DRONACHARYA
College of Engineering

LABORATORY MANUAL

B.Tech. Semester- IV

TRANSMISSION AND DISTRIBUTION LAB
Subject code: LC-EE-212G

Prepared by:	**Checked by:**	**Approved by:**
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DEPARTMENT OF ELECTRICAL & ELECTRONICS ENGINEERING
DRONACHARYA COLLEGE OF ENGINEERING
KHENTAWAS, FARRUKH NAGAR, GURUGRAM (HARYANA)

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Vision and Mission of the Institute

Vision:

To impart Quality Education, to give an enviable growth to seekers of learning, to groom them as World Class Engineers and managers competent to match the expending expectations of the Corporate World has been ever enlarging vision extending to new horizons of Dronacharya College of Engineering

Mission:

M1: To prepare students for full and ethical participation in a diverse society and encourage lifelong learning by following the principle of 'Shiksha evam Sahayata' i.e. Education & Help.

M2: To impart high-quality education, knowledge and technology through rigorous academic programs, cutting-edge research, & Industry collaborations, with a focus on producing engineers& managers who are socially responsible, globally aware, & equipped to address complex challenges.

M3: Educate students in the best practices of the field as well as integrate the latest research into the academics.

M4: Provide quality learning experiences through effective classroom practices, innovative teaching practices and opportunities for meaningful interactions between students and faculty.

M5: To devise and implement programmes of education in technology that are relevant to the changing needs of society, in terms of breadth of diversity and depth of specialization.

Vision and Mission of the Department

Vision:

Our vision for the Electrical and Electronics Engineering (EEE) Department is to be a globally recognized Centre of excellence in education, research, and innovation in the field of electrical and electronics engineering. We strive to produce competent engineers with strong technical knowledge, ethical values, and a passion for lifelong learning. And also to contribute to the sustainable development of society through cutting-edge research, industry collaborations, and community engagement.

Mission:

M1. To provide a high-quality education that equips students with a strong foundation in electrical and electronics engineering.

M2. To conduct pioneering research in diverse areas of electrical and electronics engineering. **M3.** To establish strong ties with industry partners to bridge the gap between academia and the professional world.

M4. To instilling ethical values, social responsibility, and environmental consciousness in our students.

M5. To regularly assess and upgrade our teaching methodologies, infrastructure, and facilities.

Programme Educational Objectives (PEOs)

PEO1: Engineers will practice the profession of engineering using a systems perspective and analyse, design, develop, optimize & implement engineering solutions and work productively as engineers, including supportive and leadership roles on multidisciplinary teams.

PEO2: Continue their education in leading graduate programs in engineering & interdisciplinary areas to emerge as researchers, experts, educators & entrepreneurs and recognize the need for, and an ability to engage in continuing professional development and life-long learning.

PEO3: Engineers, guided by the principles of sustainable development and global interconnectedness, will understand how engineering projects affect society and the environment.

PEO4: Promote Design, Research, and implementation of products and services in the field of Engineering through Strong Communication and Entrepreneurial Skills.

PEO5: Re-learn and innovate in ever-changing global economic and technological environments of the 21st century.

Programme Outcomes (POs)

Engineering Graduates will be able to:

PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: 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.

PO3: 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.

PO4: 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.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and software tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilitiesrelevant to the professional engineering practice.

PO7: 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.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

PO9: Individual and team work: Function effectively as an individual, and as a member or leader in diverse teams, and in multidisciplinary settings.

PO10: 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.

PO11: 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.

PO12: 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 (PSOs)

PSO1: Equip themselves to potentially rich & employable field of Engineering. Analyse and design electrical machines, circuits, controls and systems which makes the part of Power generation, transmission, distribution, utilization and conservation

PSO2: Pursue higher studies in the contemporary Technologies and multidisciplinary fields with an inclination towards continuous learning in the area of Power quality, high voltage, power electronics and Renewable energy systems

PSO3: Take up-self- employment in Indian and global electrical market in designing, implementing and testing analog, digital, embedded and signal processing systems

PSO4: Meet the requirements of the Indian Standards and use knowledge in different domains to identify the research gaps and to provide innovative solutions.

University Syllabus

1. To study the Power System blocks in MATLAB.
2. To design short and long transmission line using MATLAB.
3. To study and calculate the transmission line parameters.
4. To study the corona loss in power distribution system.
5. To study the proximity and skin effect.
6. To find ABCD parameters of a model of transmission line.
7. To study performance of a transmission line under no load condition & under load at different power factors.
8. To observe the Ferranti effect in a model of transmission line.
9. To study performance characteristics of typical DC distribution system in radial & ring main configuration.

Course Outcomes (COs)

Upon successful completion of the course, the students will be able to:

C323.1: To study MATLAB software

C323.2: Identify distribution system and analyse performance characteristics

C323.3: Identify & design transmission system and find transmission line parameters.

C323.4: To study corona loss, skin effect and proximity effect

C323.5: To study performance of a transmission line under different loading condition

CO-PO Mapping

	PO1	PO2	PO3	PO4	PO5	PO6	PO7	PO8	PO9	PO10	PO11	PO12
C323.1		3			3			2	2	2	2	2
C323.2			2		3			2	2	2	2	2
C323.3				2	3			2	2	2	2	2
C323.4				2	3			2	2	2	2	2
C323.5				2	3			2	2	2	2	2
C323		**3**	**2**	**2**	**3**			**2**	**2**	**2**	**2**	**2**

CO-PSO Mapping

	PSO1	PSO2	PSO3	PSO4
C323.1	2	2	3	3
C323.2	2	2		2
C323.3	2	2		2
C323.4	2	2	3	3
C323.5	2	2	3	3
C323	**2**	**2**	**3**	**3**

Course Overview

This laboratory provides students with hands-on experience on the analysis, operation, and planning of both transmission and distribution systems. This laboratory has played a role in on-going development of the power system curriculum at institute. This laboratory is to provide students with experience on various power distribution system operating and planning functions, a set ofexperiments have been designed and are under design for use with MATLAB.

List of Experiments mapped with COs

Sl No.	*List of Experiments*	*Course Outcome*
1	TO STUDY THE POWER SYSTEM BLOCKS IN MATLAB.	C323.1
2	TO DESIGN SHORT AND LONG TRANSMISSION LINE USING MATLAB.	C323.1
3	TO STUDY AND CALCULATE THE TRANSMISSION LINE PARAMETERS.	C323.3
4	TO STUDY THE CORONA LOSS IN POWER DISTRIBUTION SYSTEM.	C323.4
5	TO STUDY THE PROXIMITY AND SKIN EFFECT.	C323.4
6	TO FIND ABCD PARAMETERS OF A MODEL OF TRANSMISSION LINE.	C323.3
7	TO STUDY PERFORMANCE OF A TRANSMISSION LINE UNDER NO LOAD CONDITION & UNDER LOAD AT DIFFERENT POWER FACTORS.	C323.5
8	TO OBSERVE THE FERRANTI EFFECT IN A MODEL OF TRANSMISSION LINE.	C323.3
9	TO STUDY PERFORMANCE CHARACTERISTICS OF TYPICAL DC DISTRIBUTION SYSTEM IN RADIAL & RING MAIN CONFIGURATION.	C323.2
10	TO STUDY MECHANICAL DESIGN OF TRANSMISSION LINE	C323.4

DOs and DON’Ts

DOs

1. Enter the lab on time and leave at proper time.
2. Keep the bags outside in the racks.
3. Utilize lab hours in the corresponding experiment.
4. Make the Supply off the Kits/Equipments after completion of Experiments.
5. Maintain the decorum of the lab.

DON’Ts

1. Don’t bring any external material in the lab.
2. Don’t make noise in the lab.
3. Don’t bring the mobile in the lab.
4. Don’t enter in Faculty room without permission.
5. Don’t litter in the lab.
6. Don’t carry any lab equipments outside the lab

General Safety Precautions

Precautions (In case of Injury or Electric Shock)

1. To break the victim with live electric source, use an insulator such as fire wood or plastic to break the contact. Do not touch the victim with bare hands to avoid the risk of electrifying yourself.
2. Unplug the risk of faulty equipment. If main circuit breaker is accessible, turn the circuit off.
3. If the victim is unconscious, start resuscitation immediately, use your hands to press the chest in and out to continue breathing function. Use mouth-to-mouth resuscitation if necessary.
4. Immediately call medical emergency and security. Remember! Time is critical; be best.

Precautions (In case of Fire)

1. Turn the equipment off. If power switch is not immediately accessible, take plug off.
2. If fire continues, try to curb the fire, if possible, by using the fire extinguisher or by covering it with a heavy cloth, if possible, isolate the burning equipment from the other surrounding equipment.
3. Sound the fire alarm by activating the nearest alarm switch located in the hallway.
4. Call security and emergency department immediately:

Emergency	**:**	**201 (Reception)**
Security	**:**	**231 (Gate No.1)**

Guidelines to students for report preparation

All students are required to maintain a record of the experiments conducted by them. Guidelines for its preparation are as follows: -

1) All files must contain a title page followed by an index page. ***The files will not be signed by the faculty without an entry in the index page.***

2) Student's Name, Roll number and date of conduction of experiment must be written on all pages.

3) For each experiment, the record must contain the following

- (i) Aim/Objective of the experiment
- (ii) Pre-experiment work (as given by the faculty)
- (iii) Lab assignment questions and their solutions
- (iv) Test Cases (if applicable to the course)
- (v) Results/ output

Note:

1. Students must bring their lab record along with them whenever they come for the lab.
2. Students must ensure that their lab record is regularly evaluated.

Lab Assessment Criteria

An estimated 10 lab classes are conducted in a semester for each lab course. These lab classes are assessed continuously. Each lab experiment is evaluated based on 5 assessment criteria as shown in following table. Assessed performance in each experiment is used to compute CO attainment as well as internal marks in the lab course.

Grading Criteria	**Exemplary (4)**	**Competent (3)**	**Needs Improvement (2)**	**Poor (1)**
AC1: **Pre-Lab written work (this may be assessed through viva)**	Complete procedurewith underlined concept is properly written	Underlined concept is written but procedure is incomplete	Not able to write concept and procedure	Underlined concept is not clearly understood
AC2: **Program Writing/ Modeling**	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/ tools are applied, Program/solution written is readable	Assigned problem is properly analyzed, correct solution designed, appropriate language constructs/ tools are applied	Assigned problem is properly analyzed & correct solution designed	Assigned problem is properly analyzed
AC3: **Identification of problem & Removal of errors**	Able to identify errors and remove them	Able to identify errorsand remove them with little bit of guidance	Is dependent totally on someone for identification of errors and their removal	Unable to understand the reason for errors even after they are explicitly pointed out
AC4:Execution & Demonstration	All variants of input /output are tested, Solution is well demonstrated and implemented concept is clearly explained	All variants of input /output are not tested, However, solution is well demonstrated and implemented concept is clearly explained	Only few variants of input /output are tested, Solution is well demonstrated but implemented concept is not clearly explained	Solution is not well demonstrated and implemented concept is not clearly explained
AC5:Lab Record Assessment	All assigned problemsare well recorded with objective, design constructs and solution along with Performance analysis using all variants of input and output	More than 70 % of the assigned problems arewell recorded with objective, design contracts and solution along with Performance analysis is done with all variants of input and output	Less than 70 % of the assigned problems are well recorded with objective, design contracts and solution along with Performance analysis is done with all variants of input and output	

LAB EXPERIMENTS

EXPERIMENT No. 1

AIM: To study the power system blocks in MATLAB

SOFTWARE REQUIRED: MATLAB

THEORY:

SimPowerSystems^{TM} provides component libraries and analysis tools for modeling and simulating electrical power systems. The libraries offer models of electrical power components, including three-phase machines, electric drives, and components for applications such as flexible AC transmission systems (FACTS) and renewable energy systems. Harmonic analysis calculation of total harmonic distortion (THD), load flow, and other key electrical power system analysis are automated. SimPowerSystems libraries contain two top-level block libraries, representing two different technologies.

