Power System Laboratory-I
B.Tech. (Electrical Engineering)

Department of Electrical Engineering
Veer Surendra Sai University of Technology Burla

Vision

To be recognized as a center of excellence in education and research in the field of Electrical Engineering by producing innovative, creative and ethical Electrical Engineering professionals for socio-economic development of society in order to meet the global challenges.

Mission

Electrical Engineering Department of VSSUT Burla strives to impart quality education to the students with enhancement of their skills to make them globally competitive through:

1. M1. Maintaining state of the art research facilities to provide enabling environment to create, analyze, apply and disseminate knowledge.
2. M2. Fortifying collaboration with world class R& D organizations, educational institutions, industry and alumni for excellence in teaching, research and consultancy practices to fulfil 'Make in India' policy of the Government.
3. M3. Providing the students with academic environment of excellence, leadership, ethical guidelines and lifelong learning needed for a long productive career.

Program Educational Objectives

The program educational objectives of B.Tech. in Electrical Engineering program of VSSUT Burla are to prepare its graduates:

1. To have basic and advanced knowledge in Electrical Engineering with specialized knowledge in design and commissioning of electrical systems/renewable energy systems comprising of generation, transmission and distribution to become eminent, excellent and skillful engineers.
2. To succeed in getting engineering position with electrical design, manufacturing industries or in software and hardware industries, in private or government sectors, at Indian and in Multinational organizations.
3. To have a well-rounded education that includes excellent communication skills, working effectively on team-based projects, ethical and social responsibility.
4. To have the ability to pursue study in specific area of interest and be able to become successful entrepreneur.
5. To have broad knowledge serving as foundation for lifelong learning in multidisciplinary areas to enable career and professional growth in top academic, industrial and government/corporate organizations.

Program Outcomes

1. Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.
2. Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.
3. Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.
4. Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.
5. Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.
6. The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.
7. Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.
8. Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice. Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.
9. Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.
10. Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.
11. Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

Program Specific Outcomes

1. Apply the knowledge of electric circuits, control systems, electrical machines, power electronics and power systems to solve complex engineering problems in the discipline of Electrical Engineering
2. Develop suitable techniques and cutting-edge engineering hardware and software tools in electrical engineering to solve practical problems.
3. Aware of the impact of professional electrical engineering solutions on social, economic, environmental and technological sustainability.

List of Experiments

1. Determination of operating characteristics of biased differential relay.
2. Determination of operating characteristics of an induction type overcurrent relay.
3. Operation and performance of Numeric Relays.
4. Operation and performance of Microprocessor based relays.
5. Study of Ferro resonance phenomenon of no-load, light load & critical load conditions.
6. Determination of A, B, C, D parameters of an artificial transmission line a transmission line.
7. Performance analysis using transmission line simulator.

Course Outcomes

1. Demonstrate the operation of electromagnetic relays.
2. Demonstrate the operation of numeric and digital relays.
3. Implement relay setting.
4. Demonstrate ferroresonance phenomenon.
5. Demonstrate the determination of A, B, C, D parameters experimentally.

