ELECTRICAL POWER TRANSMISSION AND DISTRIBUTION LAB

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Vision of the Department

To provide holistic education to build competent and productive researchers and graduates.

Mission of the Department

M1: To provide quality education facilities for preparing professionals who match global standards.

M2: To create good atmosphere for research and innovation by providing state of the art laboratories.

M3: To prepare a cadre of engineers and scientists who will cater to the industrial development and economic growth of the society and country in future.

M4: To strengthen industry- institute interactions and interactions with alumni for mutual benefits by the exchange of knowledge, ideas and visions to promote lifelong learning.

Program Outcomes:

PO1	**Engineering knowledge:** Apply the knowledge of basic sciences and fundamental engineering concepts in solving engineering problems.
PO 2	**Problem analysis:** Identify and define engineering problems, conduct experiments and investigate to analyze and interpret data to arrive at substantial conclusions.
PO 3	**Design/development of solutions:** Propose an appropriate solution for engineering problems complying with functional constraints such as economic, environmental, societal, ethical, safety and sustainability.
PO 4	**Conduct investigations of complex problems:** Perform investigations, design and conduct experiments, analyze and interpret the results to provide valid conclusions.
PO 5	**Modern tool usage:** Select/ develop and apply appropriate techniques and IT tools for the design and analysis of the systems.
PO 6	**The engineer and society:** Give reasoning and assess societal, health, legal and cultural issues with competency in professional engineering practice.
PO 7	**Environment and sustainability:** Demonstrate professional skills and contextual reasoning to assess environmental/ societal issues for sustainable development.
PO 8	**Ethics:** An ability to apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.
PO 9	**Individual and team work:** Function effectively as an individual and as a member or leader in diverse teams and in multi-disciplinary situations.
PO 10	**Communication:** An ability to communicate effectively.
PO 11	**Project management and finance:** Demonstrate apply engineering and management principles in their own / team projects in multi-disciplinary environment.
PO 12	**Life-long learning:** An ability to do the needs of current technological trends at electrical industry by bridging the gap between academic and industry.

Program Specific Outcomes:

PSO 1	Apply the knowledge of electrical engineering to analyze and solve the complex problems in electrical power and engineering with social utility.
PSO 2	The application of recent techniques along with modern software tools for design, simulation and analyzing electrical systems.
PSO 3	Adapting to technological changes and professional and societal needs by engaging in lifelong learning, thereby contributing to career development.

Program Educational Objectives:

PEO 1	To apply fundamental knowledge in mathematics, science and engineering concepts in electrical engineering for the development of engineering field.
PEO 2	To analyze, plan and design electrical system including modern methodologies to address the issues in a technically sound and economically viable manner.
PEO 3	To develop a skilful workforce who can practice as a team professionally and ethically in a wide range of electrical engineering related fields.
PEO 4	To prepare them for lifelong learning for successful carrier development by giving them the state- of the-art technology in the learning process

Course Objectives:

- To determine the ABCD parameters of transmission line
- To determine string efficiency of insulators.
- Testing of transformer oil

Course Outcomes:

After completion of this lab, the student will be able to:

- Determine ABCD parameters of transmission line.
- Can able to test transformer Oil.
- Can able to perform high voltage insulation test.

Syllabus

(Perform any 08 Experiments)

1. Study of Ferranti Effect.
2. Determination of ABCD Parameter.
3. Determination of string efficiency
4. Earth resistance measurement.
5. Series and shunt capacitance computation in transmission line
6. Transformer oil test.
7. Study of various lightning arresters.
8. Distribution system power factor improvement using switched capacitor.
9. Study of corona discharge

ATTAINMENT OF PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES

Exp. No.	Name of the Experiment	Program Outcomes Attained	Program Specific Outcomes Attained
1	Study of Ferranti Effect.	PO1,PO2,PO5	PSO2
2	Determination of ABCD Parameter.	PO1,PO2,PO5	PSO2
3	Determination of string efficiency.	PO1,PO2,PO5	PSO2
4	Earth resistance measurement.	PO1,PO2,PO5	PSO2
5	Series and shunt capacitance computation in transmission line .	PO1,PO2,PO5	PSO2
6	Transformer oil test.	PO1,PO2,PO5	PSO2
7	Study of various lightning arresters.	PO1,PO2,PO5	PSO2
8	Distribution system power factor improvement using switched capacitor.	PO1,PO2,PO5	PSO2
9	Study of corona discharge.	PO1,PO2,PO5	PSO2

LABORATORY PRACTICE SAFETY RULES

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.

GUIDELINES FOR LABORATORY NOTEBOOK

The laboratory notebook is a record of all work pertaining to the experiment. This record should be sufficiently complete so that you or anyone else of similar technical background can duplicate the experiment and data by simply following your laboratory notebook. Record everything directly into the notebook during the experiment. Do not use scratch paper for recording data. Do not trust your memory to fill in the details at a later time.

Organization in your notebook is important. Descriptive headings should be used to separate and identify the various parts of the experiment. Record data in chronological order. A neat, organized and complete record of an experiment is just as important as the experimental work.

1. Heading:

The experiment identification (number) should be at the top of each page. Your name and date should be at the top of the first page of each day's experimental work.

2. Object:

A brief but complete statement of what you intend to find out or verify in the experiment should be at the beginning of each experiment .

3. Diagram:

A circuit diagram should be drawn and labeled so that the actual experiment circuitry could be easily duplicated at any time in the future. Be especially careful to record all circuit changes made during the experiment.

4. Equipment List:

List those items of equipment which have a direct effect on the accuracy of the data. It may be necessary later to locate specific items of equipment for rechecks if discrepancies develop in the results.

5. Procedure:

In general, lengthy explanations of procedures are unnecessary. Be brief. Short commentaries alongside the corresponding data may be used. Keep in mind the fact that the experiment must be reproducible from the information given in your notebook.

6. Data:

Think carefully about what data is required and prepare suitable data tables. Record instrument readings directly. Do not use calculated results in place of direct data; however, calculated results may be recorded in the same table with the direct data. Data tables should be clearly identified and each data column labeled and headed by the proper units of measure.

7. Calculations:

Not always necessary but equations and sample calculations are often given to illustrate the treatment of the experimental data in obtaining the results.

8. Graphs:

Graphs are used to present large amounts of data in a concise visual form. Data to be presented in graphical form should be plotted in the laboratory so that any questionable data points can be checked while the experiment is still set up. The grid lines in the notebook can be used for most graphs. If special graph paper is required, affix the graph permanently into the notebook. Give all graphs a short descriptive title. Label and scale the axes. Use units of measure. Label each curve if more than one on a graph.

9. Results:

The results should be presented in a form which makes the interpretation easy. Large amounts of numerical results are generally presented in graphical form. Tables are generally used for small amounts of results. Theoretical and experimental results should be on the same graph or arrange in the same table in a way for easy correlation of these results.

10. Conclusion:

This is your interpretation of the results of the experiment as an engineer. Be brief and specific. Give reasons for important discrepancies.

MARK DISTRIBUTION

Sl. No	Content	Marks
1	Attendance	10
2	Record	10
3	Experiment and viva	25
4	Quiz	05
	Total marks:	50

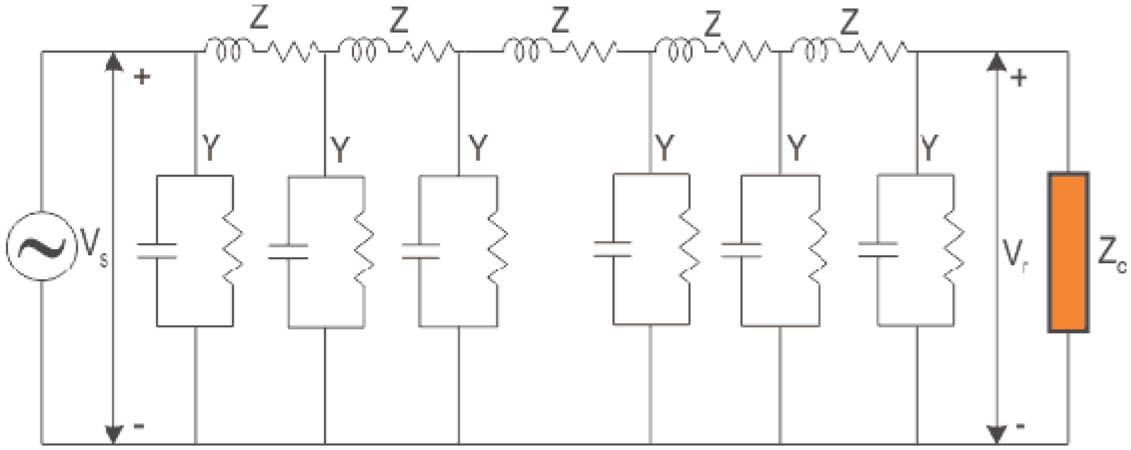
EXPERIMENT 01

AIM OF THE EXPERIMENT:-To observe Ferranti effect of a 220KV transmission line model.

APPARATUS REQUIRED:-

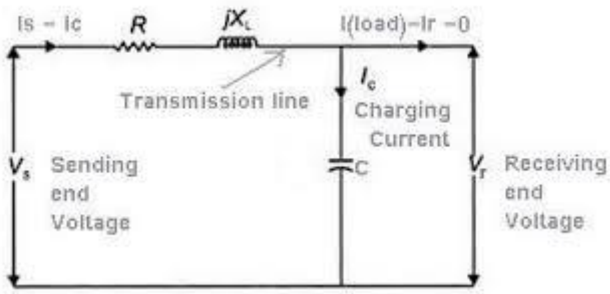
1. 220 KV HV/AC Transmission Line Kit.
2. Patch Cords.
3. Auto Transformer.

