Yashoda Shiskshan Prsarak Mandal's

Yashoda Technical Campus

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Faculty of Engineering

Department of Electrical Engineering

LABORATORY MANUAL

OF

HIGH VOLTAGE ENGINEERING

FOR

B.Tech. Semester – VII

Name of Student:- ………………………………………………..

Class:-……………………. DIV:-……………

Roll No:-……………….. PRN No:-…………..

SEM:- ODD Academic Year:- 2024-25

Vision of the Department

To emerge as a center of excellence in Electrical Engineering education producing knowledgeable, employable, and ethical engineering graduates to serve industry/society

Mission of the Department

We, at Department of Electrical Engineering, are committed to achieve our vision by-

M1: Preparing technically and professionally competent engineers by imparting quality education through effective teaching learning methodologies.

M2: Developing professional skills and right attitude among students that will help them to succeed and progress in their personal and professional career.

M3: Inculcating moral and ethical values in students with concern to society and environment.

SAFTEY INSTRUCTIONS

1. **SAFETY** is of paramount importance in the **Electrical Engineering** Laboratories.
2. Electricity NEVER EXECUSES careless persons. So, exercise enough care and attention in handling **electrical** equipment and follow **safety** practices in the laboratory. (Electricity is a good servant but a bad master).
3. Avoid direct contact with any voltage source and power line voltages. (Otherwise, any such contact may subject you to **electrical** shock)
4. Wear rubber-soled shoes. (To insulate you from earth so that even if you accidentally contact a live point, current will not flow through your body to earth and hence you will be protected from **electrical** shock)
5. Wear laboratory-coat and avoid loose clothing. (Loose clothing may get caught on an equipment/instrument and this may lead to an accident particularly if the equipment happens to be a rotating machine)
6. Girl students should have their hair tucked under their coat or have it in a knot.
7. Do not wear any metallic rings, bangles, bracelets, wristwatches and neck chains. (When you move your hand/body, such conducting items may create a short circuit or may touch a live point and thereby subject you to **electrical** shock)
8. Be certain that your hands are dry and that you are not standing on wet floor. (Wet parts of the body reduce the contact resistance thereby increasing the severity of the shock)
9. Ensure that the power is OFF before you start connecting up the circuit.(Otherwise you will be touching the live parts in the circuit)
10. Get your circuit diagram approved by the staff member and connect up the circuit strictly as per the approved circuit diagram.
11. Check power chords for any sign of damage and be certain that the chords use **safety** plugs and do not defeat the **safety** feature of these plugs by using ungrounded plugs.
12. When using connection leads, check for any insulation damage in the leads and avoid such defective leads.
13. Do not defeat any **safety** devices such as fuse or circuit breaker by shorting across it. **Safety** devices protect YOU and your equipment.
14. Switch on the power to your circuit and equipment only after getting them checked up and approved by the staff member.
15. Take the measurement with one hand in your pocket. (To avoid shock in case you accidentally touch two points at different potentials with your two hands)
16. Do not make any change in the connection without the approval of the staff member.
17. In case you notice any abnormal condition in your circuit (like insulation heating up, resistor heating up etc.), switch off the power to your circuit immediately and inform the staff member.
18. Keep hot soldering iron in the holder when not in use.
19. After completing the experiment show your readings to the staff member and switch off the power to your circuit after getting approval from the staff member.

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This is certify that ………..………………………………………………. and Roll No………………of B.Tech. Electrical has completed all the experiment in the subject High Voltage Engineering during academic Year 2024-25.

Sign of Student **Sign of Faculty** **HOD- Electrical**

INTRODUCTION

STUDY OF IMPULSE WAVE SHAPE OF STANDARD LIGHTNING AND SWITCHING IMPULSE

AIM : To study the impulse wave shape of standard lightning and switching impulse as per standards with its tolerance levels.

BACKGROUND:

In the field of electrical engineering, high voltages i.e. dc, ac, impulse are required for several application. High voltage engineering deals with study of voltages above 132 KV.

In AC transmission, low voltages are below 11 KV and medium voltages are in range of 22 KV to 66 KV. The voltages 132 KV, 169KV, 220 KV and 275 KV are termed as High voltages. Above 132 KV to 750KV are Extra High Voltages (EHV). Above 750 KV voltages are called as Ultra High Voltage (UHV).

Different forms of high voltage are given below:

1. High dc voltage
2. High ac voltage of power frequency
3. High ac voltage of high frequency
4. High transient or impulse voltage of very short duration such as lightning overvoltage
5. Transient voltages of longer duration such as switching surges.

The application like electron microscope and X-ray unit required high voltage of order of 100 KV or more. Electrostatic precipitators, particles accelerator in nuclear physics etc. require high voltage dc of KV. High voltage of one million voltage or even more required for testing power apparatus rated EHV (400 KV system and above). High impulse voltages are required for testing purpose to stimulate overvoltage that occurs in power system due to lightning or switching action.

In Electrical Power Systems there are three main types of wave shapes (Wave forms) i.e. DC, AC & impulse. The example of DC source is battery, cells, PV panels, etc. The examples of AC source is AC generators, Domestic supply, etc. The examples of impulse source is lightning wave, faults occurs, impulse generators, etc.

High impulse voltages are required for testing purpose to stimulate overvoltage that occurs in power system due to lightning or switching action. It is used to assess the performance of the apparatus in power system under simulated worst-case conditions.

Impulse Voltage

An impulse voltage is a unidirectional voltage which, without including oscillations, rises rapidly to a maximum value and falls more or less rapidly to zero.

The maximum value is called the peak value of the impulse and the impulse voltage is specified by this value. Small oscillations are tolerated, provided that their amplitude is less than 5% of the peak value of the impulse voltage. In case of oscillations in the wave shape, a mean curve should be considered. If an impulse voltage develops without causing flash over or puncture, it is called a full impulse voltage; if flash over or puncture occur, thus causing a sudden collapse of the impulse voltage, it is called a chopped impulse voltage.

Lightning and Switching Impulse

A distinction is made between lightning and switching impulses on the basis of duration of the front impulses with front duration up to 20μS are defined as lightning impulses and those with longer fronts are defined as switching impulses. Generally switching impulse are characterized by total duration considerably longer than those of lightning impulses.

Standard Lightning Impulse

Standard Lightning Impulse is a full lightning impulse having front time of 1.2 μS and a time to half value of 50 μS. It is described as a 1.2/50 μS impulse.

Tolerances:

- Peak Value ± 3%

- Front Time ± 30%
- Time to half -value ± 20%

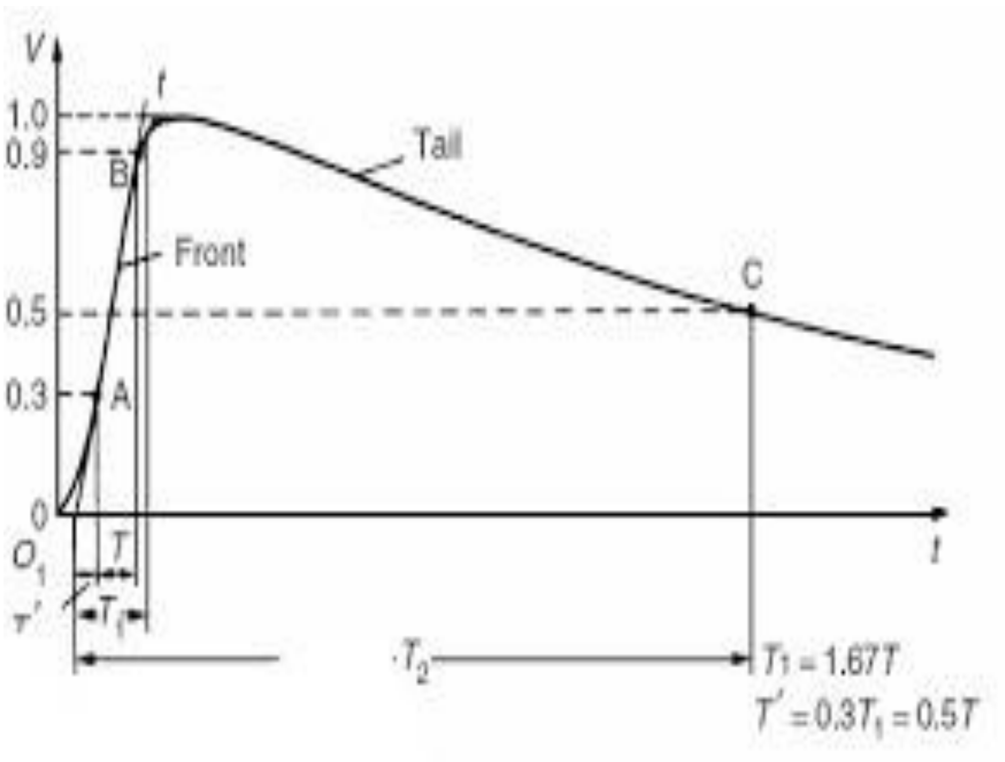
Standard Switching Impulse

Standard Switching Impulse is a impulse having a time to peak T_p of 250 µS and a time to half value T_2 of 2500µS. It is described as a 250/2500 µS impulse.

