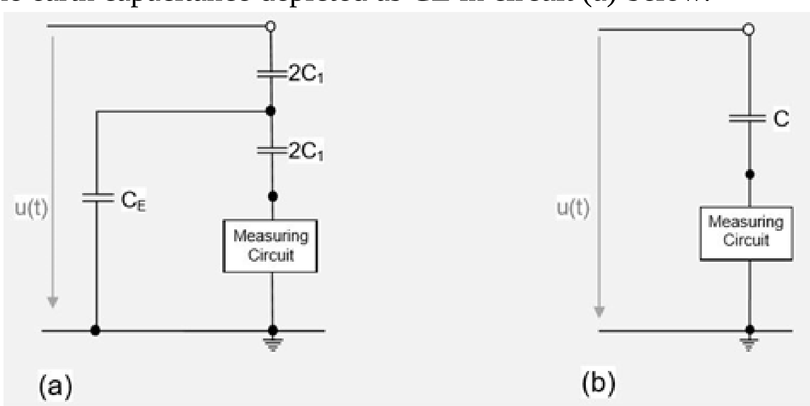

Fig. 1.3 (a) with Earth Capacitance (b) Equivalent Capacitance

The measuring circuit is connected at the low-voltage output terminal. For the current flowing through the measuring circuit, which is determined by the primary capacitance C1, the earth capacitance reduces the effective primary capacitance to:

$$C = C_1 \frac{4}{1 + \frac{C_E}{4 * C_1}} \approx C(1 - \frac{C_E}{4 * C_1})$$

Under the assumption of homogenous distribution of earth capacitance, it can be shown the CE is equal to 2/3 of the total earth capacitance Ce acting at C1.

For cylindrical dividers, Ce can be calculated at a value of 12 - 20 pF/m in height.

The effect of change of capacitance must remain small to ensure adequate measuring accuracy.

This can be achieved in practice by making the high voltage capacitors static (always the same Ce).

Experiment and procedure

Checking the Experimental Setup

The complete circuit diagram of the control desk and the current paths of the safety circuits should be discussed and wherever possible, the actual wiring of the experimental setup traced. A series of measures which guarantee protection against electrical accidents can be identified in the circuit and the fulfillment of the safety regulations of Appendix-A should be determined using the following methods.

Procedure

1. Ensure access to the specific manuals for the HV 9103 Control Desk and HV 9150 AC voltmeter.

2. Check earth points. Always make sure there is a good quality earth connection, to which all the components can be connected. This should be a high-quality busbar, situated inside the cage, such as the one shown below.

Fig. 1.4 (a) Earthing Bushbar

If earthing plates are present, check all connections between them and connect directly to the bushbar.

3. Make the transformer connections. Check that the 2 jumpers are present and connected as indicated in the picture below.

Fig. 1.5 HV Transformer Connections

4. With the relevant connection cable, connect earth then the phases. The earthing connector should be of an O-ring type to prevent accidental disconnections. Jumpers to ground plates earth Bus-Bar and control desk.

5. Connect the transformer to the Control Desk. Insert the cable connector through the cable

opening and into the Regulated Voltage output at the rear of the Control Desk.
Note that this is a twist connector. The plug is inserted at the 10 o'clock position and twisted clockwise to the 12 o'clock position to secure.

Fig. 1.6 (a) Control Desk Regulated Output

Fig 2.7 regulated Voltage Connector

6. Position the Measuring Capacitor. First, a HV 9110 Floor Pedestal will be required. The measuring capacitor will stand upright on this. Position the floor pedestal about 60cm from the transformer where it will not cause an obstruction.
Note: The measuring capacitor should be positioned so that the signal output connector is at the bottom (indicated by the blue ring, below).

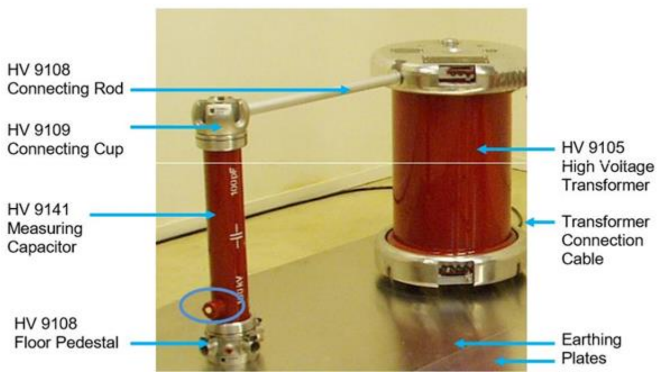

Fig. 1.8 AC Voltage measurement Component Placement

7. Connect the capacitor to the transformer. Place a Connecting Cup on top of the upright Measuring Capacitor, adjust the distance to the transformer and connect with a Connecting Rod.
Note: If no Earthing Plates are used, connect the measuring capacitor to the earth busbar.
8. Connect the Measuring Capacitor output to the Control Desk input. Connect the appropriate coaxial cable from the Measuring Capacitor to the HV 9150 input, situated on the rear panel of the Control desk.

Fig. 1.9 HV 9150 AC Voltmeter **Fig 2.10 AC Measuring Capacitor output**

Note! how the excess cable has been hung up on the cage with quick ties to help protect the cable and to prevent accidents inside the HV area.

9. Make sure the Control Desk has an earth connection to the busbar.

10. After double-checking all connections and ensuring good earthing for all relevant components, the Control Desk can be connected to the power supply.

11. The rear of the Control desk should resemble the picture below, except for the cable hanging to the left, which is the connection cable for the DC voltmeter. This is covered in future experiments. Note the Door Contact connection at the bottom left (white cable).

Fig. 1.11 Control Desk connected and ready for AC voltage measurement

Note! On leaving the HV cage, place the HV 9107 earthing-rod across the door opening in a way that anyone entering must first pick it up. This is good practice and very important for the continued safety of participants as it serves as a reminder to discharge any components which may hold a charge on entering the HV area.

12. Perform an Analysis. With the equipment ready to start, calculate the following expected AC values using the transformer ratio method and enter the results in the results table.

13. Prepare for measurement. With the key, unlock the Control Desk and turn it on by the mains switch.

14. At this point, make sure the AC voltmeter is set to the desired measurement position. Reset using the reset button if required. (For more information, please see the dedicated HV 9150 AC voltmeter manual.)

15. Begin measurement. Switch on the primary side by pressing the corresponding button (B). Next, do the same for the secondary side (B).
16. Gradually increase the voltage using the controllers (C). At each primary voltage level in the results table, record the displayed value.
17. Decrease the voltage back to zero.
18. Switch off the Control Desk.
Note! On entering the cage, always use the earthing rod to discharge any potential live power sources

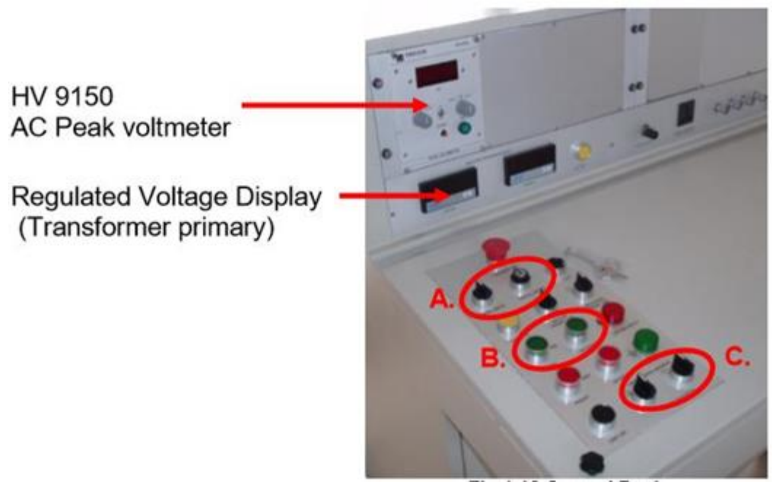

Fig. 1.12 Control Desk

Results

Results Table

Primary (regulated) Voltage	Calculated Secondary Voltage	Indicated Secondary Voltage

OBSERVATION:

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UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 2 Manual
Generation and Measurement of AC Voltage through Oscilloscope.

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

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Instructor Signature	

SAFETY PRECAUTIONS!!!

It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the Safety Regulations for High Voltage Experiments section before commencing experiments.

Objective

Alternating voltages are required for most high-voltage tests. The investigations are performed either directly with this type of voltage or used in circuits for the generation of high DC voltage and impulse voltages. This experiment examines the generation of High AC Voltage using a TERCO test transformer.

Reference

Terco HV 9150 Digital AC Voltmeter Manual.

Terco HV 9103 Control Desk Manual.

Equipment to be used

COMPONENT DESCRIPTION	TERCO TYPE No.	QUANTITY
HV Test Transformer	HV9105	1
Control Desk	HV9103	1
Measuring Capacitor	HV9141	1
AC Peak Voltmeter	HV9150	1
Connecting Rod	HV9108	1
Connecting Cup	HV9109	1
Floor pedestal	HV9110	1
Oscilloscope	HV9159	1
Earthing Rod	HV9107	1

High voltage measurement

AC measurement

Test setup

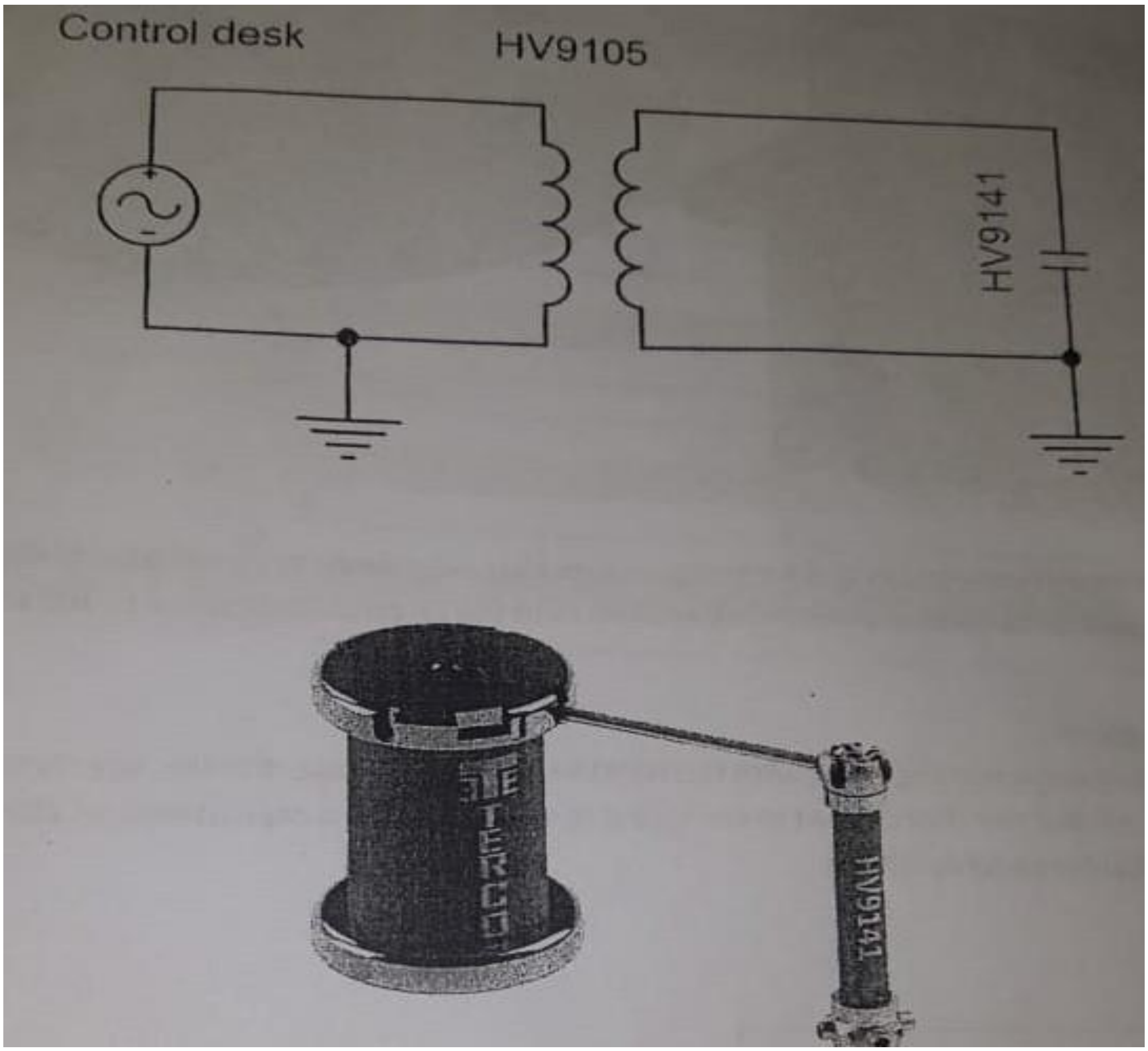

Fig. 2.1 Circuit for AC Voltage measurement

This experiment assumes that power is supplied to the control desk and the door contact has been connected. High Voltage AC is generated in the Laboratory using the 220V/100kV Test Transformer (HV9105). This is fed and controlled from the Control Desk. For voltage measurement, one instrument for measuring the primary voltage of the transformer and one AC peak voltmeter HV9150 are provided at each desk. Connect the appropriate coaxial cable between the HV9141 measuring capacitor output and the X17 HV9150 capacitor divider input on the back of the HV9103 Control desk.

Connect the the 10:1 probe between the X27 peak voltmeter output on the front of the control des and the channel 1 input of the HV9159 oscilloscope.

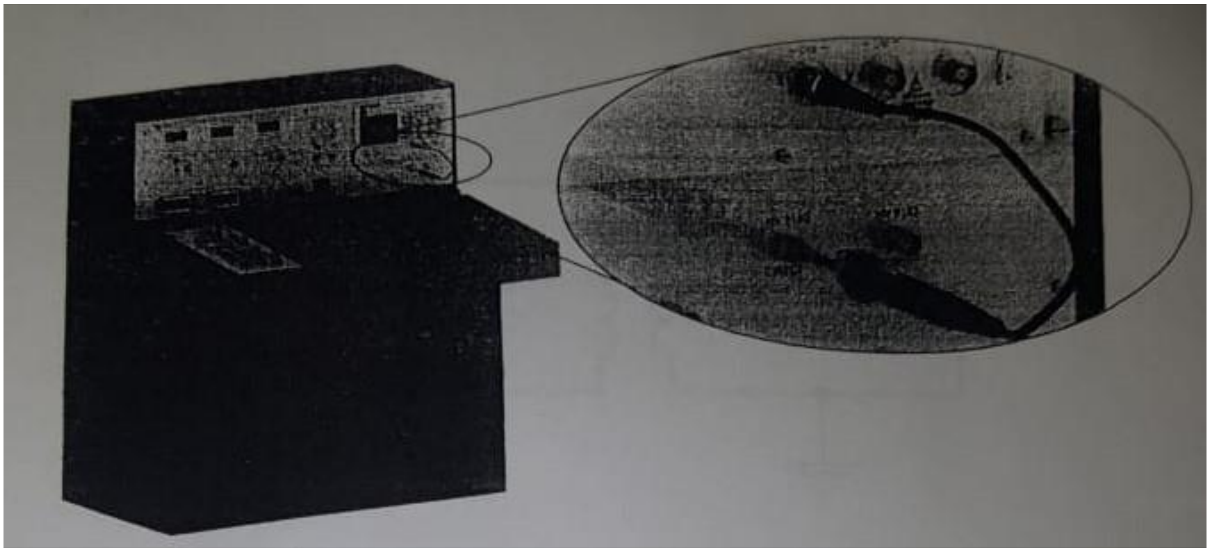

Fig. 2.2 Oscilloscope connection

After double-checking all connections and earthing, ensure that everybody has exited the HV cage. Then proceed with switching on the control desk and increase the alternating voltage to 100 kV Ú/v2.

