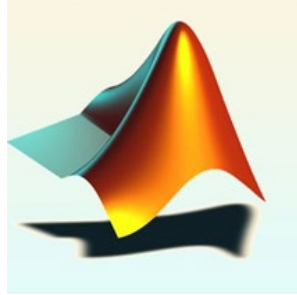# ELECTRICAL POWER SYSTEMS LAB

III B.Tech - II Sem.

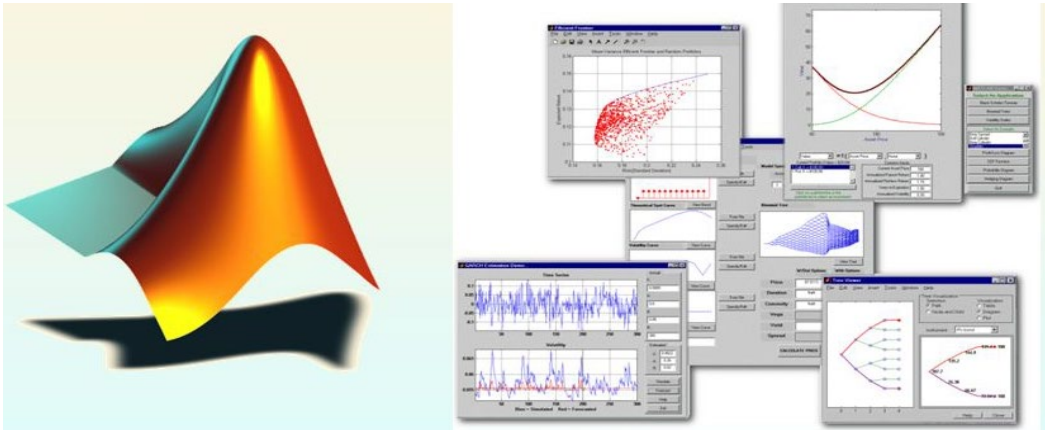# M A N U A L

EEE

DEPARTMENT OF ELECRICAL & ELECTRONICS ENGINEERING

BALAJI INSTITUTE OF TECHNOLOGY AND SCIENCE
NARSAMPET, WARANGAL.

EEE

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Head of Department

Vision and Mission of EEE Department

Vision:

To nurture excellence in the field of Electrical & Electronics Engineering by imparting core values to the learners and to mould the institution into a centre of academic excellence and advanced research.

Mission:

M1: To impart students with high technical knowledge to make globally adept to the new Technologies

M2: To create, disseminate and integrate knowledge of engineering, science and technology that expands the electrical engineering knowledge base towards research

M3: To provide the students with a platform for developing new products and systems that can help industry and society as a whole.

Program Outcomes

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

Program Specific Outcomes

PSO1	Apply fundamental knowledge to identify, analyze diverse problems associated with electrical and electronic circuits, power electronics drives and power systems.

PSO2	Understand the current technological developments in Electrical & Electronics Engineering and develop the innovative products/software to cater to the needs of society & Industry.

Program Educational Objectives

PEO1	To prepare students with solid foundation in Mathematics, Sciences and Basic Engineering to cover multi-disciplinary subjects enabling them to comprehend, analyze Electrical & Electronics Engineering problems and develop solutions.
PEO2	To design and develop an electrical system component or process to meet the needs of society and industry with in realistic constraints.
PEO3	To prepare students with technical competence to use advance techniques, skills and modern engineering tools that allow them to work effectively as electrical and electronics engineer.

Course Objectives:

- perform testing of CT, PT's and Insulator strings
- To find sequence impedances of 3-Φ synchronous machine and Transformer
- To perform fault analysis on Transmission line models and Generators.

Course Outcomes:

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

- Perform various load flow techniques
- Understand Different protection methods
- Analyze the experimental data and draw the conclusions.