EXPERIMENT NO: 01

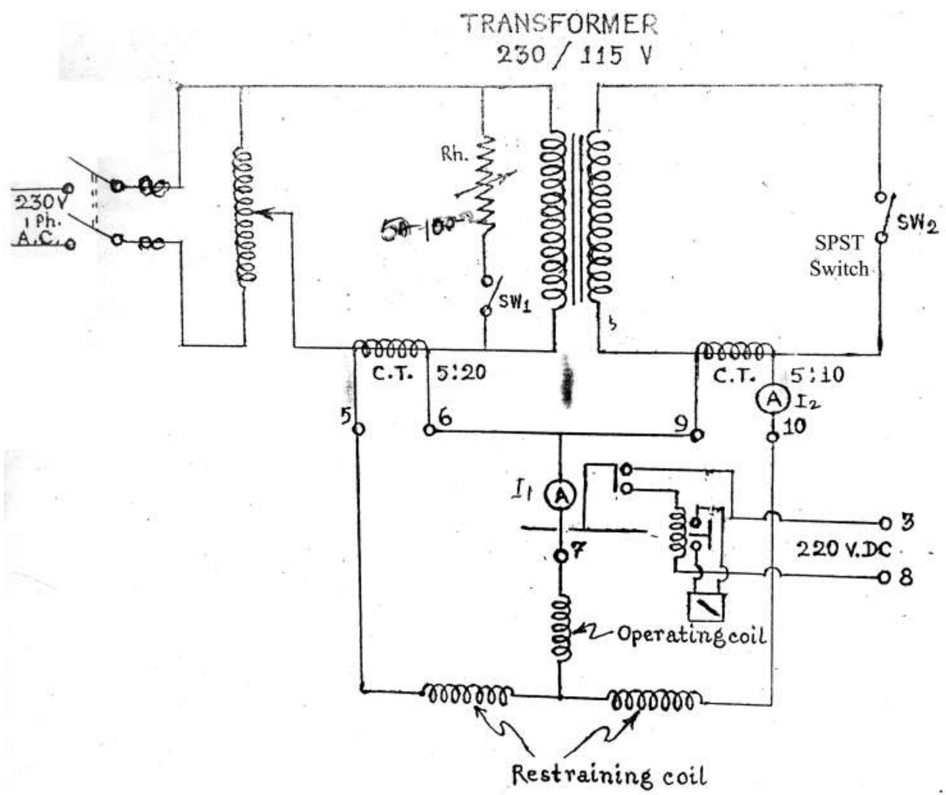
AIM OF THE EXPERIMENT:

a. To obtain the operating characteristics of biased differential relay with different percentage of biasing.

APPARATUS REQUIRED:

Sl. No.	Item	Range	Nos.

CIRCUIT DIAGRAM



CONNECTION DIAGRAM OF BIAS RELAY

THEORY:

The differential relay is one that operates when the vector difference of two or more similar electrical quantities exceeds a predetermined value. This means for a differential relay, it should have (1) two or more similar electrical quantities and (2) these quantities should have phase displaced for operation of relay.

Two current transformers are connected in such a way that two secondary currents cancel each other during healthy condition and through fault condition. For a fault within protected zone unbalance current will flow through the relay operating coil and relay operators the relay may operate during through fault or no fault condition due to mismatch of two CTs. To avoid spurious operation of the relay biasing is provided by a restraining coil of suitable number of turns.

To accommodate these features, we use biased relay. This is commonly known as biased differential protection or percentage differential protection.

TABULATION: (for operating characteristics of biased differential relay)

(i) For 20% biasing

Sl. No.	Operation current in Amp	Through current in Amp

(ii) For 30% biasing

Sl. No.	Operation current in Amp	Through current in Amp

(iii) For 40% biasing

Sl. No.	Operation current in Amp	Through current in Amp

PROCEDURE: (For Differential Relay)

1. Connection was made as per ckt diagram (As the transformer has a voltage ratio of 2:1 the CTs used on the both sides have different ratio i.e. 5:20 and 5:10, respectively.
2. Percentage bias was set CH 20% as instructed on the relay front.
3. Single phase supply & 220V DC supply was switched on
4. Switch S_2 was kept closed and the i/p voltage was increased by variac. As switch S_1 is open there is no fault and the relay should not operate. The supply voltage was reduced.

5. Switch S_2 was open and close. S_1 the its voltage was increased by variac till the relay operate. The reading of through current was noted (I_2) and also the operating current (I_1-I_2)., it is the operating current at open condition.
6. Switch S_2 is closed and the through current was adjusted to a value. The operating current was increased till the relay operates.
7. Step (6) is repeated for different value of through current.
8. The percentage bias was changed bias was changed and stop (5) & (6) were repeated for 30% & 40% bias.

PRECAUTION

1. Power supply was not given without the prior permission of the Lab Instructor.
2. The fault created by closing switch S_1 should be within the protected region.
3. In step 1 if relay operates, then change the connection of secondary of any one of the CTs. This should be done by switching off the main supply.
4. Don't touch any other part of the relay.