Voltage dividers : The HV9141 measuring capacitor together with the HV9150 makes a voltage divider. The HV9141 has a capacitance of 100 pF and the HV9150 set in the one stage position has a capacitance of 200 nF making the voltage divider roughly 2000:1

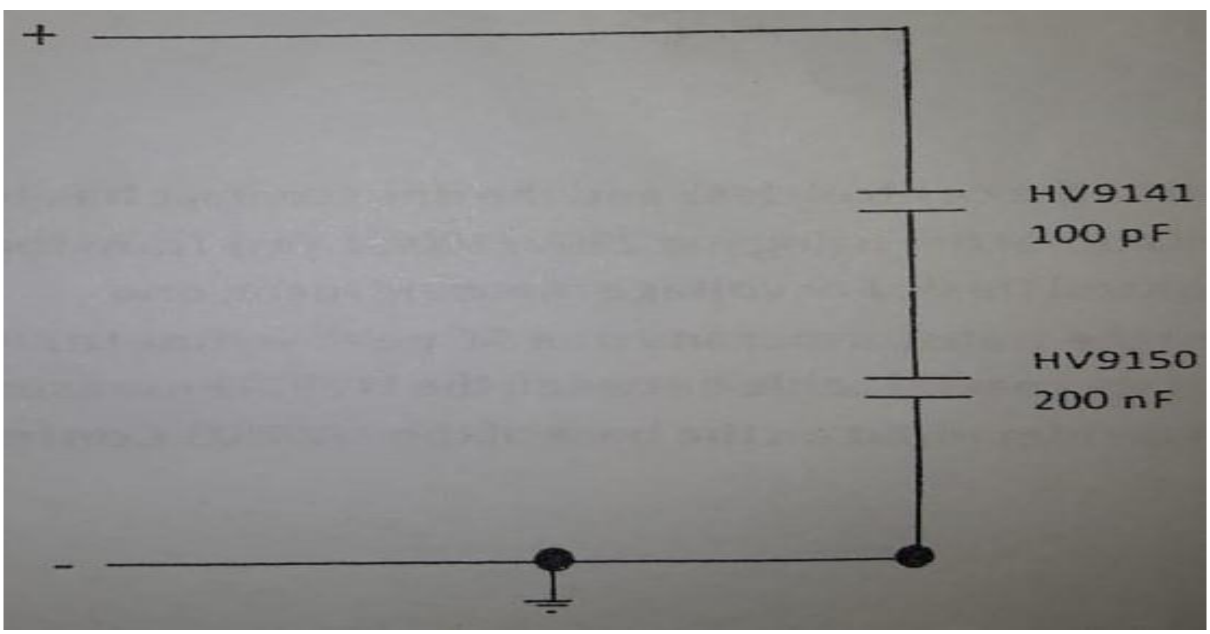

Fig. 2.3 Voltage divider connection

Oscilloscope settings

There are two ways to make the accurate settings for a AC measurement on the HV9159 oscilloscope. The correct settings can either be loaded from the internal/external memory on configured manually. The table below provides a summary of the oscilloscope settings for measuring AC voltage.

Vertical Controls	
Probe attenuation	10x
Scale	25V
Position	0V
Trigger Controls	
Mode	Edge
Source	CH1
Sweep	Auto
Measure	
Source	CH1
Voltage	V_{max}, V_{rms}
Time	Frequency
Horizontal Controls	
Scale	5ms
Position	0
Curser setup	
Mode	Auto

Oscilloscope setting

There are two ways to make the correct settings for a DC measurement on the HV 9159 oscilloscope. The accurate setting can either be loaded from external/internal memory or configured manually. The table below provides a summary of the oscilloscope setting for measuring a AC voltage

Manual setup

Press the CH1 button under the vertical control group. Turn the position knob until the channel 1 signal indicator is at the 0V position (signal in the middle of screen). Turn the scale knob to until the volt per division indicator states 20mV

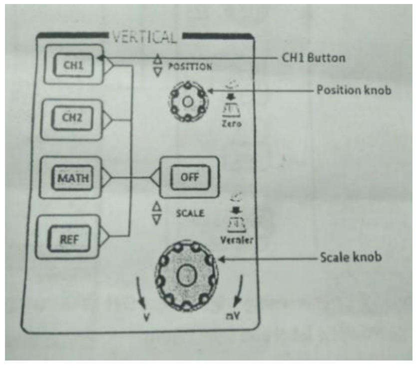

Fig. 2.4 Vertical control setting

Under the probe menu select 10X to match the attenuation factor of the probe. To adjust the vertical scaling go to the second menu and select fine under the Volts/Div label or press the vertical scale knob. Turn the vertical scale knob to adjust the volts per division to 300mV

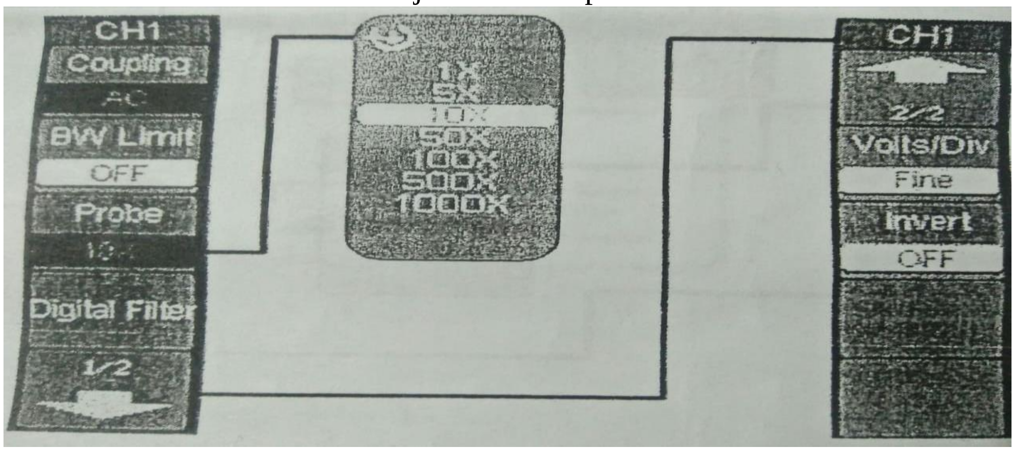

Fig. 2.5 Attenuation factor of probe

Turn the scale knob in the Horizontal controls group until the time per division indicator states 5 ms

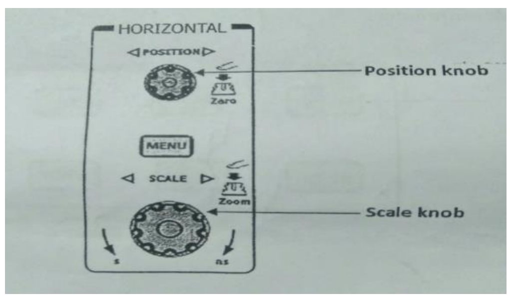

Fig. 2.6 Horizontal Control

Press the menu button in the trigger control group to activate the trigger control menu

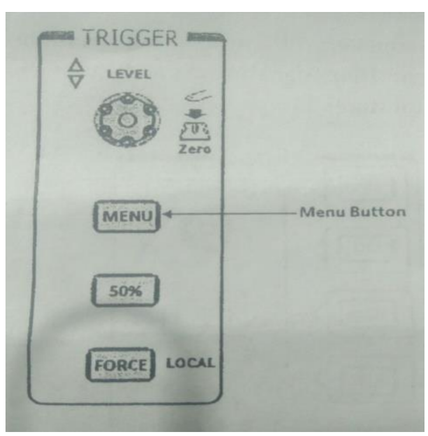

Fig. 2.7 Trigger Control

Select Edge under the Model label to trigger on rising edge. Select CH1 as the trigger signal under the source label. Finally press the trigger sweep label and select auto

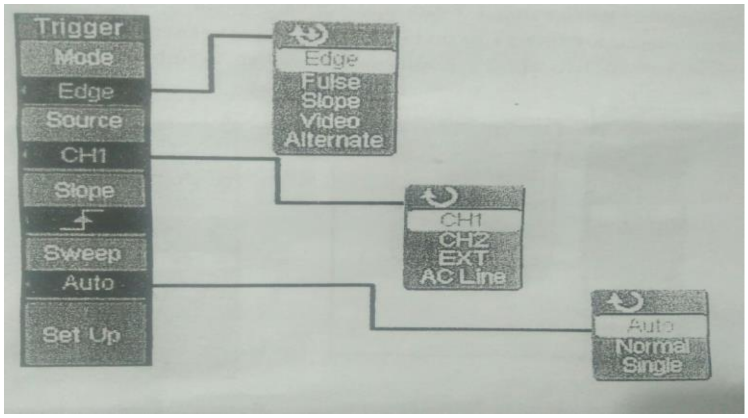

Fig. 2.8 Trigger sweep label

Under the common buttons group press the Measure Button to display the menu for the settings of Automatic Measurements

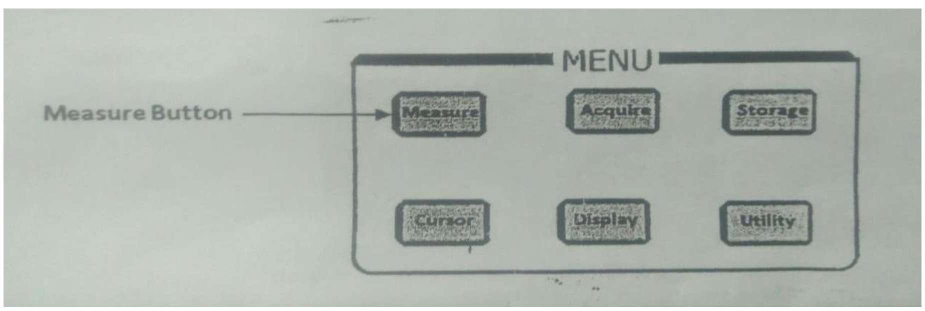

Fig. 2.9 Measurement Setting

First press the Source label to make sure that CH1 is selected source channel. Then press the Time Label and select the Freq. finally select vpp located in the voltage menu.

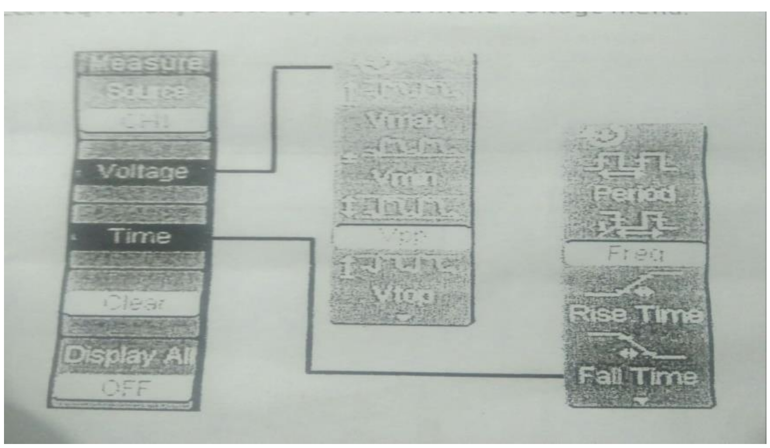

Fig. 2.10 Source Channel Setting

Press the Cursor setup button in the Common Menu buttons group and make sure that the Auto Measure mode is selected.

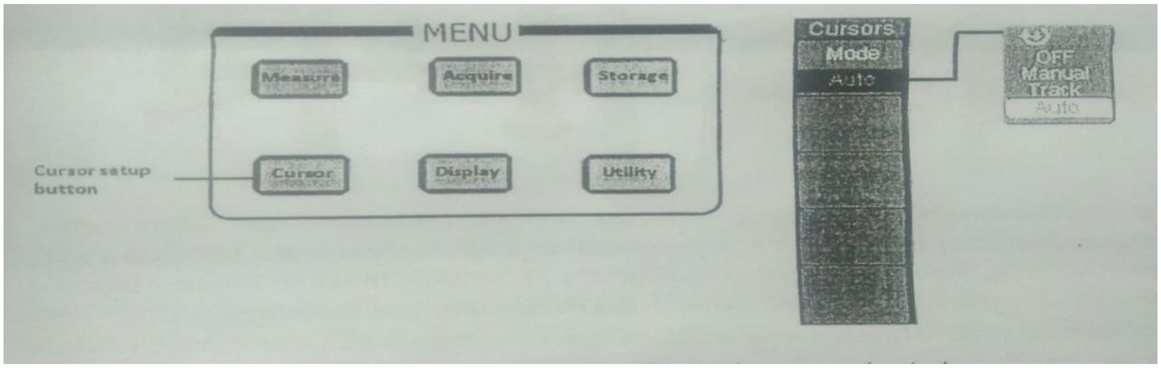

Fig. 2.11 Cursor Setup Button

Results

Results Table

Primary (regulated) Voltage	Calculated Secondary Voltage	Indicated Secondary Voltage

OBSERVATION/DISCUSSION:

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 3 Manual
Generation and Measurement of AC Voltage through Sphere Gaps.

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!

It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the Safety Regulations for High Voltage Experiments section before commencing experiments

Objective

To further investigate the generation of High AC Voltage using a Terco test transformer and measurement of such by way of a Measuring Sphere Gap.

Reference

Terco HV 9150 Digital AC Voltmeter Manual

Terco HV 9103 Control Desk Manual

Terco HV 9133 Measuring Sphere Gap Manual

Equipment to be used

COMPONENT DESCRIPTION	TERCO TYPE No.	QUANTITY
HV Test Transformer	HV9105	1
Control Desk	HV9103	1
Measuring Capacitor	HV9141	1
AC Peak Voltmeter	HV9150	1
Measuring Sphere Gap	HV9133	1
Connecting Rod	HV9108	2
Charging Resistor	HV9121	1
Connecting Cup	HV9109	2
Floor pedestal	HV9110	1
Earthing Rod	HV9107	1

Test setup

The test setup builds on the previous setup with the addition of the HV 9121 Charging Resistor and the HV 9133 Measuring Sphere Gap. Two connecting cups are required.

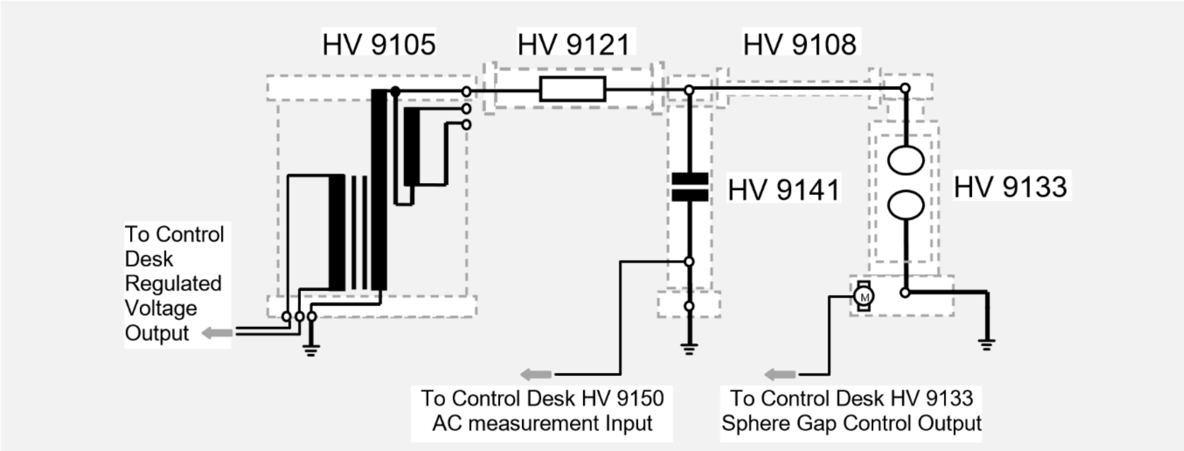

Fig. 3.1 Circuit for Sphere Gap AC Voltage Measurement via Control Desk Instrumentation

Introduction

Setting up the HV experiment

The high-voltage experiments must be carried out in dedicated HV experimental areas, enclosed with metal barriers.

Methods of Measuring High Alternating Voltages

High Alternating Voltages can be measured by different methods:

- Measurement of $\mathbf{U_{rms}}$ using primary input voltage and Transformer Ratio
- Measurement of $\hat{\mathbf{U}}$ with the peak voltmeter (HV9150) in conjunction with AC Measuring Capacitor (HV9141)
- Determination by using the breakdown voltage $\hat{\mathbf{U}}_{\mathbf{d}}$ of a sphere gap;
- Determination of $\hat{\mathbf{U}}$ using a circuit after Chubb and Fortescue.

This experiment utilizes the Terco HV 9133 Measuring Sphere Gap to determine the breakdown voltage.

Breakdown Voltage $\hat{\mathbf{U}}_{\mathbf{d}}$ of a Sphere Gap

At high voltage, almost anything can become a conductor of electricity - even air. Proof of this is seen in an everyday lightning strike. The point at which a gas or material stops being as insulator and becomes conductive is known as its ‘Dielectric Breakdown’ point.

The voltage which must be applied for dielectric breakdown to occur is referred to as ‘Breakdown Voltage’.

Paschen’s Law

Paschen's law describes how the breakdown voltage of a spark gap depends on electrode separation and the pressure of the surrounding gas.
It states that the voltage required to spark a specific gas is constant, if the same is true for the product of pressure and separation.

Breakdown voltage in a gas:

$$V = \frac{a(pd)}{\ln(pd) + b}$$

- V is the breakdown voltage in volts
- p is the pressure in atmospheres
- d is the gap distance in meters

The constants a and b depend upon the composition of the gas. For air at standard atmospheric pressure, a = 43600000 and b = 12.8.

This relationship breaks down completely at low pressures and very short distances (less than 5.7mm).
Procedure
This experiment assumes the transformer and control desk have been connected and tested in accordance with the previous experiment.

1. Ensure access to the specific manuals for the HV 9103 Control Desk, HV 9150 AC voltmeter and HV 9133 Measuring spark Gap for reference.

2. Check earth points. Always make sure there is a good quality earth connection, to which all the components can be connected. This should be a high-quality busbar, situated inside the cage, such as the one shown below.