Simscape Components Library:

The SimPowerSystems Simscape Component library contains Simscape blocks specifically developed for working with multiphase electrical domains. In addition to the Simscape Foundation domains, the product contains a three-phase electrical domain and you can use this domain to develop your own custom three-phase blocks with Simscape language. The main Simscape components library is called pe_lib. It contains Simscape blocks with three-phase and single-phase electrical ports, as well as mechanical rotational and translational ports. These blocks are organized into sublibraries according to their function. You can connect these blocks directly to other Simscape blocks, from the Foundation library or from the other add-on products.

Simscape components also provides three-phase electrical connection ports, which you can individually expand into separate phases as needed. By default, these three-phase ports are collapsed, to support single-line diagrams.

Specialized Technology Library:

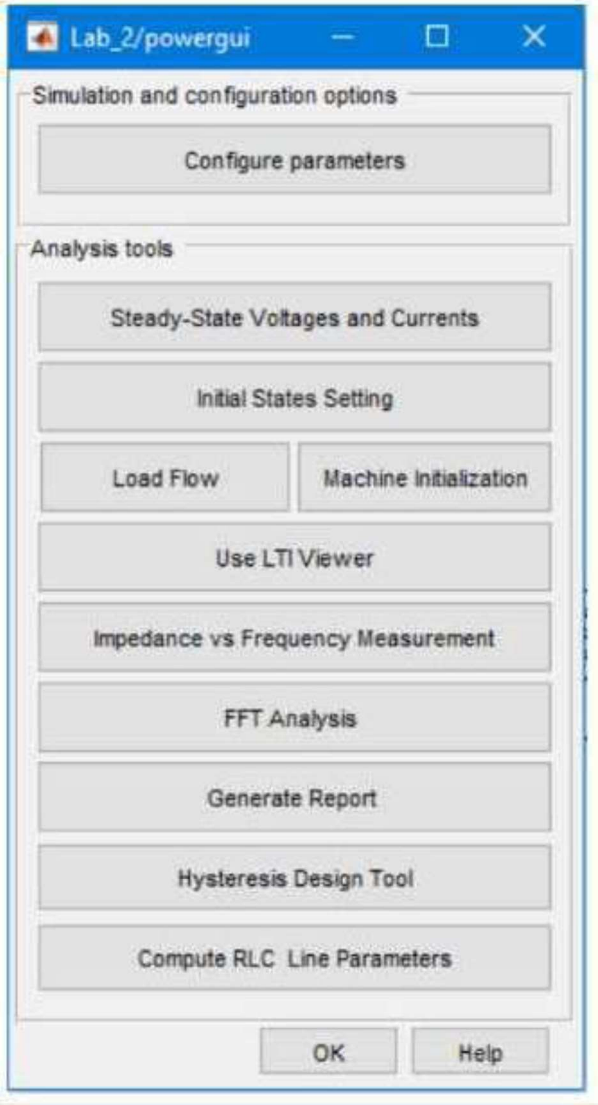
The SimPowerSystems specialized Technology library contains models of typical power equipment such as transformers, lines, machines and power electronics. The main specialized technology library is called powerlib. It contains sub libraries of blocks, organized according to their behavior, as well as the Powergui block that opens a graphical user interface for the steady-state analysis of electrical circuits. You connect Specialized Technology blocks to other Simscape elements ultimately through Simulink signals. The Specialized Technology software provides a variety of simulation methods (continuous, discrete, phasor) and analysis tools. You can add mechanical, hydraulic, pneumatic, and other components to the model using Simscape and test them together in a single simulation environment.

Using the Powergui Block to Simulate SimPowerSystems Models

The Powergui block is necessary for simulation of any Simulink model containing SimPowerSystems blocks. It is used to store the equivalent Simulink circuit that represents the state-space equations of the SimPowerSystems blocks.

To specify the simulation type, parameters, and preferences, select Configure parameters in the Powergui dialog box. This selection opens another dialog box with the Powergui block parameters. This dialog box contains three tabs, Solver, Load Flow, and Preferences.

- The Powergui block allows you to choose one of the following methods to solve your circuit.
- Continuous, to perform a continuous solution of the model.
- Ideal switching continuous
- Discretization of the electrical system for a solution at fixed time steps
- Phasor solution to perform phasor simulation of the model, at the frequency specified by the Phasor frequency parameter.



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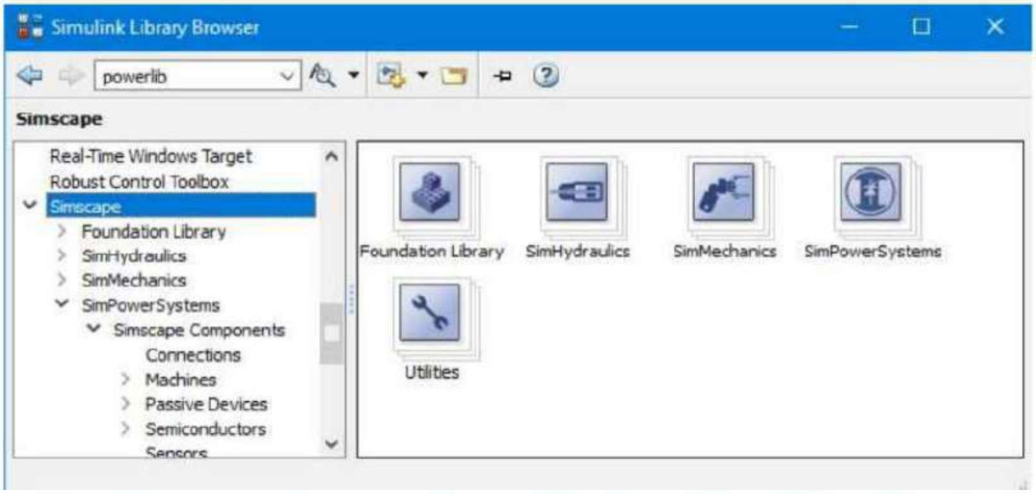
You must follow these rules when using this block in a model:

- Place the Powergui block at the top level of diagram for optimal performance. However, you can place it anywhere inside subsystems for your convenience; its functionality will not be affected.
- You can have a maximum of one Powergui block per model
- You must name the block powergui

The Powergui block also gives you access to various graphical user interface (GUI) tools and functions for the steady-state analysis of SimPowerSystems models, the analysis of simulation results and for the design of advanced block parameters.

Using the Simulink Library Browser to Access the Block Libraries

You can access SimPowerSystems libraries through the Simulink library browser. To display the library browser, click the Simulink Library button in the MATLAB toolstrip, or click the Library Browser button in the Simulink model window.



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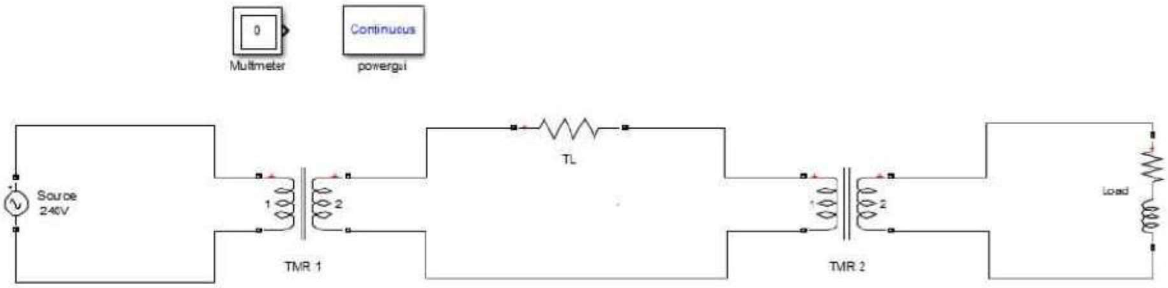
Alternatively, you can type Simulink in the MATLAB Command Window. Expand the Simscape entry in the contents tree, then expand the SimPowerSystems entry.

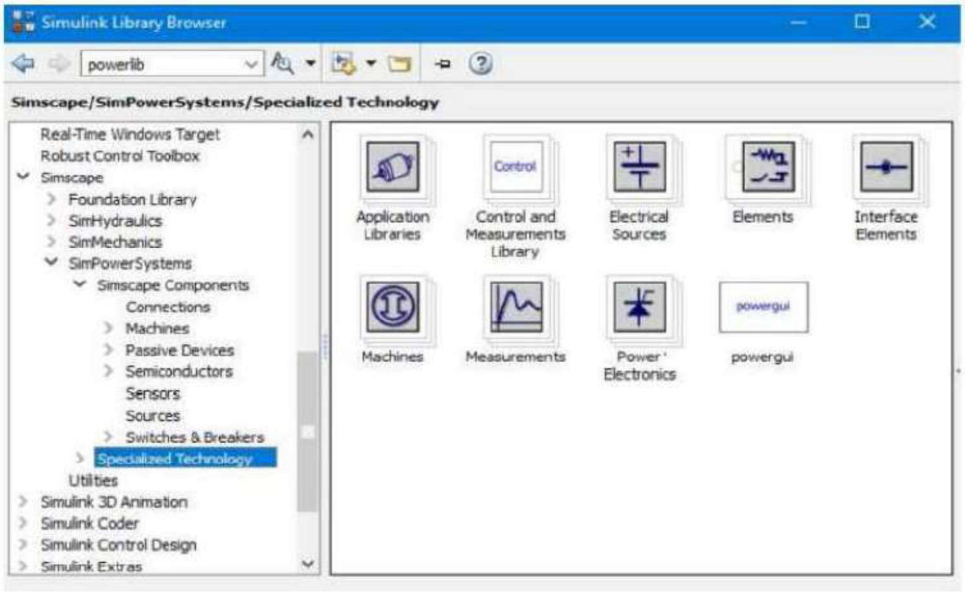
Building the Electrical Circuit with powerlib Library

The graphical user interface makes use of the Simulink functionality to interconnect various electrical components. The electrical components are grouped in a library called powerlib. Consider the following single line diagram of single-phase power system to build with powerlib library



Procedure:

- Open the SimPowerSystems main library by entering the following command in MATLAB command window.
  - powerlib
- This will open the library of the "SimPowerSystems" block set like in the figure below.
- From the File menu of the powerlib window, open a new window to contain your first circuit and save it as circuit1.



- ➢ Open the Electrical Sources library and copy the AC Voltage Source block into Circuit1 window. Open the AC Voltage Source dialog box by double-clicking the icon and enter the Amplitude, Phase, and Frequency parameters according to the values shown in circuit to be modeled.
- ➢ Now open the "Elements" library and drag "Linear Transformer" on to your model file. Open the block parameters dialog box to change its parameters according to the given circuit.
- ➢ Similarly, drop the series RLC branch, Transformer, and another R LC branch (For Load). Open their parameter dialog box to change their parameters to meet our requirements. Note that putting inductance equal to 0 and capacitance equal to infinity converts the series RLC branch to resistive branch.
- ➢ Resize the various components and interconnect blocks by dragging lines from outputs to inputs of appropriate blocks.
- ➢ Now open the dialog box of each element on the model file and change the measurements dialog in the following way:

Source:	Voltage
Transformers:	All voltages and currents
Series RLC branch:	Branch voltage and current

- ➢ Now drag "powergui" from the powerlib library on to the file.
- ➢ Place multimeter from the measurement library.
- ➢ Select Simulation > Run.
- ➢ Open the powergui by double clicking on its icon. This will show various types of analysis that are available to you to perform on the circuit. Click on the "Steady-State Voltages and Currents" for steady state analysis of system. This will open a new window in which all the steady state voltages and currents will be given.

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CONCLUSION: Study of power system blocks in MATLAB has been done.

EXPERIMENT No. 2

AIM: To design short, medium and long transmission line using MATLAB.