CIRCUIT DIAGRAM:

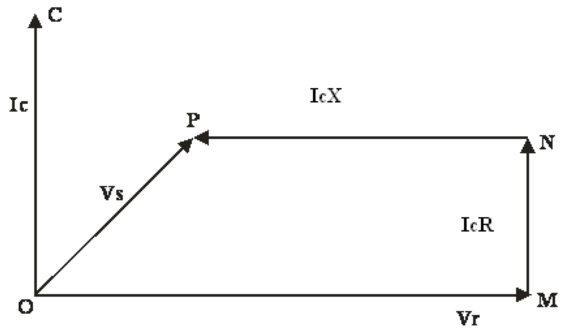


THEORY:-

When a long line is operating under no load or light load condition, shunt capacitance predominates, and then receiving end voltage becomes greater than the sending end voltage. This phenomenon is called Ferranti effect. This is due to voltage drop across the line inductance being in phase with the sending end voltage. Thus both capacitance and inductance are necessary to produce this phenomenon.



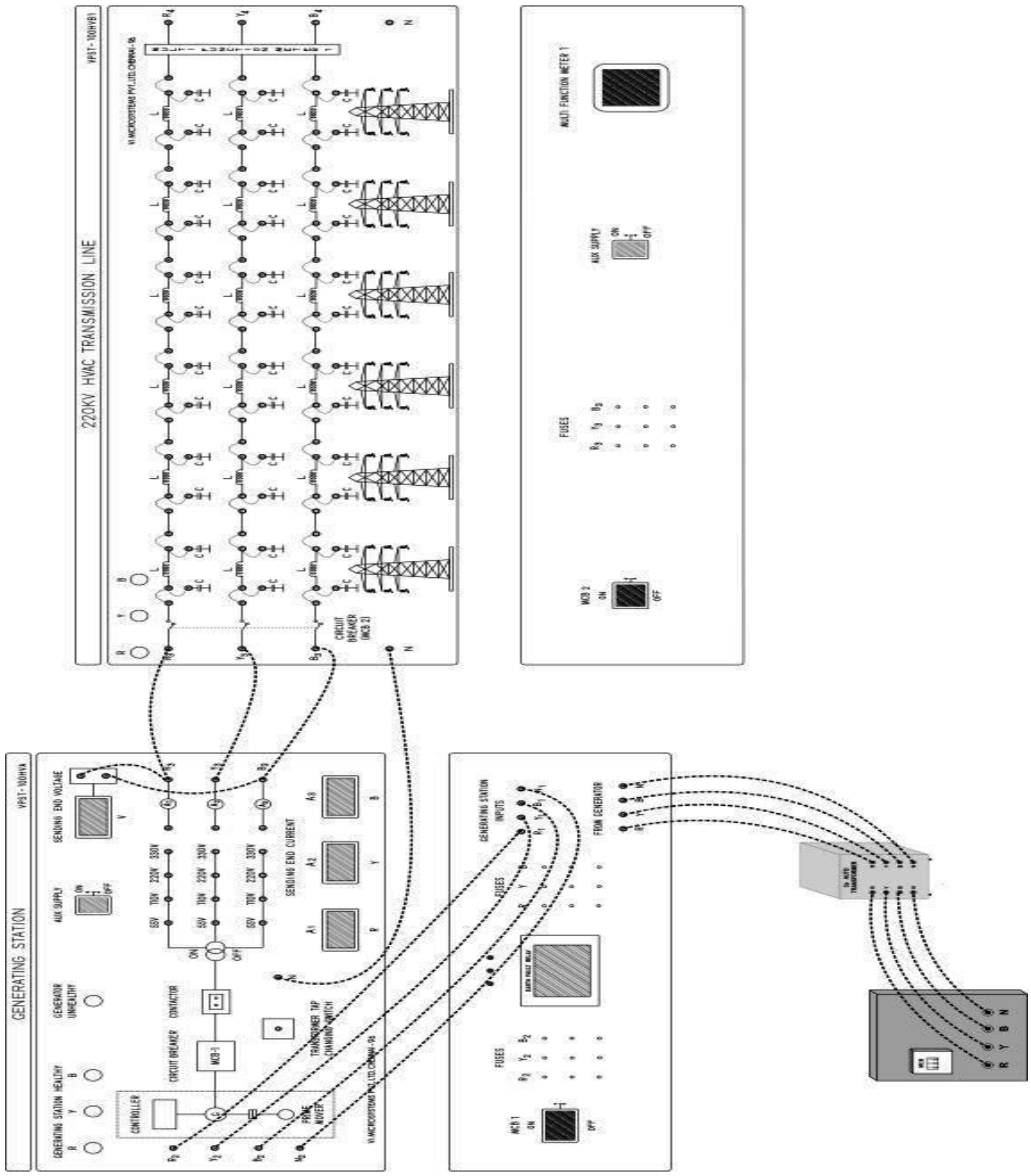
The above figure represents a model of transmission line at no load. As the line is at no load only charging current flows through it which creates an inductive drop in the line due to line inductance. Due to the leading charging current the receiving end voltage becomes more than that of sending end voltage popularly known as Ferranti effect. This can be explained by the phasor diagram given below.



Phasor diagram of Ferranti Effect

In the above phasor diagram OM represents the receiving end voltage. OC represents the current drawn by capacitance assumed to be concentrated at the receiving end. MN represents the resistance drop and NP represents the inductive reactance drop. OP is the sending voltage under no load condition and is less than receiving end voltage. From the above phasor diagram it is quite clear that the inductive drop due to charging current is exactly opposite to the receiving end voltage and it results to the sending end voltage which justifies the Ferranti effect in a transmission line at no load.

CONNECTION DIAGRAM FOR 220KV LINE:



PROCEDURE:

1. Connect the circuit as per the connection diagram.
2. Open the receiving end of the transmission line model.
3. Give a supply voltage of 110 V.
4. Measure the receiving end voltage and the charging current.

TABULATION:

Sl.No.	Sending end voltage in Volt (V_s)	Receiving end voltage in Volt (V_r)	Charging current in A(I_c)	Remark

CONCLUSION:

To be written by the student

DISCUSSION QUESTIONS:

1. What is Ferranti effect?
2. In which transmission line is Ferranti effect observed usually?
3. What is the method applied two reduce Ferranti effect?
4. What is the cause of Ferranti effect?

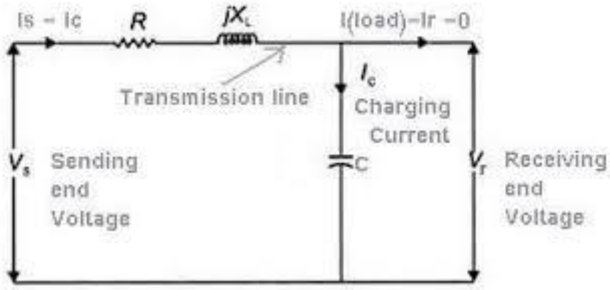
EXPERIMENT 02

AIM OF THE EXPERIMENT:- To obtain the ABCD parameters of 220KV transmission line model.

APPARATUS REQUIRED:-

1. 220 KV HV/AC Transmission Line Kit.
2. Patch Cords.
3. Auto Transformer.

CIRUIT DIAGRAM:



THEORY:-

To obtain the ABCD parameters we need to consider the following equations.

$V_s = AV_r + BI_r$

$I_s = CV_r + DI_r$

Where ABCD are called as the transmission line parameters or chain parameters or circuit parameters.

Now by making the receiving end open circuit we can make $I_r = 0$.

$\mathbf{A = V_s / V_r \mid I_r = 0}$ This gives A is the ratio of the voltage impressed on the line at sending end to the receiving end, when the receiving end is open circuited. It is a dimension less quantity.

$\mathbf{C = I_s/V_r \mid I_r = 0}$ this gives C which is the ratio of the sending end current to the receiving end voltage. It is measured in mho.

Now by making the receiving end short circuited then we can make $V_r = 0$.

$\mathbf{B = V_s/I_r \mid V_r = 0}$ This gives the relation between the sending end voltage to receiving end current, when receiving end is short circuited. It measured in Ohm.

$\mathbf{D = I_s/I_r \mid V_r = 0}$ This give the relation between the sending end current to receiving end current, when receiving end is short circuited. It is a dimension less quantity.

The constants ABCD are related for passive network AD-BC = 1 gives that the network is the reciprocal and A = D gives that the network is symmetrical. The π network assumes that total capacitance is divided equally at the both the ends.

Voltage at the sending end or generating end.