Fig. 3.2 Earthing Busbar

If earthing plates are present, check all connections between them and connect directly to the busbar.

3. Ensure the transformer is connected correctly to the control desk. For instructions on how to do this, see previous experiment.

4. Stand the HV 9141 Measuring Capacitor on a Floor Pedestal and position a Connecting Cup on top as in Experiment 1A.

Fig. 3.3 Setup Step 1

5. Connect the Measuring Capacitor to the Control desk. (See preceding experiment)

6. Place the HV 9121 Charging Resistor between the transformer and the Measuring Capacitor.

Fig. 3.4 Setup Step 2

7. Now position the Measuring Sphere Gap. This will be connected via the Connecting Cup on top of the Measuring Capacitor by a HV 9108 Connecting Rod so the distance should reflect this. (For more information on the Measuring Sphere gap, please see the dedicated manual).

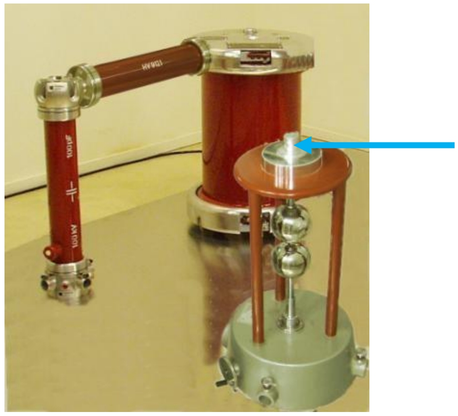

Fig 3.5 Setup step 3

8. Place a Connecting Cup on the top of the Measuring Sphere Gap and connect to the Measuring Capacitor with a HV 9108 Connecting Rod.

Note! The Measuring Sphere Gap requires individual earthing.

9. Connect a suitable earth cable, with o-ring type connector, to the Earth Point near the base of the HV 9133. Fasten the other end securely to the Earthing Busbar.

Fig. 3.6 Sphere gap Earth Connection point to bushbar

10. With the cable provided, connect the HV 9133 Measuring Sphere Gap to the HV 9133 Motor Control Input at the rear of the Control desk.

Fig 3.7 HV 9133 Sphere Gap Motor Control Input

11. After double-checking all connections and earthing, ensure that everybody has exited the HV cage. On exiting, the last person should position the HV 9107 Earthing Rod across the entrance before closing and locking the gate.

12. Switch on the Control Desk. Note the status of the warning lights above the gate. Answer questions 1, 2 and 3 in the Questions section.

13. Adjust the sphere gap to the desired distance using the controller switches indicated by the red ring, Fig 2.9 below.

Fig. 3.8 Sphere Gap Adjustment Switches

14. Make sure the AC voltmeter is set to measure peak voltage, reset if necessary.

15. Sound the horn to warn others that loud noises may occur. (Blue ring, Fig 2.9)

16. Increase the voltage slowly and record the breakdown voltage indicated on the AC peak voltmeter for each distance in the results table. Repeat each distance a few times for improved accuracy.

17. Once the breakdown occurs, decrease the voltage until the spark is extinguished.

18. Cause a breakdown once again but this time, instead of decreasing the voltage, increase the gap. Answer question 5 in the Questions section.

Results

Results table

Sphere Gap Distance (mm)	Theoretical Breakdown Voltage (kV)	Observed Breakdown Voltage (kV)
10		
20		
30		
40		
50		
60		

OBSERVATION/DISCUSSION:

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 4 Manual
Generation and measurement of DC voltage

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!

It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the Safety Regulations for High Voltage Experiments section before commencing experiments

Objective

The objective of this experiment is to investigate high voltage generation and measurement using Terco HV equipment. The knowledge gained is s prerequisite for performing following experiments.

Note: Extra care is essential in direct voltage experiments, since the high-voltage capacitors in many circuits retain their full voltage, for a long time even after disconnection. Earthing regulations are to be strictly observed. Even unused capacitors can acquire dangerous charges!

Reference

Terco HV 9103Control Desk Manual

Terco HV 9150 Digital AC Voltmeter Manual

Terco HV 9151 Digital DC Voltmeter Manual

Equipment to be use

COMPONENT DESCRIPTION	TERCO TYPE No.	QUANTITY
HV Test Transformer	HV9105	1
Control Desk	HV9103	1
Measuring Capacitor	HV9141	1
Rectifier	HV9111	2
Smoothing capacitor	HV9112	2
Measuring Resistor	HV9113	1
Insulating Rod	HV9124	1
Connecting Rod	HV9108	3
Connecting cup	HV9109	5
Floor Pedestal	HV9110	5
Spacer Bar	HV9119	4
Electrode	HV9138	1
Earthing Switch	HV9120	1
Earthing Rod	HV9107	1
DC Voltmeter	HV9151	1
Resistor	HV9121	1
Load Capacitor	HV9127	1

Test setup

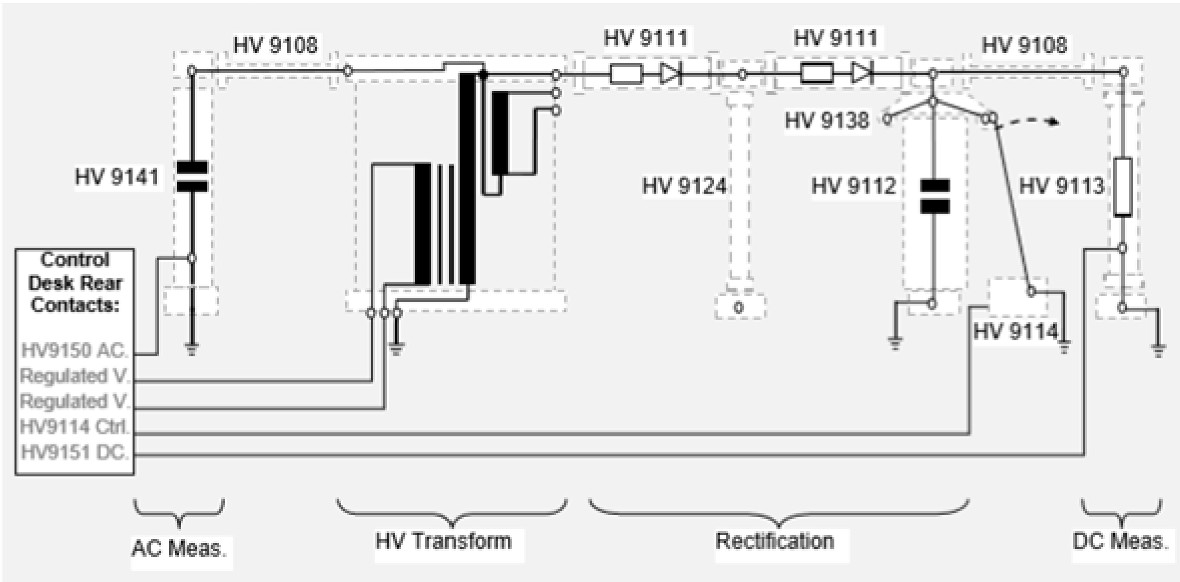

Fig 4.1 Test setup

Recommended external equipment

None

Introduction

Generation of High Direct Voltages

High direct voltages required for testing purposes are mostly produced from high alternating voltages by rectification and wherever necessary, subsequent multiplication. Multiplication can be performed by way of a Greinacher Doubler Circuit which is outside the scope of this Beginners Experiments manual but discussed further in the High Voltage Experiments manual.

In this setup, the alternating high voltage is rectified with 2 HV 9111 rectifiers, placed in series. The HV 9112 capacitor then smoothes the half-wave rectified voltage. Atop the smoothing capacitor, an electrode is placed to provide a good contact surface for the HV 9114 Grounding Switch. The Grounding Switch contacts the electrode on loss of supply current to the transformer, subsequently discharging the capacitor. This can occur when the transformer supply current is switched off via the control panel or if the HV cage door is opened while an experiment is in progress.

Note! Because of the potentially lethal voltages involved, the HV 9107 earthing rod should always be used when entering the HV area.

The smoothed direct voltage is measured by voltage division in the HV9113 measuring resistor and the value displayed on the HV9151 DC voltmeter, situated on the front panel of the HV 9103 control desk.

Procedure

1. To use space more efficiently, the setup can be built in an ‘L’ shape as seen below. The alternating voltage measurement setup in the left of the picture is positioned at a 90-degree angle to the rectification step, which is built to the right.

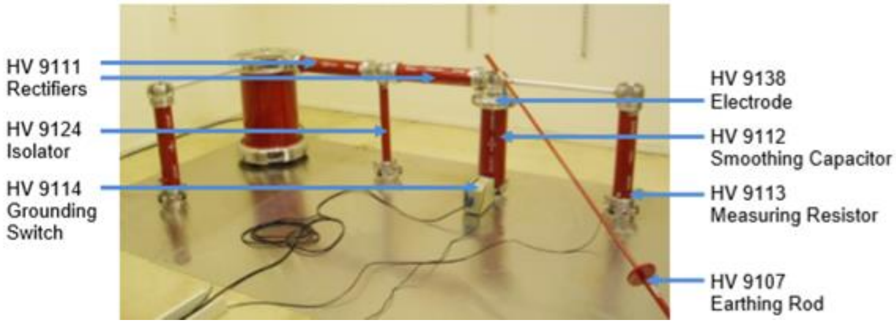

Fig 4.2 Direct Voltage Measurement Setup

Note: If earth-plates such as those above are not present, make sure each component is sufficiently grounded by a suitable cable with O-ring connectors to prevent accidental disconnection.

2. Start by building the alternating current setup from Experiment 1.

Fig 4.3 AC Voltage Measurement Setup

2. Next position 3 floor pedestals in a line as seen in Fig 3.2, above.

3. Place the Positioning Ring of the HV 9114 Earthing Switch over the second-floor pedestal. The Smoothing Capacitor will then hold this in place when mounted.

4. Erect the HV 9124 Isolator first and place a Connecting Cup on top.

5. Secure the first section in place by adding the first HV 9111 Rectifier. It is good practice to continue constructing each section until it is secure before moving on to the next. This prevents any components being damaged from being accidentally knocked over.

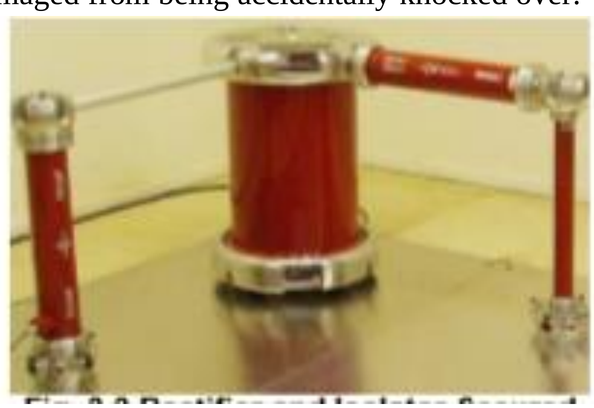

Fig 4.4Rectifier and Isolator secured

Note! Do not pick up the capacitor by the ends as a substantial charge may have accumulated while at rest. It is good practice to always discharge a capacitor before handling it. This is done easily by short-circuiting the ends with any electrical laboratory cable.

6. Resist picking the HV 9112 smoothing capacitor up by the ends, maneuver the bottom connector through the Earthing-Switch Positioning-Ring and into the Floor Pedestal.

7. Place the HV 9138 Electrode atop the capacitor, making sure not to trap the Earthing Switch Rod underneath (the rod should be able to drop away without hindrance).

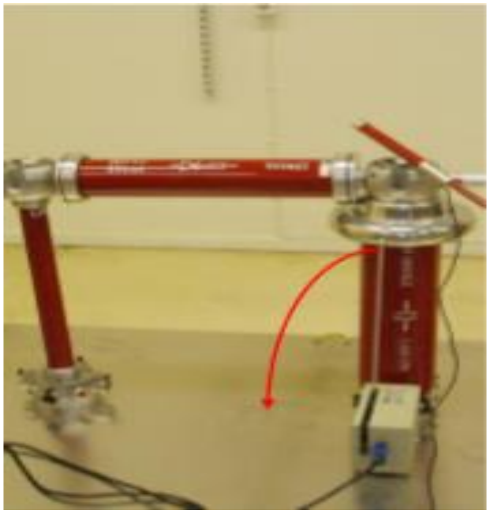

Fig 4.5 Rectifier and Smoothing Capacitor Section

8. Add the Connecting Cup and position the second rectifier to secure the section.

9. Construct the next section including the HV 9113 Measuring Resistor, a Connecting Rod, Floor Pedestal and Connecting Cup.

Note! Ensure the signal output connector is closest to the floor as indicated below. Failure to do so will result in high voltage being sent directly into the Control Panel.

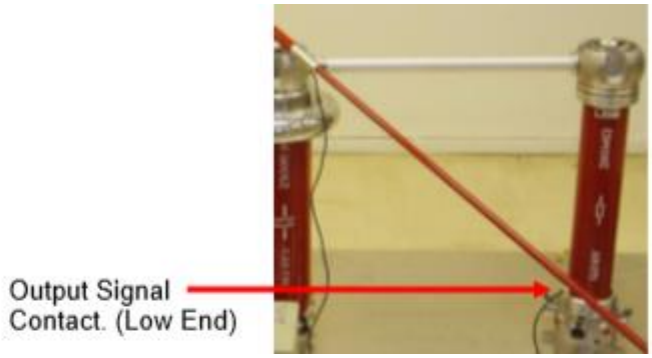

Fig 4.6 Measuring Resistor Orientation

10. Double-check all connections and exit the cage, leaving the Earthing Rod positioned across the doorway, as usual.

11. Switch on the Control Desk. Make sure the regulated voltage is at minimum before applying any power to the transformer.

12. Reset the AC voltmeter if desired; check that the correct stage level is set on both instruments.
Note: Before starting the experiment, sound the warning horn to inform people close by that an experiment is in progress and sudden loud noises can occur.

Fig 4.7 Control Desk

13. Answer questions 1 and 2 in the Questions section.
14. After sounding the horn, power may be provided to the transformer primary and secondary sides.
15. At several levels, note the measured AC voltage levels and calculate the expected DC voltage level. Compare with the rectified DC voltage level displayed. Note! Before switching off the transformer from the Control Desk, remember to decrease the regulated voltage down to zero.
Note: On entering the HV cage be sure to use the earthing rod to discharge any possible sources of remaining voltage.

Results

Results Table

Alternating voltage peak (kV)	Theoretical Direct Voltage (kV)	Displayed Direct Voltage (kV)

OBSERVATION/DISCUSSION:

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 5 Manual
Generation and measurement of DC voltage through oscilloscope

---

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!

It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the Safety Regulations for High Voltage Experiments section before commencing experiments

Objective

The objective of this experiment is to investigate high voltage generation and measurement using Terco HV equipment. The knowledge gained is s prerequisite for performing following experiments.

Note: Extra care is essential in direct voltage experiments, since the high-voltage capacitors in many circuits retain their full voltage, for a long time even after disconnection. Earthing regulations are to be strictly observed. Even unused capacitors can acquire dangerous charges!