Tolerances:

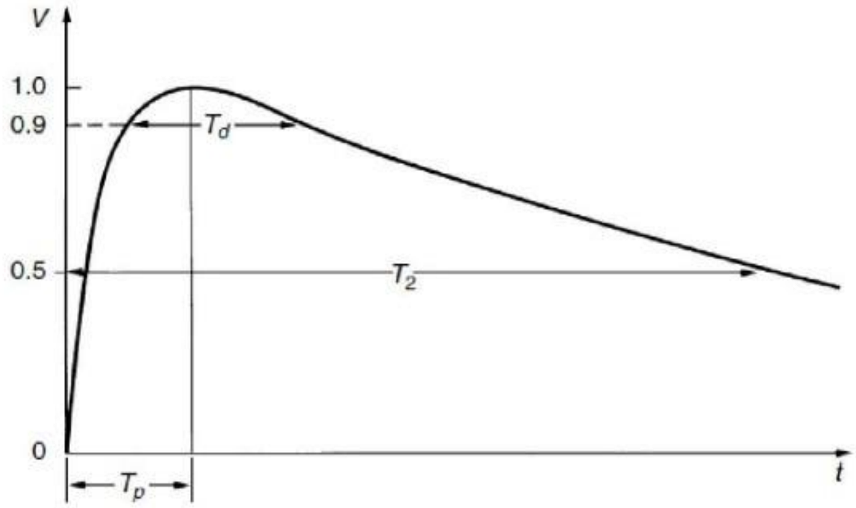
- Peak Value ± 3%
- Time to Peak ± 20%
- Time to half -value ± 60%

Standard Lightning Impulse Waveshape



Standard Switching Impulse Waveshape

$$T_p = 250\,\mu s \pm 20\%$$
$$T_2 = 2500\,\mu s \pm 60\%$$



General shape of switching impulse voltages. Tp: time to peak. T_2 : time to half-value. Td: time above 90 per cent

CONCLUSION:

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Questions to be Answered:

1. **How Impulse waves are specified?**

2. **Why we have to define the front time and tail time of an impulse?**

3. **Define Front Time T_1 of Lightning Impulse and how it will be computed?**

4. **Define Virtual Origin O_1 in Lightning Impulse.**

5. **Define Time to half value T_2 of Lightning Impulse.**

6. **Define Time to Peak T_p in Switching Impulse.**

7. **Define Time to half value T_2 of Switching Impulse.**

8. **Define Time above 90% T_1 in Switching Impulse.**

EXPERIMENT NO. 1

GENERATION OF LIGHTNING IMPULSE VOLTAGE WAVE WITH MULTISTAGE MARX GENERATOR

AIM: To study of 5-stage, 150kV, and 225J impulse generator and to measure wave shape (front time, tail time and peak voltage) of impulse wave.

APPARATUS:

1.	5-stage, 150kV, and 225J impulse generator	1No
2.	Control panel	1No.
3.	Oscilloscope	1No.

INTRODUCTION:

The arrangement for charging the capacitors in parallel and then connecting them in series for discharging was originally proposed by Marx shown in Fig 1 . Now-adays modified Marx circuits are used for the multistage impulse generators. For producing very high impulse voltages, a bank of capacitors are charged in parallel through the charging resistance and then discharged in series through the spark gaps.

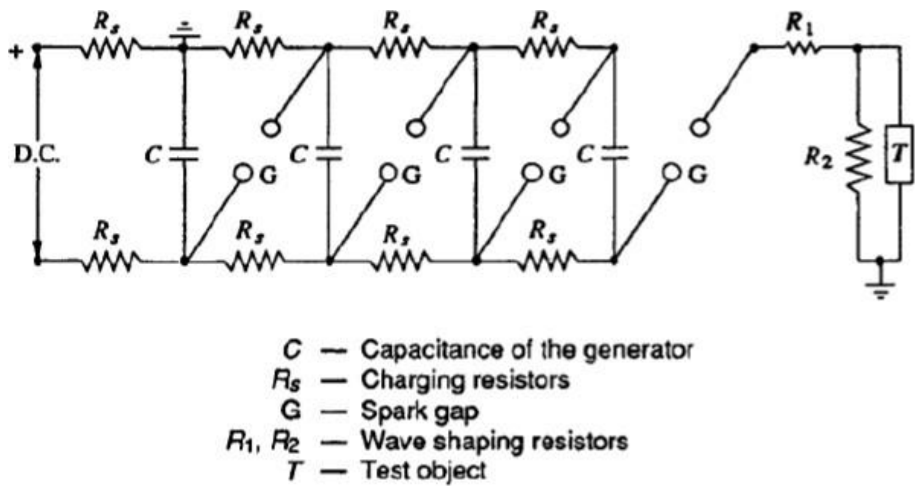


Fig 1 : Schematic Diagram of Marx Arrangement for Multistage Generator

The generator has five stages of 30kV each. Each stage has two capacitors in series. The rating of each capacitor is 0.2□f, 15kv. Thus, the stage energy is

E = (1/2)*CV2

= (1/2) * (0.1□F)*(30kV) 2

= 45 joules each stage * 5 stage

= 225 Joules.

CONSTRUCTION

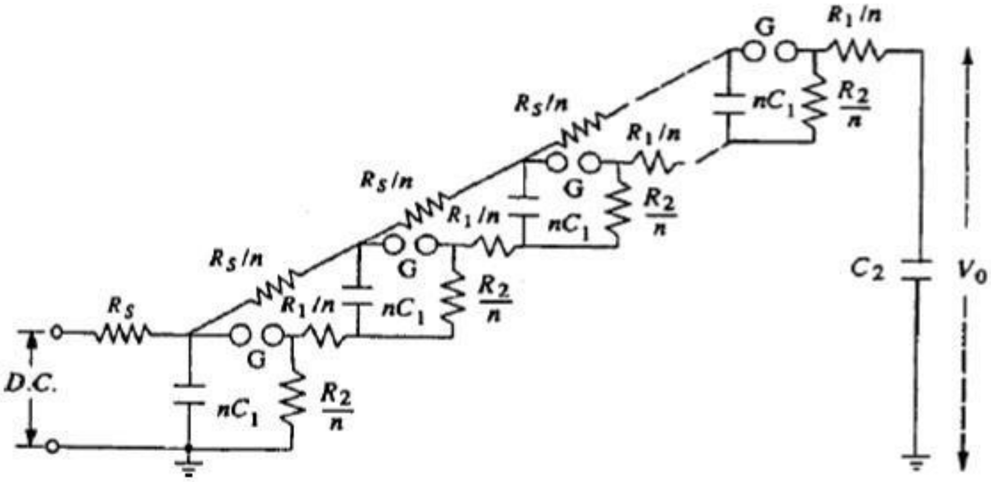


Fig.2: Multistage impulse generator incorporating the series and wave tail resistances within the generator

The schematic diagram of the generator is shown in Fig.2, A 0-230Volts variable input from the control panel is fed to the primary of the charging transformer ‘T’ rated 230V/30kV, 2KVA. This output voltage of the transformer is rectified using a high voltage rectifier ‘D’ rated for 1A peak forward current and 60kV PIV. This rectified voltage charges both the capacitors of each stage through current limiting resistors. For the first stage charging resistance has been taken as 600k Ω to make the charging slow and for other four stages the value of the charging resistors is 16kΩ per stage. These resistors limit the charging current to a safe value.

SPECIFICATIONS OF IMPULSE GENERATOR:

Input Voltage	0- 230 V
Generator input voltage	30kV (Max) per Stage
Energy rating of the generator	225 Joules
Wave Front Resistor	22.5Ω
External wave front Resistor	Nil
Wave tail Resistor	695Ω
Resistance Divider	14.5kΩ

Resistance of LV unit of the resistance divider	14.5 Ω
Loading Capacitor	2000 pf
Equipotential resistance per stage	100 KΩ
Wave shape	1.2/50μs

The impulse generator is fabricated to deliver the impulse of 1.2 micro –second rise time and 50 microseconds fall time.

The generator consists of the following:

1. Control panel
2. High Voltage Transformer
3. Rectifier
4. Bleeding Resistor.
5. Sphere and capacitor stages.
6. Wave front resistor.
7. Wave tail resistor.
8. Loading capacitor
9. Charging resistor
10. Discharge resistor

1. CONTROL PANEL:

The control panel has been made versatile for the easy of operation and taken into consideration the safety factors. The control panel has built in dimmer so adjusted that the voltage is fed to the capacitors at the rate of 2 kV/sec by manually for the safe operation of the impulse generator. Specially made isolation transformer has also been installed inside the control panel to avoid the entry of the unwanted surges to the generator of back to the transformer and hence the safety of the operator is ensured. The panel contains the necessary meters, switches and indicators.

2. HIGH VOLTAGE TRANSFORMER:

This is oil-cooled step up transformer with one end ground and the high voltage terminal brought out through the bushing. This is a mobile type transformer having the following specifications.

Input voltage : 0-230V ac
Output voltage : 0 – 30kV ac
KVA rating : 2KVA

3. RECTIFIER:

The variable output of the transformer is fed to the high voltage rectifier such designed that the 30kv, PIV of this is 90KV. The rectifier is mounted on a mobile base with insulating supports. Changing the position of the rectifier manually changes the polarity of the voltage.

4. BLEEDING RESISTOR:

The value of the bleeding resistor is 30M-Ohms and is connected to control panel meter to read the charging voltage of each stage. It is calibrated in such a way that 1mA current flows it when 30kV is applied. The bleeding resistor has been designed in such a way that it contains high voltage resistors in series.