CONCLUSION

EXPERIMENT NO: 02

AIM OF THE EXPERIMENT:

To determine the operating time characteristics of an induction type over current relay.

APPARATUS REQUIRED:

Sl. No.	Item	Range	Nos.

THEORY:

The function of a relay is to detect abnormal conditions in the system and to initiate through appropriate circuit breakes the disconnection of faulty circuits so that interference with general supply is minimised. Relays are of many times.

An induction type over current relay has got two electromagnets. The primary winding is wound over the upper electromagnet and secondary winding is would over the lower electromagnet. The primary winding of the upper electromagnet is connected to the secondary of C.T. and is tapped. The tapings are connected to a play setting bridge by which the no. of turns in use can be adjusted, thereby giving the desisted current setting.

This torque is controlled by a spiral spring. The operating torque is given by $T = K_1\ l_{2ms}{}^2$

The restraining torque $T_{res} = K_2$

The relay operates when $T > 0 \Rightarrow K_1 l^2 - K_2 > 0$

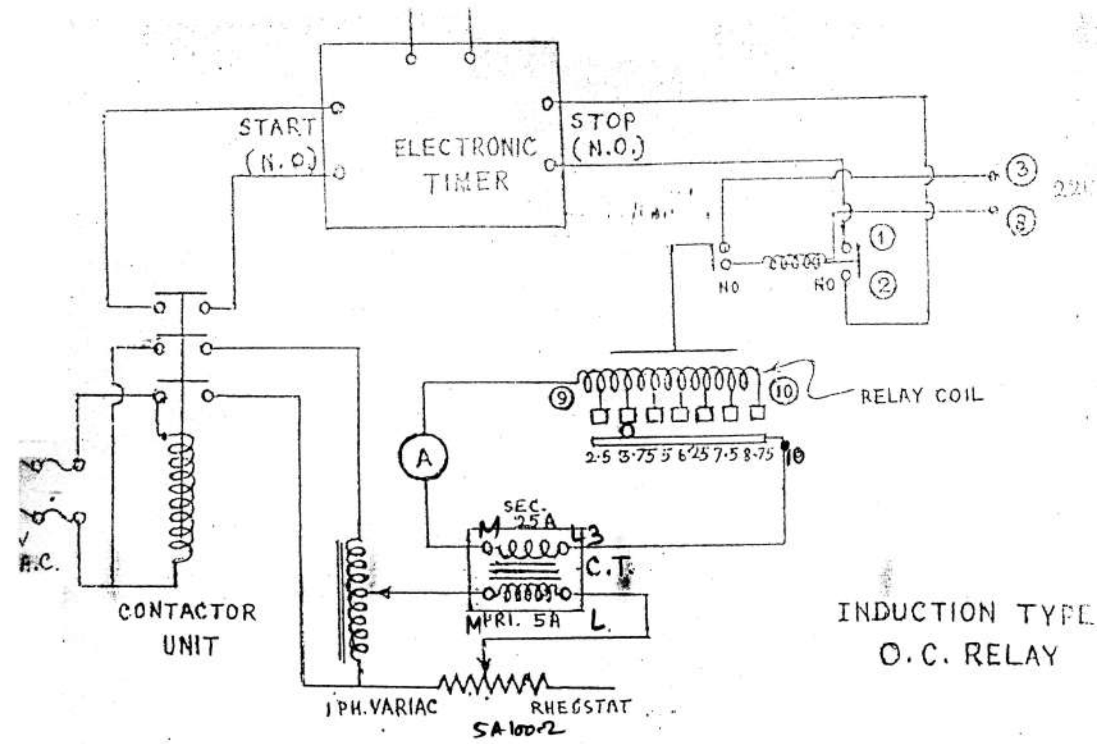
Or

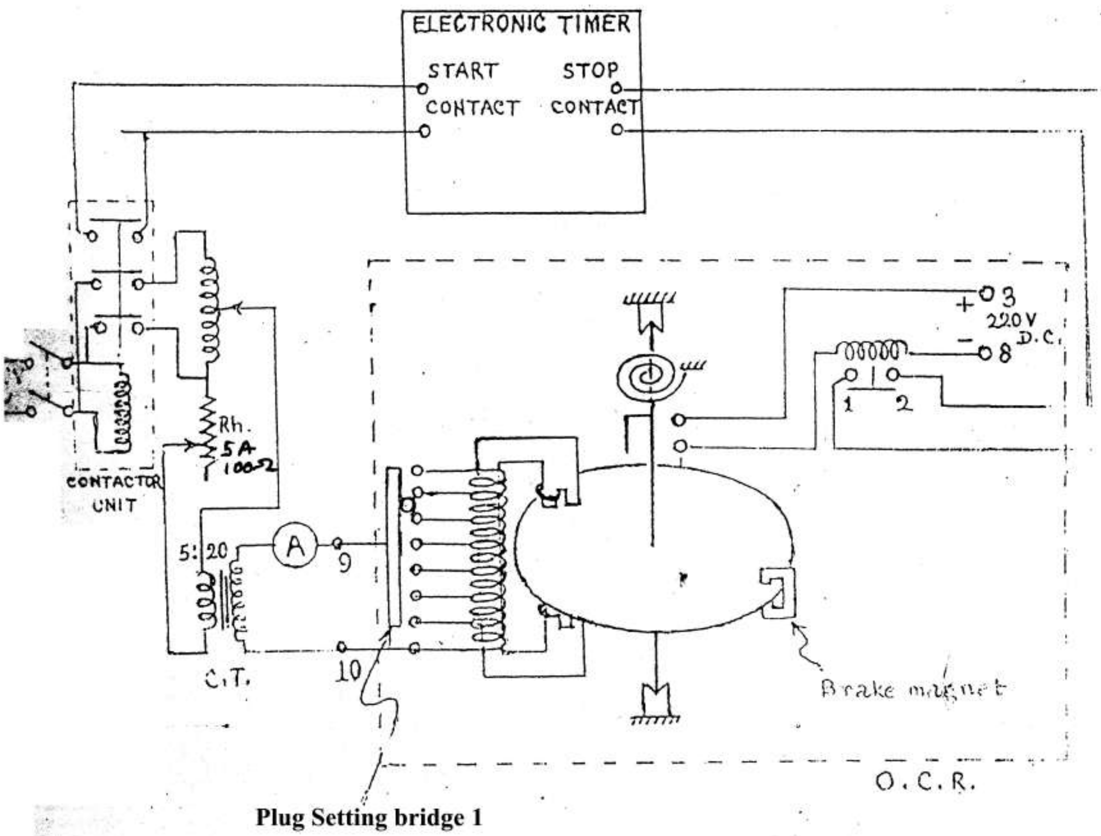
$$I > \sqrt{K_2/K_1}$$

Called the setting of the relay

$$\text{P.S.M.} = \frac{\text{Secondary curent or operation current}}{\text{Plug setting current}}$$