Reference

Terco HV 9103Control Desk Manual

Terco HV 9150 Digital AC Voltmeter Manual

Terco HV 9151 Digital DC Voltmeter Manual

Equipment to be use

COMPONENT DESCRIPTION	TERCO TYPE No.	QUANTITY
HV Test Transformer	HV9105	1
Control Desk	HV9103	1
Measuring Capacitor	HV9141	1
Rectifier	HV9111	2
Smoothing capacitor	HV9112	2
Measuring Resistor	HV9113	1
Insulating Rod	HV9124	1
Connecting Rod	HV9108	3
Connecting cup	HV9109	5
Floor Pedestal	HV9110	5
Spacer Bar	HV9119	4
Electrode	HV9138	1
Earthing Switch	HV9120	1
Earthing Rod	HV9107	1
DC Voltmeter	HV9151	1
Resistor	HV9121	1
Oscilloscope	HV9159	1
Load Capacitor	HV9127	1

DC measurement

Test setup

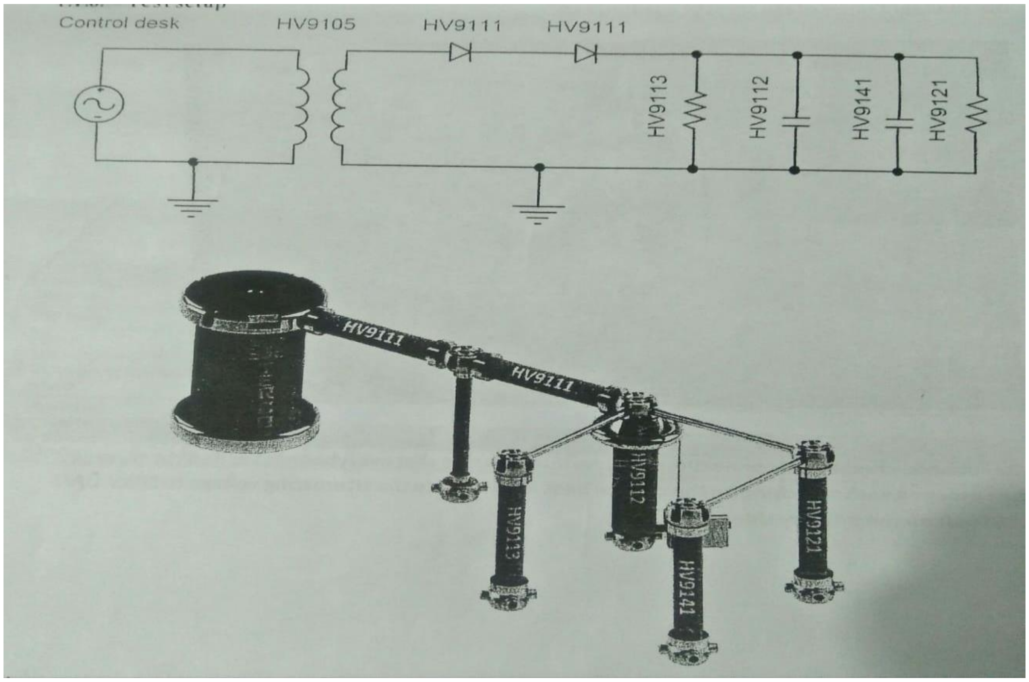

Fig 5.1 Test setup

This experiment assumes that power is supplied to control desk and the door contact has been connected. High voltage AC is generated in the laboratory using the 220KV/100KV test transformer (HV9105). This is fed and controlled from control desk. In this setup, the alternating high voltage is rectified with two HV9111 rectifiers placed in the series. The HV 9112 capacitor then smoothen the rectified DC voltage. For the voltage measurement, one instrument for measuring the primary voltage of transformer, one AC peak voltmeter HV 9150 and a DC voltmeter HV9151 are provided at each desk. Connect the appropriate coaxial cable from the measuring capacitor HV9141 to the X17 HV9150 input and the measuring resistor HV 9113 to the X21 HV 9151 input, situated on the rear panel of the control desk. On the top of smoothing capacitor an electrode is placed that provide a good contact surface for the HV 9114 grounding switch. The HV 9114 grounding switch is then connected to the control desk.
Connect the 10.1 probe between the X27 peak voltmeter output on the front of control desk and the channel 1 input of HV 9159 oscilloscope

After double checking all connections and earthing, ensure that everybody has exited the HV cage. Then proceed with switching on the control desk and increase the alternating voltage to 32150KV.

Oscilloscope setting

There are two ways to make the correct settings for a DC measurement on the HV 9159 oscilloscope. The accurate setting can either be loaded from external/internal memory or configured manually. The table below provides a summary of the oscilloscope setting for measuring a DC voltage.

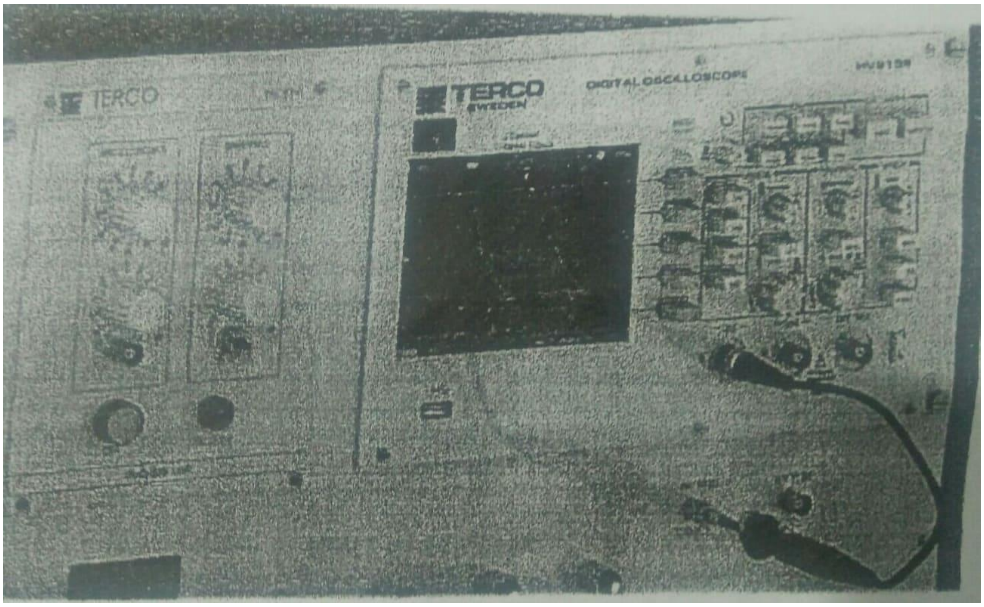

Fig 5.2 Oscilloscope setting

Manual setup

Press the CH1 button under the vertical control group. Turn the position knob until the channel 1 signal indicator is at the 0V position (signal in the middle of screen). Turn the scale knob to until the volt per division indicator states 20mV

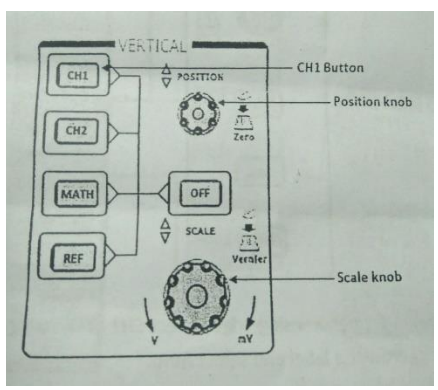

Fig 5.3 vertical controls

Under the probe menu select 10X to match the attenuation factor of the probe. To adjust the vertical scaling go to the second menu and select fine under the Volts/Div label or press the vertical scale knob. Turn the vertical scale knob to adjust the volts per division to 300mV

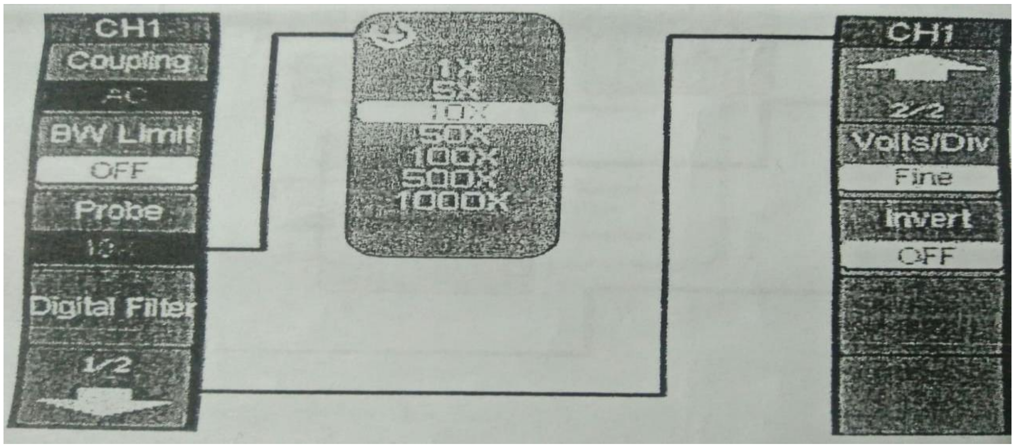

Fig 5.4 Attenuation factor of probe

Turn the scale knob in the Horizontal controls group until the time per division indicator states 5 ms

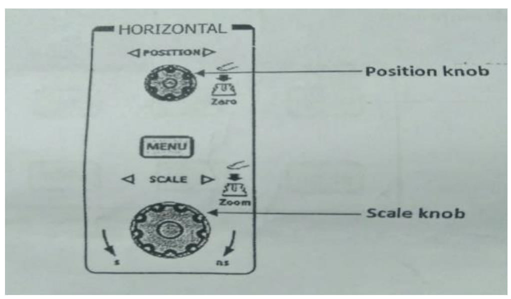

Fig 5.5 horizontal controls

Press the menu button in the trigger control group to activate the trigger control menu

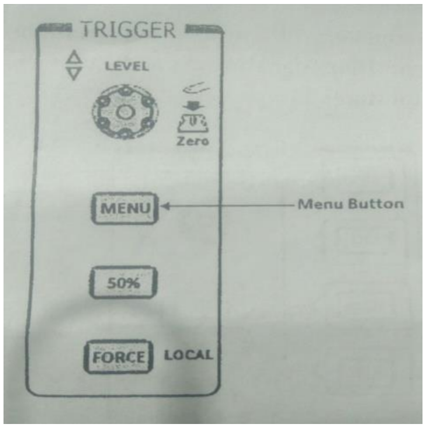

Fig 5.6 Tigger control

Select Edge under the Model label to trigger on rising edge. Select CH1 as the trigger signal under the source label. Finally press the trigger sweep label and select auto

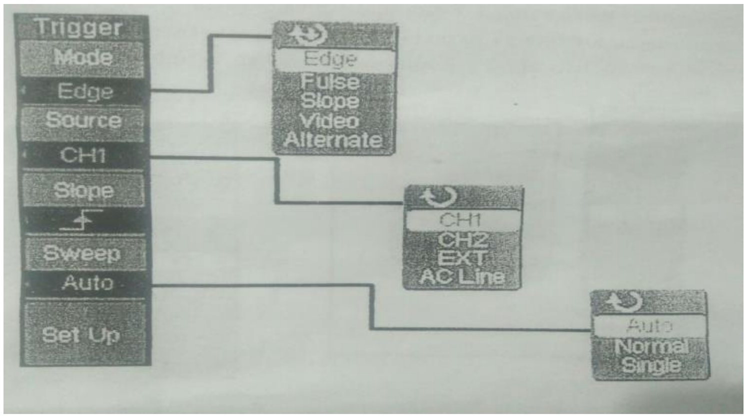

Fig 5.7 Trigger sweep label

Under the common buttons group press the Measure Button to display the menu for the settings of Automatic Measurements

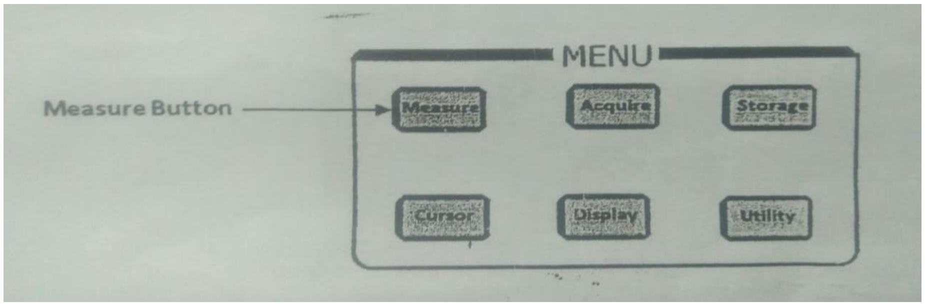

Fig 5.8 Measurement controls

First press the Source label to make sure that CH1 is selected source channel. Then press the Time Label and select the Freq. finally select Vp-p located in the voltage menu.

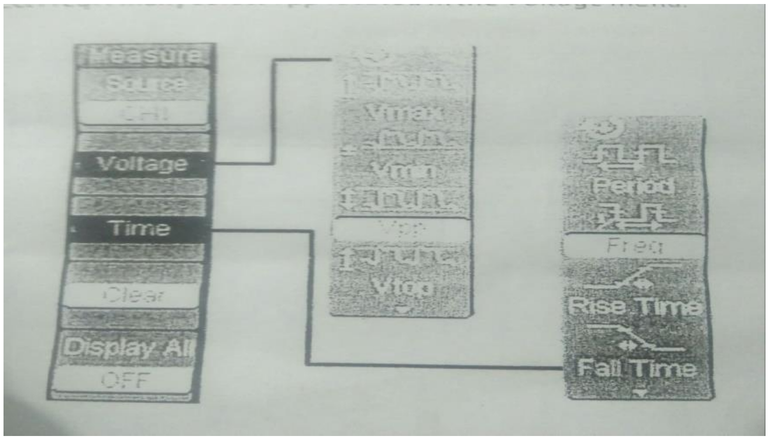

Fig 5.9

Press the Cursor setup button in the Common Menu buttons group and make sure that the Auto Measure mode is selected.

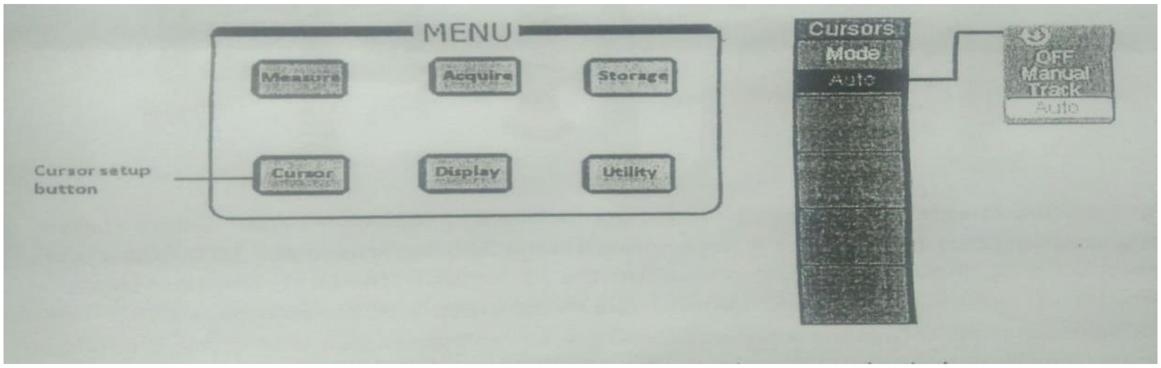

Fig 5.10 Cursor setting

Results

Results Table

Alternating voltage peak (kV)	Theoretical Direct Voltage (kV)	Displayed Direct Voltage (kV)

OBSERVATION/DISCUSSION:

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 6 Manual
Voltage Doubler Circuit.

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!

It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the Safety Regulations for High Voltage Experiments section before commencing experiments

Objective

High direct voltages are necessary for testing insulation systems, for charging capacitive storage devices and for many other applications in physics and technology. The topic covered in this experiment is:

I) Greinacher Voltage doubler-circuit

Note: Extra care is essential in direct voltage experiments, since the high-voltage capacitors in many circuits retain their full voltage, for a long time even after disconnection. Earthing regulations are to be strictly observed. Even unused capacitors can acquire dangerous charges!

Reference

See Appendix 1- Experiment 3

Equipment to be used

COMPONENT DESCRIPTION	TERCO TYPE No.	QUANTITY
HV Test Transformer	HV9105	1
Control Desk	HV9103	1
Rectifier	HV9111	2
Smoothing capacitor	HV9112	2
Measuring Resistor	HV9113	1
Measuring Sphere-gap	HV9133	1
Connecting Rod	HV9108	1
Connecting cup	HV9109	4
Floor Pedestal	HV9110	3
Spacer Bar	HV9119	3
Electrode	HV9138	1
Earthing Switch	HV9114	1
Earthing Rod	HV9107	1
DC Voltmeter	HV9151	1
Load Resistor 2.5 M Ohms	HV9127	1