5. SPHERES AND CAPACITORS:

Each stage of the impulse generator has a set of capacitors and spheres. The capacitors are impulse type, hermetically sealed and they have the minimum inductance to insure better wave shape. Each capacitor is rated for 15kV, 0.2MFD. The spheres of the generator are made of pure copper and its diameter is 50mm.

6. WAVE FRONT RESISTORS:

Wave front resistors are made of high quality resistance wire. The resistance are wound in such a way that they are non-inductive and can withstand the energy dissipated by the stage capacitors is 22.5 ohms per stage and the external resistance are not connected . so the total wave front resistance of the generator is 90 Ohms. The resistor controls the wave front time to 1.2 microseconds ±20%.

7. WAVE TAIL RESISTORS:

Similarly wave tails resistors are made and fixed at the proper places as indicated in the fig1. These resistors are of value of 695 Ohms each. So 3475 ohms resistors are distributed inside the generator. The resistance divider value is 14.75kOhms, and the LV side is 14.6 Ohms. As per standards it be ± 30% micro seconds.

8. RESISTANCE DIVIDER:

The resistance divider value is 14.75k Ohms , and LV is 14.6Ohms.

9. LOADING CAPACITOR:

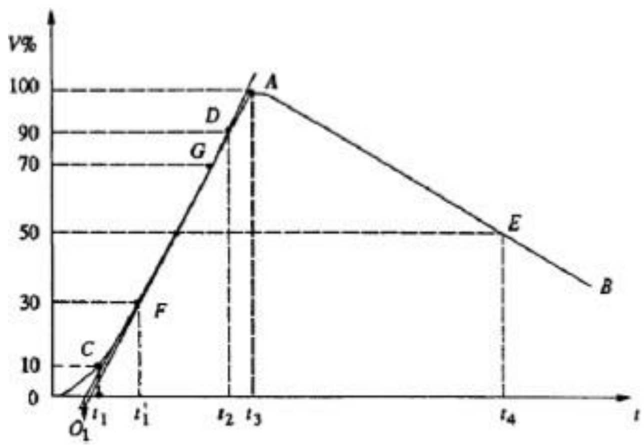
This capacitor is high voltage capacitor and this also forms a part of the impulse generator. This is made using high voltage capacitors in series and the value of the capacitors is 2000pf and it is rated for 200kV impulse application. The entire assembly is mounted and housed in a fibre glass tube and these capacitors are immersed in oil for better cooling.

10. DISCHARGE RESISTOR:

The resistance is used for discharge the voltage, which is stored in the capacitor while HT is OFF condition.

PROCEDURE:

1. Check all the connections and grounding properly.
2. Open the Emergency switch and switch on the control panel with the help of the Mains ON push button.
3. Bring the Dimmer to zero Position.
4. Bring the sphere gap to Zero position and set the gap of spheres with the help of the “sphere gap increase” and “sphere gap decrease” push button.
5. Open the earth with the help of “earth open” push button till to earth open.
6. Select the polarity with the help of “Polarity” selector switch.
7. Press the HT ON switch as a result ‘HT ON’ indicator will glow.
8. Charge the capacitor little less than the required level by increasing the DIMMER by manually.
9. Trigger the generator with the help of TRIGGER switch.
10. See the generated impulse wave across test specimen with the help of Oscilloscope. (Which will be similar with the following wave shape)



11. Measure peak voltage at point ‘A’
12. Calculate front time by following formula
13. Front time= (t2 – t1) × 1.25 OR Front time= (t2 – t'1) × 1.67
14. Measure tail time ‘t4’
15. After testing press the Mains OFF switch, press the Emergency button and ground all the capacitors with the help of grounding rod.

PRECAUCTIONS:

1. Charging voltage should never exceed 30kV.
2. Open earthing rod before putting HT ON.
3. After completion of experiments input power supply should be disconnect.
4.

OBSERVATIONS:

1. Peak voltage of generated impulse wave =___________kV
2. Front time of impulse wave =_____________s
3. Tail time of impulse wave =______________s

CONCLUSION:

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Questions to be answered:

1. Give the expression for double exponential wave of lightning overvoltage.

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2. What are the difficulties encountered for the single stage impulse generator? (reason for moving to multistage impulse generator)

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3. How are the wave front and wave tail times controlled in impulse generator circuits?

4. Write down the expression to determine the front time and tail time of the impulse wave.

EXPERIMENT NO. 2
MEASUREMENT OF AC BREAKDOWN VOLTAGE OF AIR USING SPHERE GAP ASSEMBLY

AIM: To study measurement of ac breakdown voltage of air using sphere gap assembly.

APPARATUS:

1. 62.5mm sphere gap assembly-------------------------------------- 1 No. (Quantity)
2. 50kv AC/70kv DC test set with control panel -------------------1 No.
3. Grounding Rod...1 No.
4. Barometer..1 No.
5. Thermometer...1 No.

INTRODUCTION:

Sphere gap is an absolute method of measurement of the peak value of high voltage, for alternating and 1/50 microseconds impulse voltages for spacing up to 0.5D (where D is sphere diameter). It can be measured accurately with + or – 3%. For direct voltage measurement in the absence of excessive dust, the results are considered accurate within + or – 5% for spacing not greater than 0.4D.

Types of Sphere Gaps:

The sphere gaps are two types.

1. Vertical sphere gap, and
2. Horizontal sphere gap.

In a vertical sphere gap two identical spheres are arranged vertically such that lower sphere is grounded permanently. And, in the horizontal sphere gap assembly both spheres are connected to the source or one sphere is grounded. In horizontal configuration it is generally arranged such that both spheres are symmetrically at high voltage above the ground.

The sphere may make of Aluminum, brass, bronze or light alloys and the surface should be free from burrs. The radius of curvature should be uniform. The radius of curvature measured with spereo-meter at various points over an area enclosed by a circle 0.3D around the sparking points should not differ by more than +or- 2% of is the nominal value . The surface of the sphere should be free from dust, grease or any other coating.

The high voltage, to be measured, is applied to the upper sphere through a water resistor, the purpose of the water resistor is to limit the break down current and to suppress the unwanted oscillations of the source voltage.

Effect of Humidity on Measurements:

The break down voltage of an air gap is affected by the atmospheric conditions and a correction factor has been worked out to convert the break down voltage to the standard atmospheric conditions of 760mm Hg and 20^0C temperature. The break down voltage V at relative density 'ρ', and voltage V_0 at standard atmospheric conditions are related by

$$V = KV_0$$

Where, V- break down voltage at relative density 'ρ', under actual test condition
V_0 - voltage at standard atmospheric conditions
K - Correction factor depending on 'ρ'

$$\rho = \frac{P}{760} \times \frac{293}{(273 + T)}$$

Where, ρ – air density factor
P - air pressure in mm of Hg.
T - air temperature in ^{0}C.

Table 1: Air Density Correction Factor

ρ	0.70	0.75	0.80	0.85	0.90	0.95	1.00	1.05	1.10
K	0.72	0.76	0.81	0.86	0.90	0.95	1.00	1.05	1.09

Effect of Near By Earthed Objects

The accuracy of measurement of voltage with sphere gap is considerably affected by earthed objects around the gap. The breakdown voltages reduces considerably in such cases. So, care should be taken to see that there should be no earthed objects near by when measurements are being made.

PRECAUTIONS:

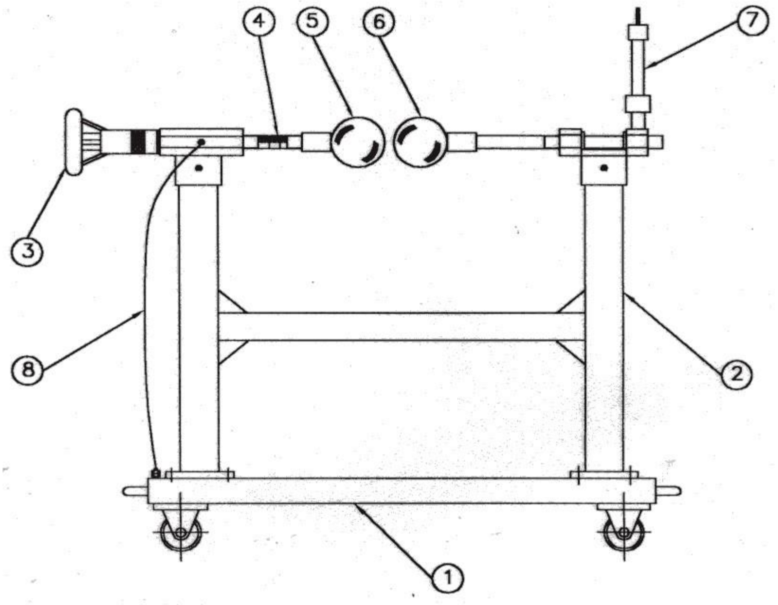
1. In no case gap should increase more that 0.5D (i.e. 50mm in the present case). If the gap is between 0.5D and 0.75D the accuracy of the equipment will be + or – 5%
2. The equipment must be grounded.
3. The first two flash-over readings of the sphere gap should be ignored as the air gap is not ionized and may contain dust particles before starting the experiment.
4. It is advisable to clean the spheres immediately before and after the use.

5. After measuring the gap the sphere should be locked with the help of lock nuts provided with the moving shafts to avoid any change in the set gap (In case of horizontal sphere gap assembly.