The following experiments are required to be conducted as compulsory experiments: Part

- A

1. Characteristics of IDMT Over Current Relay.

2. Differential protection of 1-Φ transformer.

3. Characteristics of Micro Processor based Over Voltage/Under Voltage relay.

4. Testing of CT, PT's and Insulator strings.

5. Finding the sequence impedances of 3-Φ synchronous machine.

6. Finding the sequence impedances of 3-Φ Transformer.

In addition to the above six experiments, at least any four of the experiments from the following list are required to be conducted.

Part - B

1. Formation of Y_{BUS}.

2. Load Flow Analysis using Gauss Seidal (GS) Method.

3. Load Flow Analysis using Fast Decoupled (FD) Method.

4. Formation of Z_{BUS}.

5. LG, LL and 3-Φ fault analysis of 3-Φ synchronous machine.

6. Power circle diagrams of a 3-Φ transmission line model.

7. ABCD constants and Regulation of a 3-Φ transmission line model.

8. Transient Stability Analysis for Single Machine connected to Infinite Bus by Point by Point method.

ATTAINMENT OF PROGRAM OUTCOMES & PROGRAM SPECIFIC OUTCOMES

Exp .No	Name of the Experiment	Program Outcomes Attained	Program Specific Outcomes Attained
1	Characteristics of IDMT Over Current Relay.	PO1, PO2, PO5	PSO2
2	Differential protection of 1-Φ transformer.	PO1, PO2, PO5	PSO2
3	Characteristics of Micro Processor based Over Voltage/Under Voltage relay.	PO1, PO2, PO5	PSO2
4	Testing of CT, PT's and Insulator strings.	PO1, PO2, PO5	PSO2
5	Finding the sequence impedances of 3-Φ synchronous machine.	PO1, PO2, PO5	PSO2
6	Finding the sequence impedances of 3-Φ Transformer.	PO1, PO2, PO5	PSO2
7	**SIMULATION EXPERIMENTS**	PO1, PO2, PO5	PSO2
8	Formation of YBUS.	PO1, PO2, PO5	PSO2
	Load Flow Analysis using Gauss Seidal (GS) Method.	PO1, PO2, PO5	PSO2
9	Load Flow Analysis using Fast Decoupled (FD) Method.	PO1, PO2, PO5	PSO2
10	Formation of ZBUS.	PO1, PO2, PO5	PSO2
11	LG, LL and 3-Φ fault analysis of 3-Φ synchronous machine.	PO1, PO2, PO5	PSO2
12	Power circle diagrams of a 3-Φ transmission line model.	PO1, PO2, PO5	PSO2
13	ABCD constants and Regulation of a 3-Φ transmission line model.	PO1, PO2, PO5	PSO2
14	Transient Stability Analysis for Single Machine connected to Infinite Bus by Point by Point method.	PO1, PO2, PO5	PSO2

PREFACE

This Laboratory book in Electrical Measurements has been revised in order to be up to date with Curriculum changes, laboratory equipment upgrading and the latest circuit simulation.

Every effort has been made to correct all the known errors, but nobody is perfect, if you find any additional errors or anything else you think is an error, please contact the HOD/EEE at mallik95_eee@yahoo.com

The Authors thanked all the staff members from the department for their valuable Suggestion and contribution.

The author would welcome the advice and suggestions leading to the improvement of the book.

The Authors,
Department of EEE.

DO'S and Don't's in Computer Lab
Do's:
1. Remove your shoes or wear foot socks before you enter the lab.
2. Clean your computer with a soft, dry cloth.
3. Always keep quiet. Be considerate to other lab users.
4. Report any problems with the computer to the person in charge.
5. Shut down the computer properly.

Don'ts:
1. Do not bring any food or drinks in the computer room.
2. Do not touch any part of the computer with wet hands.
3. Do not hit the keys on the computer too hard.
4. Don't damage, remove, or disconnect any labels, parts, cables or equipment.
5. Do not install or download any software or modify or delete any system files on any lab computers.
6. CD – ROM's and other multimedia equipment are for school work only. Do not use them for playing music or other recreational activities.
7. If you leave the lab, do not leave your personal belongings unattended.