SOFTWARE REQUIRED: MATLAB

THEORY:

The generalized circuit constant values are depending upon the particular method adopted for solving a transmission line. Once the values of these constants are known the performance calculations of the line can be easily found out. The constants A &D are dimension less, whereas the constants B & D are having ohms & mhos respectively. In short transmission lines the effect of capacitance is neglected. So, this line is considered to have only series impedance.

$$V_s = AV_R + BI_R$$

$$I_s = CV_R + DI_R$$

TYPE	METHOD	ABCD PARAMETERS
Short	-------------------	A=D=1; B=Z; C=0.
Medium	Nominal T Method	A=D=1+YZ/2; B=Z(1+YZ/4); C=Y;
	Nominal π Method	A=D=1+YZ/2; B=Z; C=Y(1+YZ/4);
Long	Rigorous Method	A=D=cos h(γℓ); B=Z_c sin h(γℓ); C=1/Z_c sin h(γℓ); γ=√(ZY); Z_c=√(Z/Y);
	Equivalent π Method	A=D=1+YZ/2; B=Z; C=Y(1+YZ/A); Z=Z sin h(γℓ)/ γℓ; Y=Y tan h(γℓ/2)/ (γℓ/2); γ=√(ZY); Z_c=√(Z/Y);
	Equivalent T Method	A=D=1+YZ/2; B=Z; C=Y(1+YZ/A); Z=Z tan h(γℓ/2)/ (γℓ/2); Y=Y sin h(γℓ)/ γℓ; γ=√(ZY); Z_c=√(Z/Y);

Procedure:

1. Enter the command window of the MATLAB.
2. Create a new M – file by selecting File - New – M – File

3. Type and save the program in the editor window.
4. Execute the program by either pressing Tools – Run.
5. View the results.

Q.1. An overhead 3 phase transmission line delivers 4000KW at 11 KV at 0.8 pf lagging. The resistance and reactance of each conductor are 1.5Ω and 4Ω per phase. Determine the line performance.

SHORT TRANSMISSION LINE

```
clc;
clear all;
R=input('Resistance :');
XL=input('Inductive Reactance :');
XC=input('Capacitive Reactance :');
G=input('Conductance :');
length=input('Length of Transmission Line :');
f=input('Frequency :');
Z1= (R+j*XL)*length;
Y1= (G+j*XC)*length;
A = 1;
B = Z1;
C = 0;
D =1;
TM = [ A B; C D ];
VRL=input('ENTER RECEIVEING END VOLTAGE :');
VRP=VRL/(sqrt(3));
PR = input('ENTER RECEIVING END LOAD IN MW :');
Pf=input('ENTER THE RECEIVING END LOAD POWER FACTOR :');
h=acos(Pf);
SR=PR/Pf;
SR=SR*(cos(h)+j*sin(h));
QR=imag(SR);
IR=conj(SR)/(3*conj(VRP));
SM=TM*[VRP;IR];
VS=SM(1,1);
IS=SM(2,1);
Pfs=cos(angle(VS)-angle(IS));
SS=3*VS*conj(IS);
VSA=angle(VS)*(180/pi);
ISA=angle(IS)*(180/pi);
VS=sqrt(3)*abs(VS);
IS=abs(IS)*1000;
VREG=((VS/(abs(TM(1,1)))-VRL)/VRL)*100;
PS=real(SS);
QS=imag(SS);
eff=PR/PS*100;
```

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```
PL=PS-PR;
QL=QS-QR;
Z1
Y1
TM
fprintf('SENDING END LINE VOLTAGE %g at %g degrees \n',VS,VSA);
fprintf('SENDING END LINE CURRENT %g at %g degrees \n',IS,ISA);
fprintf('SENDING END POWER FACTOR %g\n',Pfs);
fprintf('SENDING END REAL POWER %g\n',PS);
fprintf('SENDING END REACTIVE POWER %g\n',QS);
fprintf('PERCENTAGE VOLTAGE REGULATION %g\n',VREG);
fprintf('REAL POWER LOSS %g\n',PL);
fprintf('REACTIVE POWER LOSS %g\n',QL);
fprintf('EFFICIENCY %G', eff);
```

OUTPUT:

```
Resistance : 1.5
Inductive Reactance : 4
Capacitive Reactance : 0
Conductance : 0
Length of Transmission Line : 1
Frequency : 50
ENTER RECEIVEING END VOLTAGE : 11
ENTER RECEIVING END LOAD IN MW : 4
ENTER THE RECEIVING END LOAD POWER FACTOR : 0.8
Z1 = 1.5000 + 4.0000i
Y1 = 0
TM = 1.0000      1.5000 + 4.0000i
          0          1.0000
SENDING END LINE VOLTAGE 12.6795 at 4.72953 degrees
SENDING END LINE CURRENT 262.432 at -36.8699 degrees
SENDING END POWER FACTOR 0.747805
SENDING END REAL POWER 4.30992
SENDING END REACTIVE POWER 3.82645
PERCENTAGE VOLTAGE REGULATION 15.2685
REAL POWER LOSS 0.309917
REACTIVE POWER LOSS 0.826446
EFFICIENCY 92.8092
```

Q. 2. A balanced 3 phase load of 30 MW is supplied at 132KV, 50Hz and 0.85 pf lag by means of a line. The series impedance is $20+j52\Omega$ and total admittance is 315*10-6Ʊ .Using Normal T method determine A,B,C,D parameters and regulation.

MEDIUM TRANSMISSION LINE

```
clc;
clear all;
R=input('Resistance :');
XL=input('Inductive Reactance :');
XC=input('Capacitive Reactance :');
G=input('Conductance :');
length=input('Length of Transmission Line :');
f=input('Frequency :');
Z1= (R+j*XL)*length;
Y1= (G+j*XC)*length;
m=menu('ENTER THE TYPE OF NETWORK','NOMINAL T', 'NOMINAL PI');
switch m
case {1}
A = 1+(Z1*Y1/2);
B=Z1*(1+(Z1*Y1/4));
C=Y1;
D=A;
otherwise
A = 1+(Z1*Y1/2);
B=Z1;
C=Y1*(1+(Z1*Y1/4));
D=A;
end
TM = [ A B; C D ];
VRL=input('ENTER RECEIVEING END VOLTAGE :');
VRP=VRL/(sqrt(3));
PR = input('ENTER RECEIVING END LOAD IN MW :');
Pf=input('ENTER THE RECEIVING END LOAD POWER FACTOR :');
h=acos(Pf);
SR=PR/Pf;
SR=SR*(cos(h)+j*sin(h));
QR=imag(SR);
IR=conj(SR)/(3*conj(VRP));
SM=TM*[VRP;IR];
VS=SM(1,1);
IS=SM(2,1);
Pfs=cos(angle(VS)-angle(IS));
SS=3*VS*conj(IS);
VSA=angle(VS)*(180/pi);
ISA=angle(IS)*(180/pi);
VS=sqrt(3)*abs(VS);
IS=abs(IS)*1000;
VREG=((VS/(abs(TM(1,1)))-VRL)/VRL)*100;
PS=real(SS);
```

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```
QS=imag(SS);
eff=PR/PS*100;
PL=PS-PR;
QL=QS-QR;
Z1
Y1
TM
fprintf('SENDING END LINE VOLTAGE %g at %g degrees \n',VS,VSA);
fprintf('SENDING END LINE CURRENT %g at %g degrees \n',IS,ISA);
fprintf('SENDING END POWER FACTOR %g\n',Pfs);
fprintf('SENDING END REAL POWER %g\n',PS);
fprintf('SENDING END REACTIVE POWER %g\n',QS);
fprintf('PERCENTAGE VOLTAGE REGULATION %g\n',VREG);
fprintf('REAL POWER LOSS %g\n',PL);
fprintf('REACTIVE POWER LOSS %g\n',QL);
fprintf('EFFICIENCY %G', eff);
```

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OUTPUT:

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```
Resistance : 20
Inductive Reactance : 52
Capacitive Reactance : 315*10^(-6)
Conductance : 0
Length of Transmission Line : 1
Frequency : 50
ENTER RECEIVEING END VOLTAGE : 132
ENTER RECEIVING END LOAD IN MW : 30
ENTER THE RECEIVING END LOAD POWER FACTOR : 0.85
Z1 = 20.0000 +52.0000i
Y1 = 0 +3.1500e-004i
TM = 0.9918 + 0.0031i    19.8362 +51.8186i
          0 + 0.0003i          0.9918 + 0.0031i
SENDING END LINE VOLTAGE 143.035 at 3.76761 degrees
SENDING END LINE CURRENT 142.007 at -23.3284 degrees
SENDING END POWER FACTOR 0.890244
SENDING END REAL POWER 31.3199
SENDING END REACTIVE POWER 16.0245
PERCENTAGE VOLTAGE REGULATION 9.25407
REAL POWER LOSS 1.31989
REACTIVE POWER LOSS -2.56785
EFFICIENCY 95.7858
```

Q. 3. A 50Hz, 3 phase, 100 km transmission line has total impedance of 35Ω, reactance of 140Ω and shunt admittance of 930*10-6 Ʊ . It delivers 40 MW at 220KV, 0.9 pf lag.Using nominal π determine A,B ,C,D Vs, VSA,ISA , pf, Ps Qs,η.

NOMINAL PI
OUTPUT:

```
Resistance : 20
Inductive Reactance : 52
Capacitive Reactance : 315*10^-6
Conductance : 0
Length of Transmission Line : 1
Frequency : 50
ENTER RECEIVEING END VOLTAGE : 132
ENTER RECEIVING END LOAD IN MW : 30
ENTER THE RECEIVING END LOAD POWER FACTOR : 0 .85
Z1 = 20.0000 +52.0000i
Y1 = 0 +3.1500e-004i
TM = 0.9918 + 0.0031i        20.0000 +52.0000i
        -0.0000 + 0.0003i        0.9918 + 0.0031i
SENDING END LINE VOLTAGE 143.099 at 3.77321 degrees
SENDING END LINE CURRENT 142.011 at -23.3709 degrees
SENDING END POWER FACTOR 0.889862
SENDING END REAL POWER 31.3214
SENDING END REACTIVE POWER 16.0584
PERCENTAGE VOLTAGE REGULATION 9.30284
REAL POWER LOSS 1.32135
REACTIVE POWER LOSS -2.53394
EFFICIENCY 95.7813
```

Q.4. The following data refers to a 3-phase overhead transmission line. The voltage is 220KV. Total series impedance /ph=200∟30˚. Total shunt admittance/ph= 0.0013∟90˚℧ . Load delivers is 100MW at 0.8pf lag. Using rigorous method determine line performance.

LONG TRANSMISSION LINE (RIGOROUS METHOD)

```
clc;
clear all;
R=input('Resistance :');
XL=input('Inductive Reactance :');
XC=input('Capacitive Reactance :');
G=input('Conductance :');
length=input('Length of Transmission Line :');
f=input('Frequency :');
z= (R+j*XL);
y= (G+j*XC); gm=sqrt(z*y);
zc=sqrt(z/y);
A=cosh(gm*length);
B=zc*sinh(gm*length);
C=1/zc *sinh(gm*length);
D=A;
```

```
TM=[A B;C D]; Z=B;
Y=2/zc*tanh(gm*length/2);
VRL=input('ENTER RECEIVEING END VOLTAGE :');
VRP=VRL/(sqrt(3));
PR = input('ENTER RECEIVING END LOAD IN MW :');
Pf=input('ENTER THE RECEIVING END LOAD POWER FACTOR :');
h=acos(Pf);
SR=PR/Pf;
SR=SR*(cos(h)+j*sin(h));
QR=imag(SR);
IR=conj(SR)/(3*conj(VRP));
SM=TM*[VRP;IR];
VS=SM(1,1);
IS=SM(2,1);
Pfs=cos(angle(VS)-angle(IS));
SS=3*VS*conj(IS);
VSA=angle(VS)*(180/pi);
ISA=angle(IS)*(180/pi);
VS=sqrt(3)*abs(VS);
IS=abs(IS)*1000;
VREG=((VS/(abs(TM(1,1)))-VRL)/VRL)*100;
PS=real(SS);
QS=imag(SS);
eff=PR/PS*100;
PL=PS-PR;
QL=QS-QR;
z
y
zc
Z
Y
TM
fprintf('SENDING END VOLTAGE %g at %g degrees \n',VS,VSA);
fprintf('SENDING END CURRENT %g at %g degrees \n',IS,ISA);
fprintf('SENDING END POWER FACTOR %g\n',Pfs);
fprintf('SENDING END REAL POWER %g\n',PS);
fprintf('SENDING END REACTIVE POWER %g\n',QS);
fprintf('PERCENTAGE VOLTAGE REGULATION %g\n',VREG);
fprintf('REAL POWER LOSS %g\n',PL);
fprintf('REACTIVE POWER LOSS %g\n',QL);
fprintf('EFFICIENCY %G', eff);
```

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OUTPUT:

```
Resistance : 35
Inductive Reactance : 197
```

```
Capacitive Reactance : 0.0013
Conductance : 0
Length of Transmission Line : 1
Frequency : 50
ENTER RECEIVEING END VOLTAGE : 220
ENTER RECEIVING END LOAD IN MW : 100
ENTER THE RECEIVING END LOAD POWER FACTOR : 0.8
z = 3.5000e+001 +1.9700e+002i
y = 0 + 0.0013i
zc = 3.9080e+002 -3.4446e+001i
Z = 3.2069e+001 +1.8895e+002i
Y = 0.0000 + 0.0013i
TM =
1.0e+002 *
0.0087 + 0.0002i    0.3207 + 1.8895i
-0.0000 + 0.0000i   0.0087 + 0.0002i
SENDING END VOLTAGE 282.874 at 16.3752 degrees
SENDING END CURRENT 232.732 at -2.03335 degrees
SENDING END POWER FACTOR 0.948829
SENDING END REAL POWER 108.192
SENDING END REACTIVE POWER 36.0088
PERCENTAGE VOLTAGE REGULATION 46.9731
REAL POWER LOSS 8.19239
REACTIVE POWER LOSS -38.9912
EFFICIENCY 92.4279
```

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<u>CONCLUSION:</u> Design of short, medium and long transmission line is done by using MATLAB.

EXPERIMENT 3

AIM: To study and calculate the transmission line parameters.

APPARATUS REQUIRED:

Sl. No.	Apparatus	Range
1.	Transmission Line Model	Different π sections
2.	Power Analyzer	-
3.	Voltmeter	0–750V AC
4.	Ammeter	0–20A AC
5.	Variac	1ϕ 0-230V AC
7.	Patch Cords/Connecting wires	As required

THEORY:

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Transmission line has four parameters – resistance, inductance, capacitance and conductance. The inductance and capacitance are due to the effect of magnetic and electric fields around the conductor. The resistance of the conductor is best determined from the manufactures data, the inductances and capacitances can be evaluated using the formula.

Inductance:
The general formula:
$L = 0.2 \ln (Dm / Ds)$
Where, Dm = geometric mean distance (GMD)
Ds = geometric mean radius (GMR)

I. Single phase 2 wire system
GMD = D
GMR = $re^{-1/4} = r'$
Where, r = radius of conductor

II. Three phase – symmetrical spacing
GMD = D
GMR = $re^{-1/4} = r'$
Where, r = radius of conductor

III. Three phase – Asymmetrical Transposed
GMD = geometric mean of the three distance of the symmetrically place conductors
$= \sqrt[3]{D_{AB} D_{BC} D_{CA}}$
GMR = $re^{-1/4} = r'$
Where, r = radius of conductors

Composite conductor lines

The inductance of composite conductor X., is given by

$L_x = 0.2 \ln (GMD/GMR)$

where, GMD = $\sqrt[mn]{(D'_{aa} D'_{ab}) \ldots\ldots (D'_{na} \ldots\ldots D'_{nm})}$

GMR = $\sqrt[n^2]{(D_{aa} D_{ab} \ldots\ldots\ldots D_{an}) \ldots\ldots (D_{na} D_{nb} \ldots\ldots D_{nn})}$

where, $r'_a = r_a e^{(-1/4)}$

Bundle Conductors:

The GMR of bundle conductor is normally calculated

GMR for two sub conductor $c = (D_s * d)^{1/2}$

GMR for three sub conductor $D_s^b = (D_s * d^2)^{1/3}$

GMR for four sub conductor $D_s^b = 1.09 (D_s * d^3)^{1/4}$

where, D_s is the GMR of each subconductor and d is bundle spacing

Three phase – Double circuit transposed:

The inductance per phase in milli henries per km is

$L = 0.2 \ln (GMD / GMR_L)$ mH/km

where, GMR_L is equivalent geometric mean radius and is given by

$GMR_L = (D_{SA} D_{SB} D_{SC})^{1/3}$

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where,

$D_{SA} D_{SB}$ and D_{SC} are GMR of each phase group and given by

$D_{SA} = \sqrt[4]{(D_S^b D_{a1a2})^2} = \sqrt{D_S^b D_{a1a2}}$

$D_{SB} = \sqrt[4]{(D_S^b D_{b1b2})^2} = \sqrt{D_S^b D_{b1b2}}$

$D_{SC} = \sqrt[4]{(D_S^b D_{c1c2})^2} = \sqrt{D_S^b D_{c1c2}}$

where, D_s^b = GMR of bundle conductor if conductor $a_1, a_2 \ldots\ldots$ are bundle conductor.

$D_s^b = r_{a1}' = r_{b1} = r_{a'2} = r_{b'2} = r_{c'2}$ if $a_1, a_2 \ldots\ldots$ are bundle conductor

GMD is the equivalent GMD per phase & is given by

$GMD = [D_{AB} * D_{BC} * D_{CA}]^{1/3}$ where, D_{AB}, D_{BC} & D_{CA} are GMD between each phase group A-B, B-C, C-A which are given by

$D_{AB} = [D_{a1b1} * D_{a1b2} * D_{a2b1} * D_{a2b2}]^{1/4}$

$D_{BC} = [D_{b1c1} * D_{b1c2} * D_{b2c1} * D_{b2c2}]^{1/4}$

$D_{CA} = [D_{c1a1} * D_{c2a1} * D_{c2a1} * D_{c2a2}]^{1/4}$

Capacitance

A general formula for evaluating capacitance per phase in micro farad per km of a transmission line is given by

$C = 0.0556 / \ln (GMD/GMR)$ μF/km

Where, GMD is the "Geometric mean distance" which is same as that defined for inductance under various cases.

PROCEDURE:

1. The AC supply is off and variac knob is at zero position
2. Make the connection according to the diagram.

3. Select the switch as you want.
4. After completion of the entire connection. connect the main cord to the panel & switch on the power supply.
5. Measure the parameters.
6. Switch off the power system.

CONCLUSION: Transmission line parameters is done and its values are ________________________.

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EXPERIMENT 4

AIM: To study the corona loss in power distribution system.

THEORY:

Corona is a type of electrical conduction that generally occurs at or near atmospheric pressure in gases. Coronas can generate audible and radio-frequency noise, particularly near electric power transmission lines. They also represent a power loss, and their action on atmospheric particulates, along with associated ozone and NOx production, can also be disadvantageous to human health where power lines run through built-up areas. Therefore, it is one of the most important factors when designing high voltage equipments. Corona's long term effect results damages in motors, transformers, capacitors by destroying their insulation.

In transmission lines, it causes power loss, audible noise, electromagnetic interference, purple glow, ozone production, etc. Hence to minimize this negative effects, the conductor surface condition, size, distance to ground and other conductors has to be considered when planning and construction of overhead power lines. In transmission of electricity ac voltages are used to transmit electric power because of their efficiency against dc voltage. The basic difference between ac and dc coronas is the periodic change in direction of the applied field under ac, and its effect on the residual space charge left over from the discharge during preceding half-cycles. In an ac corona trichel pulses, negative glow and positive glow and streamer coronas can be observed.

For calculating ac corona power losses several empirical formulas have been suggested. To calculate the fair-weather corona losses of transmission lines the very common experimental formula is Peterson's:

$$P_c = \frac{3.73K}{(D/r)^2} f.V^2 \ \ \text{kW/km}$$

where f is the frequency, V the line voltage, and D and r the phase conductor separation and radius. K is a factor depending on the ratio of the operating voltage V to the corona onset line voltage V_0.

Corona onset voltage is calculated as,

$$V_0 = E_0.r\ln(D/r) \ \ kV_{peak}$$

Here, E_0 is calculated by the empirical formula

$$E_0 = 30\delta\left(1+0.3/\sqrt{\delta r}\right) \ \ kV_{peak}/cm$$

where r is the conductor radius in cm. At standard temperature and pressure, $\delta=1$

Factors affecting corona:

The following are the factors affecting the corona:

- **Effect of supply voltage –** If the supply voltage is high corona loss is higher in the lines. In low-voltage transmission lines, the corona is negligible, due to the insufficient electric field to maintain ionization.
- **The condition of conductor surface –** If the conductor is smooth, the electric field will be more uniform as compared to the rough surface. The roughness of conductor is caused by the deposition of dirt, dust and by scratching, etc. Thus, rough line decreases the corona loss in the transmission lines.

- **Air Density Factor –** The corona loss in inversely proportional to air density factor, i.e., corona loss, increase with the decrease in density of air. Transmission lines passing through a hilly area may have higher corona loss than that of similar transmission lines in the plains because in a hilly area the density of air is low.
- **Effect of system voltage –** Electric field intensity in the space around the conductors depends on the potential difference between the conductors. If the potential difference is high, electric field intensity is also very high, and hence corona is also high. Corona loss, increase with the increase in the voltage.
- **The spacing between conductors –** If the distance between two conductors is much more as compared to the diameter of the conductor than the corona loss occurs in the conductor. If the distance between them is extended beyond certain limits, the dielectric medium between them get decreases and hence the corona loss also reduces.

Disadvantages of corona discharge:

- The undesirable effects of the corona are:
- The glow appears across the conductor which shows the power loss occur on it.
- The audio noise occurs because of the corona effect which causes the power loss on the conductor.
- The vibration of conductor occurs because of corona effect.
- The corona effect generates the ozone because of which the conductor becomes corrosive.
- The corona effect produces the non-sinusoidal signal thus the non-sinusoidal voltage drops occur in the line.
- The corona power loss reduces the efficiency of the line.
- The radio and TV interference occurs on the line because of corona effect.

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Minimizing corona:

Corona decreases the efficiency of transmission lines. Therefore, it is necessary to minimize corona. The following factors may be considered to control corona:

- **Conductor diameter –** For reducing corona loss, this method of increasing conductor diameters is very effective. Diameters of conductors can be increased by using hollow conductors and by using steel-cored aluminum conductors (ACSR) conductors.
- **The voltage of the line –** Voltage of transmission lines is fixed by economic considerations. To increase the disruptive voltage the spacing of the conductors is to be increased, but this method has some limitations.
- **Spacing between conductors –** If the space between conductors increases, then the voltage drops between them also increases due to increase in inductive reactance.

<u>**CONCLUSION**</u>: Study of CORONA in transmission line has been done.

EXPERIMENT 5

AIM: To study the proximity and skin effect.

THEORY:

Proximity Effect

- An increase in apparent resistance in a conductor causes a voltage drop and power loss. This phenomenon is called the proximity effect.
- A conductor's material, diameter, and structure all influence the intensity of the proximity effect.
- It is possible to reduce the proximity effect by reducing the size of the conductor and the frequency and by increasing the voltage and space between conductors.
- The proximity effect is present in transmission lines when conductors are too close together

Delta-connected ac transmission lines transmit three-phase ac power between substations. When conductors are too close to each other in a delta arrangement, the proximity effect is present in transmission lines. The proximity effect could be avoided by keeping conductors spaced equally. However, extending the distance between transmission lines inflates the expense of the support structures, directly affecting the efficiency of the ac power transmission. In this article, we will discuss how to reduce the influence of the proximity effect in transmission lines.