As the speed of the relay is dependent upon the setting of the relay, the time of operation will fall with increase in current. This is known as inverse time characteristics.





OPERATING CHARACTERISTICS OF OVER-CURRENT RELAY

PROCEDURE:

1. Connect the relay terminals as per the circuit diagram.
2. Set a current plug setting of the relay by inserting a plug in groove at a desired level (starting valve 2.5, step 1.25, maximum 10.0)
3. Set the time multiplier setting (TMS) to be 1.0.
4. Switch on the DC supply and make sure the relay is reset.
5. Switch on the AC supply through AC contactor and set the current through secondary of the current transformer (25A) to operate the relay. This value of the current should be slight greater than the plug setting valve.
6. This will operate the relay which can be indicated by disc rotor and count the time of operation. The red mark flag drops to ensure that the relay has operated (circuit is tripoed). Note down the current and time
7. Increase the current by varying supply voltage through variac and rheostat.
8. Switch off AC supply, rest the relay first.
9. Repeat 5,6 & 7 for different values of current.
10. Repeat the procedure from (2) for two more sets of current plug setting.

TABULATION:

Sl. No.	Current in Amp	Operating time in Sec.	PSM = $\frac{O.Current}{Plug\ Setting}$

GRAPH:

Draw the curve of operating time Vs. PSM for each set of reading.