$V_s = V_r + IZ$

$V_s = V_r + (I_r + V_r\, Y / 2)\, Z$

$V_s = (1+Y Z / 2) + ZI_r$

Sending end current

$I_s = I + V_s\, Y / 2$

$I_s = (I_r + V_r\, Y/2) + (1+YZ/2)\, V_r + ZI_r$

$I_s = Y\, (1+YZ/4V_r)\, V_r + (1+YZ/2)\, I_r$

On comparing the equations 1 & 2 with

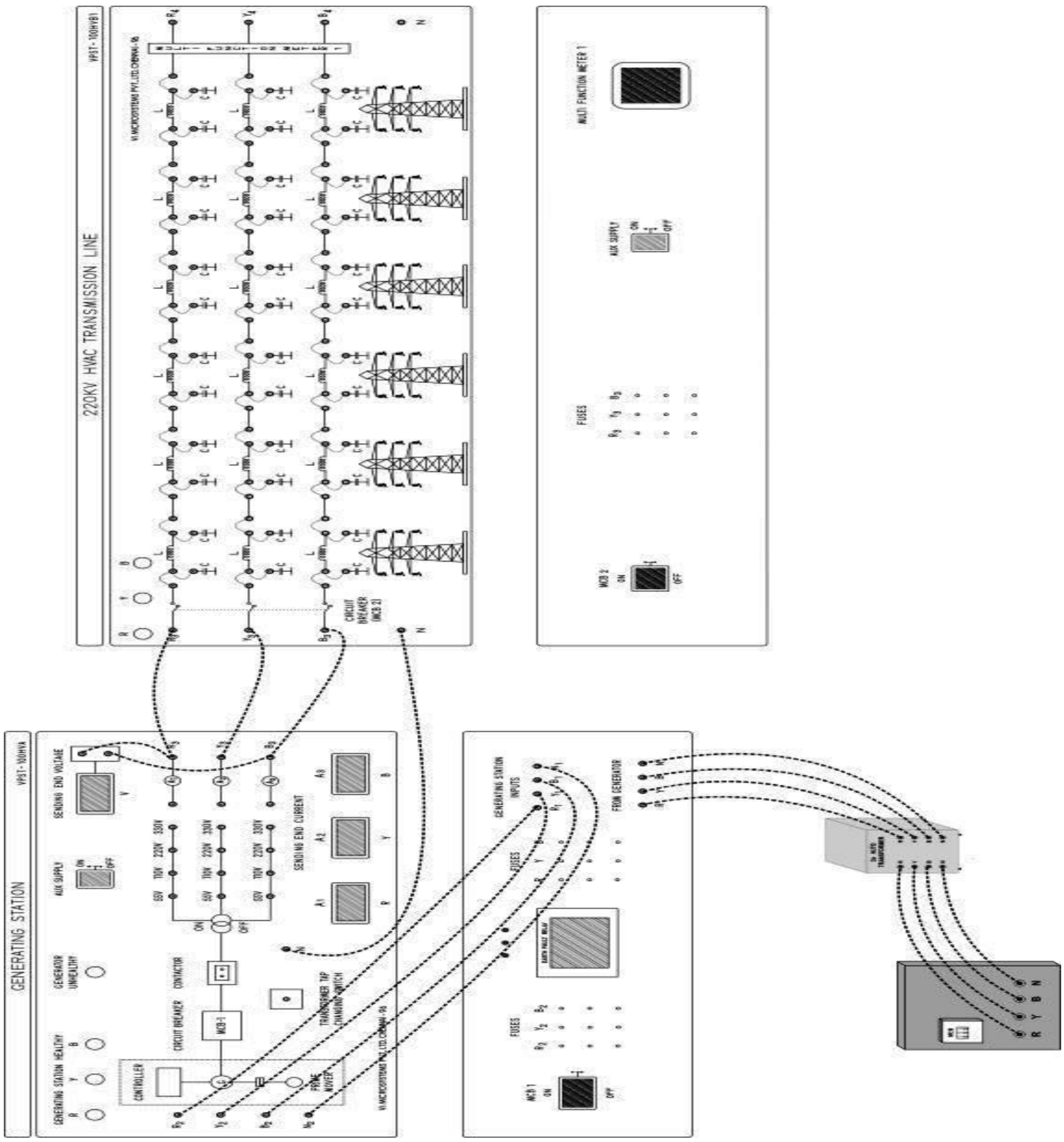
A = D = (1+YZ/2)

C=Y (1+YZ/4) and B = Z.

PROCEDURE:

1. Open the receiving end of the transmission line model.
2. Give the AC supply to the sending end (100 V).
3. Note down the sending end voltage, current and receiving end voltage.
4. Calculate transmission line parameters A and C by using the formula.
5. Short the receiving end of the transmission line model.
6. Again give the AC supply to the sending end (100 V).
7. Calculate the transmission line parameters B and D by using the formula.

CONNECTION DIAGRAM:



TABULATION:

Sl. No.	V_s in volt	I_s in A	V_r in volt	I_r in A	$A=V_s/V_r$	$B=V_s/I_r$	$C=I_s/V_r$	$D=I_s/I_r$

CONCLUSION: To be written by the student

DISCUSSION QUESTIONS:

1. Why are ABCD parameters called transmission line parameters?
2. Which are called open circuit and short circuit parameters among ABCD parameters and why?
3. When is the transmission network called symmetrical?
4. When is the transmission network called reciprocal?

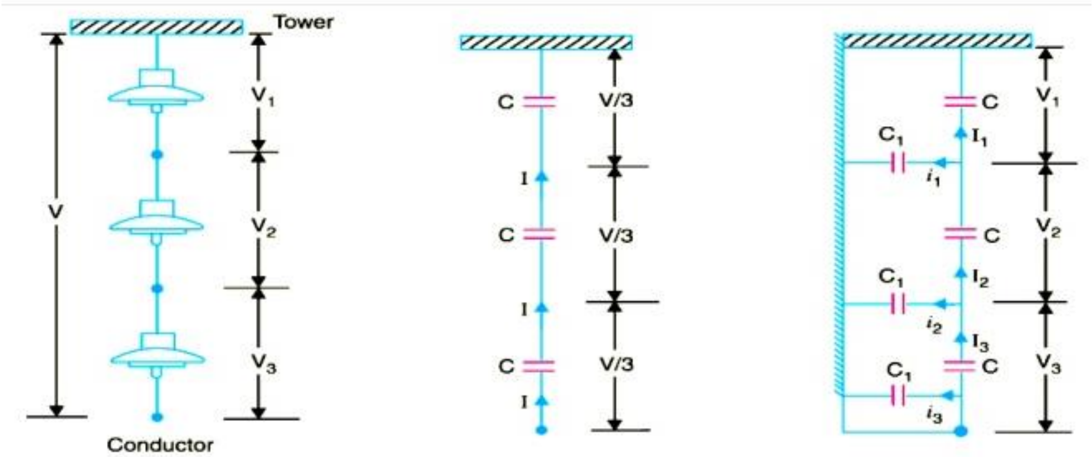
EXPERIMENT 03

AIM OF THE EXPERIMENT: To determine the string efficiency of an insulator string used in transmission line.

APPARATUS REQUIRED:

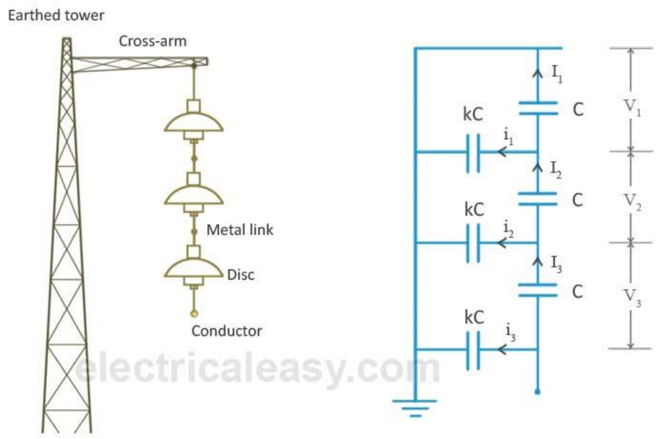
Sl. No.	Name of the apparatus	Range	Quantity
1.	High voltage trans-former	230V/ 50 kV	2
2.	Voltmeter	0-230 V	1
3.	Voltmeter	0-100 kV	1
4.	Milli-ammeter	0-50 mA	1
5.	Disc insulator	11 kV	5
6.	Connecting rods		As per requirement

CIRCUIT DIAGRAM:



THEORY:

A suspension type string insulator consists of a number of porcelain discs connected in series through metallic links. Suspension insulators or string insulators are very widely used in electrical overhead transmission system. However, there is a significant thing to be considered in case of these string insulators, known as string efficiency.



(a) 3-disc string insulator (b) equivalent circuit

The figure above shows a 3-disc string of suspension insulator. As each porcelain disc lies in between two metal links, it forms a capacitor. This capacitance is known as self-capacitance or mutual capacitance. Moreover, air capacitance is also present between metal links and the earthed tower. This is known as shunt capacitance. The figure above illustrates the equivalent circuit of a 3-disc suspension insulator (assuming that shunt capacitance is some fraction of self-capacitance i.e shunt capacitance = k * self-capacitance). f there were only mutual capacitances, then the charging current would have been the same through all the discs. In this case, the voltage would have been uniformly distributed across the string, i.e. voltage across each disc would have been the same. But, due to the shut capacitances, charging current is not the same through all the discs.

From the above equivalent circuit, applying Kirchhoff's current law to node A,
$I_2 = I_1 + i_1$
$V_2\omega C = V_1\omega C + V_1\omega kC$
$V_2 = V_1 + V_1k$
$V_2 = (1 + k)V_1$ ...... eq.(i)

applying Kirchhoff's current law to node B,
$I_3 = I_2 + i_2$
$V_3\omega C = V_2\omega C + (V_2 + V_1)\omega kC$
$V_3 = V_2 + (V_1 + V_2)k$
$V_3 = kV_1 + (1 + k) V_2$
$V_3 = kV_1 + (1 + k)^2 V_1$ ...... from eq.(i)
$V_3 = V_1 [k + (1 + k)^2]$
$V_3 = V_1 [k + 1 + 2k + k^2]$
$V_3 = V_1 (1 + 3k + k^2)$ ...... eq.(ii)

Now, voltage between the conductor and the earther tower is,
$V = V_1 + V_2 + V_3$
$V = V_1 + (1 + k)V_1 + V_1 (1 + 3k + k^2)$
$V = V_1 (3 + 4k + k^2)$ ...... eq.(iii)

from the above equations (i), (ii) & (iii), it is clear that the voltage across the top disc is minimum while voltage across the disc nearest to the conductor is maximum, i.e. $V_3 = V_1 (1 + 3k + k^2)$. As we move towards the cross arm, voltage across the disc goes on decreasing. Due to this non-uniform voltage distribution across the string, the unit nearest to the conductor is under maximum electrical stress and is likely to be punctured.