PROCEDURE:

1. Check all connections are made as per the circuit diagram using sphere gap model.
2. Ensure all earth potentials are properly connected to the main earth point.
3. Keep the diameter to zero position, make zero adjustment and keep certain space between the sphere electrodes configuration using standard chart.
4. Switch 'ON' the mains supply to the control panel.
5. Slowly and gradually increase the voltage with the help of dimmer until the flashover occurs.
6. Note down the gap length and flash over voltage with the help of meter provided in the control panel.
7. Repeat the above procedure for same gap length for DC.
8. Note down the temperature and pressure using the thermometer and barometer and make the calculation.

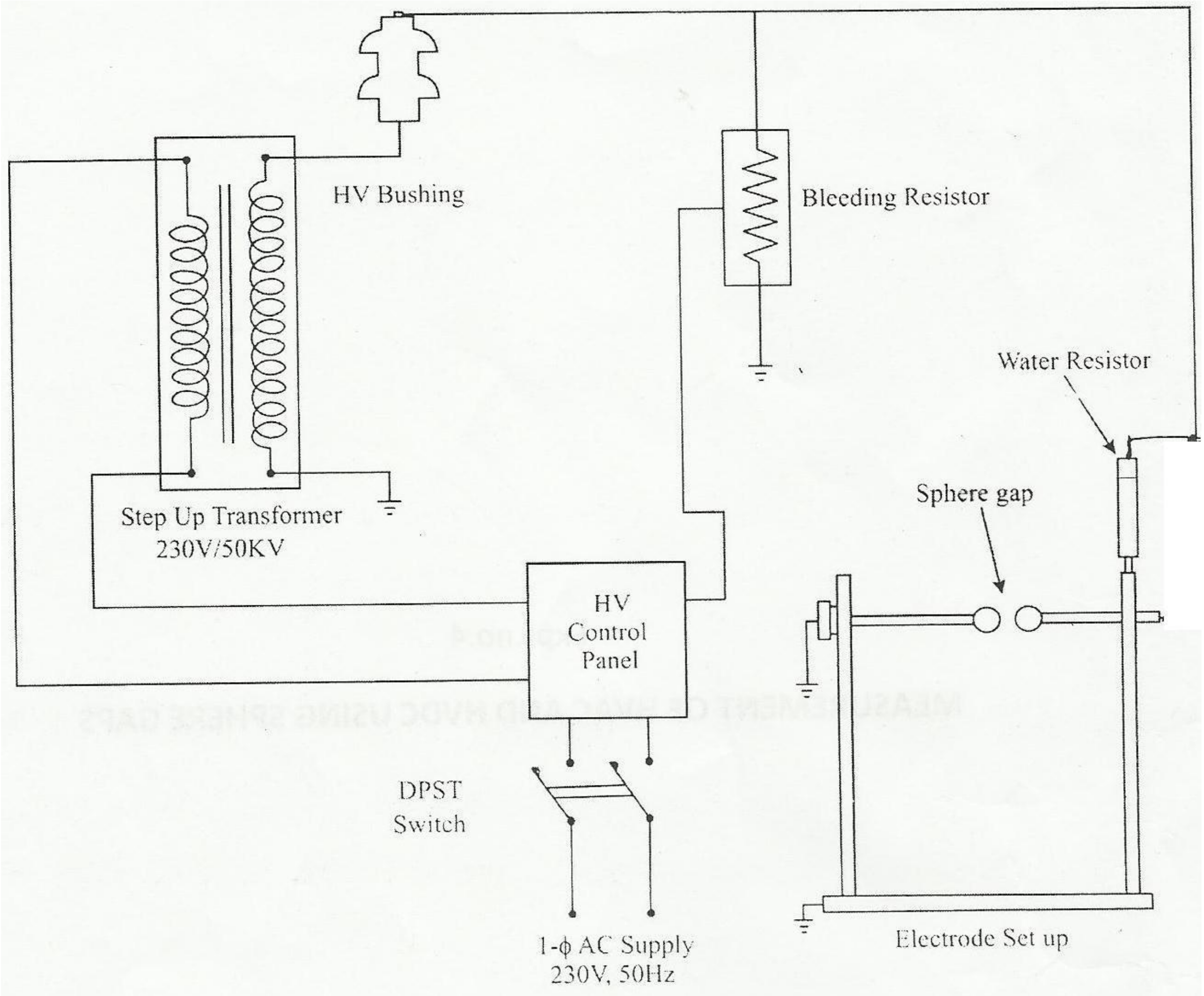
SCHEMATIC DIAGRAM:



1. BASE
2 SUPPORTING STAND
3 HAND WHEEL
4 MEASURING SCALE
5 GROUND SPHERE
6 H.T. SPHERE
7. WATER RESISTOR
8. GROUNDING CONNECTION

CIRCUIT DIAGRAM:

Measurement of AC breakdown voltage of air using sphere gap assembly:



OBSERVATIONS: (For AC Voltage)

Note down the temperature and pressure reading of the HVE lab

Air Temperature‘t’ =__________ ^{0}C Air pressure ‘P’ =____________mm of Hg

Sr. No.	Gap Length (mm)	Measured Breakdown Voltage at relative air density V (in kv)	Breakdown Voltage at standard atmospheric conditions V_0 (in kV) $V_0 = \frac{V}{k}$
1.			
2.			
3.			

CALCULATION:

Determine the air density factor as $\rho = \frac{P}{760} \times \frac{293}{(273+T)}$

From the Table 1, find air density correction factor (K) to be applied for above air density factor (ρ)

CONCLUSION:

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Questions to be answered:

1. List out the factors that are influencing the peak voltage measurement using sphere gap.

2. What are the effects of humidity on the spark over voltage?

3. What are the effects of atmospheric conditions on the spark over voltage of air?

4. Write the effect of nearby earthed object on the spark over voltage of sphere gap.

5. Write the standard atmospheric condition for high voltage testing as per Indian standards.

6. What are the advantages of spark gap measurement for high dc, ac, impulse voltages?

EXPERIMENT NO. 3
MEASUREMENT OF DC BREAKDOWN VOLTAGE OF AIR USING SPHERE GAP ASSEMBLY

APPARATUS:

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4.	Barometer	1 No.
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The break down voltage of an air gap is affected by the atmospheric conditions and a correction factor has been worked out to convert the break down voltage to the standard atmospheric conditions of 760mm Hg and 20^0C temperature. The break down voltage V at relative density 'ρ', and voltage V_0 at standard atmospheric conditions are related by

$$V = KV_0$$

Where, V- break down voltage at relative density 'ρ', under actual test condition
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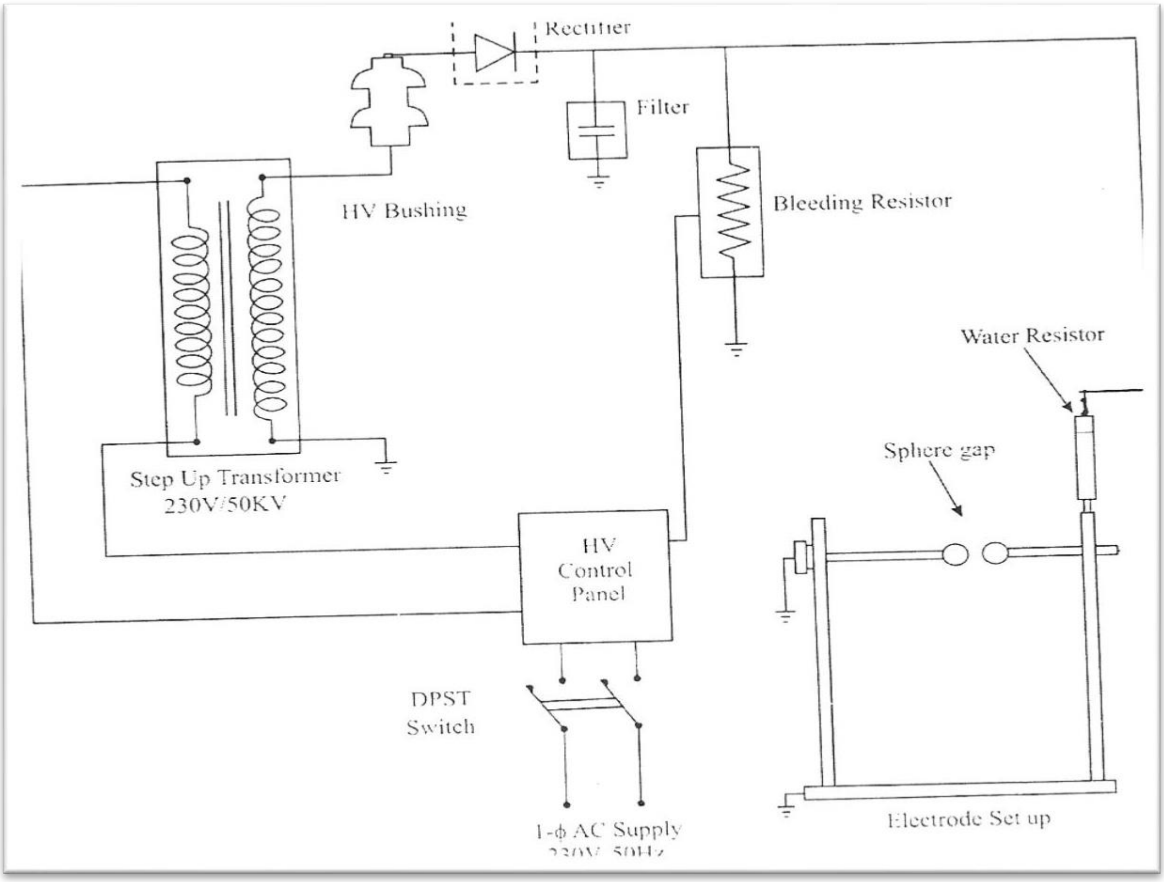
6. Note down the gap length and flash over voltage with the help of meter provided in the control panel.
7. Repeat the above procedure for same gap length for DC.
8. Note down the temperature and pressure using the thermometer and barometer and make the calculation.