PRECAUTION:

1. Don't touch any part of the relay.
2. Secondary of the CT should not be open

CONCLUSION:

EXPERIMENT NO: 03

AIM OF THE EXPERIMENT:

Operation and Performance of Numeric Relays.

Note: Please refer the separate manual used for this experiment.

EXPERIMENT NO: 04

AIM OF THE EXPERIMENT:

Operation and Performance of Microprocessor based Relays.

Note: Please refer the separate manual used for this experiment.

EXPERIMENT NO: 05

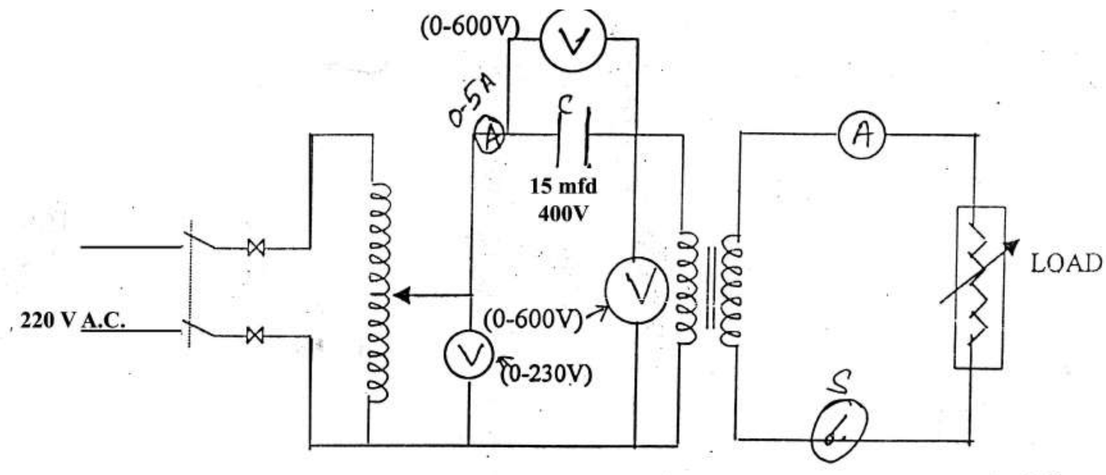
AIM OF THE EXPERIMENT:

To study the Ferro-resonance effect on a single phase transformer with and without load.

APPARATUS REQUIRED:

Sl. No.	Item	Range	Nos.

CIRCUIT DIAGRAM



THEORY:

The phenomenon of Ferro resonance occurs in a circuit having a liner element (capacitor) connected to a nonlinear inductance in series. When such a series circuit is excited by a variable AC voltage and the voltage is increased, the voltage across the inductance increases steadily at first. At certain voltage the voltage across the inductor jumps to a very high value. After that even if the input voltage is increased, the voltage across the inductor remains practically constant. Similar phenomenon of jump down occurs when the input voltage is decreased.

TABULATION:

For No load

Sl. No.	Input Voltage Vi	Voltage across capacitor Vc	Voltage across transformer

For Light load

Sl. No.	Input Voltage Vi	Voltage across capacitor Vc	Voltage across transformer

PROCEDURE:

1. Make the connection as per the circuit diagram.
2. For no load (o.c. secondary) the i/p voltage varied slowly.
3. At every steps input voltage was taken.
4. The voltage at which jump up occur was note down and the input voltage was further increased.
5. Again the input voltage was decreased when the capacitor reached its rated value.
6. The point where jump down occur was noted down. The input voltage was decreased further.
7. Steps (2) & (6) repeated for light and heavily loaded secondary side.
8. Perform the open circuit test and obtain the magnetization curve.

GRAPH

1. Plot the magnetization curve and voltage across the capacitor Vs input current.
2. Curve between input voltage and o/p voltage was drawn.