LABORATORY   PRACTICE
SAFETY RULES

1. SAFETY is of paramount importance in the Electrical Engineering Laboratories.

2. Electricity NEVER EXECUSES careless persons. So, exercise enough care and attention in handling electrical equipment and follow safety practices in the laboratory. (Electricity is a good servant but a bad master).

3. Avoid direct contact with any voltage source and power line voltages. (Otherwise, any such contact may subject you to electrical shock)

4. Wear rubber-soled shoes. (To insulate you from earth so that even if you accidentally contact a live point, current will not flow through your body to earth and hence you will be protected from electrical shock)

5. Wear laboratory-coat and avoid loose clothing. (Loose clothing may get caught on an equipment/instrument and this may lead to an accident particularly if the equipment happens to be a rotating machine)

6. Girl students should have their hair tucked under their coat or have it in a knot.

7. Do not wear any metallic rings, bangles, bracelets, wristwatches and neck chains. (When you move your hand/body, such conducting items may create a short circuit or may touch a live point and thereby subject you to Electrical shock)

8. Be certain that your hands are dry and that you are not standing on wet floor. (Wet parts of the body reduce the contact resistance thereby increasing the severity of the shock)

9. Ensure that the power is OFF before you start connecting up the circuit. (Otherwise you will be touching the live parts in the circuit).

10. Get your circuit diagram approved by the staff member and connect up the circuit strictly as per the approved circuit diagram.

11. Check power chords for any sign of damage and be certain that the chords use safety plugs and do not defeat the safety feature of these plugs by using ungrounded plugs.

12. When using connection leads, check for any insulation damage in the leads and avoid such defective leads.

13. Do not defeat any safety devices such as fuse or circuit breaker by shorting across it. Safety devices protect YOU and your equipment.

14. Switch on the power to your circuit and equipment only after getting them checked up and approved by the staff member.

15. Take the measurement with one hand in your pocket. (To avoid shock in case you accidentally touch two points at different potentials with your two hands)

16. Do not make any change in the connection without the approval of the staff member.

17. In case you notice any abnormal condition in your circuit (like insulation heating up, resistor heating up etc), switch off the power to your circuit immediately and inform the staff member.

18. Keep hot soldering iron in the holder when not in use.

19. After completing the experiment show your readings to the staff member and switch off the power to your circuit after getting approval from the staff member.

20. Determine the correct rating of the fuse/s to be connected in the circuit after understanding correctly the type of the experiment to be performed: no-load test or full-load test, the maximum current expected in the circuit and accordingly use that fuse-rating.(While an over-rated fuse will damage the equipment and other instruments like ammeters and watt-meters in case of over load, an under-rated fuse may not allow one even to start the experiment)

21. Moving iron ammeters and current coils of wattmeters are not so delicate and hence these can stand short time overload due to high starting current. Moving iron meters are cheaper and more rugged compared to moving coil meters. Moving iron meters can be used for both a.c. and d.c. measurement. Moving coil instruments are however more sensitive and more accurate as compared to their moving iron counterparts and these can be used for d.c. measurements only. Good features of moving coil instruments are not of much consequence for you as other sources of errors in the experiments are many times more than those caused by these meters.

22. Some students have been found to damage meters by mishandling in the following ways:

   i.   Keeping unnecessary material like books, labrecords, unused meters etc. causing meters to fall down the table.
   ii. Putting pressure on the meter (especially glass) while making connections or while talking or listening somebody.

STUDENTS ARE STRICTLY WARNED THAT FULL COST OF THE METER WILL BE RECOVERED FROM THE INDIVIDUAL WHO HAS DAMAGED IT IN SUCH A MANNER.

Copy these rules in your Lab Record. Observe these yourself and help your friends to observe.

I have read and understand these rules and procedures. I agree to abide by these rules and procedures at all times while using these facilities. I understand that failure to follow these rules and procedures will result in my immediate dismissal from the laboratory and additional disciplinary action may be taken.