IRCUIT DIAGRAM:

Measurement of DC breakdown voltage of air using sphere gap assembly: (for positive polarity)



OBSERVATIONS: (For DC Voltage)

Note down the temperature and pressure reading of the HVE lab

Air temperature ‘t’ =__________^{0}C Air pressure ‘P’ =____________mm of Hg

Sr. No.	Gap Length (mm)	Measured Breakdown Voltage at relative air density V (in kv)	Breakdown Voltage at standard atmospheric conditions V_0 (in kv) $V_0 = \frac{V}{k}$
1.			
2.			
3.			

CALCULATION:

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Questions to be answered:

1. AC breakdown voltage is slightly less than DC breakdown voltage, is it true?

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2. What are various methods other than sphere gap used for HV measurement?

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3. What is the use of rod gaps?

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4. What will happen if sphere gap surface are coated with particles due to oxidation during sparking or dust and other particles, if regards with its sparking performance.

5. How a sphere gap can be used to measure the peak value of voltages.

6. How are Spark Gaps for Measurement of High d.c., a.c. and Impulse Voltages are arranged?

EXPERIMENT NO. 4

ESTIMATION OF BREAKDOWN STRENGTH OF TRANSFORMER OIL

AIM : To determine the Breakdown strength of the given Transformer oil at a specified gap distance

APPARATUS:

1.	Oil test kit (0-60kV)	1No.
2.	Transformer oil	1No.
3.	‘GO’ / ‘NO GO’ gauge	1No.

0-60kV MANUAL OIL TEST KIT:

The test kit operates from single phase mains supply. The circuit comprises of the following.

1. Auto transformer 0-2A, 230V, 50Hz.
2. Step up transformer 230V / 60,000V ac.
3. Control panel.

Main supply is connected to the auto transformer through a fuse and switch. Output of the auto variable transformer feeds the primary winding of the H.V. step up transformer through a push button actuated relay. Midpoint of the H.V. transformer is solidly earthed. Theset is complete with an oil test cup, made of high impact transparent, acrylic sheet and 2.5mm“GO”, “NO GO” gauge.

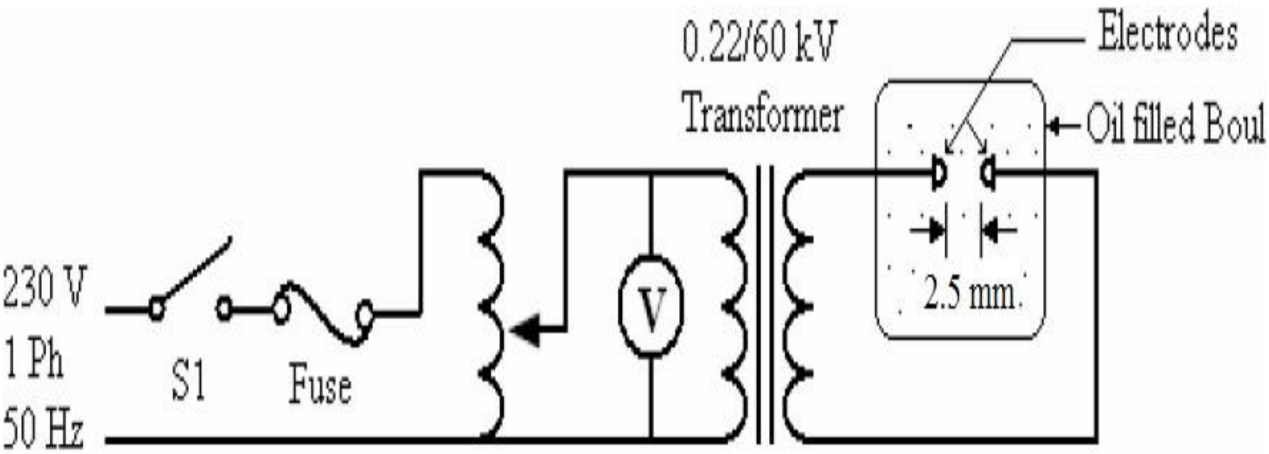
PROCEDURE:

1. Adjust the electrodes in the oil test cup for the required gap and lock it in position with the help of screws provided.
2. Fill 80% of the cup with oil to be tested and place the cup on the HV transformer bushings.
3. Close the top door, switch the MAINS “ON” bring variable transformer to Zero position by means of switch provided for the reverse and forward of a auto – variable transformer.

When it comes to zero position unit ready indicator will glow. And press “HT” push button; HT ON indicator will glow.

4. Increase the voltage to the required level. Voltmeter will indicate the output voltage. In case of break-down “HV” will get disconnected. By pressing “MEMORY” push button read the level of break down voltage.
5. Repeat the same procedure for 3 times and note down break over voltage at each case.
6. The average value gives the break over voltage of given insulating oil.

CIRCUIT DIAGRAM:



TABULATION:

1. Breakdown voltage of transformer oil

No. of Trials	Breakdown voltage in kV
1.	
2.	
3.	

Mean breakdown voltage of transformer oil =_________kV

2. Dielectric strength of oil $= \frac{Average\ value\ of\ break\ over\ voltage}{Gap\ Between\ electrodes}$ kV/Cm

CONCLUSION

Questions to be answered:

1. What is breakdown voltage?

2. What are the factors affecting the breakdown strength of oil?

3. List out the applications of liquid dielectrics.

4. Show the power law dependence between the gap spacing and the applied voltage of the oil.

5. How do you conclude whether oil is good or bad.

6. Why transformer oil is most commonly used liquid dielectric in transformers?

7. Why is Transformer Oil Testing Important?

EXPERIMENT NO. 5
5 kV AC INSULATION TEST

AIM : To determine the Breakdown strength of the given solid insulation.

INTRODUCTION:

This 5 KV ac set is the most necessary equipment for any high voltage or industry it is required to conduct most of the high voltage experiments & tests in the laboratory.

The unit consists of two parts.

a) Control panel. (HT Transformer In-build)
b) Dimmer

Specification of the Transformer:

Input voltage	:	0 - 230V ac.
Output Voltage	:	0 – 5 kV ac.
Output current (Max.)	:	30mA

In this transformer High voltage is brought out through the high voltage bushing and one end of the H.T coil is grounded.

CONTROL PANEL:

The control panel of this equipment is very versatile and it includes most of the facilities needed for educating the students and operational safety. It includes the following meters, push buttons, indicators and toggle switches etc.

Meters:

1. A.C. Charging voltage. (0 – 5 kv)
   This measure the A.C. output and is fixed to the primary side and calibrated.
2. Leakage current (30mA) – 15Ma (pos1)/30ma (pos2)
   This measure the leakage current of the specimen.

Timer:

The timer is used to perform the withstand test. The Range of this timer is 1 second to 30 hours.

Push Button Switches:

1. H.T OFF: This push button is used for put OFF the H.T.
2. H.T.ON: This push button is pressed to make the H.T.ON
3.

Toggle Switchs:

1. TIMER BY PASS: This switch can be put on “BYPASS” position when timer is not required. If with strand test is being conducted it should be put in “ON” position.
2. Mains On/off : This switch for Mains on / off purpose.

Indicators:

1. MAINS ON: This indicates the power is present in the control panel.
2. H.T.OFF: It indicates that H.T is OFF.
3. H.T.ON: It indicates that H.T. is ON.
4. UNIT READY: This indicates that dimmer is in the zero interlock position. H.T. can be put on only after zero interlocking.
5. TRIP: It indicates the specimen is failed, or leakage current is crossed the set current value.

PROCEDURE:

1. Connect variable 230V to the input of the Transformer.
2. Connect H.T lead of the transformer to test specimen and that specimen ground to the control panel ground and mother ground.
3. Give the 230V, 50Hz to the control panel.
4. Put the “Mains ON” then MAINS ON, H.T. OFF INDICATORS will start glowing.
5. If trip indicator glows Reset the equipment, the trip indicator goes OFF.
6. Bring the Dimmer to zero position (for zero interlock) by manually, and then UNIT READY indicator will start glowing.
7. Put the H.T. ON then H.T.ON indicator will start glowing, H.T.OFF indicator goes OFF.
8. Increase the voltage at required level by manually.
9. If you want “TIMER” put the switch in ‘ON’ “POSITION” If equipment trips within the set time, then we conclude specimen has failed the TRIP indicator will glow.
10. If specimen withstands the voltage in set time, we conclude specimen has passed the test.

PRECAUTION:

The ground points of the equipment’s must be grounded firmly with the mother ground.