CONCLUSION

<u>EXPERIMENT NO: 06</u>

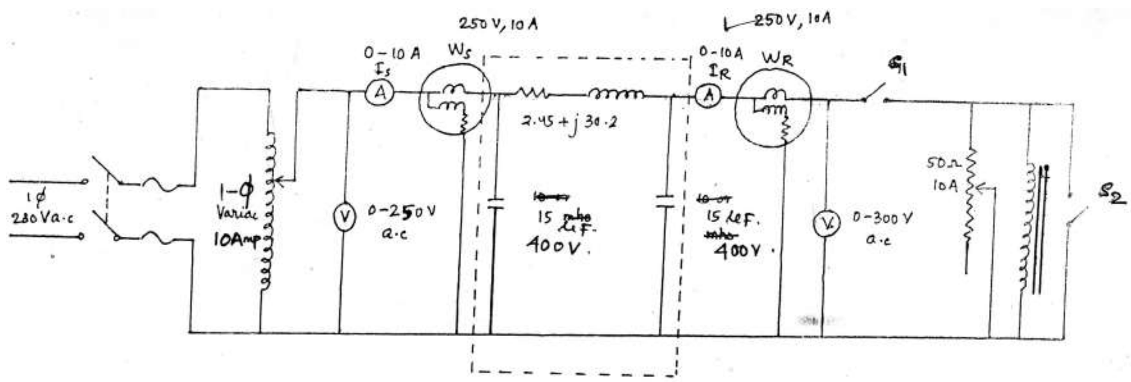
AIM OF THE EXPERIMENT:

To determine A,B,C,D parameters of medium length transmission line by nominal l method.

APPARATUS REQUIRED:

Sl. No.	Item	Range	Nos.

CIRCUIT DIAGRAM



CIRCUIT DIAGRAM FOR
CALCULATION OF A,B,C,D PARAMETERS OF MEDIUM (NOMINAL Pi) TRANSMISSION LINE AND STUDY ITS PERFORMANCE

THEORY:

In case of Medium Length transmission line the capacitor current or charging current is appreciable and so line capacitance is to be taken into account. The capacitor current always flows in the line even if the receiving end of the line is open circuited. The magnitude of the capacitive current flowing at any point along the line is that required to change the section of the line between the given point and he receiving end and diminishes at a particular uniform rate down to zero at receiving end.

To get the solution of medium transmission line, they are represented as:

i. End condenser or Nominal T method.

ii. Split condenser or Nominal π method.

Tabulation for calculation of A,B,C,D parameters

TABULATION:

i. Supply given to sending end of transmission line

Sl. No.	Sending end voltage Vs In volt	Sending end currend Is in Amp.	Sending end power Ps in watt	Receiving end voltage Vr in Mr volt (2)	Receiving end Ir in Amp	Receiving end power Pr (2) in watt	Remark

ii. Supply given to receiving end of transmission line

Sl. No.	Sending end voltage Vs In volt	Sending end currend Is in Amp.	Sending end power Ps in watt (2)	Receiving end voltage Vr in Mr volt	Receiving end Ir in Amp	Receiving end power Pr (2) in watt	Remark

PROCEDURE:

1. The ckt connection was done as per the ckt diagram.
2. The receiving end was made open circuit and here we use (250V, 2.5A/5A), LPF Wattmeter. The supply voltage (230V) was applied at the sending and measures Is, Vr.
3. Then sending end was short circuited and here we use (250V, 10A) UPF Wattmeter and corresponding instruments reading were taken. Here we adjust the supply voltage so that rated line current (8A) flows in the transmission line.
4. Again the inductive load was connected across the receiving end and voltage was supplied at sending end and corresponding instrument readings were taken.
5. The same procedure was repeated by changing the load.
6. Measures series impedance values and capacitance values.

CALCULATION:

1. Calculate A,B,C,D constants

$$A = \sqrt{\frac{Z_{so}}{Z_{ro} - Z_{rs}}}$$

$$C = \frac{1}{Z_{so}}\sqrt{\frac{Z_{so}}{Z_{ro} - Z_{rs}}}$$

$$B = Z_{rs}\sqrt{\frac{Z_{so}}{Z_{ro} - Z_{rs}}}$$

$$D = A$$

2. Verify AD-BC =1
3. From measured values of Vr and Ir phasors compute Vs and Is phasors using ABCD values already calculated both in magnitude and direction.