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The Proximity Effect in Transmission Lines

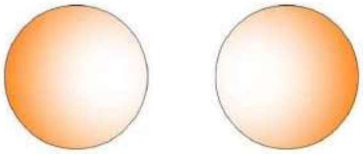
Conductors carrying alternating current will produce alternating flux in adjacent conductors. This alternating flux will cause a circulating current to start flowing in the conductor, creating a non-uniform current distribution in the transmission line, increasing the conductor's apparent resistance. The increased resistance along the transmission line causes a voltage drop and power loss. This phenomenon is called the proximity effect.

How Does the Proximity Effect Impact Transmission Lines?

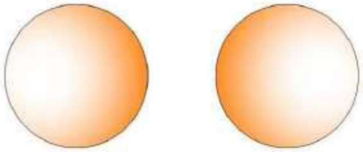
The concentration of current through adjacent conductors varies with the alternating magnetic field and its associated eddy currents. When conductors carry current in the same direction, the currents flowing through them get concentrated at the conductors' farthest side. In contrast, when currents flowing through adjacent conductor's flow in opposite directions, the currents get concentrated in the nearest side of both conductors.

As the alternating current frequency increases, the proximity effect becomes more intense. Conductors carrying 50Hz current endure less of the proximity effect than conductors carrying 60Hz current. The effective resistance and power loss is higher in 60Hz transmission lines than in 50Hz transmission lines. Most countries worldwide use 50Hz ac frequency, but the United States is not one of them. The 60Hz frequency in the transmission line causes more of the proximity effect than the 50Hz supply.

The proximity effect is due to varying magnetic fields, making it an impossible phenomenon in dc transmission. As dc frequency is zero, it fails to produce an alternating magnetic field in adjacent conductors. The current concentration remains uniform in dc transmission lines, apart from the influence of the skin effect.



Current in same direction



Current in opposite direction

🟧 Density of current

Factors Influencing the Proximity Effect

Both transmission lines and nearby conductors carrying alternating currents experience the proximity effect. In ac transformers and inductors, the windings are close enough that the proximity effect is more predominant than the skin effect. If the conductors are stranded, both the internal proximity effect and external proximity effect exist. Several factors influence the proximity effect in transmission lines, including:

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- **The conductor's material -** High ferromagnetic materials experience more proximity effects than non-ferromagnetic materials.
- **The conductor's diameter -** As the conductor's diameter increases, the proximity effect also increases. The conductor's diameter is dependent on current, and when the system current is high, the proximity effect becomes stronger.
- **Frequency -** As the frequency increases, the proximity effect becomes more intense.
- **The conductor's structure -** The proximity effect is higher in solid conductors than in stranded conductors. The decreased surface area of stranded conductors causes the proximity effect to be less than in solid conductors, which have more surface area. However, the internal proximity effect and external proximity effect exist in stranded conductors such as ACSR.

How to Reduce the Proximity Effect

Knowing the factors that create the proximity effect in transmission lines, it is possible to implement some changes. Several fixes can reduce the influence of the proximity effect, which include:

- **Reducing the size of the conductor -** The proximity effect is directly proportional to the surface area of the conductor. Therefore, as the surface area increases, the proximity effect becomes stronger. Replacing solid conductors with stranded conductors helps reduce the conductor's surface area, decreasing the proximity effect.
- **Increasing the space between conductors -** Dummy conductors can help increase the space between conductors. However, this will come at an added cost in support structures.
- **Increasing voltage and reducing frequency -** Transferring power constantly through transmission lines increases voltage and decreases current—the reduced size of conductors decreases the proximity effect. Although not as practical, reducing the transmission voltage and current frequency is another means of reducing the proximity effect.

The proximity effect in transmission lines is a limitation in electrical ac power transmission. The proximity effect is present not only in high voltage systems, but also in medium and low voltage systems.

Skin Effect

The phenomena arising due to unequal distribution of current over the entire cross section of the conductor being used for long distance power transmission is referred as the skin effect in transmission lines. Such a phenomena does not have much role to play in case of a very short line, but with increase in the effective length of the conductors, skin effect increases considerably. So the modifications in line calculation needs to be done accordingly.

The distribution of current over the entire cross-section of the conductor is quite uniform in case of a DC system. But what we are using in the present era of power system engineering is predominantly an alternating current system, where the current tends to flow with higher density through the surface of the conductors (i.e., the skin of the conductor), leaving the core deprived of a necessary number of electrons.

In fact, there even arises a condition when absolutely no electric current flows through the core, and concentrating the entire amount on the surface region, thus increasing the effective electrical resistance of the conductor. This particular trend of an AC transmission system to take the surface path for the flow of current depriving the core is referred to as the skin effect in transmission lines.

Why Skin Effect Occurs in Transmission Lines?

Having understood the phenomena of skin effect let us now see why this arises in case of an AC system. To have a clear understanding of that look into the cross-sectional view of the conductor during the flow of alternating current given in the diagram below.

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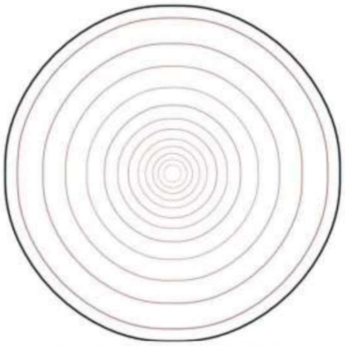


Cross Sectional View of a Conductor

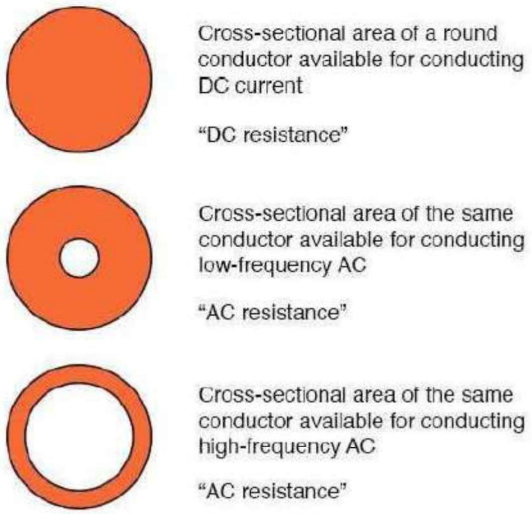
Let us initially consider the solid conductor to be split up into some annular filaments spaced infinitely small distance apart, such that each filament carries an infinitely small fraction of the total current.

Like if the total current = I

Let us consider the conductor to be split up into n filament carrying current 'i' such that I = n i.

Now during the flow of an alternating current, the current carrying filaments lying on the core has a flux linkage with the entire conductor cross-section including the filaments of the surface as well as those in the core. Whereas the flux set up by the outer filaments is restricted only to the surface itself and is unable to link with the inner filaments. Thus, the flux linkage of the conductor increases as we move closer towards the core and at the same rate increases the inductance as it has a direct proportionality relationship with flux linkage.

As a result, a larger inductive reactance gets induced into the core as compared to the outer sections of the conductor. The high value of reactance in the inner section results in the current gets distributed in an un-uniform manner and forcing the bulk of the current to flow through the outer surface or skin giving rise to the phenomena called **skin effect in transmission lines**.



Skin Effect in AC Conduction

For Direct Current through a wire, the resistance of the wire can be calculated from its length, diameter and resistivity since it may be assumed that the electric current is essentially uniform over the cross-section of the wire. However, for Alternating Current, the interaction of electric and magnetic fields in the conductor distributes the current preferentially to the outside of the wire. This skin effect increases with frequency so that for high Radio Frequencies (RF) a thin outside layer of the conductor carries essentially all the current.

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The AC current density J drops exponentially from the outside radius in a way that can be quantified in terms of a parameter called the "skin depth" δ:

$$J = J_S e^{-d/\delta}$$

where J_S is the current density at the surface and d is the depth beneath the surface. The skin depth δ can be calculated from:

where,
ρ = electrical resistivity
ω = angular frequency = 2πf
μ = magnetic permeability

The skin effect becomes a major consideration in RF circuits. From the exponential nature of the drop in current density, you can show that 63% of the current will flow within one skin depth δ of the surface and 98% will flow within 4δ of the surface. For frequencies above 100MHz it is wasteful of conductive metals to use solid conductors, so multiconductor straps or tubing can be used to utilize the larger surface areas.

Factors affecting skin effect

- **Frequency –** Skin effect increases with the increase in frequency.
- **Diameter –** It increases with the increase in diameter of the conductor.

- **The shape of the conductor –** Skin effect is more in the solid conductor and less in the stranded conductor because the surface area of the solid conductor is more.
- **Type of material –** Skin effect increase with the increase in the permeability of the material (Permeability is the ability of material to support the formation of the magnetic field).

The Skin effect is negligible if the frequency is less than the 50Hz and the diameter of the conductor is less than the 1cm. In the stranded conductors like ACSR (Aluminium Conductor Steel Reinforced) the current flows mostly in the outer layer made of aluminum, while the steel near the center carries no current and gives high tensile strength to the conductor. The concentration of current near the surface enabled the use of ACSR conductor.

CONCLUSION: Study of skin effect and proximity effect has been done.

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EXPERIMENT 6

AIM: To find ABCD parameters of a model of transmission line.

APPARATUS REQUIRED: Connecting Leads

THEORY:

The transmission lines which have length less than 80 km are generally referred as **short transmission lines**. For short length, the shunt capacitance of this type of line is neglected and other parameters like electrical resistance and inductor of these short lines are lumped. *(Note: - same procedure for medium and long transmission line also)*

1. Open Circuit the Output Terminal

Procedure:

1. The AC supply is off and variac knob is at zero position
2. Make the connection according to the diagram.
3. Measure the sending end receiving end current and voltage respectively with the help of switch S1, S2, S3.
   S1 Switch: Simultaneously get sending end and receiving end voltage, current, active, reactive, apparent power and power factor.