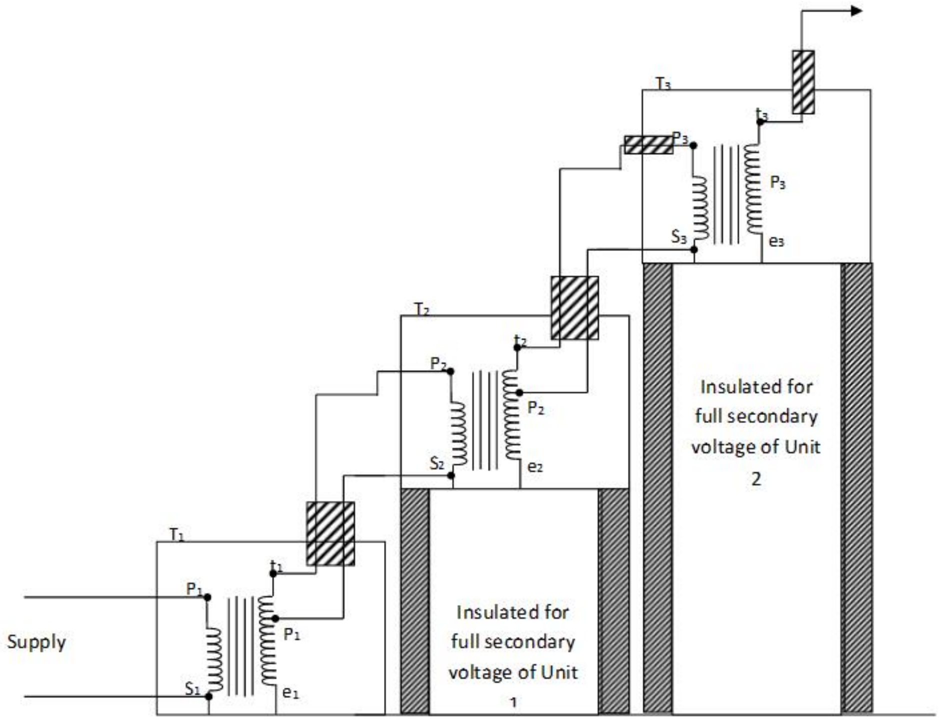
As explained above, voltage is not uniformly distributed over a suspension insulator string. The disc nearest to the conductor has maximum voltage across it and, hence, it will be under maximum electrical stress. Due to this, the disc nearest to the conductor is likely to be punctured and subsequently, other discs may puncture successively. Therefore, this unequal voltage distribution is undesirable and usually expressed in terms of string efficiency. The ratio of voltage across the whole string to the product of number of discs and the voltage across the disc nearest to the conductor is called as string efficiency

String efficiency = Voltage across the string / (number of discs X voltage across the disc nearest to the conductor).

Greater the string efficiency, more uniform is the voltage distribution. String efficiency becomes 100% if the voltage across each disc is exactly the same, but this is an ideal case and impossible in practical scenario. However, for DC voltages, insulator capacitances are ineffective and voltage across each unit would be the same. This is why string efficiency for DC system is 100%. Inequality in voltage distribution increases with the increase in the number of discs in a string. Therefore, shorter strings are more efficient than longer string insulators.

Cascaded Transformer:

For voltages higher than 400 kV it is desired to cascade two or more transformers depending upon the voltage requirements. Single unit testing transformers are available up to 750 kV but is has been found that the cost of test unit increases rapidly with voltage due to good insulation requirements. There is also problem of transportation and erection due to large size of bushings. To overcome these difficulties two or three units of same rating are cascaded whereby only the L.V. winding of the first unit is connected to the supply and H.V. winding of all the units are in effect connected in series. The figure given below shows a schematic diagram for connecting three identical testing transformers in cascade. The primary of the first transformer T1is supplied from a low voltage 50 Hz supply P_1 S_1, the tank of which is earthed.



t_1 e_1 forms the secondary of this unit, the end e1of which is connected to the tank which is at earth potential. A tapping t_1 P_1 is taken from the secondary of the transformer T_1 and it is made to supply the primary of transformer T_2 in such a way that the tapped voltage is equal to the primary supply voltage of T_1. e_2 t_2 is the secondary of transformer T_2, the end e_2 being connected to the tank which is insulated from earth for the full secondary voltage of transformer T_1. In the same way transformer T_3 is energized, the end e_3 of which is connected to the tank which is insulated from the earth for the full secondary voltage of transformer T_2. The output voltage between the terminal t_3 and earth is approximately equal to the sum of three secondary voltages. Thus depending upon the test voltage required the number of units are cascaded.

PROCEDURE:

1. Connect one end of the five disc suspension insulator to the ground.
2. Connect the conductor to the other end of the string.
3. Give the AC supply (up to 40 kV) to the conductor through an Auto transformer gradually and increase it till the spark occurs.
4. Measure the voltage across each insulator named V_1,V_2,V_3,V_4 and V_5 respectively.
5. Calculate the string efficiency by using the formula.

TABULATION:

Sl.No.	Supply voltage in volt	V_1 in volt	V_2 in volt	V_3 in volt	V_4 in volt	V_5 in volt	% string efficiency

CONCUSION: To be written by the student.

DISCUSSION QUESTIONS:

1. What is string efficiency?
2. What is the significance of string efficiency?
3. What is the cause of lower string efficiency?
4. What are the methods of improving the string efficiency?
5. Which insulator is stressed most in a string?

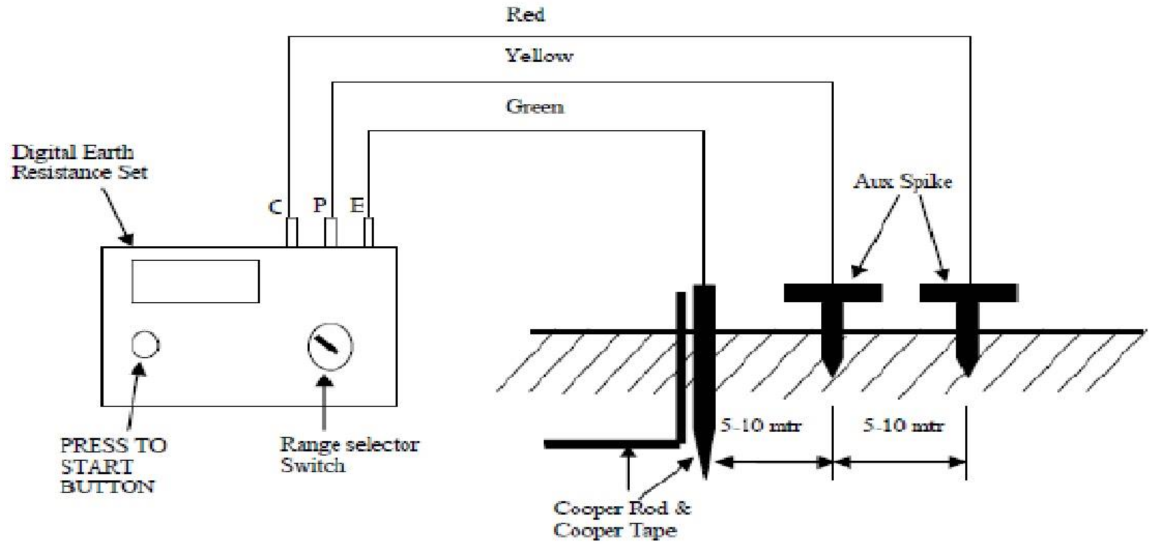
EXPERIMENT 04

AIM OF THE EXPERIMENT: To measure the earth resistance by earth tester.

APPARATUS REQUIRED:

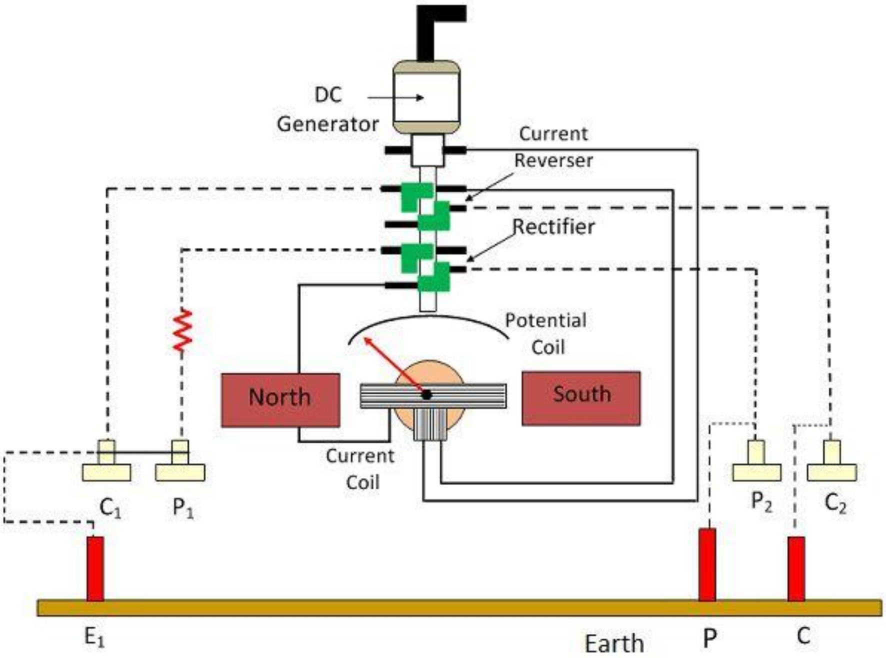
1. Earth tester (Crank type).
2. Electrodes (3 No.s)

CIRCUIT DIAGRAM:



THEORY:

The instrument used for measuring the resistance of the earth is known as earth tester**.** All the equipment of the power system is connected to the earth through the earth electrode. The earth protects the equipment and personnel from the fault current. The resistance of the earth is very low. The fault current through the earth electrode passes to the earth. Thus, protects the system from damage. The earth electrodes control the high potential of the equipment which is caused by the high lightning surges and the voltage spikes. The neutral of the three-phase circuit is also connected to the earth electrodes for their protection. Before providing the earthing to the equipment, it is essential to determine the resistance of that particular area from where the earthen pit can be dug. The earth should have low resistance so that the fault current easily passes to the earth. The resistance of the earth is determined by the help of earth tester instrument. The earth tester uses the hand driven generator. The rotational current reverser and the rectifier are the two main parts of the earth tester**.** The current reverser and the rectifier are mounted on the shaft of the DC generator. The earth tester works only on the DC because of the rectifier. The tester has two commutators place along with the current reverser and rectifier. The each commutator consist four fixed brushes. The commutator is a device used for converting the direction of flows of current. It is connected in series with the armature of the generator. And the brushes are used for transferring the power from the stationary parts to the moving parts of the devices.