Test setup

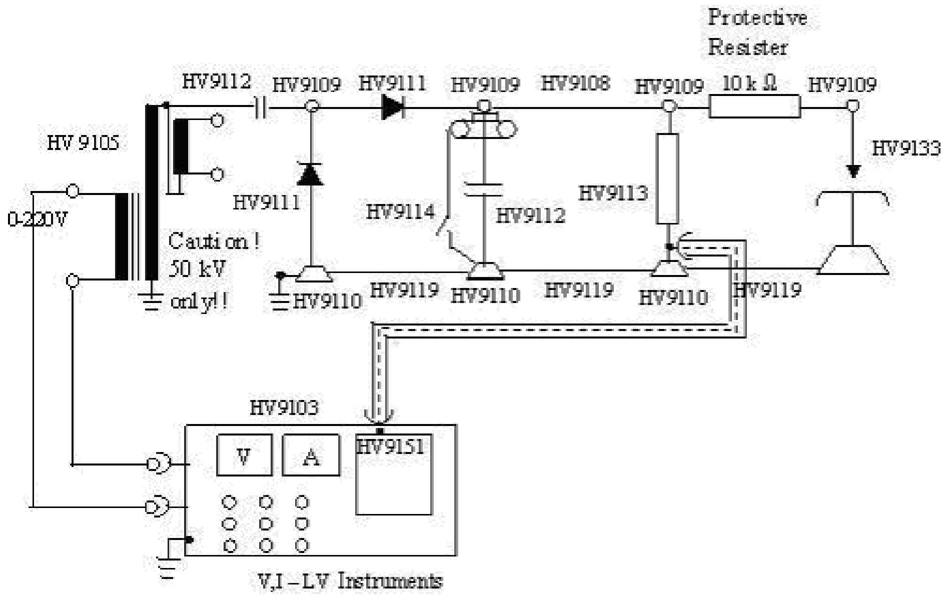

Fig. 6.1 Experimental Setup of Greinacher Doubler Circuit

Recommended external equipment

I) General Purpose Digital Storage Oscilloscope

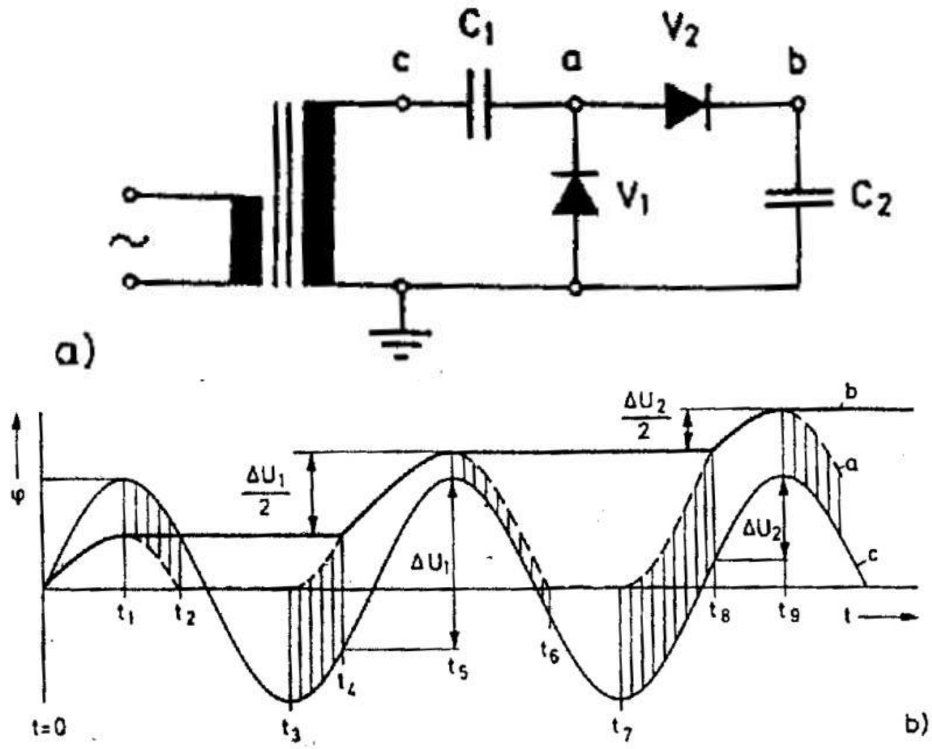

Fig. 6.2 Circuit diagram and voltage curves in a Greinacher doubler-circuit
a) Circuit diagram, b) voltage curves for C1 = C2

Introduction

Greinacher Doubler-Circuit

The circuit in Fig. 6.1 should be set up. The variation in potential at point b with respect to earth is to be recorded. The amplitude of the direct voltage at b, as well as the primary voltage of the transformer, should also be measured.
The relationship between breakdown voltage and spacing shown in Fig. 6.4 was obtained for this experiment. One can see that for larger spacings and a positive point electrode, the excess positive ions in the field region lead to a lower breakdown voltage.

OBSERVATION/DISCUSSION:

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 7 Manual
Polarity Effect and Insulation Screen.

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!

It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the Safety Regulations for High Voltage Experiments section before commencing experiments

Objective

High direct voltages are necessary for testing insulation systems, for charging capacitive storage devices and for many other applications in physics and technology. The topics covered in this experiment are:

I) Polarity effect,

II) Effect of insulating screens.

Equipment to be used

COMPONENT DESCRIPTION	TERCO TYPE No.	QUANTITY
HV Test Transformer	HV9105	1
Control Desk	HV9103	1
Rectifier	HV9111	2
Smoothing capacitor	HV9112	2
Measuring Resistor	HV9113	1
Measuring Sphere-gap	HV9133	1
Connecting Rod	HV9108	1
Connecting cup	HV9109	4
Floor Pedestal	HV9110	3
Spacer Bar	HV9119	3
Electrode	HV9138	1
Earthing Switch	HV9114	1
Earthing Rod	HV9107	1
DC Voltmeter	HV9151	1
Load Resistor 2.5 M Ohms	HV9127	1

Test setup

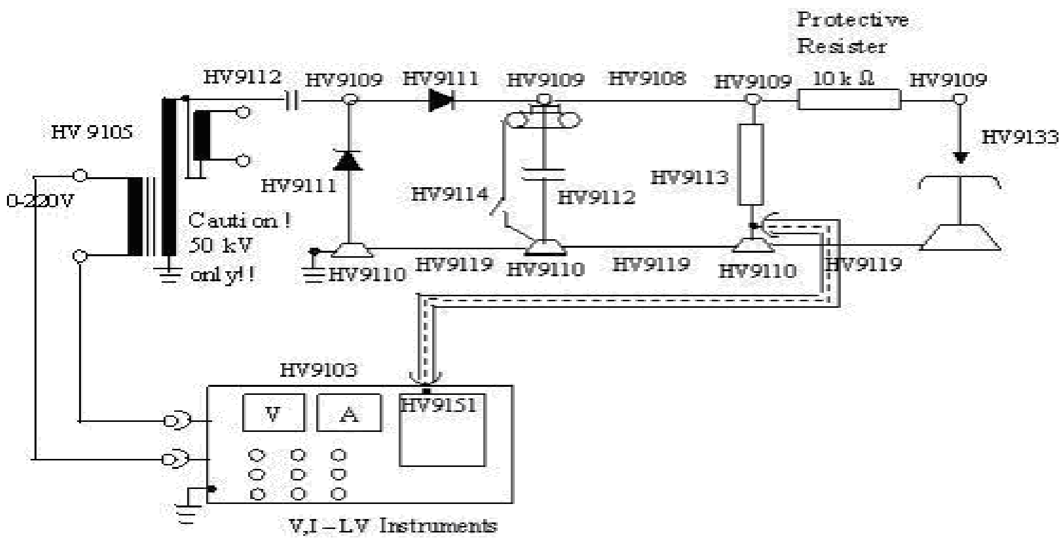

Fig. 7.1 Test Setup

Introduction

Polarity Effect in a Point-Plane Gap

At an electrode with strong curvature in air, collision ionization results when the onset voltage is exceeded. On account of their high mobility, the electrons rapidly leave the ionizing region of the electric field. The slower ions build up a positive space charge in front of the point electrode and change the potential distribution as shown in Fig. 6.2.

When the point electrode is negative, the electrons move towards the plate. The remaining ions cause very high field strengths immediately at the tip of the point electrode, whereas the rest of the field region shows only slight potential differences. This prevents the growth of discharge channels in the direction of the plate.

For a positive point electrode, the electrons move towards it and the remaining ions reduce the field strength immediately in front of the point electrode. Hence, since the field strength in the direction of the plate then increases, this favors the growth of discharge channels.

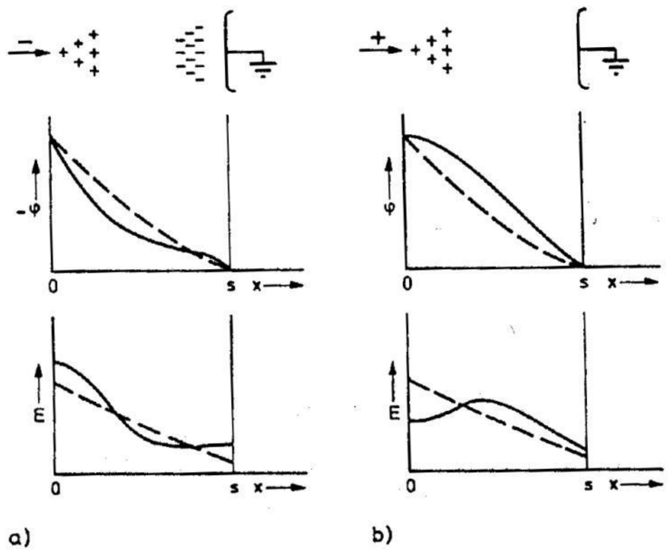

Fig. 7.2

Polarity Effect

A point-plane gap, in series with a 10 kΩ protective resistance, is connected in parallel to the measuring resistance HV9113 in the circuit of Fig. 6.1. The breakdown voltage of this spark gap should be measured for both polarities, at spacing s = 10, 20, 30, 40, 60 and 80 mm. The transformer voltage may not be increased beyond 50 kV in this experiment, to avoid overloading of the rectifiers and capacitors.

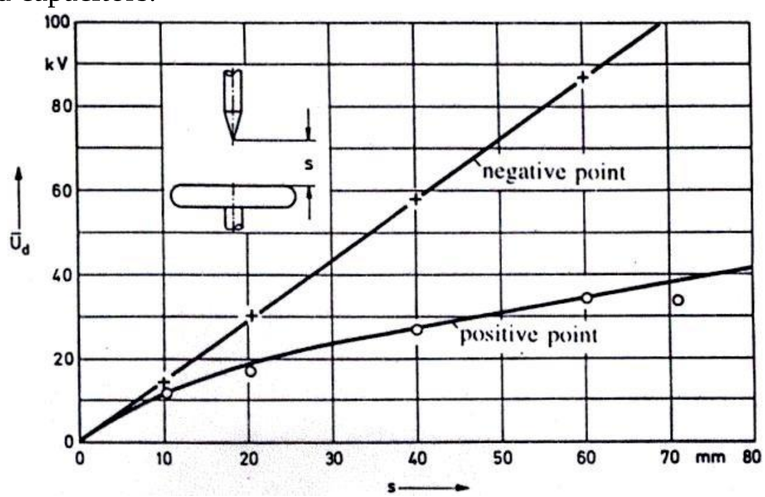

Fig. 7.3 Polarity effect in a point plane Gap

The relationship between breakdown voltage and spacing shown in Fig. 6.3 was obtained for this experiment. One can see that for larger spacing and a positive point electrode, the excess positive ions in the field region lead to a lower breakdown voltage.

Distance mm	Positive Polarity Voltage	Distance mm	Negative Polarity Voltage

OBSERVATION:

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 8 Manual
Generation and Measurement of Impulse Voltage.

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!
It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the Safety Regulations for High Voltage Experiments section before commencing experiments

Objective

The objective of this experiment is to investigate impulse voltage generation and measurement using Terco HV equipment. The knowledge gained is a prerequisite for following the High Voltage Experiments manual.

Note: Extra care is essential in direct voltage experiments, since the high-voltage capacitors in many circuits retain their full voltage, for a long time even after disconnection. Earthing regulations are to be strictly observed. Even unused capacitors can acquire dangerous charges!

Reference

Preceding manuals plus:
Terco HV 9152 Digital Impulse Voltmeter Manual

Equipment to be used

COMPONENT DESCRIPTION	TERCO TYPE	QUANTITY
HV Test Transformer	HV9105	1
Control Desk	HV9103	1
Smoothing Capacitor	HV9112	1
Load Capacitor	HV9120	1
Silicon Rectifier	HV9111	2
Measuring Resistor	HV9113	1
Charging Resistor	HV9121	1
Wave front Resistor	HV9122	1
Wave tail Resistor	HV9123	1
Sphere Gap	HV9125	1
Drive for sphere gap	HV9126	1

Insulating Rod	HV9124	2
Connecting Rod	HV9108	2
Connecting cup	HV9109	7
Floor Pedestal	HV9110	6
Spacer Bar	HV9119	4
Electrode	HV9138	1
Earthing Switch	HV9114	1
Earthing Rod	HV9107	1
DC Voltmeter	HV9151	1
Impulse Peak voltmeter	HV9152	1
Low Voltage Divider	HV9130	1

Test setup

The test setup is based on the DC measurement setup from the preceding experiment with the addition of a HV 9121 Resistor. To accommodate the extra space needed for the extended setup, the HV 9113 DC Measuring Resistor is positioned at a 90° angle from the line of the rectifiers. It is still connected to the HV 9112 Smoothing Capacitor.
The HV 9114 Earthing Switch has been moved to the left of the Smoothing Capacitor to make room for the extra components to be added.

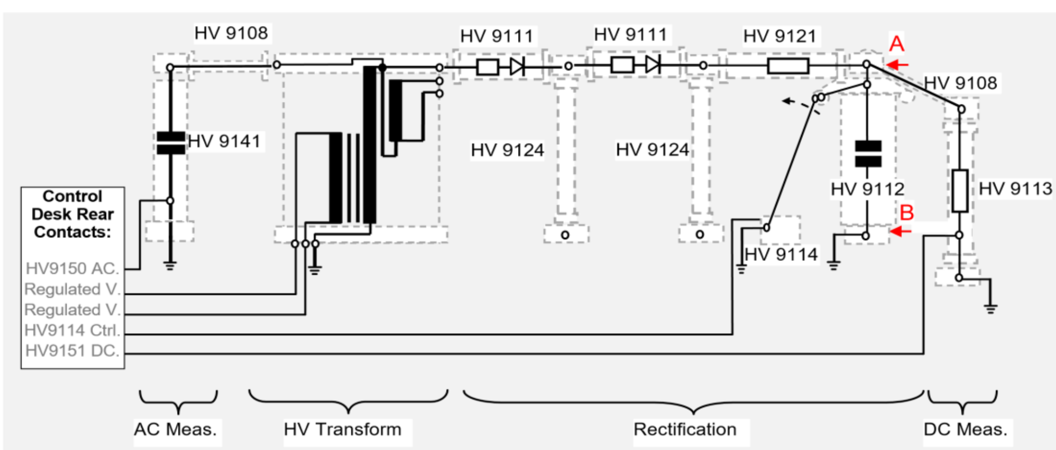

Fig. 8.1 Impulse Voltage Measurement Setup Diagram Part 1

The figure below shows the continuation from points **A** and **B** in the slightly adjusted DC measurement setup above. The components below complete the Impulse measuring setup.

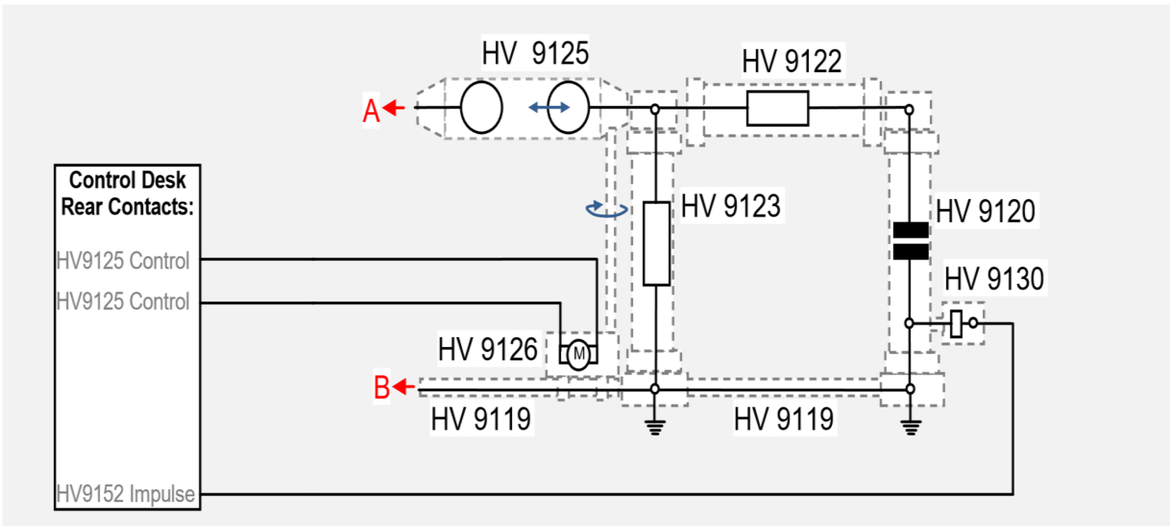

Fig. 8.2 Impulse Voltage Measurement Setup Diagram Continued

Introduction

Generation of Impulse Voltages

The identifying time characteristics of impulse voltages are given in Fig. 7.2. In this experiment lightning impulse voltages with a front time $T_1 = 1.2$ µs and a time to half value $T_2 = 50$ µs are mostly used. This 1.2/50 µs form is the one commonly chosen for impulse testing purposes.

As a rule, impulse voltages are generated in either of the two basic circuits shown in Fig. 7.3. The relationships between the values of the circuit elements and the characteristic quantities describing the time-dependent curve are given by the time constants:

$$\tau_1 \approx Re\,(Cs+Cb) \qquad \tau_2 \approx Rd\{CsCb)/(Cs+Cb)\}$$

Where Cs – Impulse capacitor, C_b- Load Capacitor, Rd- Front Resistor and Re - tail resistor. For lightning impulse voltages of the standard form 1.2/50 the time constants are

$$\tau_1 = 68.22\ \mu s \qquad \tau_2 = 0.405\ \mu s$$

When designing impulse voltage circuits, one should bear in mind that the capacitance of the test object is connected parallel to C_b, hence the front time and the efficiency η can be affected. This has been allowed for in the standards by way of comparatively large tolerances on T_1.