   S2 Switch: get sending end and receiving end active, reactive, apparent power.
   S3 Switch: get sending end and receiving end voltage, current, and power factor.
4. Select the switch as you want.
5. After completion of the entire connection, connect the main cord to the panel & switch on the power supply.
6. With the help of variac adjust the voltage up to 110 volt.
7. Now by using the values of Vs, Is, & Vr we can easily calculate the dimensionless coefficient A and admittance C.
8. Switch off the power system.

Observation Table:

S.No	Sending End Current(Is)	Sending End Voltage(Vs)	Receiving End Current(Ir)	Receiving End Voltage(Vr)

Dimensionless Coefficient (A) = Vs/Vr
Admittance C = Is/Vr

2. Short Circuit the Output Terminal

Procedure:

1. Short line connection remains same; you have to just short output terminal.
2. Measure the sending end receiving end current and voltage respectively with the help of switch S1,S2,S3 .
   S1 Switch: Simultaneously get sending end and receiving end voltage, current, active, reactive,

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apparent power and power factor.

S2 Switch: get sending end and receiving end active, reactive, apparent power.

S3 Switch: get sending end and receiving end voltage, current, and power factor.

3. Select the switch as you want.
4. After completion of the entire connection ,connect the main cord to the panel & switch on the power supply.
5. With the help of variac adjust the voltage up to 110 volts.
6. In short test you will get Vs, Is, Ir values and the values of Vr is zero because output terminal is short circuited.
7. By using their values easily find short transmission line Impedance Band Dimensionless Coefficient D.
8. Switch off the power supply.

Observation Table:

S.No	Sending End Current(Is)	Sending End Voltage(Vs)	Receiving End Current(Ir)	Receiving End Voltage(Vr)

Impedance (B) = Vs/Ir

Dimensionless Coefficient (D)= Is/Ir

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CONCLUSION: ABCD parameters of a model of transmission line calculation is done and its values are ____________________________________

EXPERIMENT 7

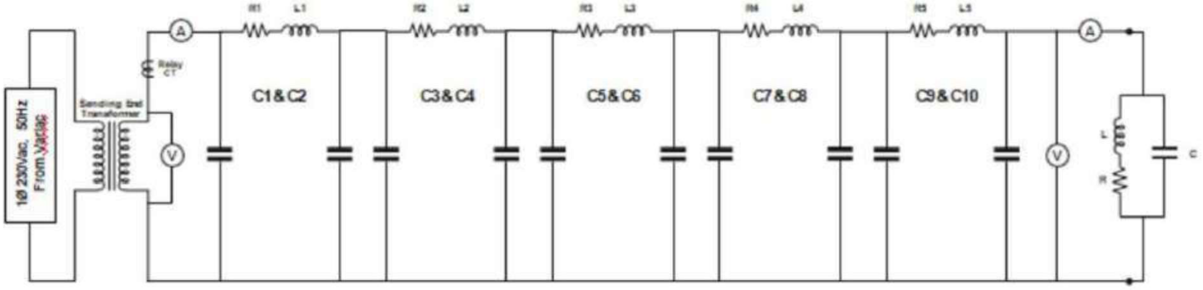
AIM: To study performance of a transmission line under no load condition & under load at different power factors.

APPARATUS REQUIRED:

Sl. No.	Apparatus	Range
1.	Transmission Line Model	Different π sections
2.	Power Analyzer	-
3.	Voltmeter	0–750V AC
4.	Ammeter	0–20A AC
5.	Variac	1ϕ 0-230V AC
7.	Patch Cords/Connecting wires	As required

THEORY:

The performance of a power system is mainly dependent on the performance of the transmission lines in the system. It is necessary to calculate the voltage, current and power at any point on a transmission line provided the values at one point are known. The transmission line performance is governed by its four parameters - series resistance and inductance, shunt capacitance and conductance. All these parameters are distributed over the length of the line. The insulation of a line is seldom perfect and leakage currents flow over the surface of insulators especially during bad weather. This leakage is simulated by shunt conductance. The shunt conductance is in parallel with the system capacitance. Generally, the leakage currents are small and the shunt conductance is ignored in calculations.



Performance of transmission lines is meant the determination of efficiency and regulation of lines. The efficiency of transmission lines is defined as

$$\%\, efficency\ (\eta) = \frac{Power\ delivered\ at\ the\ receiving\ end}{Power\ sent\ from\ the\ sending\ end} * 100$$

The end of the line where load is connected is called the receiving end and where source of supply is connected is called the sending end.

$$\%\, regulation\ = \frac{\left|V_{r(No\ load)}\right| - \left|V_{r(load)}\right|}{\left|V_{r(load)}\right|} * 100$$

The Regulation of a line is defined as the change in the receiving end voltage, expressed in percent of full load voltage, from no load to full load, keeping the sending end voltage and frequency constant.

PROCEDURE:

1. Connect mains cable to 230VAC. Single phase supply with proper earth connection.
2. Keep MAINS MCB in OFF position and the variac in Zero position.
3. Make the connection as per circuit diagram shown in fig.
4. Switch on MAINS+CONTROL MCB. All the meters will glow.
5. Put both the relays to UNHEALTHY state.
6. Select the values of line inductance and capacitance as required.
7. Initially keep all the loads to OFF state
8. Press CB-1 ON and CB-2 ON push button
9. Set the voltage of sending end to required level (say 220V) by varying variac-1.
10. Note down the reading of sending end and receiving end voltage, current, and power.
11. Apply loads gradually and note down the readings.
12. Tabulate the readings and calculate efficiency and regulation of the line.
13. Repeat the same for different values of line parameters.

OBSERVATION TABLE:

S.No.	Sending End			Receiving End			Efficiency	Regulation
	Voltage (Vs)	Current (Is)	Power (P)	Voltage (Vs)	Current (Is)	Power (P)		

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CONCLUSION: Performance of a transmission line calculation is done and its values are ________________________________

EXPERIMENT 8

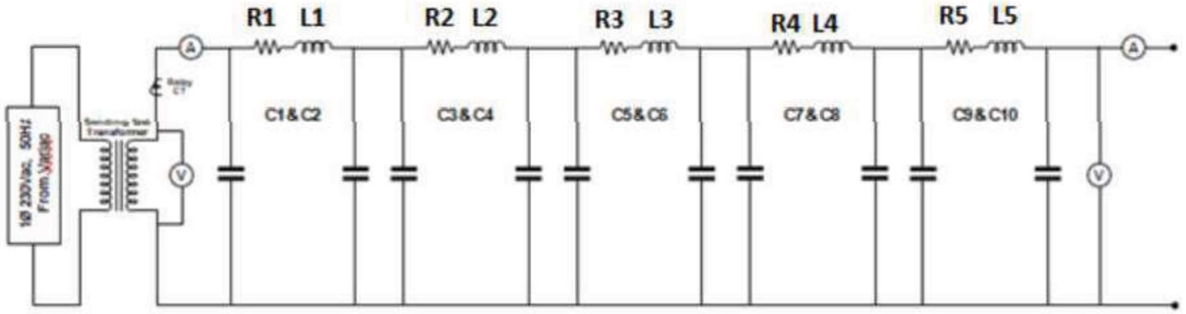
AIM: To observe the Ferranti effect in a model of transmission line.

APPARATUS REQUIRED:

S. No.	Equipments	Quantity
1	Three phase alternator rating: 400V, 5kVA, and 1500 rpm.	1
2	Ammeter	1
3	Voltmeter	1
4	Rheostat	1

THEORY:

Long transmission line/cables draw a substantial quantity of charging current. If such a line/cable is open circuited or very lightly loaded at the receiving end, the voltage at receiving end may become greater than voltage at sending end due to capacitive reactance. This is known as Ferranti Effect. Both capacitance and inductance are responsible to produce this effect. The capacitance (which is responsible for charging current) is negligible in short line but significant in medium line and appreciable in long line. Hence, this phenomenon occurs in medium and long lines. The figure shown below is representing a transmission line by an equivalent pi (π)-model. The voltage rise is proportional to the square of the line length.



In general practice we know, that for all electrical systems current flows from the region of higher potential to the region of lower potential, to compensate for the electrical potential difference that exists in the system. In all practical cases the sending end voltage is higher than the receiving end, so current flows from the source or the supply end to the load. But Sir S. Z. Ferranti, in the year 1890, came up with an astonishing theory about medium and long-distance transmission line suggesting that in case of light loading or no-load operation of transmission system, the receiving end voltage often increases beyond the sending end voltage, leading to a phenomena known as Ferranti Effect in Power System.

A long transmission line can be considered to compose a considerably high amount of capacitance and inductor distributed across the entire length of the line. Ferranti Effect occurs when current drawn by the distributed capacitance of the line itself is greater than the current associated with the load at the receiving end of the line (during light or no load).

This capacitor charging current leads to voltage across the line inductor of the transmission system which is in phase with the sending end voltages. This voltage drop keeps on increasing additively as we move towards the load end of the line and subsequently the receiving end voltage tends to get larger than applied voltage leading to the phenomena called Ferranti Effect.

PROCEDURE:

1. Connect mains cable to 230VAC, Single phase supply with proper earth connection.
2. Keep MAINS MCB in OFF position and the variac in Zero position.
3. Make the connection as per circuit diagram shown in fig.
4. Switch on MAINS+CONTROL MCB. All the meters will glow.
5. Put both the relays to UNHEALTHY state.
6. Select the values of line inductance and capacitance as required.
7. Set the voltage of sending end to required level by varying variac-1.
8. Note down the reading of sending end and receiving end voltage, current, and power.
9. You can observe that the receiving end voltage will be higher than sending end voltage.
10. Note down the value for different sending end voltage readings.
11. The receiving end voltage will be higher than sending end.

OBSERVATION TABLE:

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S.No.	Sending End Voltage		Receiving End Voltage	

CONCLUSION: Ferranti effect of a transmission line has been observed.

EXPERIMENT 9

AIM: To study performance characteristics of typical DC distribution system in radial & ring main configuration.

APPARATUS REQUIRED:

- Main Cord
- Patch Cords
- 40W bulbs (5)

Radial System

THEORY:

Whole of the power system can be subdivided in to number of radial feeders fed from one end. Generally, such radial feeders are protected by over current and earth fault relays used as primary relays for 11 kV and 66 kV lines. For lines of voltage rating beyond 66 kV, distance protection is applied as a primary protection whereas over current and earth fault relays are used as back up relays.

A simplified radial feeder network without transformers (in actual practice transformers do exist at substations) is shown in single line diagram of fig. below. If the fault occurs in distribution network, fuse should isolate the faulty section. Should the fuse fail, relay R3 shall give back-up protection. Relays R1, R2, and R3 act as primary relays for faults in section I, section I, and section III respectively. If fault in section III is not cleared by relaying scheme at relaying point R3, relay R2 will act as a back-up. Similarly, back-up protection is provided by relay R1 for faults in section II. A, B, C and D are substations in fig.

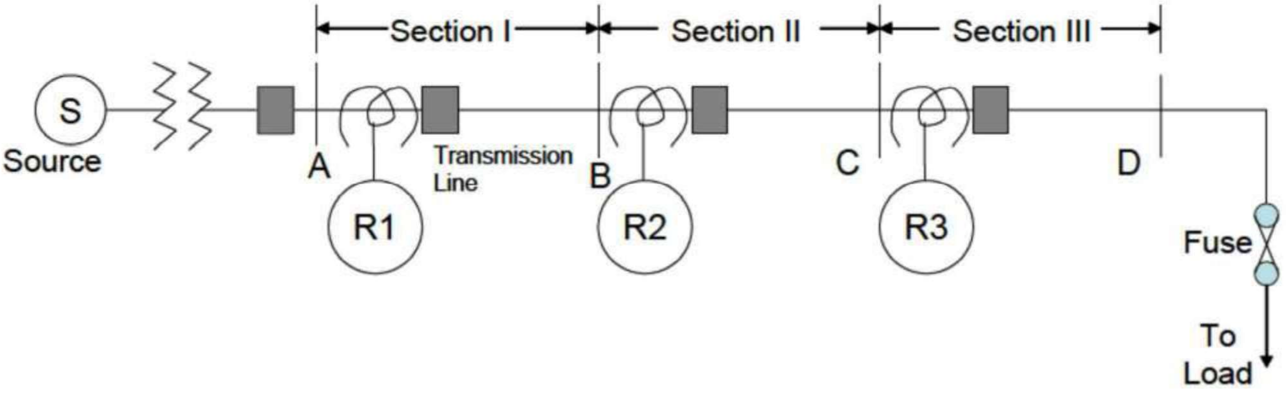

Fig. A Typical Radial Transmission Line

PROCEDURE:

1. Frist of all make sure that the earthing of your laboratory is proper and connected to the terminal provided on back side of the panel.
2. Make sure that the variac knob is at zero position.
3. Make the connection according to Diagram.
4. Now insert 40W bulbs into bulb holders.

5. Now switch ON the AC mains and MCB of your trainer.
6. Now vary the knob of variac up to 220V.
7. Switch ON all the toggle switches S1,S2,S3,S4 and S5.(Upward direction).
8. You will observe all the bulbs in Radial Distribution section will glow. That means all the connections are right.
9. Now put the variac knob at zero position.
10. Connect voltmeter terminal V4 to –(ve) terminal of Consumer4.
11. Now insert one end of patch cord to V3 terminal & second end will connect to measured terminals.
12. 12.Once again vary the knob of variac up to 220V.
13. Now observe the voltage drop in each Consumer terminal and note the readings.
14. Put the variac knob at zero postion.
15. Switch Off the mains and remove all the connection and bulbs.

OBSERVATION TABLE:

S.No.	V1 Source Voltage	V2 Consumers Voltage	I1 Source Current
Consumer1			
Consumer2			
Consumer3			