Signature   Date   Lab

GUIDELINES FOR LABORATORY NOTEBOOK

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

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

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

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

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

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

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

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

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

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

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

10. Conclusion:

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

INSTRUCTIONS TO THE STUDENT FJHINSTRUCTIONS

TO TE STUDENT

FJHFHINSTRUCTIONS TO THE STUDENT

1. Students are required to attend all labs.

2. Students will work individually in hardware laboratories and in computer laboratories.

3. While coming to the lab bring the lab manual cum observation book, record etc.

4. Take only the lab manual, calculator (if needed) and a pen or pencil to the work area.

5. Before coming to the lab, prepare the prelab questions. Read through the lab experiment to familiarize yourself with the components and assembly sequence.

6. Utilize 3 hours time properly to perform the experiment (both in software and hardware) and note down the readings properly. Do the calculations, draw the graph and take signature from the instructor.

7. If the experiment is not completed in the prescribed time, the pending work has to be done in the leisure hour or extended hours.

8. You have to submit the completed record book according to the deadlines set up by your instructor.

9. For practical subjects there shall be a continuous evaluation during the semester for 25 sessional marks and 50 end examination marks.

10. Of the 25 marks for internal, 15 marks shall be awarded for day-to-day work and 10 marks to be awarded by conducting an internal laboratory test.

IDMT CHARACTERISTICS OF OVER CURRENT RELAY

Aim: To study the Operation of a Non- Directional electromechanical type over current (I D M T relay) and plot the inverse time current characteristics.

Apparatus required:

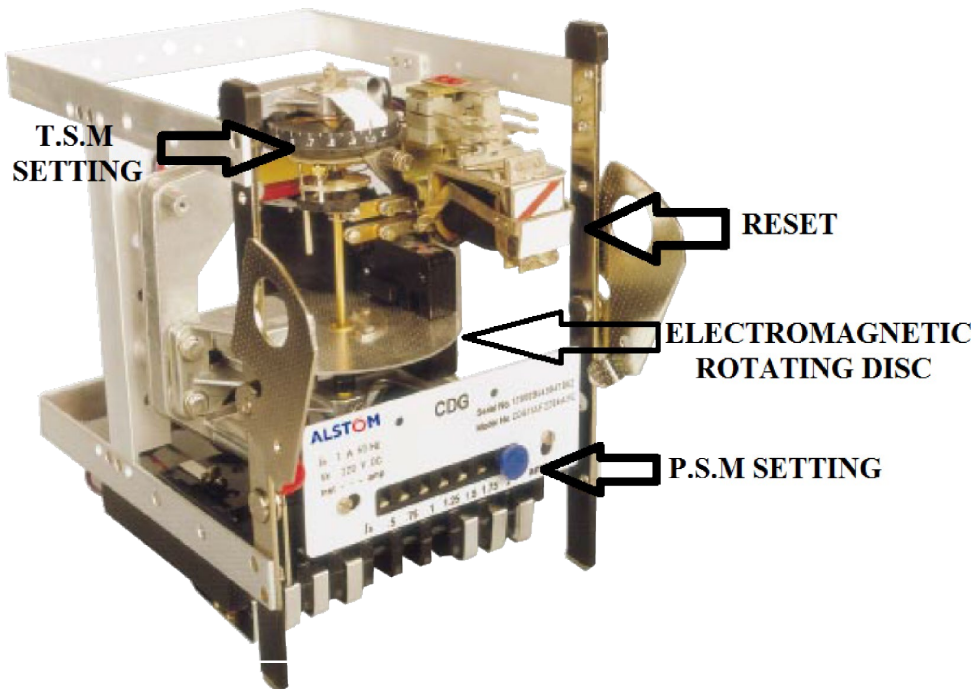| S.No	Apparatus	Type	Quantity
1	**IDMT Over current relay**	**Electro-mechanical**	**1No**
2	**Timer**	**Digital**	**1No**
3	**Fault creation Panel**	**Digital**	**1No**
4	**Ammeter**	**30A MI**	**1No**
5	**Current Transformer-40/2A**	**Core type**	**1No**

Theory:

Fig. 1 ALSTOM CDG 11 IDMT over current relay

A non-directional heavily damped induction disc relay which has an adjustable inverse time/current characteristic with a definite minimum time. The relay has a high torque movement combined with low burden and low overshoot. The relay disc is so shaped that as it rotates the driving torque increases and offsets the changing restraining torque of the control spring. This feature combined with the high torque of the relay ensures good contact pressure even at currents near pick-up. Damping of the disc movement is by a removable high retentivity permanent magnet. The unique method of winding the operating coil ensures that the time/current characteristics are identical on each of the seven current taps. Selection of the required current setting is by means of a plug setting bridge which has a single insulated plug. The maximum current tap is automatically connected when the plug is withdrawn from the bridge, allowing the setting to be changed under load without risk of open circuiting the current transformers. The IDMT relay has an auxiliary unit which is powered by a secondary winding on the electromagnet through a rectifier and as such a separate auxiliary supply is not required. The disc unit operates and closes its contacts, the auxiliary element connected across the secondary winding on the electromagnet operates, and one normally open contact of the auxiliary element reinforces the disc contact.

Pick Up Current of Relay:

In all electrical relays, the moving contacts are not free to move. All the contacts remain in their respective normal position by some force applied on them continuously. This force is called controlling force of the relay. This controlling force may be gravitational force, may be spring force, and may be magnetic force. The force applied on the relay's moving parts for changing the normal position of the contacts, is called deflecting force. This deflecting force is always in opposition of controlling force and presents always in the relay. Although the deflecting force always presents in the relay directly connected to live line, but as the magnitude of this force is less than controlling force in normal condition, the relay does not operate. If the actuating current in the relay coil increases gradually, the deflecting force in electro mechanical relay is also increased. Once, the deflecting force crosses the controlling force, the moving parts of the relay initiate to move to change the position of the contacts in the relay. The current for which the relay initiates it operation is called pick up current of relay.

Current Setting of Relay:

The minimum pick up value of the deflecting force of an electrical relay is constant. Again the deflecting force of the coil is proportional to its number of turns and current flowing through the coil.Now, if we can change the number of active turns of any coil, the required currentto reach at minimum pick value of the deflecting force, in the coil also changes. That means if active turns of the relay coil is reduced, then proportionately more current is required to produce desired relay actuating force.

Similarly if active turns of the relay coil are increased, then proportionately reduced current is required to produce same desired deflecting force.

Practically same model relays may be used in different systems. As per these systems requirement the pick-up current of relay is adjusted. This is known as current setting of relay. This is achieved by providing required number of tapping in the coil. These taps are brought out to a plug bridge. The number of active turns in the coil can be changed by inserting plug in different points in the bridge.

The current setting of relay is expressed in percentage ratio of relay pick up current to rated secondary current of CT.

For example, an over current relay should operate when the system current just crosses 125% of rated current. If the relay is rated with 1 A, the normal pick up current of the relay is 1 A and it should be equal to secondary rated current of current transformer connected to the relay.
Then, the relay will be operated when the current of CT secondary becomes more than or equal 1.25 A. As per definition,
The current setting is sometimes referred as current plug setting. The current setting of over current relay is generally ranged from 50% to 200%, in steps of 25%. For earth fault relay it is from 10% to 70% in steps of 10%.

Hence, pick up current of the relay is, $1 \times 150 \% = 1.5$ A. Now, suppose fault current in the CT primary is 1000 A. Hence, fault current in the CT secondary i.e. in the relay coil is, $1000 \times 1/200 = 5$ A. Therefore PSM of the relay is, $5 / 1.5 = 3.33$
In order to adjust the relay operating time, both of the factors are to be adjusted. The adjustment of travelling distance of an electromechanical relay is commonly known as time setting. This adjustment is commonly known as **time setting multiplier of relay**. The time setting dial is calibrated from 0 to 1 in steps 0.05 sec. But by adjusting only time setting multiplier, we cannot set the actual time of operation of an electrical relay. As the time of operation also depends upon the speed of operation. The speed of moving parts of relay depends upon the force due to current in the relay coil. Hence it is clear that, speed of operation of an electrical relay depends upon the level of fault current. In time setting multiplier, this total travelling distance is divided and calibrated from 0 to 1 in steps of 0.05. So when time setting is 0.1, the moving part of the relay has to travel only 0.1 times of the total travelling distance, to close the contact of the relay.
IDMT relay is inverse definite minimum time relay. It is one in which Time of operation is inversely proportional to magnitude of fault current near pickup value and becomes substantially constant slightly above the pickup value of the Relay. This is achieved by using a core of the Electro Magnet which gets saturated for currents slightly greater than the pickup current. Fault current and measure relay operation