The arrangement of the brushes can be done in such a way that they are alternately connected with one of the segments even after the rotation of the commutator. The brushes and the commutators are always connected to each other. The earth tester consists two pressures and the current coils. The each coil has two terminals. The pair of the pressure coil and the current coil is placed across the permanent magnet. The one pair of current and pressure coil is short-circuited, and it is connected to the auxiliary electrodes. The one end terminal of the pressure coil is connected to the rectifier, and their other end is connected to the earth electrode. Similarly, the current coil is connected to the rectifier and earth electrode. The earth tester consists the potential coil which is directly connected to the DC generator. The potential coil is placed between the permanent magnet. The coil is connected to the pointer, and the pointer is fixed on the calibrated scale. The pointer indicates the magnitude of the earth resistance. The deflection of the pointer depends on the ratio of the voltage of pressure coil to the current of the current coil. The short-circuit current passes through the equipment to the earth is alternating in nature. Thus, we can say that the alternating current flows in the soil. This alternative current reduces the unwanted effect of the soil, which occurs because of chemical action or because of the production of back emf.

PROCEDURE:

1. Join together terminals C_1 and P_1 and connect a lead from them to the earth electrode under test E. keep this lead as short as possible since its resistance will be included in the test.
2. The lead resistance can be eliminated by connecting separate leads to the electrode E from C_1 and P_1 instead of shorting them together.
3. Set the range selector to the highest range.
4. Rotate the generator handle at 160 RPM and observe the ohmmeter deflection.
5. If the ohmmeter deflection is very low, change the range selector to the next lower range.
6. Alternatively the lead resistance can be determined and deducted from the total resistance. This is carried out by moving the lead from electrode E after the test and connecting it to P_2 and C_2 joined together. It’s true resistance is then measured as described previously.

N.B: As a precaution when working near high tension systems where accidental high potentials on the structures and in the ground are possible, it is recommended to wear rubber gloves. And recommended test spikes for making temporary connections are made of solid steel spike 13 mm dia and 45 cm long should be driven to the depth of 30 cm with rapid blows from a 1kg hammer.

TABULATION:

Sl.No.	Distance between E and P_2 in mtr	Distance between E and P_2 in mtr	Earth resistance in Ω

CONCLUSION: To be written by the student.

DISCUSSION QUESTIONS:

1. What is earthing?
2. Why is earthing required?
3. What are added during earthing for domestic uses?
4. What are the different methods of earthing?
5. What are the factors on which earth resistance depends?

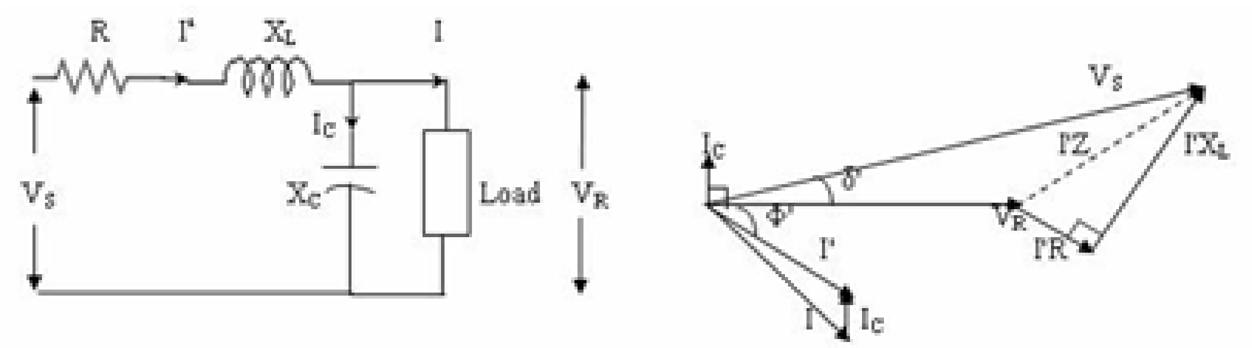
EXPERIMENT 05

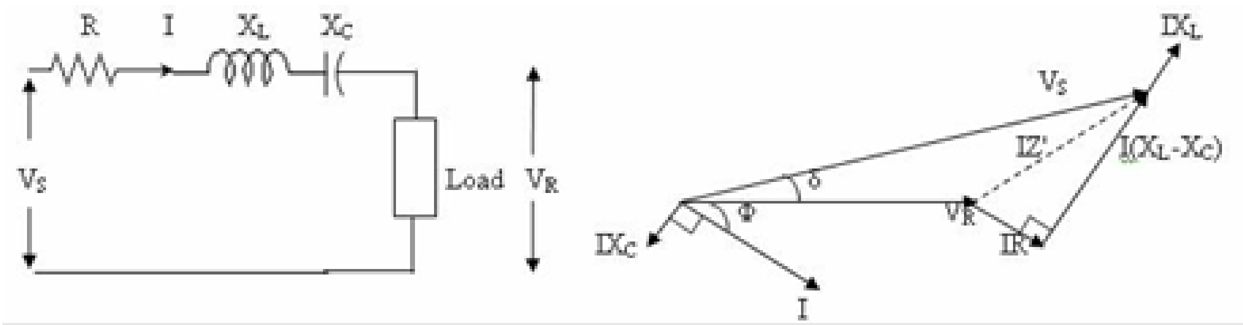
AIM OF THE EXPERIMENT: Series and shunt compensation of a 220 kV HV/AC transmission line model.

APPARATUS REQUIRED:

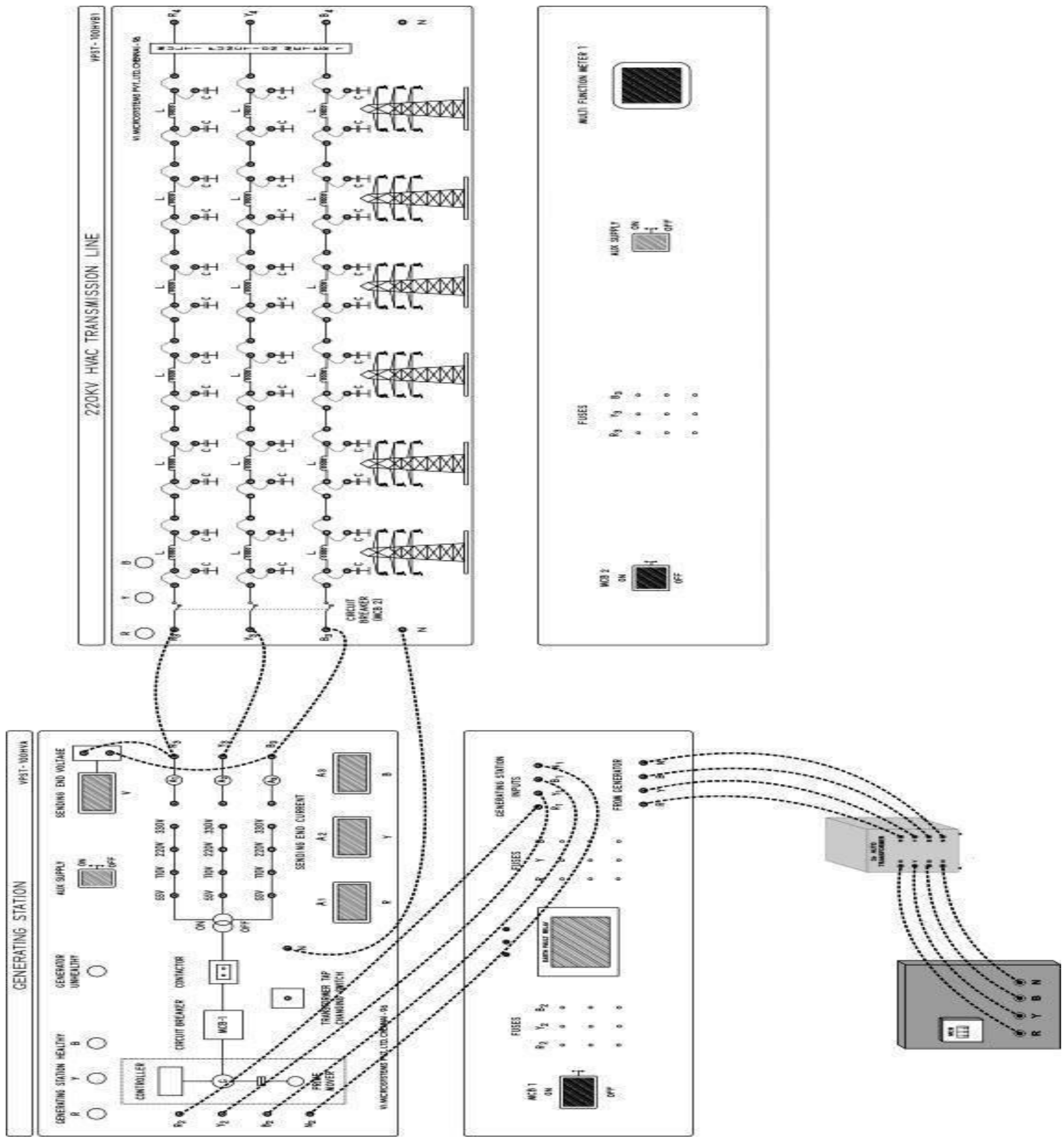
1. 220 KV HV/AC Transmission Line Kit.
2. Patch Cords.
3. Auto Transformer.
4. RLC load compensator

CIRCUIT DIAGRAM:



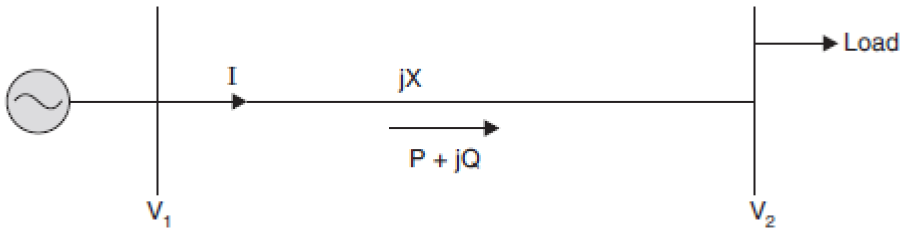


CONNECTION DIAGRAM:



THEORY:

When power is supplied to a load through a transmission line keeping the sending end voltage constant, the receiving end or load voltage undergoes variations depending upon the magnitude of the load and the power factor of the load. The higher the load with smaller power factor the greater is the voltage variation. The voltage variation at a node is an indication of the unbalance between the reactive power generated and consumed by that node. If the reactive power generated is greater than consumed, the voltage goes up and vice versa. Whenever the voltage level of a particular bus undergoes variation this is due to the unbalance between the two vars at that bus.