Consumer4			
Consumer5			

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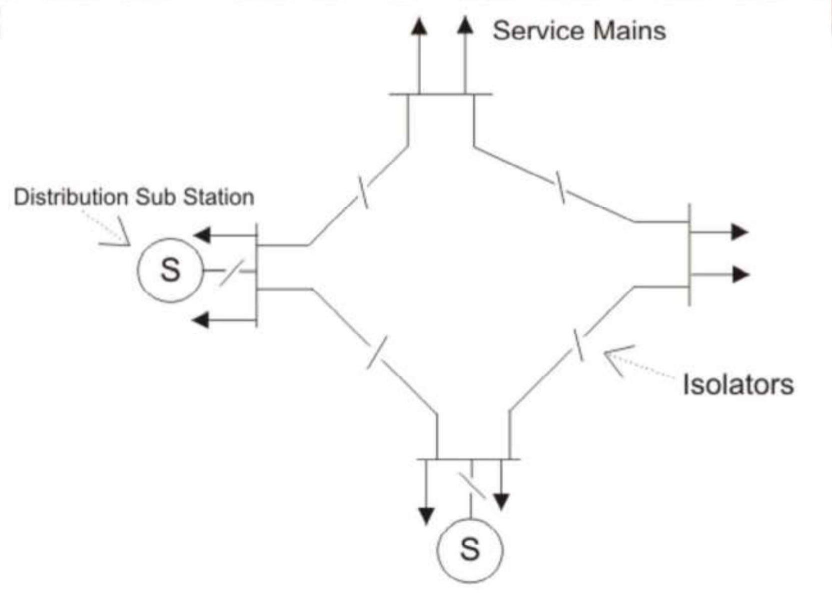
Ring Mains System

THEORY:



one ring network of distributors is fed by more than one feeder. In this case if one feeder is under fault or maintenance, the ring distributor is still energized by other feeders connected to it. In this way the supply to the consumers is not affected even when any feeder becomes out of service. In addition to that the ring main system is also provided with different section isolates at different suitable points.

If any fault occurs on any section, of the ring, this section can easily be isolated by opening the associated section isolators on both sides of the faulty zone.

PROCEDURE:

1. Frist of all make sure that the earthing of your laboratory is proper and connected to the terminal provided on back side of the panel.
2. Make sure that the variac knob is at zero position.
3. Make the connection according to Diagram.
4. Now insert 40W bulbs into bulb holders.
5. Now switch ON the AC mains and MCB of your trainer.
6. Now vary the knob of variac up to 220V.
7. Switch ON all the toggle switches S1,S2,S3,S4 and S5.(Upward direction).
8. You will observe all the bulbs in Radial Distribution section will glow. That means all the connections are right.
9. Now put the variac knob at zero position.
10. Connect voltmeter terminal V6 to –(ve) terminal of Consumer4.
11. Now insert one end of patch cord to V5 terminal & second end will connect to measured terminals.
12. Once again vary the knob of variac up to 220V.
13. Now observe the voltage drop in each Consumer terminal and note the readings.
14. Put the variac knob at zero postion.
15. Switch Off the mains and remove all the connection and bulbs.

OBSERVATION TABLE:

S.No.	V1 Source1 Voltage	V2 Source2 Voltage	V3 Consumers Voltage	I1 Source1 Current	I2 Source2 Current
Consumer1					
Consumer2					
Consumer3					
Consumer4					
Consumer5					

CONCLUSION: Performance characteristics of typical DC distribution system in radial & ring main configuration has been studied.

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EXPERIMENT 10

AIM: To study mechanical design of transmission line.

THEORY:

Electric power can be carried either by underground cables or overhead transmission and distribution lines. The underground cables are not typically used for power transmission due to two reasons.

- Power is carried over long distances to remote load centres. Obviously, the installation costs for underground transmission will be huge.
- Electric power has to be transferred at high voltages for economic reasons. It is very difficult to achieve proper insulation to the cables to withstand higher pressures.

Therefore, power transfer over long distances is done by using overhead lines. With the power demand increase and consequent voltage level rise, power transmission by overhead lines has assumed significant importance. Nevertheless, an overhead line is subjected to various weather conditions and other external interferences. This asks for the use of adequate mechanical safety factors in order to ensure the continuity of line operation. Typically, the strength of the line needs to be such so it can withstand the worst probable weather conditions. This course focuses on the different aspects of mechanical design of overhead lines.

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Overhead line main components

An overhead line may be used to transfer or distribute electric power. The proper overhead line operation depends to a big extent upon its mechanical design. While constructing an overhead line, it has to be verified that line mechanical strength is such so as to provide against the most probable weather conditions. Typically, the main elements of an overhead line are:

- Conductors which transfer power from the sending end station to the receiving end station.
- Supports which may be poles or towers. They keep the conductors at an appropriate level above the earth.
- Insulators that are connected to supports and insulate the conductors from the earth.
- Cross arms which give support to the insulators.
- Miscellaneous elements such as phase plates, danger plates, surge arrestors, etc.

The overhead line operation continuity depends upon the judicious selection of above elements.

Overhead line conductor materials

The conductor is one of the crucial items as most of the financial outlay is invested for it. Hence, correct selection of conductor material and size is of significant importance. The conductor material used for transmission and distribution of electric power needs to have the following characteristics:

- High tensile strength in order to sustain mechanical stresses
- High electrical conductivity
- Low specific gravity so that weight per unit volume is small
- Low cost so that it can be used for considerable distances

All above demands cannot be found in a single material. Hence, while choosing a conductor material for a particular application, a compromise is made between the cost and the needed electrical and mechanical characteristics.

Typically used conductor materials

Typically used conductor materials for overhead lines are copper, aluminium, steel-cored aluminium, galvanised steel and cadmium copper. The selection of a particular material is dependent on the cost, the needed electrical and mechanical characteristics and the local conditions. All conductors used for overhead lines are typically stranded in order to increase the flexibility. In stranded conductors, there is typically one central wire and around it, successive layers of wires containing 6, 12, 18, 24 ...... wires. Therefore, if there are n layers, the overall number of individual wires is $3n(n+1)+1$. In the production process of stranded conductors, the consecutive layers of wires are twisted or spiralled in different directions so that layers are bound together.

A) Copper

Copper is perfect material for overhead lines owing to its great electrical conductivity and increased tensile strength. It is typically used in the hard drawn form as stranded conductor. Even though hard drawing slightly decreases the electrical conductivity, it considerably increases the tensile strength. Copper has great current density. For example, the current carrying capacity of copper per unit of cross-sectional area is significant. This leads to two benefits. Firstly, smaller conductor cross-sectional area is needed and secondly, the area offered by the conductor to wind loads is decreased. Also, this metal is homogeneous, durable and has big scrap value. There is no doubt that copper is perfect material for electric power transmission and distribution. Nevertheless, due to its big cost and non-availability, it is not often used for these purposes. Current trend is to use aluminium instead of copper.

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B) Aluminium

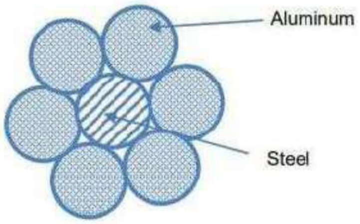
Aluminium is cheap and light in comparison to copper but it has considerably smaller conductivity and tensile strength. The relative comparison of the two materials is as follows:

- The aluminium conductivity is 60% that of copper. The lower aluminium conductivity means that for any specific transmission efficiency, the conductor cross-sectional area must be bigger in aluminium than in copper. For the same resistance, the aluminium conductor diameter is around 1.26 times the copper conductor diameter. The increased aluminium cross-section exposes a bigger surface to wind pressure and, hence, supporting towers have to be designed for greater transverse strength. Typically, this requires the use of higher towers with consequence of bigger sag.
- The aluminium specific gravity (2.71 gm/cc) is lower than that of copper (8.9 gm/cc). Hence, an aluminium conductor has almost one-half the weight of equivalent copper conductor. Due to this, the supporting structures for aluminium need not be made so strong as that of copper conductor.
- Aluminium conductor being light is liable to bigger swings and therefore bigger cross-arms are needed.
- Due to lower tensile strength and bigger co-efficient of linear expansion of aluminium, the sag is bigger in aluminium conductors.

Considering the overall characteristics that include cost, conductivity, tensile strength, weight etc., aluminium has an edge over copper. Hence, it is being predominantly used as a conductor material. It is especially profitable to use aluminium for heavy-current transmission where the conductor size is big and its cost forms a significant proportion of the total cost of complete installation.

C) Steel-cored aluminium

Due to low tensile strength, aluminium conductors have bigger sag. This forbids their application for bigger spans and makes them unsuitable for long distance transmission. In order to improve the tensile strength, the aluminium conductor is strengthened with a core of galvanised steel wires. The obtained composite conductor is known as steel-cored aluminium or ACSR (aluminium conductor steel reinforced). Steel-cored aluminium conductor has galvanised steel central core surrounded by a number of aluminium strands. Typically, diameter of both steel and aluminium wires is the same. Typically, the cross-section of the two metals is in the ratio of 1:6 but can be modified to 1:4 in order to get more conductor tensile strength. Figure 1. presents steel-cored aluminium conductor having one steel wire surrounded by six aluminium wires. The result of this composite conductor is that steel core takes bigger percentage of mechanical strength while aluminium strands transfer the bulk of current.



The steel-cored aluminium conductors have the following benefits:

- The reinforcement with steel improves the tensile strength but at the same time keeps the composite conductor light. Hence, steel-cored aluminium conductors will create smaller sag and therefore longer spans can be used.
- Due to smaller sag with steel-cored aluminium conductors, towers of smaller heights can be installed.

D) Galvanised steel

Steel has considerable tensile strength. Hence, galvanised steel conductors can be applied for long spans or for short line sections exposed to significantly high stresses due to climatic conditions. They are considered as very suitable in rural locations where cheapness is the main issue. Due to steel poor conductivity and high resistance, such conductors are not appropriate for transferring large power over a long distance. Nevertheless, they can be used to advantage for transferring a small power over a small distance where the size of the copper conductor desirable from economic considerations would be too small and therefore inappropriate for use because of poor mechanical strength.

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E) Cadmium copper

The conductor material now being used in specific installations is copper alloyed with cadmium. An addition of 1% or 2% cadmium to copper improves the tensile strength by roughly 50% and the conductivity is only decreased by 15% below that of pure copper. Hence, cadmium copper conductor can be useful for extremely long spans. Nevertheless, due to cadmium high cost, such conductors will be economical only for lines of small cross-section i.e., where the cost of conductor material is relatively small in comparison with the support cost.