OBSERVATIONS:

- Test specimen failed at voltage:**_____________**KV

CONCLUSION:

EXPERIMENT NO. 6
FIELD MAPPING USING ELECTROLYTE TANK

AIM: To draw the equi-potential lines using electrolytic tank for Co-axial cable model

APPARATUS:

1.	Electrolytic Tank with all its assembly (Tank, Pantograph and Base)		1 set
2.	Electrodes set	Co-axial cable model	1 No.
3.	Voltmeter	MI (0-100V)	1 No.
4.	Autotransformer	230V / 0-260V	1 No.
5.	Drawing sheets		2 No.
6.	Pencil and eraser		1 No.
7.	Connecting wires		

INTRODUCTION:

Electrolytic tank is useful tool to draw equipotential lines. Equipotential line is the path along which the voltage remains the same. This experiment plays very important role forthe analysis of electric field or electric stresses of a die-electric. Geometrically simple modelscan be taken and equipotential lines can be drawn.

Electrolytic tank, basically consists of the following;

1. Tank.
2. Pentagraph, and
3. Base.

The basic tank is made of high quality mild steel and it is epoxy powder coated to protect form corrosion. On the top of the tank a transparent glass is fixed with the help of frame. The drawing sheet, on which equipotential lines have to be plotted, is kept and fixed on the glass sheet. The tank has the provision to drain the water after the experiment is over. Pentagraph is the most important part of the electrolytic tank. Pentagraph is specially design to have two parallel moving arms one over the another. These arms can be moved in X or Y direction. Lower arm has the provision to hold the probe which can move between the electrodes, kept in the tank to locate the equipotential points. Upper arm has a pencil holder. This is spring loaded and by pressing the top know of the holder point can be located on the drawing sheet. The base of the equipment is made out of square tube. Provision is made to level the tank with the help of the leveling screw, and hence, water in the tank.

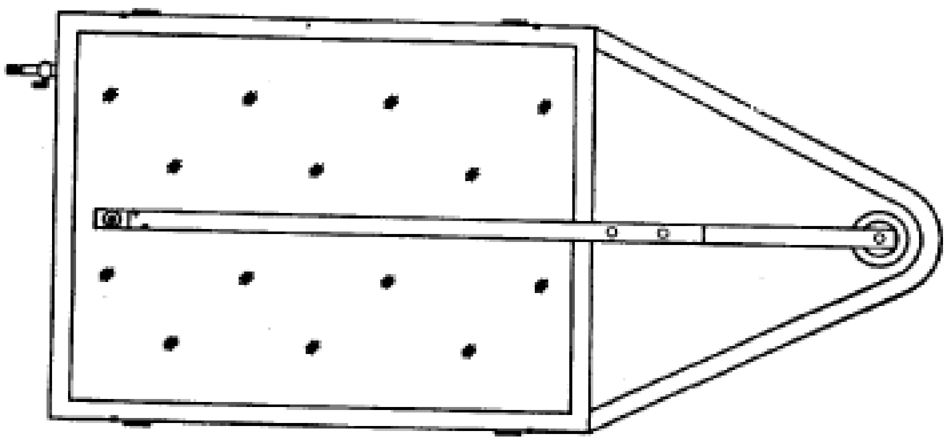
PROCEDURE:

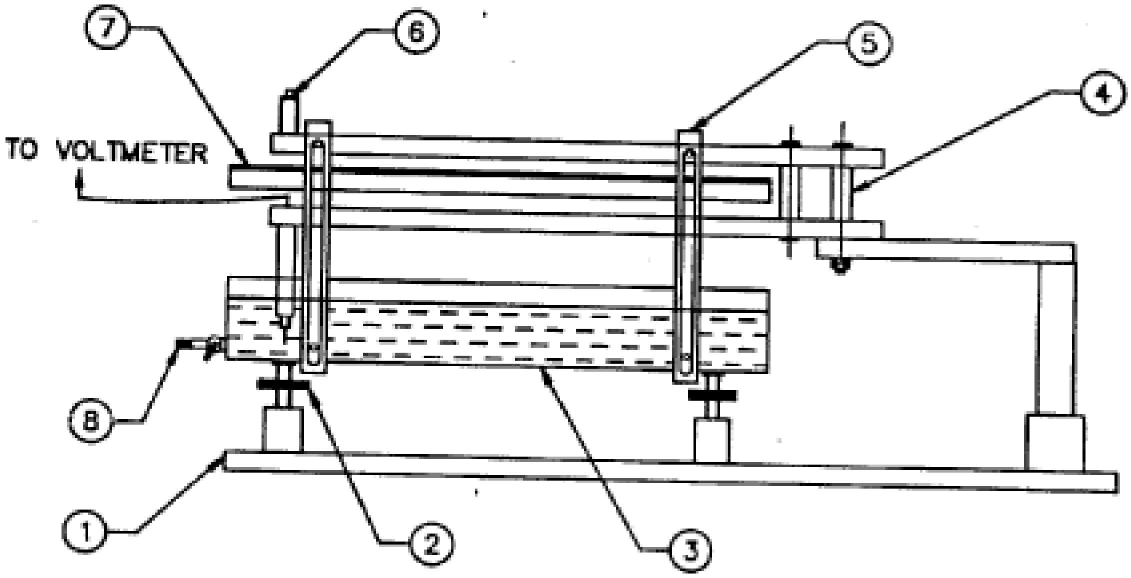
1. The parallel plate electrode model should placed inside the tank.
2. Clean water is poured (added) in the tank such that the electrodes dip at least little more than the half in the water.
3. A drawing sheet is fixed on the glass plate of the electrolytic tank.
4. Connections are made as per the circuit diagram and keep multimeter knob in the AC mode.
5. Switch ON main supply.
6. Some Voltage (say 10V) is applied to one electrode and other electrode is grounded.
7. Now equipotential lines at 10%, 20%……90% can be drawn by moving the probe to certain points, where, the high impedance meter reads the voltage.
8. First set of points is achieved at 10% i.e. 1V, second set at 20% i.e.2V and so on.
9. Finally, join the equipotential points to get the equipotential lines.
10. Repeat the above procedure for different set of electrodes.

PRECAUTIONS:

1. High impedance voltmeter should be used to read the equipotential points.
2. Drain out the water after the experiment.
3. Do not apply more voltage from the safety point of the view.
4. Do not add any salt or chemicals in the water of the tank.

SCHEMATIC DIAGRAM:

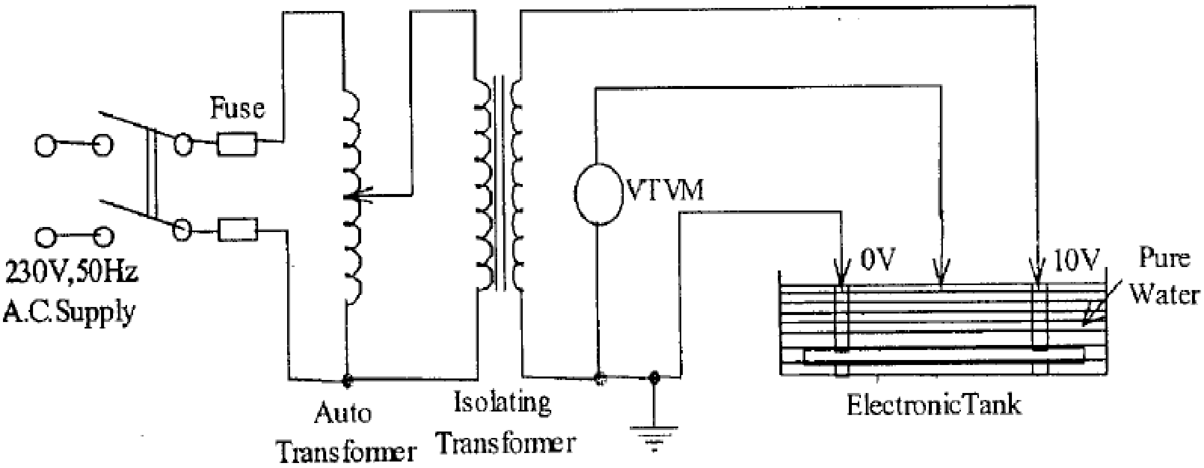




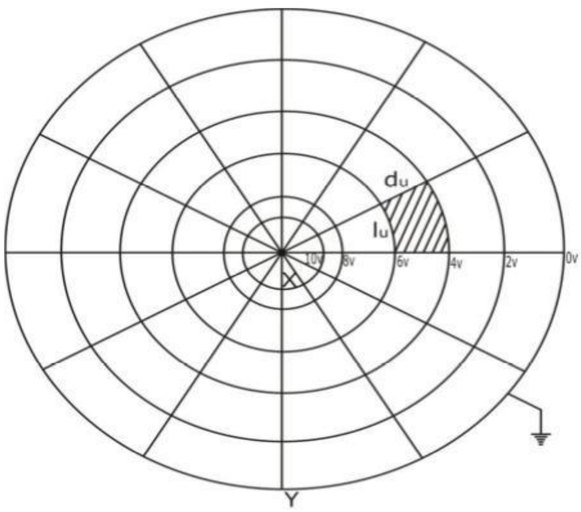
LEGEND

1) BASE
2) LEVELING SCREW
3) TANK
4) PENTAGRAPH
5) CLAMPS FOR HEIGHT ADJUSTMENT
6) PENCIL HOLDER
7) GLASS
8) WATER DRAIN

CIRCUIT DIAGRAM:



MODEL GRAPH



For co-axial cable model

CONCLUSION:

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Questions to be Answered

1. What is equipotential surface?

2. Summarize the properties of Equipotential Surfaces.

3. What is Computational Electromagnetics?

4. State the relation between the Scalar Potential (V) and Electric Field (E) and give its physical interpretation.

EXPERIMENT NO. 7
SIMULATION OF PARALLEL PLATE CAPACITOR USING QUICK FIELD SOFTWARE

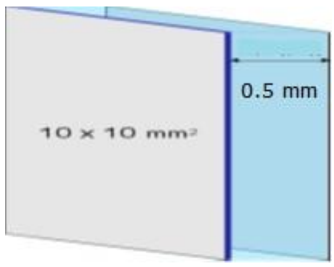
Aim

- To simulation the parallel plate capacitor with non ideal dielectric medium using quick field software
- To compute the real currents and dissipation factor (tanδ) of dielectric medium manually.
- To compare the computed values with the simulated results for validation of the proposed model.