To understand this problem refers to above figure where node one is a generator node with reference voltage V_1 and node two is the load node with voltage V_2. The two bus bars are interconnected through a short line. Assuming the interconnector to be lossless ($R = 0$) and the voltage V_1 constant (by adjusting the excitation of the generator), the following relations hold good

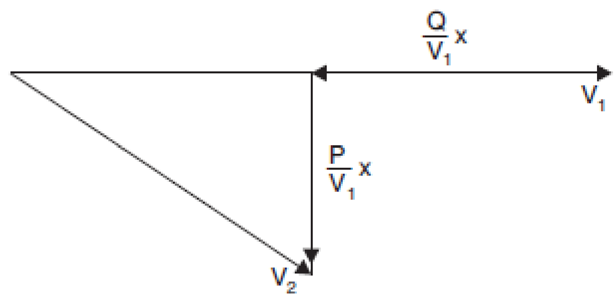
$V_2 = V_1 - IZ$

$V_1^* I = P - jQ$

=> $I = \frac{P - jQ}{V_1^*}$

$V_1^* = V_1$ as V_1 is the reference vector.

$V_2 = \left(V_1 - \frac{Q}{V_1} X\right) - j \frac{P}{V_1} X$



From the above it is clear that the load voltage V_2 is not affected much due to the real component of the load P as it is normal to the vector V_1 whereas the drop due to reactive component of load is directly subtracted from the voltage V_1. Assuming the voltage drop due to real power negligible, the voltage drop is directly proportional to the reactive power Q. The relation is given by

$$V_2 = \left(V_1 - \frac{Q}{V_1} X\right)$$

In order to keep the receiving end voltage V_2 fixed for a particular sending end voltage V_1, the drop $(Q/V_1)X$ must remain constant. Since, in this the only variable quantity is Q, it is this reactive vars which must be locally adjusted to keep this quantity fixed *i.e.*, let Q be the value of reactive vars which keeps V_2 to a specified value, any deviation in Q at node 2 must be locally adjusted. The local generation can be obtained by connecting shunt capacitors or synchronous capacitors and/or shunt inductors (for light loads or capacitive loads). In order to keep V_2 constant for fixed V_1, another possibility is that the product QX be kept constant. This is achieved by introducing series capacitors which will reduce the net reactance of the system. Since the voltage variation will be more for larger loads (larger reactive power), the variation could be controlled by switching in suitable series capacitors. The methods for voltage control are the use of (*i*) Shunt capacitors; (*ii*) Series capacitors; (*iii*) Synchronous capacitors; (*iv*) Tap changing transformers; and (*v*) Booster transformers.

The first three methods could also be categorized as reactive var injection methods. In earlier times the voltage control was done by adjusting the excitation of the generator at the sending end. The larger the reactive power required by the load the more is the excitation to be provided at the sending end. This method worked well in small isolated system where there was no local load at the sending end. Also there are limits for the excitation as well. Excitation below a certain limit may result in instability (if this machine is connected to a synchronous load) of the system and excitation above certain level will result in overheating of the rotor. Therefore, in any case, the amount of regulation by this method is limited by the permissible voltage rise at the sending end and by the difficulty of designing efficient generating plant when the range of excitation is so wide. Before we discuss the various methods in detail for voltage control it seems imperative to know the various sources and sinks of reactive power in a power system.

Series Capacitors

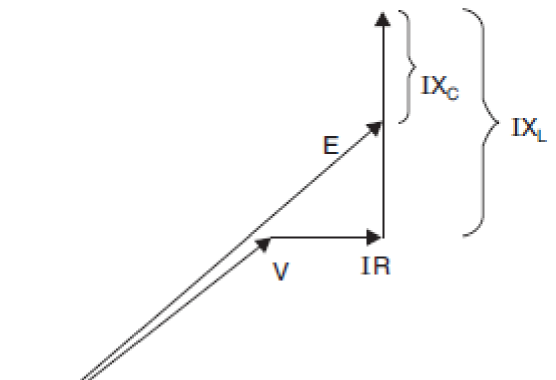
If a static capacitor is connected in series with the line, it reduces the inductive reactance between the load and the supply point and the voltage drop is approximately.

$IR \cos \varphi_r + I(X_L - X_C) \sin \varphi_r$

It is clear from the vector diagram that the voltage drop produced by an inductive load can be reduced particularly when the line has a high X/R ratio. In practice Xc may be so chosen that the factor $(X_L - X_c) \sin \varphi_r$ becomes negative and numerically equal to $R \cos \varphi_r$ so that the voltage drop becomes zero. The ratio X_c/X_L expressed as a percentage is usually referred to as the percentage compensation. If I is the full load current and Xc is the capacitive reactance of the series capacitor then the drop across the capacitor is IXc and the Var rating is I^2X_c. The voltage boost produced by the series capacitor

$\Delta V = IX_C \sin \varphi_r$

One drawback of series capacitors is the high overvoltage produced across the capacitor terminals under short circuit conditions. The drop across the capacitor is $I_f X_C$, where I_f is the fault current which is of the order of 20 times the full load current under certain circuit condition. A spark gap with a high speed contactor is used to protect the capacitor under these conditions.



Shunt Capacitors and Reactors

The shunt capacitors are used across an inductive load so as to supply part of the reactive vars required by the load so that the reactive vars transmitted over the line are reduced, thereby the voltage across the load is maintained within certain desirable limits. Similarly, the shunt reactors are used across capacitive loads or lightly loaded lines to absorb some of the leading vars again to control the voltage across the load to within certain desirable limits. Capacitors are connected either directly to a bus bar or through a tertiary winding of the main transformer and are disposed along the route to minimize the voltage drop and the losses. The disadvantage of the use of shunt capacitor or reactor is that with the fall of voltage at a particular node the correction vars are also reduced *i.e.*, when it is most needed, its effectiveness falls. Similarly, on light loads when the corrective vars required are relatively less, the capacitor output is large.

PROCEDURE:

1. Open the receiving end of the transmission line model.
2. Give the AC supply to the sending end (100 V).
3. Note down the sending end voltage, current and receiving end voltage.
4. Note down the current after connecting an inductive load. Also note down the receiving end voltage.
5. Now connect a capacitive load and note down the current and receiving voltage.
6. Do the same for resistive load too.

TABULATION:

Sl. No.	V_S at no load in volt	V_R at no load in volt	Resistive load		Inductive load		Capacitive load	
			V_R in volt	I_R in Amp	V_R in volt	I_R in Amp	V_R in volt	I_R in Amp

CONCLUSION: To be written by student

DISCUSSION QUESTIONS:

1. What do you mean by compensation of transmission line?
2. What are the methods of compensation of transmission lines?
3. Why for is series capacitor and shunt capacitors used?
4. How can a synchronous machine be used as transmission line compensator?
5. Why for is shunt and series reactor used?

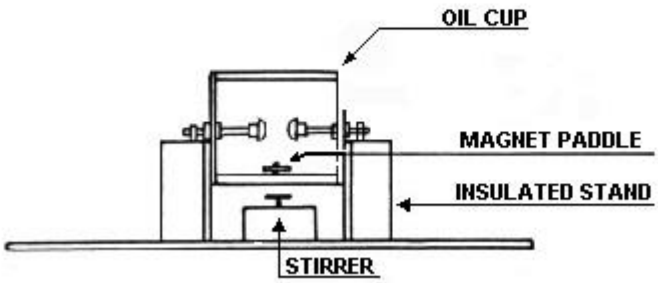
EXPERIMENT 06

AIM: To determine experimentally flash over voltage of given sample of transformer oil and hence determine the dielectric strength.

APPARATUS REQUIRED:

1. Transformer oil testing Kit.
2. Motor operated at 230V, 1ø, 50HzOutput: 0-60Kv
3. Transformer oil.

CIRCUIT DIAGRAM:



OIL JAR ARRANGEMENT

THEORY:

Dielectric strength of transformer oil is also known as breakdown voltage of transformer oil or BDV of transformer oil**.** Break down voltage is measured by observing at what voltage, sparking strands between two electrodes immerged in the oil, separated by specific gap. low value of BDV indicates presence of moisture content and conducting substances in the oil. For measuring BDV of transformer oil, portable BDV measuring kit is generally available at site. In this kit, oil is kept in a pot in which one pair of electrodes are fixed with a gap of 2.5 mm (in some kit it 4mm) between them. Now slowly rising voltage is applied between the electrodes. Rate of rise of voltage is generally controlled at 2 KV/s and observe the voltage at which sparking starts between the electrodes. That means at which voltage dielectric strength of transformer oil between the electrodes has been broken down. Generally this measurement is taken 3 to 6 times in same sample of oil and the average value of these reading is taken. BDV is important and popular test of transformer oil, as it is primary indication of health of oil and it can be easily carried out at site. Dry and clean oil gives BDV results, better than the oil with moisture content and other conducting impurities. Minimum breakdown voltage of transformer oil or dielectric strength of transformer oil at which this oil can safely be used in transformer, is considered as 30 KV

PROCEDURE:

1. The given transformer oil sample is poured into the test cup provided.
2. The gap between electrodes is adjusted to the standard values by rotating one of the electrodes.
3. Power supply switch is put in ON position.