Line supports

The supporting structures for overhead line conductors are different pole and tower types called line supports. Typically, the line supports should have the following characteristics:

- Light in weight without the loss of mechanical strength
- Big mechanical strength to sustain the conductor weight and wind loads etc.
- Longer life span
- Easy conductor accessibility for maintenance
- Cheap in cost and economical to service

The line supports used for electric power transmission and distribution are of different types including wooden poles, steel poles, RCC poles and lattice steel towers. The selection of supporting structure for a specific case is dependent upon the line span, cross-sectional area, line voltage, cost and local circumstances.

A) Wooden poles

They are made of seasoned wood and are appropriate for lines of moderate cross-sectional area and of shorter spans, say up to 50 metres. Such supports are cheap, easily available, provide insulating features and, hence, are widely used for distribution applications in rural locations as an economical proposition. Typically, the wooden poles tend to rot below the earth level, causing foundation failure. In order to avoid this, the portion of the pole below the earth level is impregnated with preservative substances like creosote oil. Double pole arrangements of the 'A' or 'H' type are typically used (Figure 2.) to obtain a bigger transverse strength than could be economically provided by means of single poles. The main disadvantages to wooden supports are:

- Tendency to rot below the earth level
- Relatively smaller life (20-25 years)
- Cannot be used for voltages above 20 kV
- Decreased mechanical strength
- Need occasional inspection

B) Steel poles

The steel poles are typically used as a substitute for wooden poles. They have bigger mechanical strength, longer life and allow longer spans. Typically, such poles are used for distribution purposes in the cities. These supports need to be galvanised or painted in order to extend their life. The steel poles are of three types:

- Rail poles
- Tubular poles
- Rolled steel joints

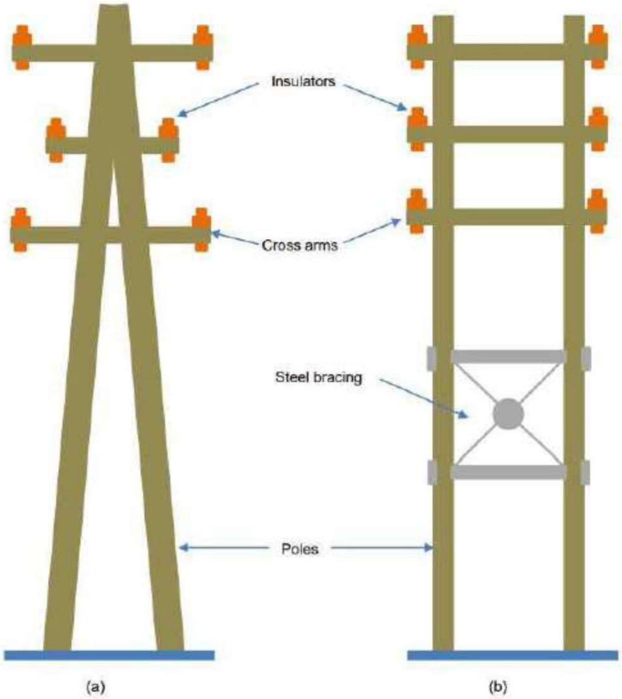

Figure 2. Wooden poles

C) RCC poles

The reinforced concrete poles have recently become popular as line supports. They have bigger mechanical strength, longer life and allow longer spans than steel poles. Nevertheless, they give good outlook, need little maintenance and have good insulating features. Figure 3 presents RCC poles for single and double circuit. The holes in the poles allow climbing of poles and at the same time decrease the line support weight. The main issue with the use of these poles is the high transport cost owing to their heavy weight. Hence, such poles are typically produced at the site in order to avoid big transportation cost.

D) Steel towers

In reality, wooden, steel and reinforced concrete poles are used for distribution installations at low voltages, say up to 11 kV. Nevertheless, for long distance transmission at higher voltage, steel towers are invariably used. Steel towers have bigger mechanical strength, longer life, can sustain most severe climatic conditions and allow the use of longer spans. The risk of interrupted operation due to broken or punctured insulation is significantly decreased owing to longer spans. Typically, tower footings are earthed by driving rods into the ground. This decreases the lightning troubles as each tower acts as a lightning conductor.

Figure 4(a) shows a single circuit tower. Nevertheless, at a moderate extra cost, double circuit tower can be provided as presented in Figure 4(b). The double circuit has the benefit that it ensures continuity of supply. In situation there is breakdown of one circuit, the continuity of supply can be kept by the other circuit.

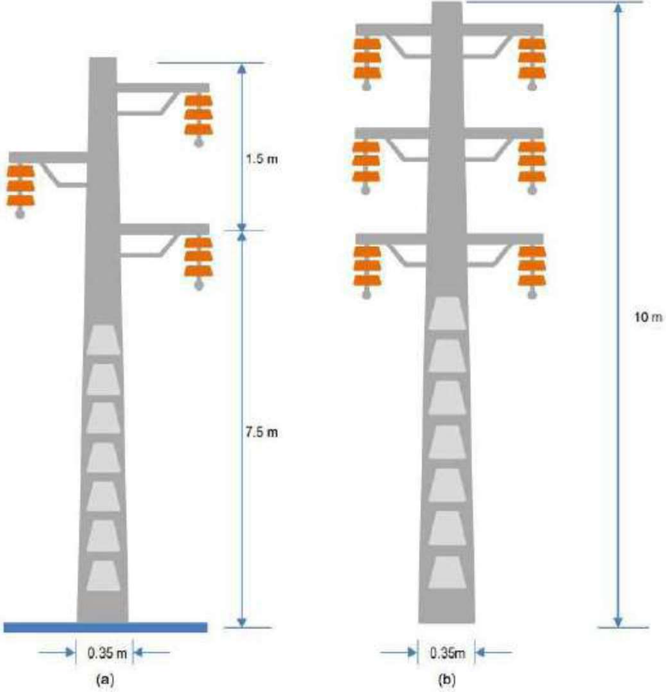

Figure 3. (a) single circuit (b) double circuit

Insulators

The overhead line conductors need to be supported on the poles or towers in such a way that conductor currents do not flow to ground through supports for example, line conductors have to be adequately insulated from supports. This is accomplished by securing line conductors to supports with the help of insulators. The insulators give necessary insulation between line conductors and supports and therefore prevent any leakage current from conductors to ground. Typically, the insulators need to have the following desirable features:

- Big mechanical strength in order to sustain conductor load, wind load etc.
- Big insulator material electrical resistance in order to avoid leakage currents to ground.
- Big insulator material relative permittivity in order that dielectric strength is high.
- The insulator material needs to be non-porous, free from impurities and cracks otherwise the permittivity will be decreased.
- Big ratio of puncture strength to flashover.

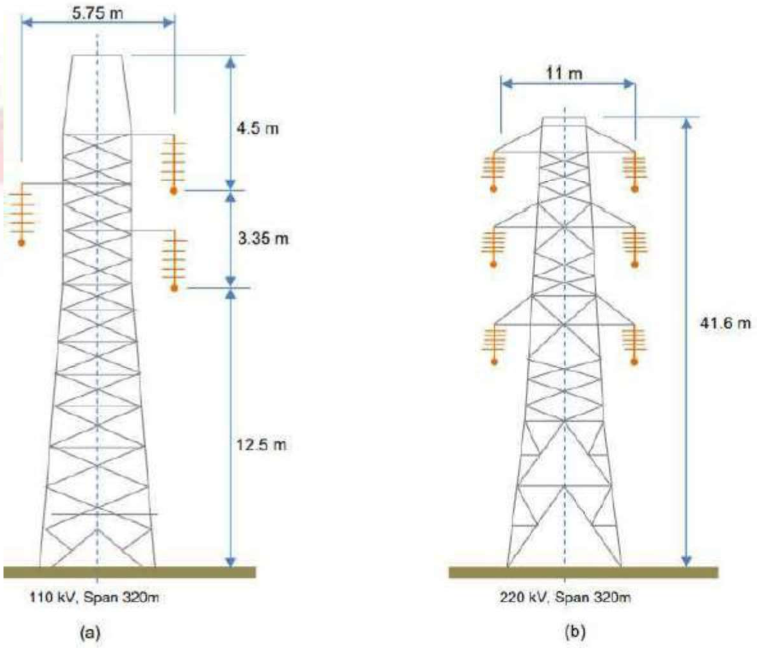

Figure 4. Steel towers (a) single circuit (b) double circuit

The most typically used material for insulators of overhead line is porcelain but glass, steatite and specific composition materials are also applied to a certain extent. Porcelain is made by firing at a high temperature a mixture of kaolin, feldspar and quartz. It is mechanically stronger than glass, gives less trouble from leakage and is less impacted by temperature changes.

Insulator Types

The proper overhead line operation depends to a significant extent upon the adequate selection of insulators.

There are few insulator types but the most typically used are pin type, suspension type, strain insulator and shackle insulator.

A) Pin type insulators

The section of a pin type insulator is presented in Figure 5. As the name implies, the pin type insulator is linked to the pole cross-arm. There is a groove on the insulator upper end for housing the conductor. The conductor goes through this groove and is bound by the annealed wire of the same material as the conductor. Pin type insulators are used for electric power transmission and distribution at voltages up to 33 kV. Above operating voltage of 33 kV, the pin type insulators become too bulky and therefore uneconomical. Insulators are required to sustain both mechanical and electrical stresses. The electrical stress is caused by line voltage and may cause the insulator breakdown. The insulator electrical breakdown can happen either by flash-over or puncture. In flashover, an arc happens between the line conductor and insulator pin (i.e., ground) and the discharge jumps across the air gaps, following shortest distance. Figure 6 presents the arcing distance (a+b+c) for the insulator. In case of flash-over, the insulator will continue to act in its adequate capacity unless extreme heat generated by the arc destroys the insulator. In case of puncture, the discharge occurs from conductor to pin through the body of the insulator. When such breakdown happens, the insulator is completely destroyed due to significant heat. In reality, proper thickness of porcelain is provided in the insulator to prevent puncture by the line voltage. The ratio of puncture strength to flashover voltage is known as safety factor:

$$Safety\ factor\ of\ insulator = \frac{Puncture\ strength}{Flash - overvoltage}$$

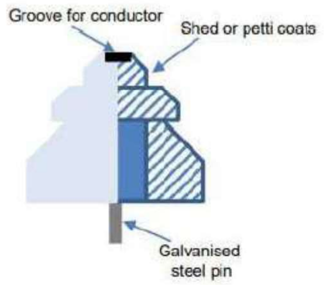

Figure 5. Pin-type insulator

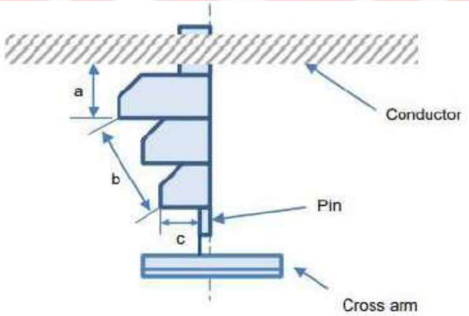

Figure 6. Arcing distance

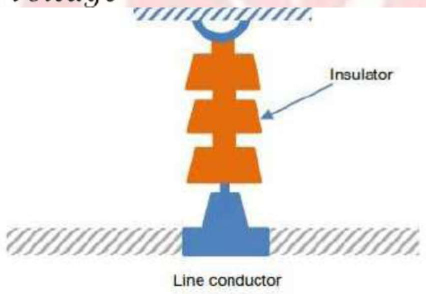

Figure 7. Suspension type insulator

It is preferable that the value of safety factor is big so that flash-over takes place before the insulator gets punctured. For pin type insulators, the value of safety factor is around 10.2.

B) Suspension type insulators.

The cost of pin type insulator quickly increases as the working voltage is increased. Hence, this insulator type is not economical beyond 33 kV. For high voltages (>33 kV), it is a typical practice to use suspension type insulators presented in Figure 7. They consist of a number of porcelain discs connected in series by metal links in the form of a string. The conductor is suspended at the bottom end of this string while the other end of the string is secured to the tower cross-arm. Each unit or disc is designed for low voltage, say 11 kV. The number of discs in series depends upon the working voltage. For example, if the working voltage is 66 kV, then six discs in series will be needed in the string.

Suspension insulator advantages are:

- Suspension type insulators are cheaper than pin type insulators for voltages above 33 kV.
- Each unit or disc of suspension type insulator is made for low voltage, typically 11 kV.

- Depending upon the working voltage, the required number of discs can be connected in series.
- If any disc is destroyed, the whole string does not become useless because the damaged disc can be replaced by the new one.
- The suspension arrangement gives line bigger flexibility. The connection at the cross arm is such that insulator string is free to swing in any direction and can take up the position where mechanical stresses are minimum.
- In case of increased power demand on the transmission line, it is found better to provide the bigger power demand by increasing the line voltage than to provide extra set of conductors. The extra insulation needed for the increased voltage can be easily obtained in the suspension arrangement by adding the needed number of discs.
- The suspension type insulators are typically used with steel towers. Since the conductors run below the tower grounded cross-arm, this arrangement gives partial protection from lightning.

C) Strain insulators

When there is a dead end of the line or there is corner or sharp curve, the line is subjected to bigger tension. In order to relieve the line of excessive tension, strain insulators are installed. For low voltage lines (< 11 kV), shackle insulators are used as strain insulators. Nevertheless, for high voltage lines, strain insulator consists of an assembly of suspension insulators as presented in Figure 8. The discs of strain insulators are installed in the vertical plane. When the tension in lines is exceedingly big, as at long river spans, two or more strings are installed in parallel.

D) Shackle insulators

The shackle insulators were used as strain insulators in the past. These days, they are normally used for low voltage distribution lines. Such insulators can be used either in a horizontal position or in a vertical position. They can be directly connected to the pole with a bolt or to the cross arm. Figure 9 presents a shackle insulator fixed to the pole. The conductor in the groove is linked with a soft binding wire.

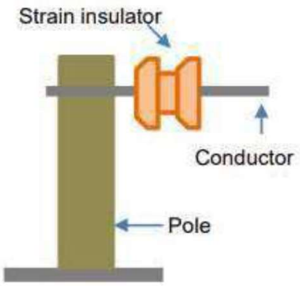

Figure 8. Strain insulators

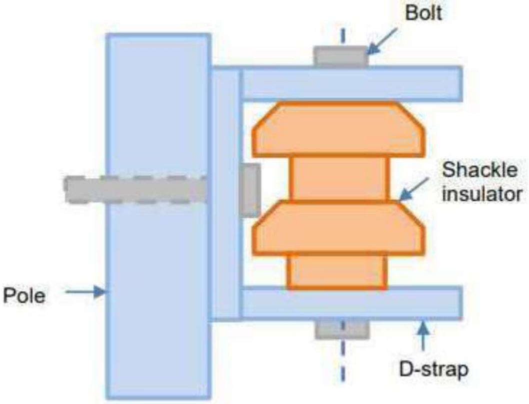

Figure 9. Shackle insulators

CONCLUSION: Mechanical design of transmission line has been studied.

This lab manual has been updated by

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Crosschecked By
HOD ECE & EEE

Please spare some time to provide your valuable feedback.