4. Verify the computed Vs and Is with the measured Vs and Is for the same load conditions.
5. Determine the voltage regulation of the line :

$$VR = \frac{\frac{V_S}{A} - V_R}{V_R} \times 100$$

6. Discuss, why the receiving end voltage at no load is higher than the sending end voltage. What this effect is called.

DISCUSSION:

CONCLUSION:

Experiment No-7

Aim of the Experiment:

Performance analysis of transmission lines.

General Instructions

1. You are required to install free and open source software SCILAB by downloading it from https://www.scilab.org/.
2. The code for solving the problems are available at https://github.com/rajatkanti/Lab-Code/tree/main/UG-PSLAB-I
3. You are required to write the theory and solution of the given problems from the textbooks as mentioned in the code.

Transmission Line Parameters

1. A conductor is composed of seven identical copper strands, each having a radius r as shown in Fig. 1. Find the self GMD of the conductor.
2. The outside diameter of the single layer of aluminium strands of an ACSR conductor is 5.04 cm. The diameter of each strand is 1.68 cm. Determine the 50 Hz reactance at 1 m spacing. Neglect the effect of central strand of steel.
3. The arrangement of conductors of a single-phase transmission line is shown in Fig. 2 wherein the forward circuit is composed of three solid wires 2.5 mm in radius and the return circuit of two wires of radius 5 mm placed symmetrically with respect to the forward circuit. Find the inductance of each side of the line and that of the complete line.
4. Calculate the capacitance to neutral/km of a single phase line composed of No. 2 single strand conductors (radius = 0.328 cm) spaced 3 m apart and 7.5 m above the ground.
5. A three-phase 50 Hz transmission line has flat horizontal spacing with 3.5 m between adjacent conductors. The conductors are No. 2/0 hand-drawn seven strand copper (outside conductor dia=1.05 cm). The voltage of the line is 110 kV. Find the capacitance to neutral and the charging current per km of the line.