Problem Type

- AC Conduction

Geometry of the Model



- Area of the Plates (A) : 100 mm^2
- Length of the Capacitor (L) : 10mm
- Distance of separation between the plates (t) : 0.5mm (thickness of the substrate / dielectric medium)

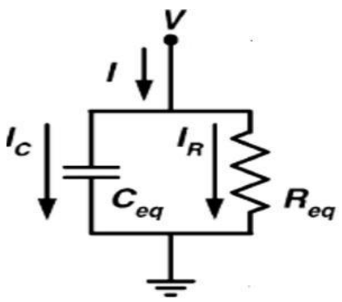
Data to be Considered

- Relative permittivity of the substrate(ε) : 10
- Permittivity of free space (ε_0) : 8.854 x10^{-12} (F/m)
- Conductivity of the substrate (σ) : 10^{-8} Siemen/m
- Voltage : 5V
- Frequency : 50Hz

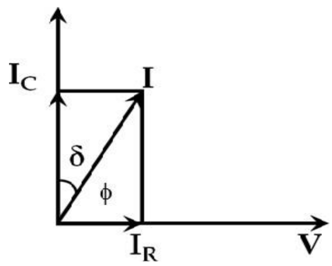
Concept :

The condition of the insulation in a high voltage winding may be estimated by treating it like the dielectric in a capacitor. Dissipation factor, also called Tan Delta (tan δ) is measure of dielectric losses in the insulation.

When voltage is impressed across the insulation, the total current that flows is similar to that of any capacitor. The total current has two components: a relatively large capacitive current (I_c), which leads the voltage by 90° and a smaller resistive current (I_R) which is in phase with the voltage.



Equivalent Circuit of an Insulation System



Vector Representation of Insulation Equivalent Model

In the vector diagram shown, the voltage is drawn along x axis. Conductive electric current i.e. resistive component of leakage current, I_R will also be along x axis. As the capacitive component of leakage electric current I_C leads system voltage by 90^o, it will be drawn along y axis. Now, total leakage electric current I (=I_C + I_R) makes an angle δ with y axis. Now, from the diagram above, it is cleared, the ratio, I_R to I_C is tanδ. This δ angle is known as loss angle. If the insulation system is healthy, the leakage current is almost capacitive in nature.

The tan δ value can be expressed in terms of impedances offered by the parallel combination of R and C as

$$\tan\delta = \frac{KC}{R} = \frac{1}{\omega CR} = \frac{1}{2\pi fCR}$$

where, X is the capacitive reactance and f is the frequency of the supply.

FORMULAE TO BE USED

- Capacitance between the plates $C = \varepsilon \varepsilon_0 \frac{A}{t}$
- Resistance of the Substrate $R_S = \rho \frac{t}{A}$
- Capacitive Reactance $X_C = \frac{1}{2\pi f C}$
- Current flow through R $I_R = \frac{V}{R_S}$
- Current flow through C $I_C = \frac{V}{X_C}$
- Dissipation Factor $\tan\delta = \frac{I_R}{I_C}$

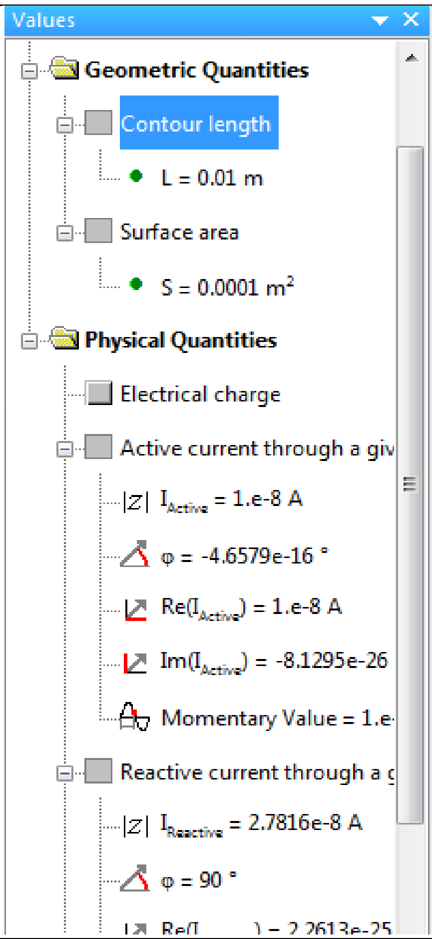
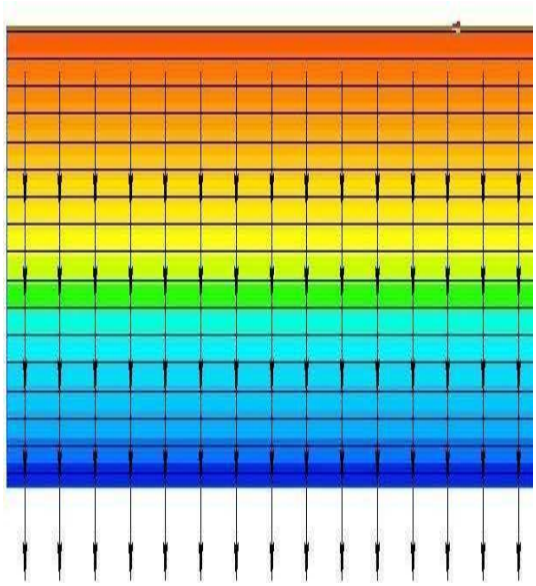
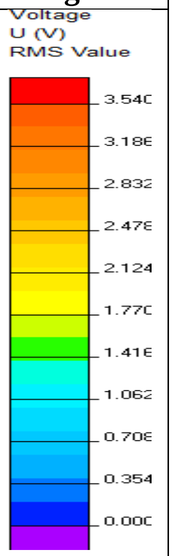
Procedure :

1. Create a New Problem
2. Specify the problem Parameters
3. Define the geometry model
4. Provide the material data and boundary conditions
5. Solve the problem and analyze the Results.

Manual Calculation:

- Capacitance = $C= \varepsilon*\varepsilon_o*A/t$,
- Resistance of the Substrate (R) = $\rho \frac{t}{A}$
- Capacitive Reactance $X_C = \frac{1}{2\pi f C}$
- Current flow through R (I_R) = V / R
- Current flow through C (I_C) = V / X_C
- Dissipation Factor $\tan\delta = \frac{KC}{R}$
- Loss angle $\delta = \tan^{-1} \frac{KC}{R} =$

Simulation Results

<table>
<tr><th>Simulated Values</th><th>Electric Field Distribution</th><th>Legend</th></tr>
<tr><td>
</td><td></td><td>
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Comparison of Manual and Simulated Values

S.No	Physical Quantities	Manual Values	Simulated Values
1.	Current flow through R		
2.	Current flow through C		

Conclusion:

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EXPERIMENT NO. 8

Simulation of Voltage Doubler Circuit for Generating the High DC Voltage.

Aim

- To simulate the Voltage Doubler Circuit for Generating the High DC Voltage Using Software tool.

Concept :

The generation of high voltages in laboratories for testing purposes is essential. Generation of high d.c. voltages is mainly required in research work in the areas of pure and applied physics. Sometimes, high direct voltages are needed in insulation tests on cables and capacitors. Impulse generator charging units also require high d.c. Rectifier circuits for producing high d.c. voltages from a.c. sources. For higher voltages, several units are to be used in series.

Both full wave and half wave rectifier circuits produce a d.c voltage less than the a.c. maximum voltage. When higher d.c. voltages are needed, a voltage doubler or cascaded rectifier doubler circuits are used. One of the most popular doubler circuit due to Greinacher is shown in Fig.