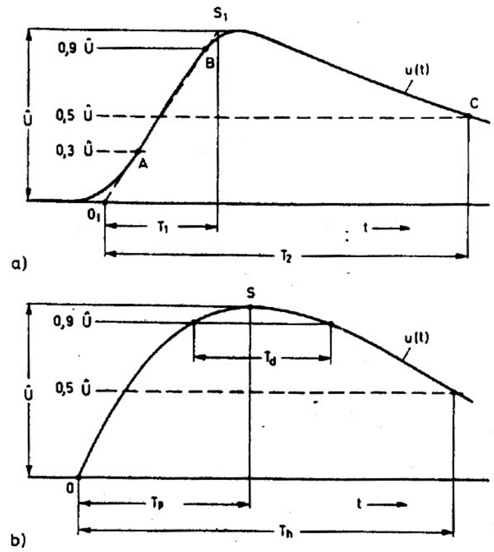

Fig. 8.3 Characteristic parameters of standard test impulse voltages a) Lightning impulse voltage b) switching impulse voltage

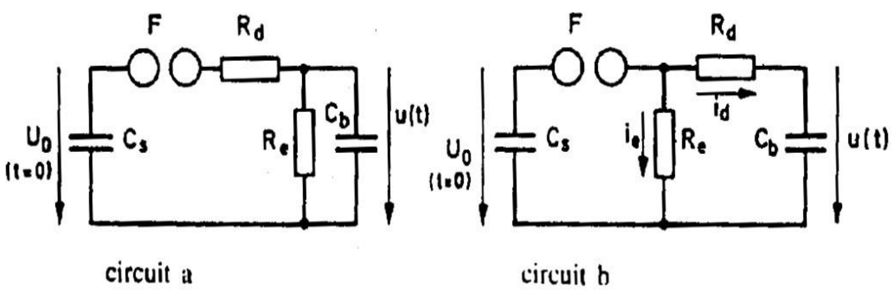

Fig. 8.4 Basic Impulse voltage circuits

Breakdown Time-Lag

The breakdown in gases occurs because of an avalanche-like growth of the number of gas molecules ionized by collision. In the case of gaps in air, initiation of the discharge is affected by charge carriers which happen to be in a favorable position in the field. If, at the instant when the voltage exceeds the required ionization onset voltage U_e, a charge carrier is not available at the appropriate place, the discharge initiation is delayed by a time referred to as the statistical time-lag t_s.

Even after initiation of the first electron-avalanche a certain time elapses, necessary for the development of the discharge channel which is known as the formative time-lag t_a. The total breakdown time-lag, between over-stepping the value of U_e at time t_1 and the beginning of the voltage collapse at breakdown, compromises these two components:

$$t_1 = t_s + t_a.$$

These relationships are shown in Fig. 8.5.

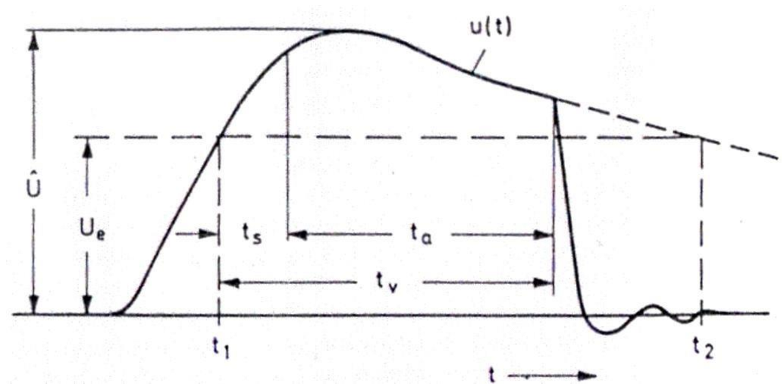

Fig. 8.5 Determination of breakdown time-lag during an impulse voltage breakdown

Experiment and procedure

Investigation of a single-stage Impulse Generator

To ascertain the correct measurement of Impulses, the value displayed on the HV 9152 Impulse Voltmeter is compared with the level of DC voltage required to cause the breakdown. in order to create sustained flashovers in a more controlled fashion, the HV 9121 Charging Resistor has been added. This will lengthen the charging time, creating a delay between flashovers, thus, allowing for more accurate observations.

Procedure

1. Construct the AC and DC voltage measurement setup as below, note the position of the additional HV 9121 Charging Resistor, the HV 9114 Grounding Switch and the HV 9113 DC Measuring Resistor.

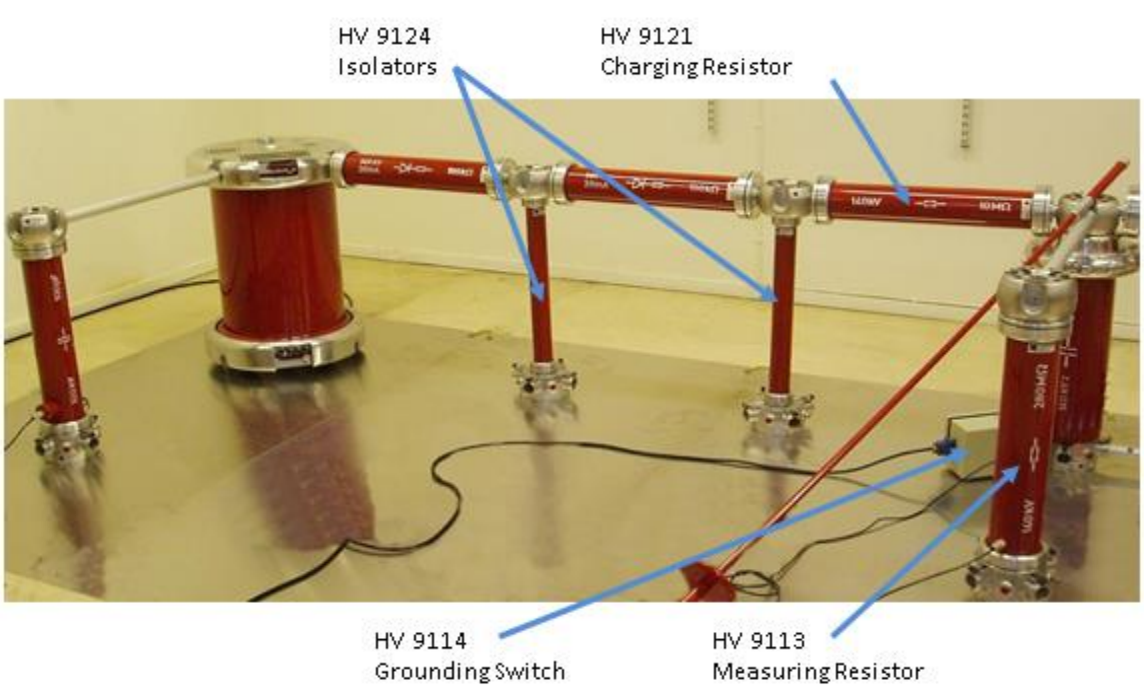

Fig. 8.6 Impulse Voltage Measurement step

2. Building to the right of the HV 9112 Smoothing Capacitor, Insert a HV 9119 spacer bar into the Floor Pedestal. At the other end of the Spacer Bar, add another Floor Pedestal.

   The HV 9126 Sphere Gap Drive Unit will be mounted to this Spacer Bar.
3. Position the Sphere Gap Drive box near the right-side Floor Pedestal. The connector for the Drive Shaft should also be to the right as shown below. Fasten the Drive to the Spacer bar using the Mounting Bracket Screws (this may need to be adjusted later).

Fig. 8.7 HV 9126 Sphere Gap Drive Placement

4. Stand the HV 9123 Wave tail Resistor upright on the free Floor Pedestal and add a Connecting Cup.

5. The HV 9125 Spark Gap can now be mounted on the Connection Cups between the Smoothing Capacitor and the Wave tail Resistor. The Sphere gap Drive Shaft Needs to be positioned while the Spark gap is lowered into place. Loosen the Drive if required to allow for better maneuverability. Tighten when finished. The Drive Shaft should rotate freely, and the closest sphere should move to the left or right when doing so.

Fig 8.8 HV 9125 Sphere Gap and Drive

6. Connect the HV 9126 Drive Signal cable to the HV 9125 Input at the rear of the Control Desk.

7. Erect the HV 9120 Load capacitor on the last Floor pedestal. This can be done at a right-angle to save space if required. Place a Connecting Cup on top.

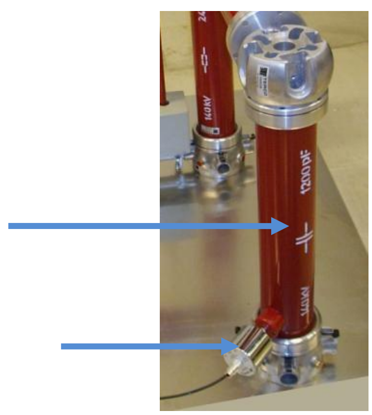

Fig 8.9Load capacitor

Note: Position the contact for the Low Voltage Divider nearest the floor.

8. Screw the HV 9130 Low Voltage Divider into place on the HV 9120 Load capacitor.

9. If more than one HV 9130 Low Voltage Divider is available, check that the divider and capacitor have corresponding numbers.

10. Secure the last section in place by adding the HV 9122 Wave front Resistor.

Fig 8.10 Impulse Setup almost complete - Cables to be organized

11. The setup should now resemble the picture above. It is important for safety and for the lifetime of the equipment to ensure all cables are neatly organized and if possible, any excess cable age hung out of the way.

Fig 8.11 Control Desk Cables

12. Double-check all connections and exit the cage, leaving the Earthing Rod positioned across the doorway, as usual.

13. Switch on the Control Desk. Make sure the regulated voltage is at minimum before applying any power to the transformer.

14. Test the Sphere gap Drive Control switches to ensure operation.

Fig 8.12 Sphere Gap Control Switches

15. Reset the voltmeters if desired; check that the correct stage level is set on all instruments.

Note! Before starting the experiment, sound the warning horn to inform people close by that an experiment is in progress and sudden loud noises can occur.

16. After sounding the horn, power may be provided to the transformer primary and secondary sides.

17. At several Sphere Gap distances, note the DC voltage levels at which breakdown occurs and observe and compare the resulting Impulse peak levels. Use the results table to record this information if desired.

Note! Before switching off the transformer from the Control Desk, remember to decrease the regulated voltage down to zero.

Note! On entering the HV cage be sure to use the earthing rod to discharge any possible sources of remaining voltage.

Results

Results Table

Sphere Gap Distance (mm)	Direct Voltage Breakdown (kV)	Displayed Peak Impulse Voltage (kV)
20		
30		
40		
50		
60		
70		

Lightning Impulse Measurement through oscilloscope.
Test setup

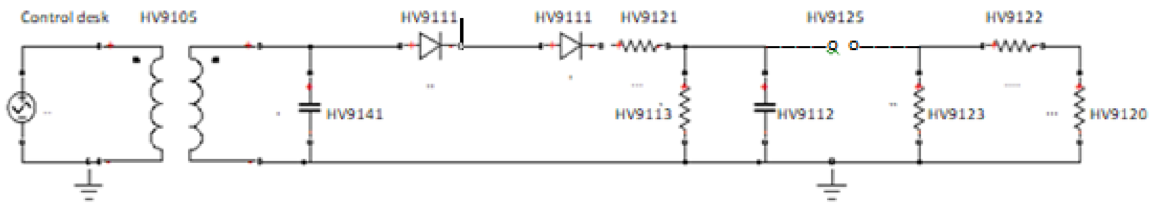

Fig 8.13 Circuit Diagram

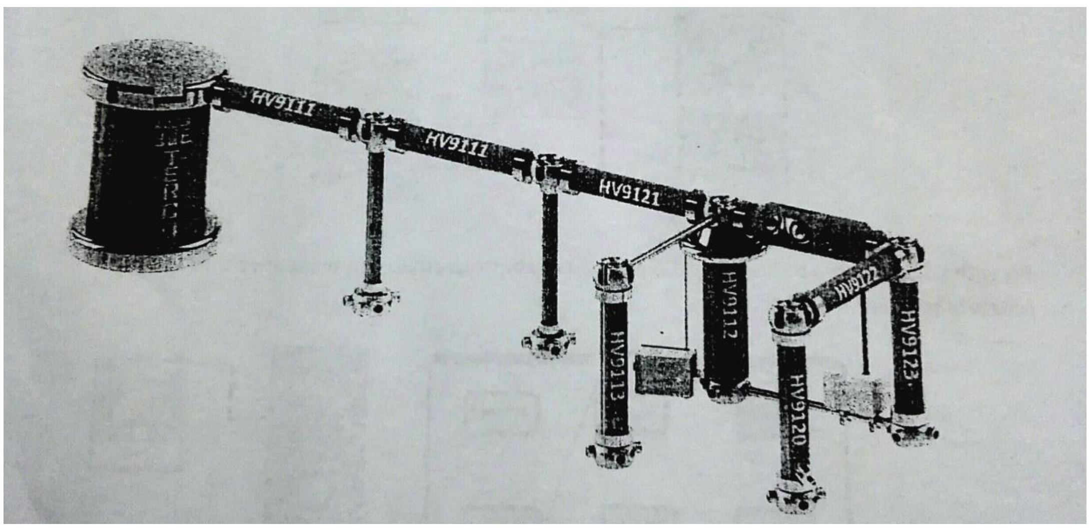

Fig 8.14 Test setup

This experiment assumes that power is supplied to the control desk through X1 and the door contact has been connected (X11). High voltage AC is generated in the laboratory using the 220V/100kV test transformer (HV9105). This is fed and controlled from the X2 output off the Control Desk. In this setup, the alternating high voltage is rectified with two HV 9111 rectifiers, placed in series. The HV9111 capacitor then smooths the rectified DC voltage. For voltage measurement, one instrument for measuring the primary voltage of the transformer one DC voltmeter FIV9151 and one impose peak voltmeter HV9152 are provided at each desk. Connect the appropriate coaxial cable from the measuring resistor HV9113 to the X21 HV9151 input and HV9130 low voltage divider placed on the load capacitor HV9120 to the X18 HV9152 input. All measuring instrument input are situated on the rear panel of the control desk. Connect the HV 9131 optical trigger cable between the HV9132 trigger or sphere and the X23 HV9131 trigger device output also situated on the rear panel of the control desk On top of the smoothing capacitor, an electrode is placed to provide a good contact surface tor the HV9114 grounding switch. The HV9114 grounding switch then connected the X12 contact. Connect the HV9126 drive signal cable to the X131-1119125 output at the rear of the control desk.

Connect the 100:1 probe between the X28 impulse voltmeter output on the front of the control desk and the channel1 input of the HV9159 oscilloscope.

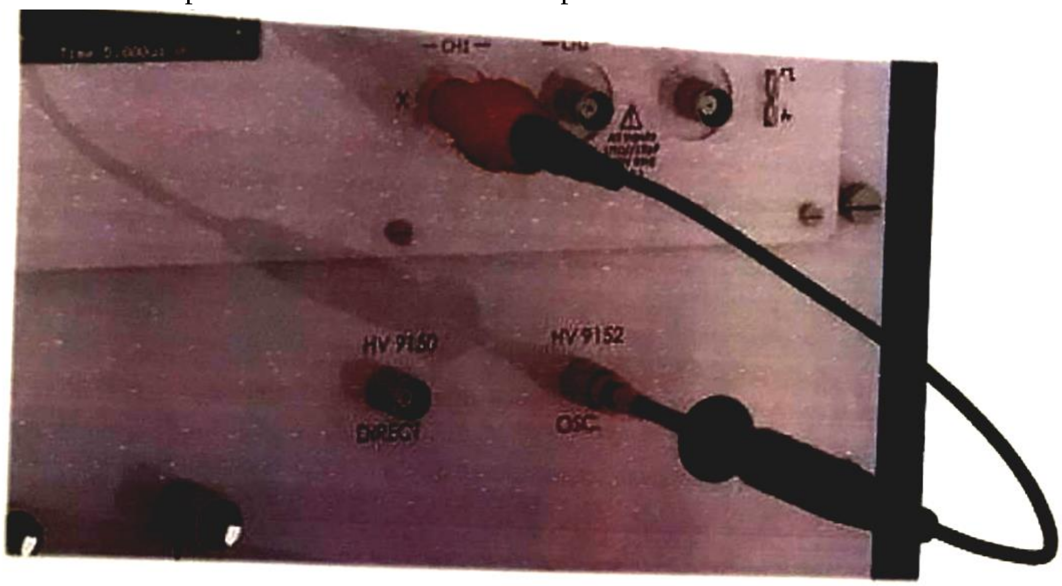

Fig 8.15 Oscilloscope connection

After double-checking all connections and earthing, ensure that everybody has exited the HV cage. Then proceed with switching on the control desk and set the distance between the spheres in the HV9125 sphere gap to around 5 cm. Then one full lightning impulse with about 100 kV charging voltage should be recorded.

Voltage dividers

The HV9120 load capacitor together with the HV9130 makes a voltage divider. The HV9130 low voltage divider is matched with a specific HV9120 load capacitor to make a voltage divider with a 400:1 ratio.