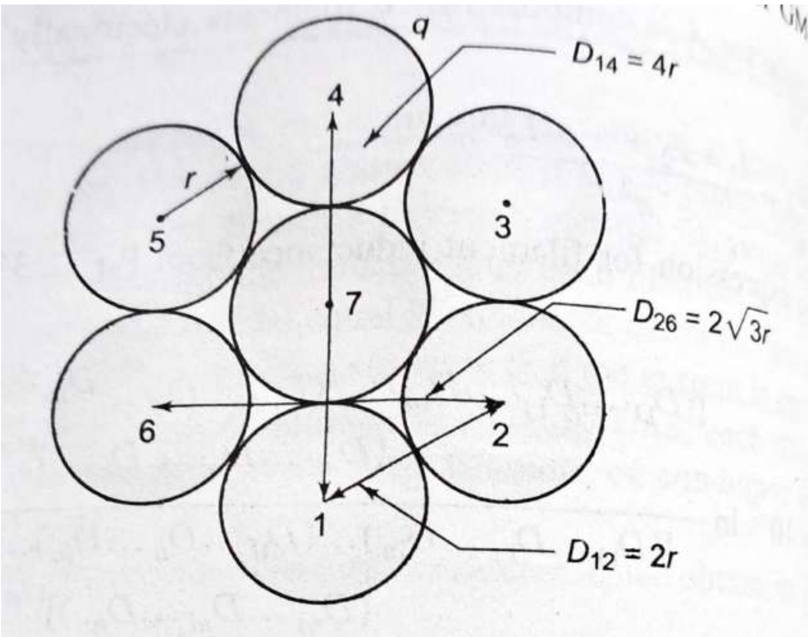


Figure 1: Pertaining to self GMD computation

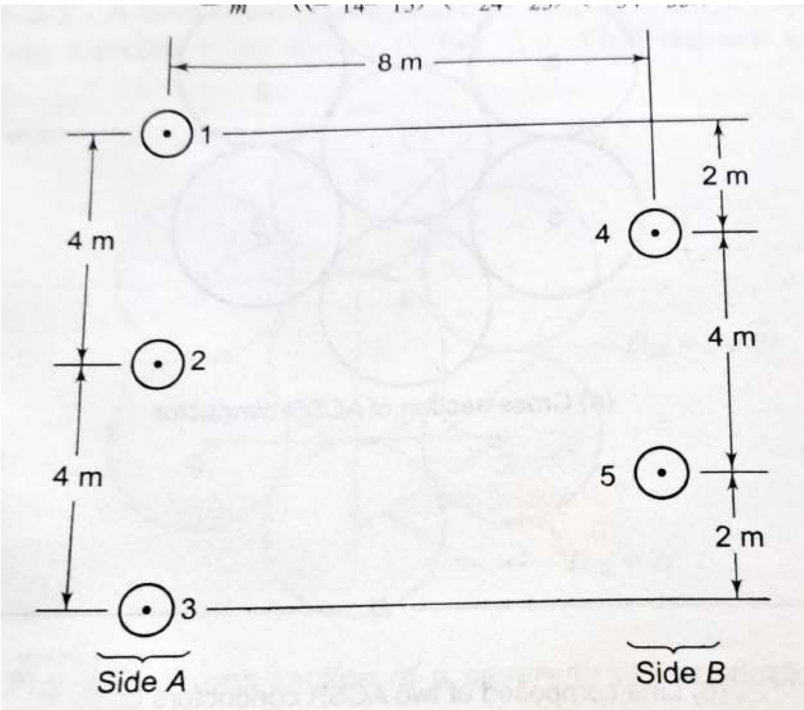


Figure 2: Pertaining to inductance of composite conductors

Performance of Transmission Line

6. A single phase 50 Hz generator supplies an inductive load of 5000 kW at a power factor of 0.707 lagging by means of an overhead transmission line 20 km long. The line resistance and inductance are 0.0195 ohm and 0.63 mH per km. The voltage at the receiving end is required to be kept constant at 10 kV. Find
   (a) the sending end voltage and voltage regulation of the line,
   (b) the value of the capacitor to be placed in parallel with the load such that the regulation is reduced to 50%.
   (c) compare the transmission efficiency in parts (a) and (b).
7. A substation receives 5 MVA at 6 kV, 0.85 lagging power factor on the low voltage side of a transformer from a power station through a cable having per phase resistance and reactance of 8 and 2.5 ohm respectively. Identical 6.6/33 kV transformers are installed at each end of the line. The 6.6 kV side of the transformer is delta connected while the 33 kV side is star connected. The resistance and reactance of the star connected windings are 0.5 and 3.75 ohms respectively and for the delta connected winding are 0.06 and 0.36 ohms. What is the bus voltage at the power station end?
8. Input to a single phase short line is 2000 kW at 0.8 lagging power factor. The line has a series impedance of (0.4 + j0.4) ohms. If the load voltage is 3 kV, find the load and receiving end power factor. Also find the supply voltage.
9. Using nominal π method, find the sending end voltage and voltage regulation of a 250 km, three phase, 50 Hz, transmission line delivering 25 MVA at 0.8 lagging power factor to a balanced load at 132 kV. The line conductors are spaced equilaterally 3 m apart. The conductor resistance is 0.11 ohm/km and its effective diameter is 1.6 cm. Neglect lekance.
10. A three phase transmission line is 400 km long. The voltage at the sending end is 220 kV. The line parameters are $r = 0.125\ \omega/km$, $x = 0.4\ \omega/km$ and $y = 2.8 \times 10^{-6}\ mho/km$. Compute the following.
    (a) the sending end current and receiving end voltage when there is no load on the line,
    (b) the maximum permissible line length if the receiving end no load voltage is to exceed 235 kV
    (c) For part (a), the maximum permissible line frequency, if the no-load voltage is not to exceed 250 kV.

References

1. D. P. Kothari, I. J. Nagrath, *Modern Power System Analysis*
2. D. P. Kothari, I. J. Nagrath, *Power System Engineering*
3. FOSSEE SCILAB Solved Examples: https://cloud.scilab.in/