4. The dimmer state (single phase auto transformer) is adjusted to zero output voltage using synchronous motor internally provided by pressing lower push button switch.
5. The HT ON push button switch is pressed.
6. The HT voltage is raised by pressing the raise push button the deserved HT voltage is reached when a flash over occurs across the electrodes.
7. As soon as the flash over occurs, the supply to the HT transformer will be cut off automatically and voltmeter point will stop indicating the flash over voltage.
8. The experiment is repeated again for some other gap distance and means value of flash over voltage is noted.
9. The above test is repeated with other samples of transformer oil.

TABULATION:

Sample	Flash Over Voltage (kV)		Dielectric strength in kV/mm	Mean kV/mm
	Gap distance = 2.5 mm	Gap distance = 4mm		

CALCULATION:

Dielectric Strength = (Flash over Voltage in kV/ Gap distance in mm) kV/mm

CONCLUSION: To be written by student

DISCUSSION QUESTIONS:

1. What is the break down strength of dielectric?
2. What is the BDV of the transformer oil?
3. What should be the gap between two electrodes for the test?
4. How is the flash over voltage related to the gap between the electrodes?
5. What is the flash over voltage?

EXPERIMENT 07

AIM OF THE EXPERIMENT: To study different type of lightening arrestor.

APPARATUS REQUIRED:

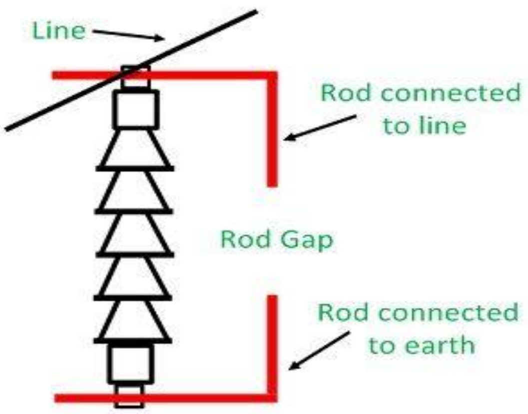
1. Road Gap Arrester
2. Sphere Gap Arrester
3. Horn Gap Arrester
4. Multiple-Gap Arrester
5. Impulse Protective Gap
6. Electrolytic Arrester
7. Expulsion Type Lightning Arrester
8. Valve Type Lightning Arresters
9. Thyrite Lightning Arrester
10. Auto valve Arrester
11. Oxide Film Arrester
12. Metal Oxide Lightning Arresters

THEORY:

The lightning arrester protects the electrical equipment from lightning. It is placed very near to the equipment and when the lightning occurs the arrester diverts the high voltage wave of lightning to the ground. The selection of arrester depends on the various factors like voltage, current, reliability, etc.

1. Rod Gap Arrester

It is one of the simplest forms of the arrester. In such type of arrester, there is an air gap between the ends of two rods. The one end of the arrester is connected to the line and the second end of the rod is connected to the ground. The gap setting of the arrester should be such that it should break before the damage. When the high voltage occurs on the line, the gap sparks and the fault current passes to the earth. Hence the equipment is protected from damage.

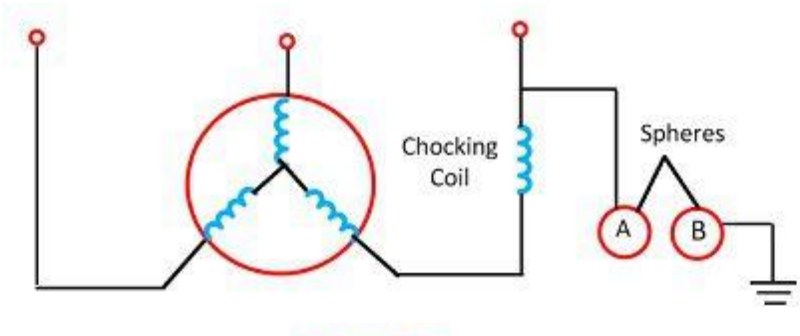


Rod gap on an insulator string

The difficulty with the rod arrester is that once the spark having taken place it may continue for some time even at low voltages. To avoid it a current limiting reactor in series with the rod is used. The resistance limits the current to such an extent that it is sufficient to maintain the arc. Another difficulty with the road gap is that the rod gap is liable to be damaged due to the high temperature of the arc which may cause the rod to melt.

2. Sphere Gap Arrester

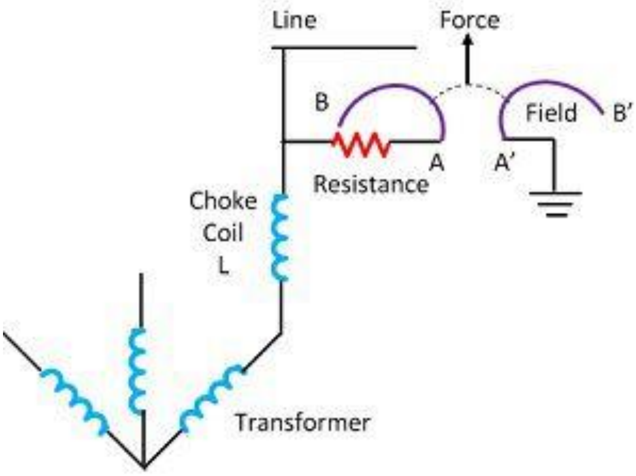
In such type of devices, the air gap is provided between two different spheres. One of the spheres is connected to the line, and the other sphere is connected to the ground. The spacing between the two spheres is very small. A choking coil is inserted between the phase winding of the transformer and spheres are connected to the line. The air gap between the arrester is set in such a way so that the discharge must not take place at normal operating condition. The arc will travel up the sphere as the heated air near the arc tend to rise upward and lengthening till it is interrupted automatically.



Sphere Gap

3. Horn Gap Arrester

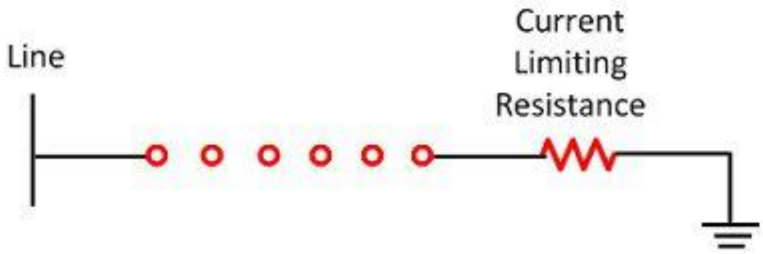
It consists of two horns shaded piece of metal separated by a small air gap and connected in shunt between each conductor and earth. The distance between the two electrodes is such that the normal voltage between the line and earth is insufficient to jump the gap. But the abnormal high voltage will break the gap and so find a path to earth.



Horn Gap With Choke Coil and Resistance

4. Multiple- Gap Arrester

The multiple gap arresters consists a series of small metal cylinder insulated from one another and separated by an air gap. The first and the last of the series is connected to ground. The number of gaps required depends on the line voltage.

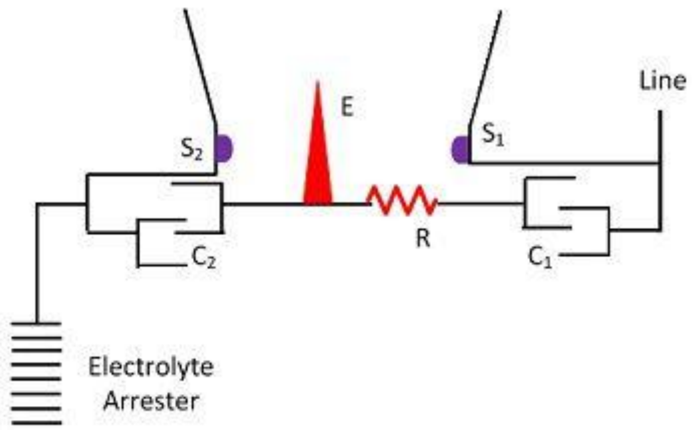


Multiple-Gap Arrester

5. Impulse Protective Gap

The protective impulse gap is designed to have a low voltage impulse ratio, even less than one and to extinguish the arc. Their working principle is very simple as shown in the figure below. It consists of two sphere electrode S_1 and S_2 which are connected respectively to the line and the arrester. The auxiliary needle is placed between the mid of two sphere S_1 and S_2. At normal frequency, the impedance of the capacitance C_1 is quite large as compared to the impedance of resistor R. If C_1 and C_2 are equal the potential of the auxiliary electrode will be midway between those of the S_1 and S_2 and the electrode has no effect on the flash over between them.

When the transient occurs the impedance of capacitor C_1 and C_2 decrease and the impedance of the resistor now become effective. Due to this, the whole of the voltage is concentrated across the gap between E and S_1. The gap at once breakdown, the rest of the length between E and S_2 immediately follow.



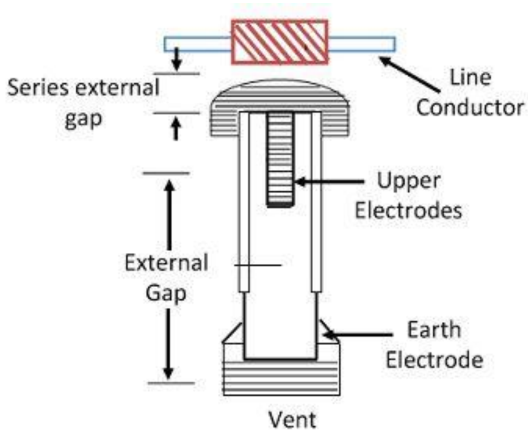
Impulse Protective Gap with Electrolytic Arrester

6. Electrolyte Arrester

In such type of arrester have high a large discharge capacity. It operates on the fact that the thin film of aluminum hydroxide deposits on the aluminum plates immersed in the electrolyte. The plate acts as a high resistance to a low value but a low resistance to a voltage above a critical value. Voltage more than 400 volts causes a puncture and a free flow of current to earth. When the voltage remains its normal value of 440 volts, the arrester again offers a high resistance in the path and leakage stops.

7. Expulsion Type Lightning Arrester

Expulsion type arrester is an improvement over the rod gap in that it seals the flow of power frequency follows the current. This arrester consists of a tube made up of fiber which is very effective, isolating spark gap and an interrupting spark gap inside the fiber tube.