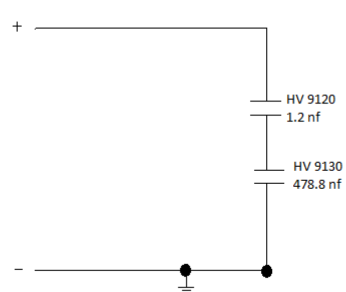

Fig 8.16 Voltage divider circuit

Oscilloscope settings

There are two ways to make the accurate settings for an impulse measurement on the HV9159 oscilloscope. The correct settings can either be loaded from the internal/external memory or configured manually. The table below a summary of the oscilloscope settings for measuring a lightning impulse.

Vertical Controls		
Probe attenuation	100x	
Scale	50 V	
Position	-150 V	
Trigger Controls		
Mode	Edge	
Source	CH1	
Sweep	Normal	
Measure		
Source	CH1	
Voltage	V max	
Horizontal Controls		
Sample Type	Wave tail	Wave front
Scale Type	5 µs	200 ns
Position	25 µs	
Cursor Setup		
Mode	Manual	
Source	CH1	

OBSERVATION:

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 9 Manual

Generation and measurement of impulse voltage using trigger sphere gap.

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!

It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the Safety Regulations for High Voltage Experiments section before commencing experiments

Objective

The objective of this experiment is to investigate the operation of the HV 9132 trigger Sphere.

Equipment to be used

As for Experiment 4, with the addition of the HV 9132 Trigger Sphere and HV 9131 Optical Trigger cable.

Test setup

The test setup is the same as the previous experiment except for the 9132 Trigger Sphere.

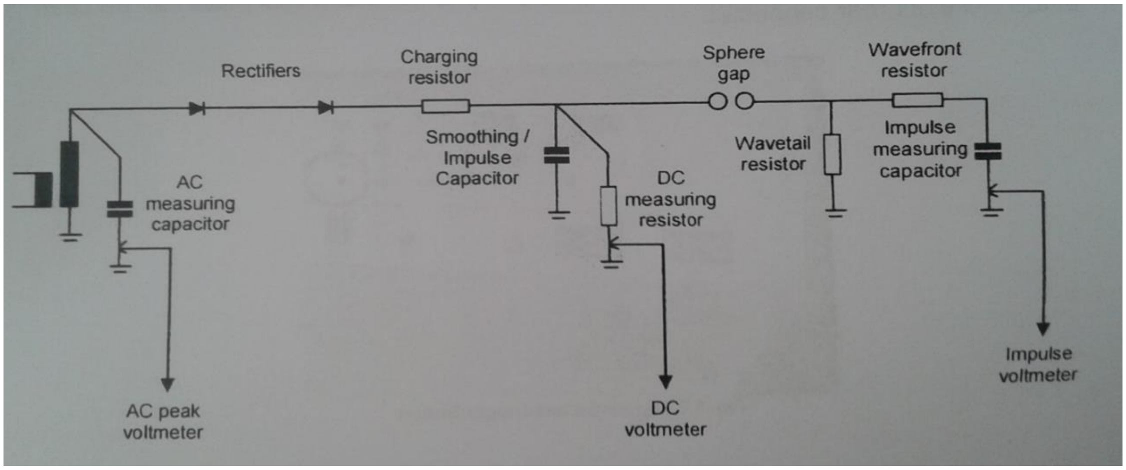

Fig. 9.1 Trigger Sphere and Cable

Trigger Sphere

The HV 9132 Trigger Sphere replaces the passive sphere nearest the transformer in the HV 9125.

Fig. 9.2 Trigger Sphere and Cable

Introduction

Triggering of Impulse Voltages

In order to study Impulse more closely, it is beneficial to have greater control over the breakdown timing.

Because of the extremely short times involved, it may be hard to capture the desired information. The trigger sphere not only provides a means of knowing when the breakdown will occur but highlights one of the key characteristics of the breakdown.

Experiment and procedure

Investigation of a single-stage Impulse Generator

The Control Desk front panel houses the trigger button for the Trigger Sphere. Pressing this button sends a light pulse along the fiber-optic cable to the Trigger Sphere where the inbuilt electronics provide current to a sparkplug. The sparkplug ignites, providing the extra voltage needed to initiate a breakdown in the air gap.

Procedure

1. Starting with the setup for Experiment 4, unscrew and remove the sphere. Every care should be taken so that no marks are made on the sphere. Store this in a safe place.

2. Locate the trigger button on the trigger unit, on the front panel of the Control Desk. Push the button (with the Control Desk switched on) and check that a light pulse can be seen in the HV 9131 rear connector.

Connect fibre optic cable to control desk and check that the pulse can now be seen at the other end of the cable.

3. Open trigger sphere and connect 2 x 9V batteries. Close again by twisting into place.

4. Connect the fiber optic cable to the trigger sphere.

5. Test the Trigger Sphere, a spark should be seen and heard from the spark plug on pressing the trigger button.

Note: Do not hold the trigger sphere near or on the spark plug!

Fig. 9.3 Trigger Sphere trigger

6. If the test is successful, the Trigger Sphere is OK for use. Remove the cable. Switch off the Control Desk.

Note: On entering the HV cage be sure to use the earthing rod to discharge any possible sources of remaining voltage.

7. Mount the Trigger Sphere in the HV 9125 Sphere gap by screwing into place, position the optic cable input in the opening.

8. Insert and fasten the fiber optic cable in the trigger sphere.

9. On leaving the HV area, leave the Discharge Rod across the doorway and lock the door.

Note: Before starting the experiment, sound the warning horn to inform people close by that an experiment is in progress and sudden loud noises can occur.

10. Try triggering a flashover at different distances and voltages. Note how much less voltage is required to create a standing arc than to spontaneously jump the air gap.

OBSERVATION:

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 10 Manual
Disruptive Discharge Voltage Tests with Alternating Current.

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!

It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the Safety Regulations for High Voltage Experiments section before commencing experiments

Objective

In order to transport electrical power and avoid flashovers and blackouts, good knowledge of how insulators should be selected and dimensioned is necessary. The dimensioning of insulators is critical in terms of electrical, mechanical and environmental stress. Outdoor insulators can become heavily coated with dirt and chemicals by environmental pollution. The insulators will be polluted with industrial contaminants, coastal fog, natural dust, bird feces, etc. The contaminant will be partially dissolved forming a conductive layer Leakage current that flows along the surface will increase and may eventually cause flashovers Service experience shows that pollution flashover is one of the main natural calamities harming high-voltage transmission lines. This test will provide an insight to now contamination affects the insulation capability of the various insulators.

Reference

Terco HV 9150 Digital AC Voltmeter Manual

Terco HV 9103 Control Desk Manual

Equipment to be used

COMPONENT DESCRIPTION	TERCO TYPE No.	QUANTITY
Control Desk	HV9103	1
AC Peak Voltmeter	HV9150	1
HV Test Transformer	HV9105	1
Load Resistor	HV9127	1
Measuring Capacitor	HV9141	1
Connecting Rod	HV9108	1

Connecting Cup	HV9109	2
Floor Pedestal	HV9110	2
HV Connection	HV9106	1
HV Insulator		1

Introduction

Setting up the HV experiment

This experiment assumes that power is supplied to the control desk and the door contact has been connected. High Voltage AC is generated in the Laboratory using the 220V/100kV Test Transformer (HV9105). This is fed and controlled from the Control Desk. For voltage measurement, one instrument for measuring the primary voltage of the transformer and one AC peak voltmeter HV91 50 are provided at each desk Connect the appropriate coaxial cable from the Measuring Capacitor HV 9141 to the HV 9150 input, situated on the rear panel of the Control desk.

Experiment and procedure

Preparation of the test object for dry test

The test object shall be carefully cleaned before testing for the first time so that all traces of dirt and grease are removed. Water, preferably heated to 50 °C with the addition of trisodium phosphate or another detergent, shall be used, after which the insulator is to be thoroughly rinsed with tap water. The insulating surfaces can be considered sufficiently clean and free of grease or other contaminating material if large continuous wet areas are observed during wetting, the insulating parts of the test object shall not be touched by hand.

Preparation of the test object for artificial solid layer contamination test

After cleaning the test object as described a contamination layer is applied to the insulator surface using slurry consisting of water, an inert material such as kaolin, and an appropriate amount of sodium chloride (NaCl).

The slurry composition consists of:

- 40 g kaolin
- 1000 g tap water
- 35 g NaCl of commercial purity

The slurry described above shall be applied by spraying it or pouring it onto the dry insulator to obtain a reasonably uniform layer. Alternatively, the insulator may be dipped in the slurry. Provided its size permits this operation. Another technique is to apply the contamination by a small paint brush

Procedure

The first lest will be carried out in and conditions where the insulators will be clean and dry the test procedure will then be repeated that this time with contaminated insulators so that test results can be compared. The voltage shall be applied to the test object starting at a value sufficiently low to prevent any effect of overvoltage due to switching transients. It should be raised sufficiently slowly to permit accurate reading of the measuring instrument but not so slowly as to cause unnecessarily prolonged stress on the test object at the test voltage. These requirements are met in general if the rate of rise above 75% of the estimated final test voltage is about 2% of the test voltage per second The voltage shall be applied and raised until a disruptive discharge occurs on the test object The value of the test voltage reached just prior to the disruptive discharge shall be recorded.

Table 10.1 Insulator voltage ratings

	Glass disc One disc	Glass disc Two discs	Ceramic Line Post	Composite Line Post
Rated system voltage	12	24	24	24
Dry flashover voltage	80	160	80	110
Wet flashover voltage	50	90	60	95
Positive impulse flashover	125	235	130	150
Negative impulse flashover	130	245	155	170
Low frequency Puncture voltage	130			

Results

Insulator Type	**Flashover voltage Dry/Clean (kV)**
Glass disc (one disc)	
Ceramic Line post	
Composite Line post	

OBSERVATION/DISCUSSION:

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 11 Manual

Disruptive Discharge Voltage Tests with Direct Current.

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!

It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the Safety Regulations for High Voltage Experiments section before commencing experiments

Objective

High voltage direct current transmission has many advantages over alternating current. The most prominent advantages are that high voltage dc is able to transmit large amounts of power over long distances with lower capital costs and with lower losses than AC. One key issue, however, for the design of the HVDC transmission lines is to select appropriate insulators. More contaminants accumulate on DC insulators because of the static electric field of DC voltage, which is 1.2-1.5 times higher than that on AC insulators under the same atmospheric environment, moreover, the DC pollution flashover voltages will decrease more than AC voltages with an increase in the degree of pollution. The arc floating led by a steady DC arc will bridge the sheds of insulators, which reduce the pollution flashover voltages of DC insulator strings and cause effective leakage distances of insulators less than those of the geometrical leakage distances. This test will provide an insight to how current contamination affects into the insulation capability of the various insulators under direct

Reference

Terco HV 9151 Digital DC Voltmeter Manual

Terco HV 9103 Control Desk Manual

Equipment to be used

COMPONENT DESCRIPTION	TERCO TYPE No.	QUANTITY
Control Desk	HV9103	**1**
AC Peak Voltmeter	HV9150	**1**
DC Digital Voltmeter	HV9151	**1**
HV Test Transformer	HV9105	**1**
Silicon Rectifier	HV9111	**2**
Load Resistor	HV9127	**1**
Impulse Capacitor	HV9112	**1**

Measuring Resistor	HV9113	**1**
Measuring Capacitor	HV9141	**1**
Top Electrode	HV9138	**1**
Earthing Switch	HV9114	**1**
Insulating rod	HV9124	**2**
Connecting Rod	HV9108	**5**
Connecting Cup	HV9109	**7**
Floor pedestal	HV9110	**7**
HV Connection	HV9106	**1**
HV Insulator		**1**

Test setup

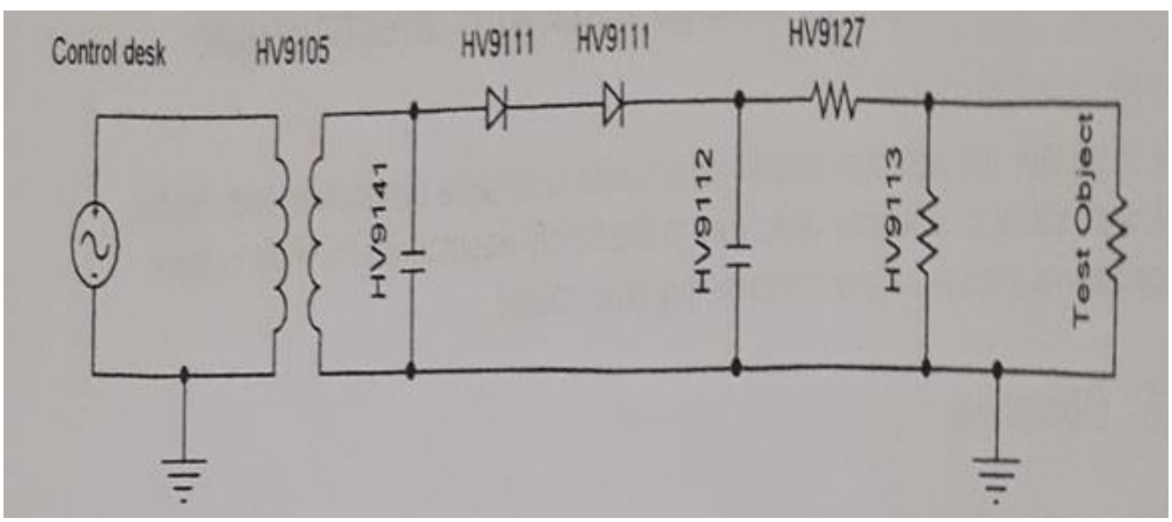

Fig. 11.1 Principle Circuit Diagram

Introduction

Setting up the HV experiment

This experiment assumes that power is supplied to the control desk and the door contact has been connected. High voltage AC is generated in the laboratory using the 220V/100kV test transformer

(HV9105). This is fed and controlled from the control desk. In this setup, the alternating high voltage is rectified with two HV 9111 rectifiers, placed in series. The HV 9112 capacitor then smoothed the rectified DC voltage. For voltage measurement, one instrument for measuring the primary voltage of the transformer, one AC peak voltmeter HV 9150 and a DC voltmeter HV9151 are provided at each desk. Connect the appropriate coaxial cable from the measuring capacitor HV 9141 to the HV 9150 input and the measuring resistor HV 9113 to the HV 9151 input, situated on the rear panel of the control desk. On top of the smoothing capacitor, an electrode is placed to provide a good contact surface for the HV 9114 grounding switch. The HV 9114 grounding switch is then connected to the control desk.

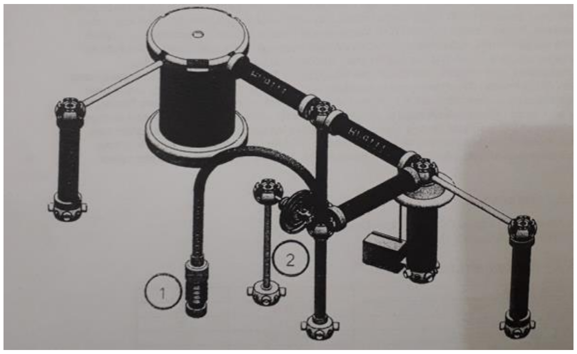

Fig. 11.2 Two different type of circuits for DC Voltages
1) Line Post Composite/Ceramic insulator
2) Suspension glass Disc

Experiment and procedure

Preparation of the test object

The test object shall be carefully cleaned before testing for the first time, so that all traces of dirt and grease are removed. Water, preferably heated to 50 °C with the addition of trisodium phosphate or another detergent, shall be used, after which the insulator is to be thoroughly rinsed with tap water. The insulating surfaces can be considered sufficiently clean and free of grease or other contaminating material if large continuous wet areas are observed during wetting. After cleaning, the insulating parts of the test object shall not be touched by hand.

Preparation of the test object for artificial solid layer contamination test

After cleaning the test object as described previously a contamination layer is applied to the insulator surface using a slurry consisting of water, an inert material such as kaolin, and an appropriate amount of sodium chloride (NaCl).

The slurry composition consists of:

(a). 40 g kaolin

(b). 1000 g tap water

(c). 35 g NaCl of commercial purity

The slurry described above shall be applied by spraying it or flowing it onto the dry insulator, to obtain a reasonably uniform layer. Alternatively, the insulator may be dipped in the slurry, provided its size permits this operation. Another technique is to apply the contamination by a small paint brush.

Procedure

The first time the test will be carried out in good conditions where the insulators will be clean and dry. The test procedure will then be repeated but this time with contaminated insulators, so that test results can be compared.

The voltage shall be applied to the test object starting at a value sufficiently low to prevent any effect of over voltages due to switching transients. It should be raised sufficiently slowly to permit accurate reading of the measuring instrument, but not so slowly as to cause unnecessarily prolonged stress on the test object at the test voltage. These requirements are met in general if the rate of rise above 75% of the estimated final test voltage is about 2% of the test voltage per second. The voltage shall be applied and raised until a disruptive discharge occurs on the test object. The value of the test voltage reached just prior to the disruptive discharge shall be recorded.