time is used to conduct the experiment. Values recorded for various TSMs and PSMs. Characteristics studied with the help of a graph and correlated with theory. This relay consists of Induction disc unit with an operation indicator and in some cases an instantaneous high set unit all assembled are in standard frame. Type disc shaft carried silver rod moving contacts which complete the auxiliary unit circuit through the fixed contract. Permanent magnet is used to control the disc speed. The setting is adjusted by the movement of the back stop which is controlled by the rotating a KNUR LED molded disc at the base of graduated time multiplier.

CIRCUIT DIAGRAM:
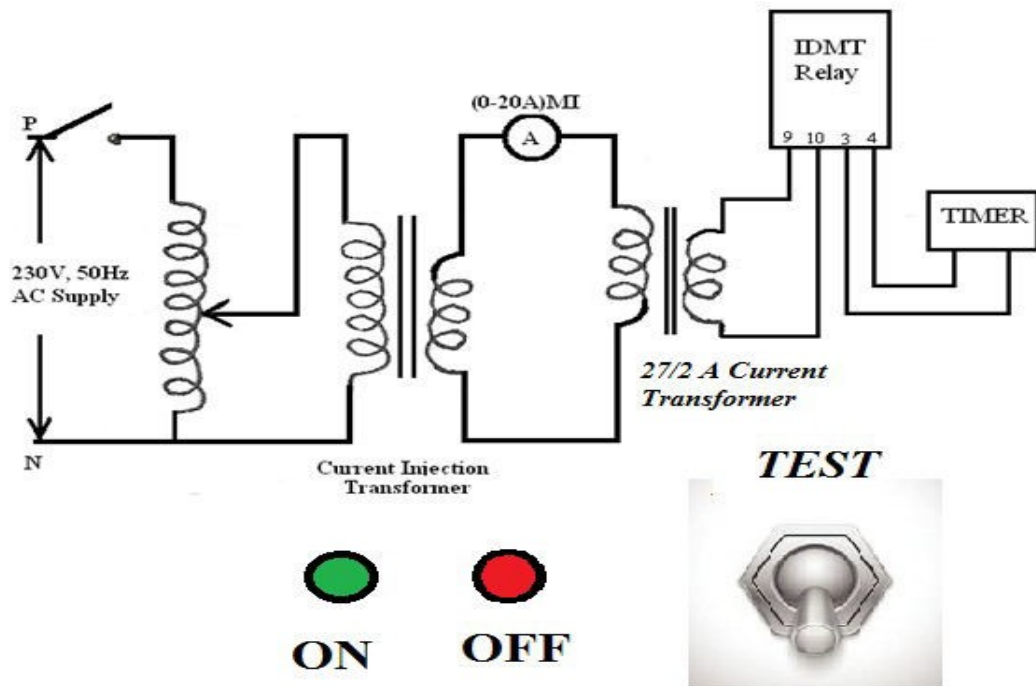
Procedure:

1. Connect the circuit as per the circuit diagram.

2. Select the P.S.M setting on the relay.

3. Make sure that the 1-phase dimmer stat is in minimum position, test switch is in ON position, and T.S.M settings of the relay are set to 0.5.

4. Increase the current in the circuit to the value calculated similar to step 2 depending on the PSM setting by varying the 1-phase variac.