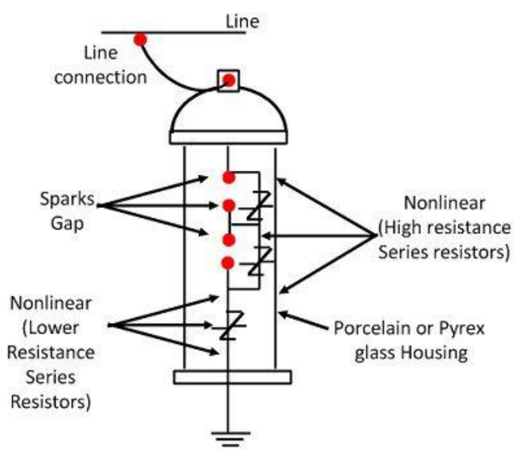


Expulsion-type Surge Diverter

During operation, the arc due to the impulse spark over inside the fibrous tube causes some fibrous material of the tube to volatile in the form of the gas, which is expelled through a vent from the bottom of the tube. Thus, extinguishing the arc just like in circuit breakers.

8. Valve Type Lightning Arrester

Such type of resistor is called nonlinear diverter. It essentially consists a divided spark gap in series with a resistance element having the nonlinear characteristic. The divided spark gap consists of some identical elements coupled in series. Each of them consists two electrodes with the pre-ionization device. Between each element, a grading resistor of high ohmic value is connected in parallel.



Valve Type Lightning Arrester

During the slow voltage variations, there is no sparks-over across the gap. But when the rapid change in voltage occurs, the potential is no longer evenly graded across the series gap. The influence of unbalancing capacitance between the sparks gaps and the ground prevails over the grounded resistance. The impulse voltage is mainly concentrated on the upper spark gap which in spark over cause the complete arrester to spark over to.

9. Thyrite Lightning Arrester

Such type of arrester is most commonly used for the protection against dangerous high voltage. It consists the thyrite which is an inorganic compound of ceramic material. The resistance of such material decreases rapidly from high value to low value and for current from a low value to high value. It consists a disc whose both the side is sprayed so as to give the electric contact between the consecutive discs. The disc is assembled inside the glazed porcelain container. It is used in conjunction with the container. When the lightning takes place, the voltage is raised, and breakdowns of the gaps occur, the resistance falls to a very low value, and the wave is discharged to earth. After the surge has passed the thyrite again come back to its original position.

10 Auto valve Arrester

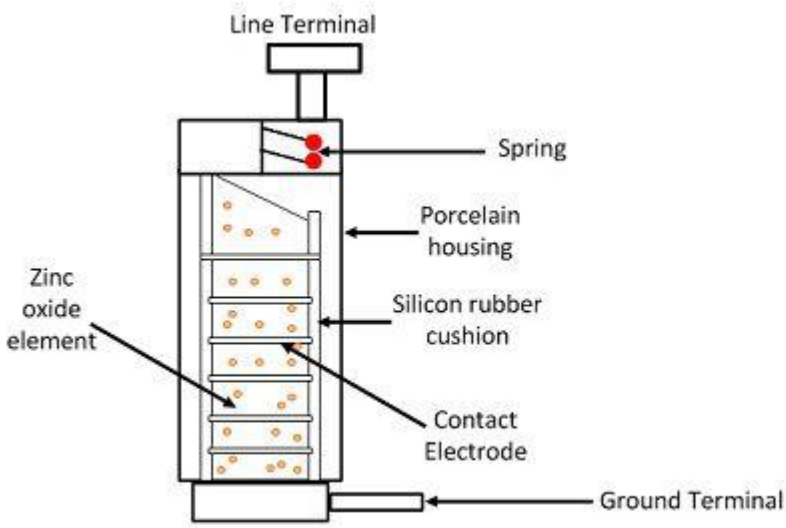
Such type of arrester consists some flat discs of a porous material stacked one above the other and separated by the thin mica rings. The disc material is not homogenous and conducting material also has been added. Therefore the glow discharge occurs in the capillaries of the material and voltage drop to about 350 volts per unit. The discs are arranged in such a way that normal voltage may not cause a discharge to occur.

11. Oxide Film Arrester

It consists of pellets of lead peroxide with a thin, porous coating of litharge arranged in a column and enclosed in a tube of diameter. Out of the two lead, the upper is connected to the line, while the lower is connected to the earth. The tube contains a series spark gap. When an overvoltage occurs an arc passes through the series spark gap and an additional voltage is applied to the pellet column and a discharge takes place. After the discharge, the resistance of the pellet gun increases till only very small current flow through it. This small current is finally interrupted by the series spark gaps.

12. Metal Oxide Lightning Arrester

Such Types of diverter are also known as gapless surge diverters, or Zinc oxide diverter. The base material used for manufacturing metal oxide resistor is zinc oxide. It is a semiconducting N-type material. The material is doped by adding some fine power of insulating oxides. The powder is treated with some processes and then it is compressed into a disc-shaped. The disc is then enclosed in a porcelain housing filled with nitrogen gas or SF6. This arrester consists a potential barrier at the boundaries of each disc of ZNO. This potential barrier controls the flow of current. At normal operating condition, the potential barrier does not allow the current to flow. When an overvoltage occurs, the barrier collapses and sharp transition from insulating to conducting takes place. The current start flowing and the surge is diverted to ground.



Zinc Oxide Surge Arrester

CONCLUSION: To be written by student.

DISCUSSION QUESTIONS:

1. What is the use of lightening arrestor?
2. What are different types of LA?
3. Where are they placed in power system?
4. Which LA is widely used?

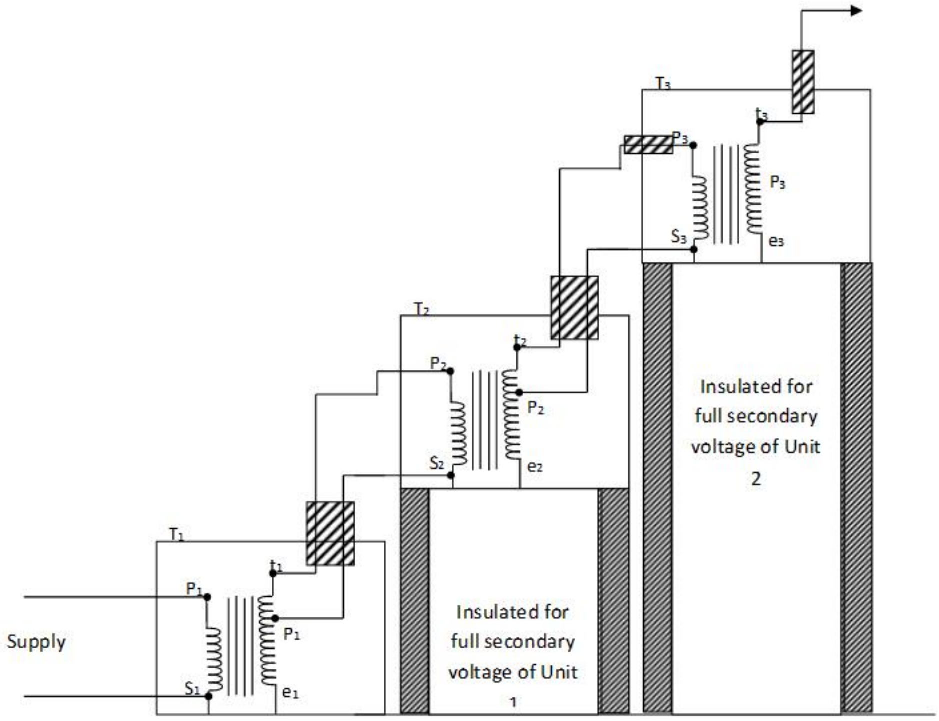
EXPERIMENT 08

AIM OF THE EXPERIMENT: Study of corona discharge.

APPARATUS REQUIRED:

1. High voltage transformer
2. Corona discharge kit

CIRCUIT DIAGRAM:



THEORY:

Corona phenomenon is the ionization of air surrounding the power conductor. Free electrons are normally present in free space because of radioactivity and cosmic rays. As the potential between the conductors is increased, the gradient around the surface of the conductor increases. Assume that the spacing between the conductors is large as compared with the diameter of the conductors. The free electrons will move with certain velocity depending upon the field strength. These electrons will collide with the molecules of air and in case the speed is large, they will dislodge electrons from these molecules, thereby the number of electrons will increase. The process of ionization is thus cumulative and ultimately forms an electron avalanche. This results in ionization of the air surrounding the conductor. In case the ratio of spacing between conductors to the radius of the conductor is less than 15, flash over will occur between the conductors before corona phenomenon occurs. Usually for overhead lines this ratio is far more than this number and hence flash-over can be regarded as impossible. Corona phenomenon is, therefore, defined as a self-sustained electric discharge in which the field intensified ionization is localized only over a portion of the distance between the electrodes. When a voltage higher than the critical voltage is applied between two parallel polished wires, the glow is quite even. After operation for a short time, reddish beads or tufts form along the wire, while around the surface of the wire there is a bluish white glow. If the conductors are examined through a stroboscope, so that one wire is always seen when at a given half of the wave, it is noticed that the reddish tufts or beads are formed when the conductor is negative and a smoother bluish white glow when the conductor is positive. The a.c corona, viewed through a stroboscope, has the same appearance as direct current corona. As corona phenomenon is initiated, a hissing noise is heard and ozone gas is formed which can be detected by its characteristic odor.

PROCEDURE:

1. Connect two high voltage transformers in cascaded manner.
2. Increase the voltage gradually till the hissing sound is observed.
3. Note down the voltage corresponding to the hissing sound

TABULATION:

Sl. No.	Voltage correspond to hissing sound in kV

CONCLUSION: To be written by the student.

DISCUSSION QUESTIONS:

1. What is corona effect?
2. What are the causes of corona?
3. Which factors does the corona power loss depend on?
4. How can be the corona effect reduced?
5. What is the advantage of corona effect?