Table 11.1 Insulator voltage ratings

	Glass disc One disc	Glass disc Two discs	Ceramic Line Post	Composite Line Post
Rated system voltage	12	24	24	24
Dry flashover voltage	80	160	80	110
Wet flashover voltage	50	90	60	95
Positive impulse flashover	125	235	130	150
Negative impulse flashover	130	245	155	170
Low frequency Puncture voltage	130			

Results

Insulator type	Flashover voltage Dry/Clean (kV)
Glass disc (one disc)	
Ceramic Line post	
Composite Line post	

OBSERVATION:

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 12 Manual
Lighting Impulse Disruptive Discharge Test.

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!

It is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in the safety Regulations for High Voltage Experiments section before commencing experiments.

Objective

Overvoltage caused by lightning must be considered when designing high voltage transmission lines. When any over voltage appears in the electrical power system, then there may be a chance of failure of its insulation system. This test will provide an insight different insulator is able to withstand overvoltage caused by the 1.2/50 lightning impulse wave.

Reference

Terco HV9103 Control Desk Manual

Terco HV 9152 Digital Impulse Voltmeter Manual

Equipment to be used

COMPONENT DESCRIPTION	TERCO TYPE No.	QUANTITY
Control Desk	HV9103	1
AC Peak Voltmeter	HV9150	1
DC Voltmeter	HV9151	1
Impulse Voltmeter	HV9152	1
Trigger Device	HV9131	1
HV Test Trans former	HV9105	1
Charging Resistor	HV9121	1
Measuring Capacitor	HV9141	1
Silicon Rectifier	HV9111	1
Impulse Capacitor	HV9112	1
Measuring Resistor	HV9113	1
Wave Tail Resistor	HV9123	1
Wave Front Resistor	HV9122	1
Load Capacitor	HV9120	1
Sphere Gap	HV9125	1
Low Voltage Divider	HV9130	1
Electronic Trigger Sphere	HV9132	1

Driver for Sphere Gap	HV9126	1
Top Electrode	HV9138	1
Earthing Switch	HV9114	1
Insulating rod	HV9124	1
Connecting Rod	HV9108	1
Floor Pedestal	HV9110	1
HV Connection	HV9110	1
HV Insulator	HV9106	1

Test Setup

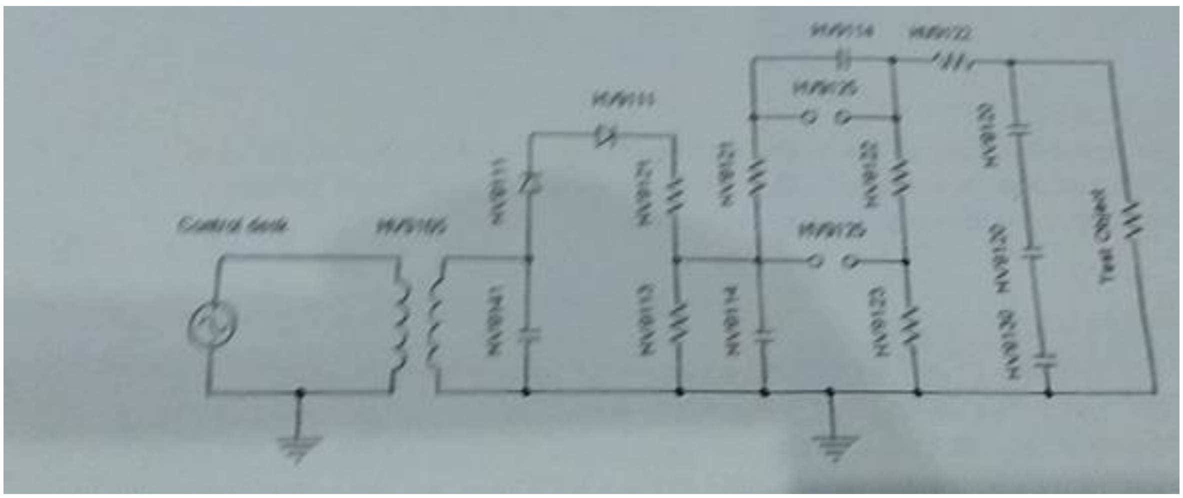

Fig. 12.1 Principle Circuit Diagram

Test Setup

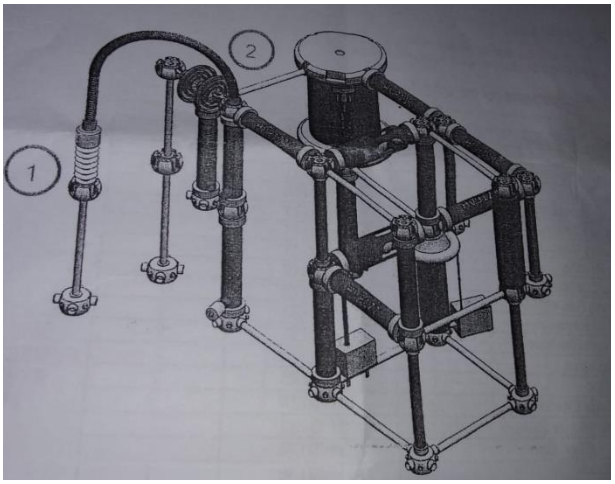

Fig. 12.2 Test Setup

Introduction

Setting up the HV Experiment

This experiment assumes that power is supplied to the control desk and the door contact has been connected. High voltage AC is generated in the laboratory using the 220V/100kV test transformer (HV9105). This is fed and controlled from the Control Desk. In this setup, the alternating high voltage is rectified with two HV 91 11 rectifiers, placed in series. The HV 9112 capacitor then smoothes the rectified DC voltage. For voltage measurement, one instrument for measuring the primary voltage of the transformer, one AC peak voltmeter HV9141 to the HV9150 input, measuring resister HV 9113 to the HV 9151 input and HV9130 low voltage divider placed on the load capacitor HV9120to the HV9152. All measuring instrument inputs are situated on the rear panel of the control desk. Connect the HV9131 optical trigger cable between the HV9132 trigger sphere and the HV9131trigger device also situated on the rear panel of the control desk. One top of the smoothing capacitor, an electrode is placed to provide a good contact surface for the HV9114 grounding switch. The HV 9114 grounding switch is then connected to the control desk. Connect the HV9126 drive signal cable to the HV 9125 input at the rear of the control desk.

Generation of Impulse Voltages

The identifying time characteristics of impulse voltages are given in Fig. 2.3. In this experiment lightning impulse voltages with a front time T_1=1.2 μs and a time to half value T_2=50μs are used. The 1.2/50 μs is defined as standard in IEC 60060-1. The Triggering device HV9131 connected as in Fig. 2.2 to the electronic trigger sphere HV 9132 via fibre-optic cable allows precise triggering of the impulse generator at an accurately preset charging voltage.

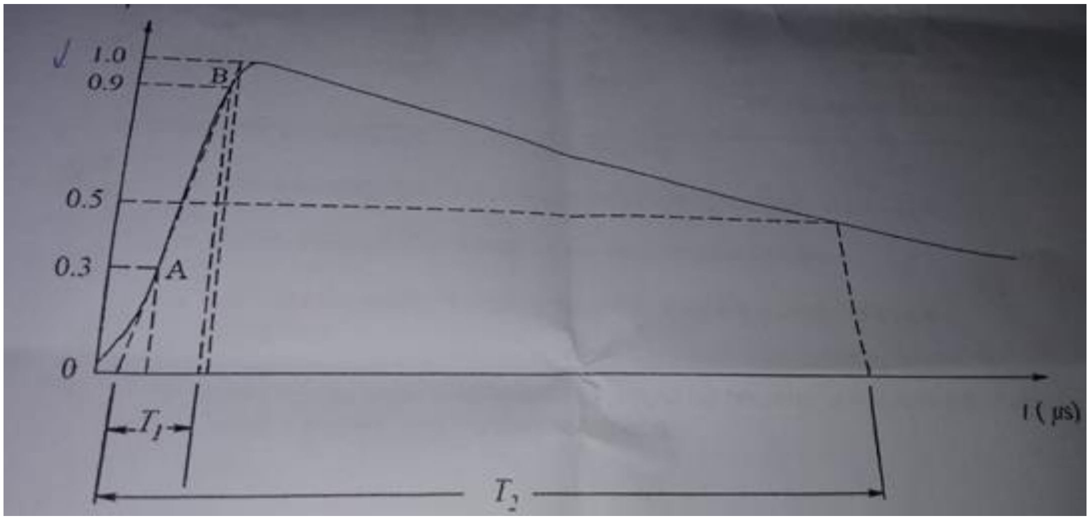

Fig. 12.3 Characteristics parameter of lightening impulse voltage

Experiment and procedure

Preparation of the test object

The test object shall be carefully cleaned before testing for the first time, so that all traces of dirt and grease are removed. Water, preferably heated to 50°C with the addition of trisodium phosphate or another detergent, shall be used, after which the insulator is to be thoroughly rinsed with tap water. The insulating surfaces can be considered sufficiently clean and free of grease or other contaminating material if large continuous wet areas are observed during wetting.

Procedure

The first test will be carried out with a positive lightning impulse. The test procedure will then be repeated but this time with the HV9111 rectifiers placed the opposite way so the insulators can be exposed to a negative lightning impulse.

Three impulses of the specified shape and polarity shall be applied to the test object starting at the rated lighting impulse withstand voltage level. The value of the test voltage reached at the disruptive discharge shall be recorded.

Table 12.1 Insulator voltage ratings

	Glass Disc One disc	Glass Two discs	Ceramic Line Post	Composite Line Post
Rated system voltage	12	24	24	24
Dry flashover voltage	80	160	80	110
Welt flashover voltage	50	90	60	95
Pos impulse flashover	125	235	130	150
Neg impulse flashover	130	245	155	170
Low freq Puncture voltage	130	-	-	-

Results

Insulator type	Impulse Flashover Positive (kV)	Impulse flashover Negative (kV)	Difference (kV)
Glass disc (one disc)			
Glass disc (two disc)			
Ceramic Line post			
Composite Line post			

OBSERVATION:

COLLEGE OF ENGINEERING & TECHNOLOGY
UNIVERSITY OF SARGODHA

ET 324: High Voltage Technology

Lab 13 Manual
Insulation Test for Transformer Oil.

Instructors & Demonstrators: Engr. Muhammad Qamar ud Din

Student Name	
Roll No.	
Date Performed	
Marks obtained	
Instructor Signature	

SAFETY PRECAUTIONS!!!

it is important and essential that all participants familiarize themselves and strictly follow all safety precautions described in ANNEXURE-A before commencing experiments

Objective

Insulation arrangement for high voltage usually contains liquid or solid insulating materials whose breakdown strength is many times that of atmospheric air. For practical application of these materials not only their physical properties but also their technological and constructional features must be considered. The topics discussed in this experiment are:

Fiber-bridge breakdown

Equipment to be used

COMPONENT DESCRIPTION	TERCO TYPE no.	QUANTITY
HV test transformer	HV9105	1
Control Desk	HV9103	1
Measuring Capacitor	HV9141	1
AC peak voltmeter	HV9150	1
Connecting rod	HV9108	1
Connecting cup	HV9109	1
Floor pedestal	HV9110	1
Oil testing cup	HV9137	1
Earthing rod	HV9107	1
Measuring sphere gap	HV9133	1
Spacer bar for HV9133	HV9118	1

Test setup

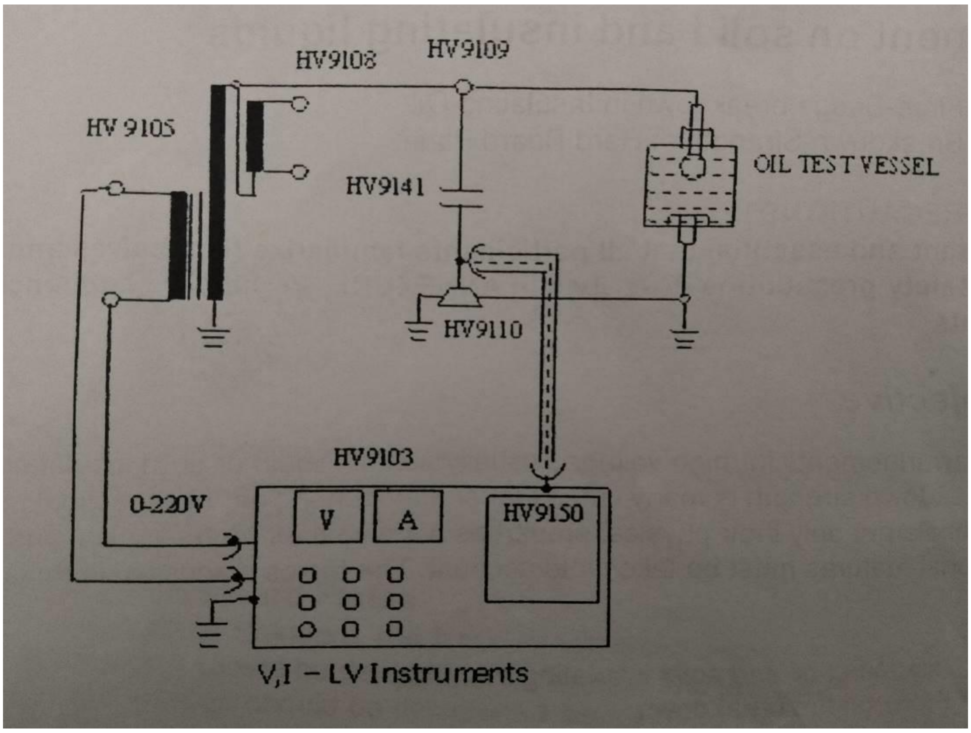

Fig.13.1 Test setup for Fiber-Bridge Breakdown in insulating Oil

Introduction

Fiber-Bridge Breakdown in insulating oil

Every technical liquid insulating material contains macroscopic contaminants in this form of fibrous element of cellulose, cottoned. Particular when these element have absorbed moisture from the insulating liquid, force act upon them, moving to the region of higher field as strength as well as aligning them in the direction of E. Charges of opposite polarity are induced at the end of short fiber, which causes a torque and forces alignment of the fibrous element in the direction of field lines. In this way, fiber-bridge comes into existence.

A conducting channel is created which can be heated due to resistance loss to such an extent that moisture contained in the element evaporates. The breakdown which then sets in comparatively low voltages can be described as local thermal breakdown at a defect The mechanism is of such great technical significance that in the electrode arrangement for high voltages pure oil sections have to be avoided. This is achieved by the introducing insulating screens, perpendicular to the direction of field strength. In the extreme case consistent application of this principle leads to oil-impregnated paper insulation which is the most important and very high stress able dielectric for cable capacitors and transformer

Experiment and procedure

Fiber-Bridge Breakdown in insulating oil

In the setup used in the experiment the upper electrode is replaced by a sphere e.g. of 20 mm diameter and the spacing is set to few cm. Some slightly moistened black threads of cotton 5mm long are contained in the coil. A voltage is about 10kv applied between the sphere and plate within few seconds result in the alignment of the threads in the direction of field a fibre-bridge is established which can neither initiate nor accelerate a breakdown. The two photographs of the model experiment shown in fig 13.2 indicate clearly the extent to which oil Gap in high-voltage apparatus, which are not subdivided are exposed to risk by dissociation product and other solid particles.

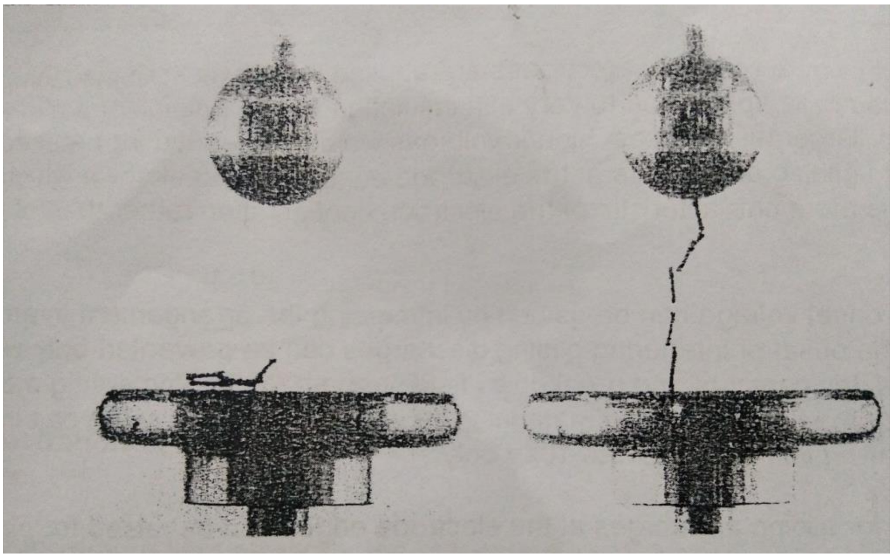

Fig. 13.2. Model experiment showing fiber-bridge formation in insulating oil

a) fibers before switching the voltage on

b) fiber-bridge 1 minute after switching the voltage on

OBSERVATION:

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