5. Observe the relay tripping condition. The circuit will be in OFF position after relay tripping.

6. OFF the test switch, reset the timer and relay and push ON button. Make sure the rotating electromagnetic disc of relay is at initial position before switching ON.

7. Note down the value of tripping time and current.

8. Repeat the steps 3,4,5,6, 7to observe the operating time of the relay by increasing the fault current above calculated value of fault current in step 2 and tabulate the readings.

9. Repeat the same procedure for various T.S.M = 0.7

10. Plot the graph between time taken for relay to operate vs fault current for various T.S.M / P.S.M.

Precautions:-

- Disc must be stationary before applying fault current.
- TSM setting must be changed with due care.

SAMPLE OBSERVATIONS:

Rated Current : 0 to 25 Amps.

CT Ratio : 40/2 Amps = 20.
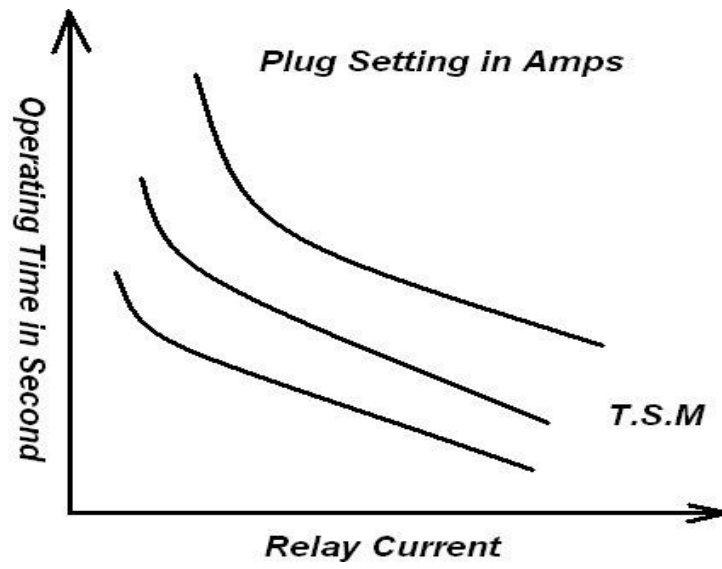
Pick-Up Current Setting = Plug setting Value X C.T

ratio TSM = 0.1 to 0.6

PS M	Pick-Up Current
0.5	10
0.75	15
1.0	20
1.25	25

Readings and Tabular forms:-

	PSM =	TSM =	
SNO.	Fault Current (A)	Time of operation TSM = 0.6(sec)	Time of operation TSM = 0.5(sec)

Expected graphs:

RESULT:

DIFFERENTIAL PROTECTION ON SINGLE PHASE TRANSFORMER

AIM: To study the differential protection scheme for a single phase transformer.

APPARATUS:

| Sl.No	Apparatus	Type	Quantity
01	1-Phase Transformer 230V/50V, (500VA)	Shell type	01 No
02	1-Phase Variac (0-250V, 6Amps)	Closed type	01 No
03	Ammeters (0-30 amps)	Digital	04 No's
04	Differential Relay,	Micro Processor type	01 No
05	Connecting wires	---	As required

THEORY :

A Differential relay responds to vector difference between two or more similar electrical quantities. From this definition the Differential relay has at least two actuating quantities say 1-1 and 2-1.

The two or more actuating quantities should be same.

Ex: Current/Current.

The Relay responds to vector difference between 1-1 &2-1which includes magnitude and /or phase angle difference. Differential protection is generally unit protection. The protection zone is exactly determined by location of CTs. The vector difference is actuated by suitable connection of CTs or PTs secondary's. Most differential relays are current differential relays in which vector difference between current entering the winding & current leaving the winding is used for relay operation. Differential protection is used for protection of Generators, Transformers etc. Internal fault is created using switch and relay operation observed for various TSMs. Relay operations for external faults can also be studied.