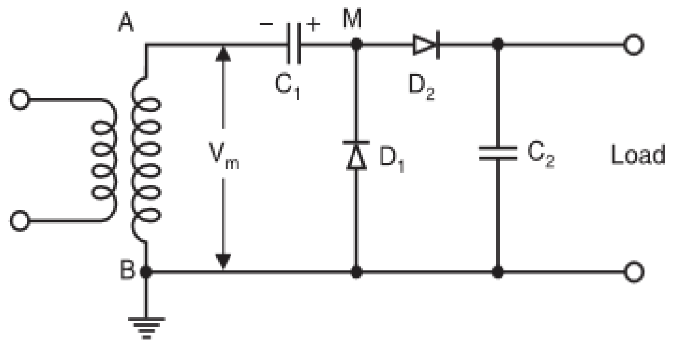
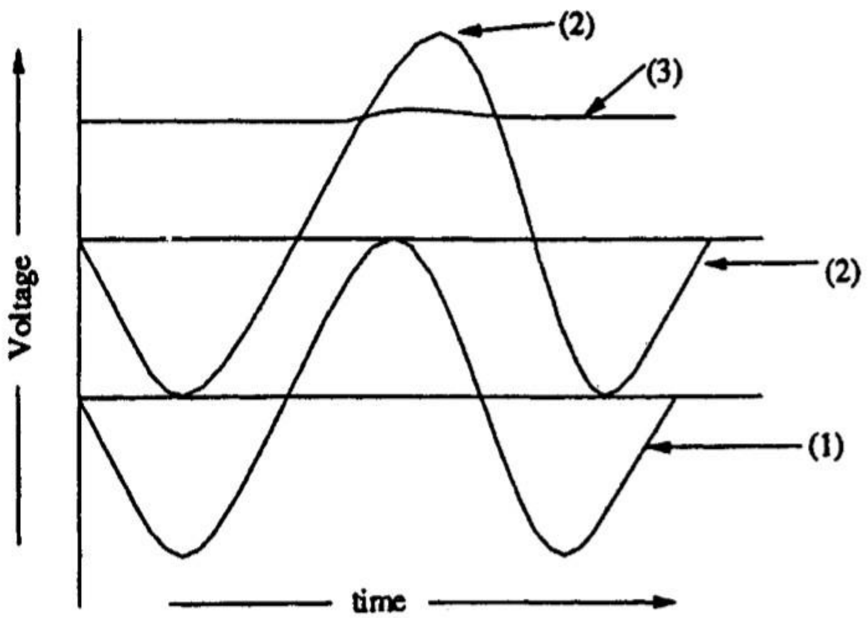


Fig. Greinacher voltage doubler circuit

In voltage doubler circuit, suppose B is more positive with respect to A and the diode D_1 conducts thus charging the capacitor C_1 to V_{max} with polarity as shown in Fig. Because there is no return path for capacitor C_1 to discharge into, it remains fully charged acting as a storage device in series with the voltage supply. During the next half cycle, terminal A of the capacitor C_1 rises to V_{max} and hence terminal M attains a potential of 2 V_{max}. Thus, the capacitor C_2 is charged to $2V_{max}$ through D_2. Normally the voltage across the load will be lessthan $2V_{max}$ depending upon the time constant of the circuit C_2R_L. The voltage across capacitor, C_2 can be calculated as: $\mathbf{V_{out} = 2V_{max}}$, (of course the voltage drops across thediodes used) where Vmax is the peak value of the input voltage. The diode rectifiers are ratedto a peak inverse voltage of $2V_{max}$, and the capacitor C_1 and C_2 must also have the same rating. If the load current is large, the ripple also is more. The advantage of this circuit is that it allows higher voltages to be created from a low voltage power source without a need for an expensive high voltage transformer as the voltage doubler circuit makes it possible to use a transformer with a lower step up ratio than would be need if an ordinary full wave supply were used.



Waveforms of a.c. voltage and the d.c. output voltage on no-load of the voltage doubler

(1) a.c input voltage waveform, (2) a.c. output voltage waveform without condenser filter, (3) a.c. output voltage waveform with condenser filter

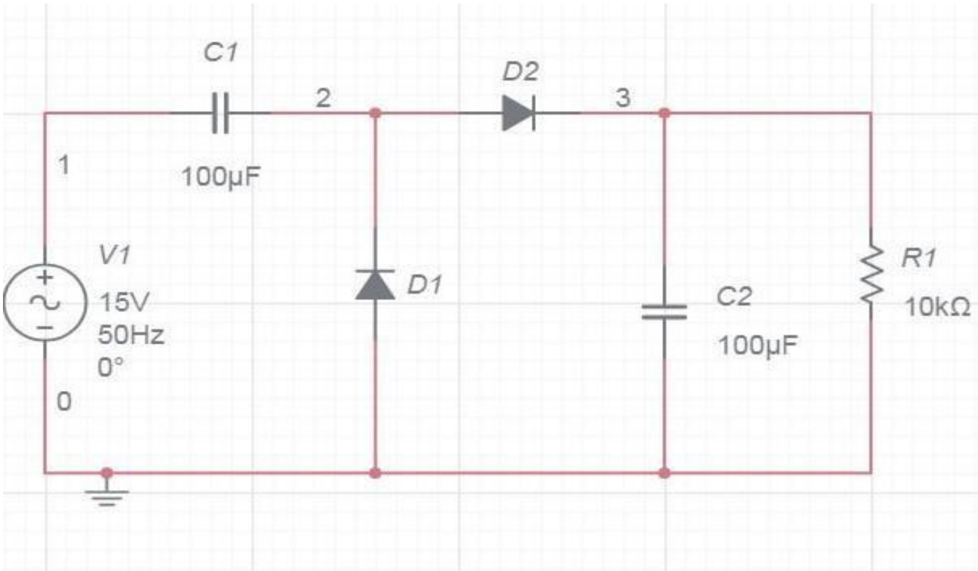
Procedure :

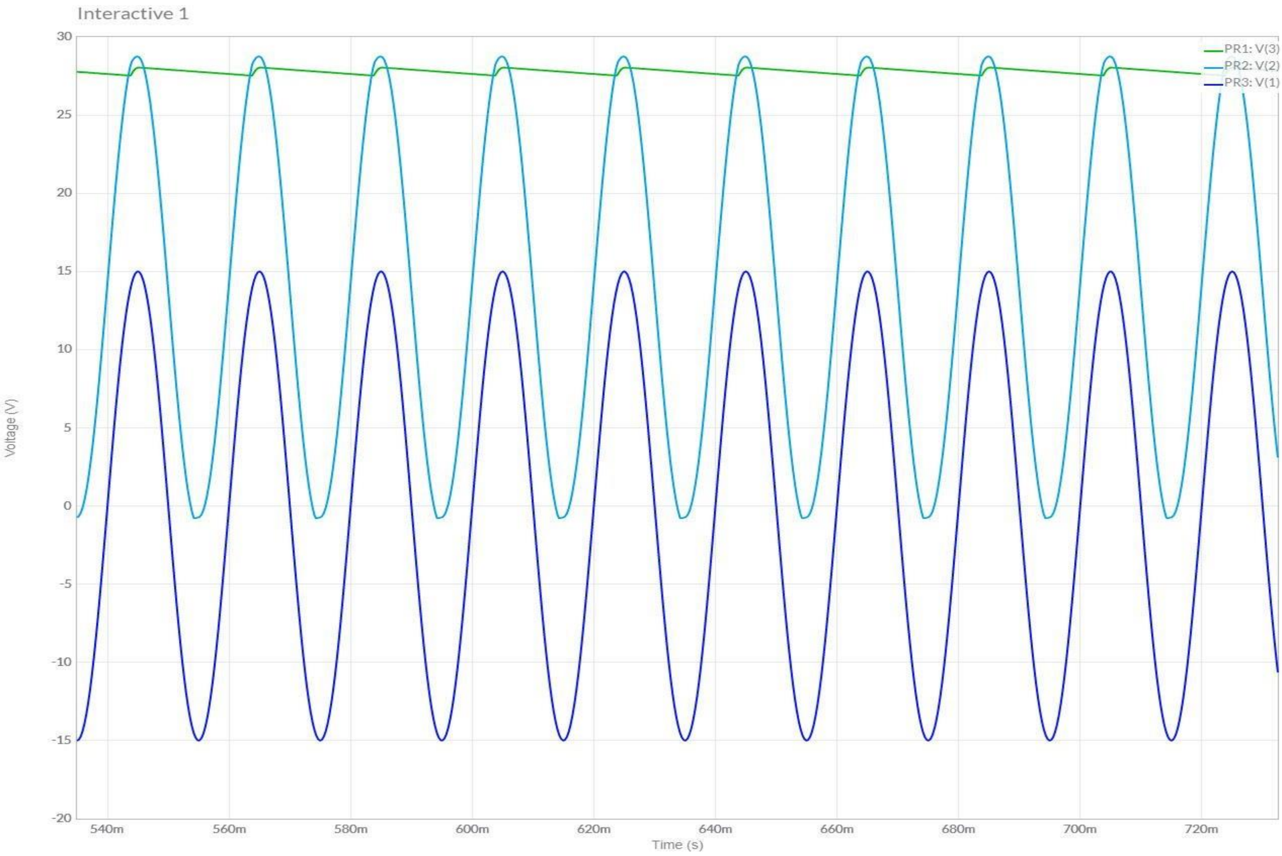
- Open the simulator, in the workspace construct the circuit diagram.
- Select all the necessary components. We need 1 ac source, 2 diodes, 2 capacitors and 1 resistor. In placing the components, just click on it then click to the circuit area then drag anywhere you want to place the component.
- Arrange all the components before constructing and connect the circuit.
- Place the voltage probes to measure the input voltage, voltage across the C_2 and the output voltage.

Simulation Parameters

- **Input Voltage: 15 V, 50Hz**
- **$C_1 = C_2 = 100\ \mu F$**
- **$R_L = 100\ k\Omega$**

Simulation Result




Interactive 1
PR1: V(3)
PR2: V(2)
PR3: V(1)
Voltage (V)
Time (s)
30
25
20
15
10
5
0
-5
-10
-15
-20
540m
560m
580m
600m
620m
640m
660m
680m
700m
720m

Conclusion:

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