CIRCUIT DIAGRAM:
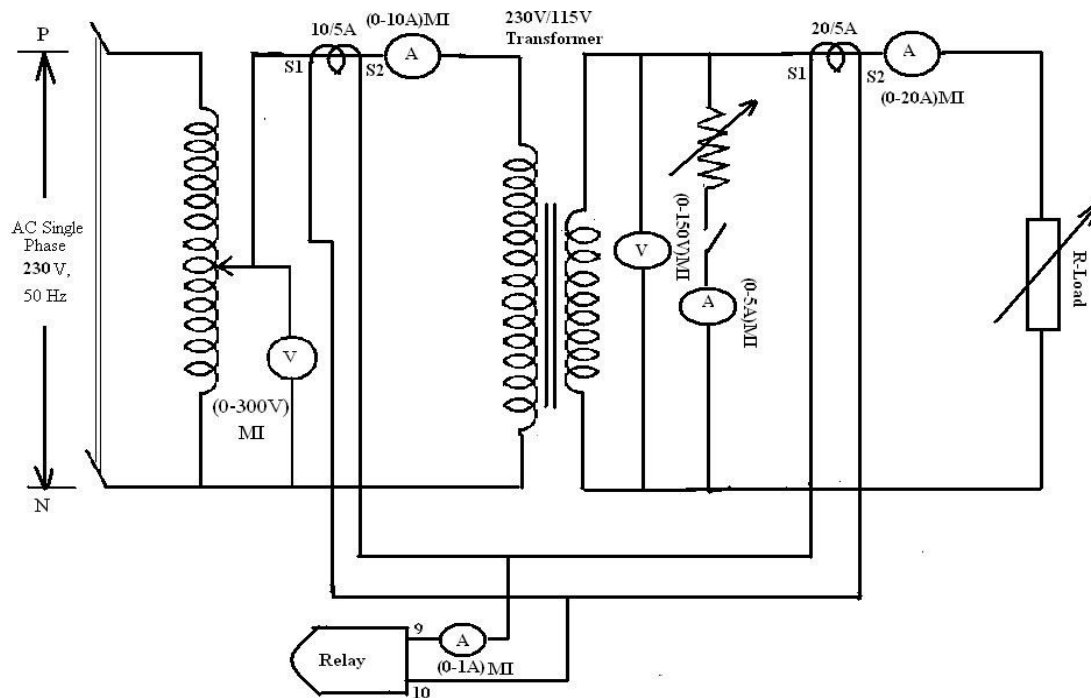
PROCEDURE:

1. Make the connections as shown in fig.

2. Apply rated voltage 230V to primary by varying the Variac.

3. By applying load observe various meter readings.

4. Now switch ON the Fault switch so as to create an internal fault.

5. Note down the various meter readings when relay operates.

6. Note down the Relay Trip condition.

7. Reset the relay after it gets tripped.

READINGS AND TABULAR FORM:

OBSERVATION: - For Internal Fault

S.No	Primary Voltage	Primary Current	Secondary voltage	Secondary Current	Fault Current	Relay Condition

RESULT:

CHARACTERISTICS OF STATIC RELAY UNDER VOLTAGE/OVER VOLTAGE

Aim: To study the operation of Microprocessor Based type under voltage relay and hence to obtain inverse time/voltage characteristics.

Apparatus required:

S.No	Apparatus	Type	Quantity
01	UV/OV Relay	μP based	01No
02	Voltage Source Unit (230/110-230V)		01No
03	Connecting Wires		As Required
04	Voltmeter (0-500V AC)	Digital	01No

Theory: Over Voltage/Under Voltage Relay is an electronic microcontroller based single- phase voltage relay. It is suitable for over voltage/under voltage protection schemes in LV, MV and HV power distribution systems. It is also suitable for over voltage protection of AC circuits, capacitors, machines such as generators, synchronous motor and under voltage protection of AC circuits, Induction motors, automatic change over schemes etc.

The microcontroller-based design offers a wide range of Trip-Time characteristics, under voltage or over voltage mode and PT rating (110V, 240V, 415V), which can all be selected in the field at the time of commissioning. It accepts very wide auxiliary supply range.Relay is designed for flush mounting. It is very compact in size, which results in saving of panel space. Its draw-out construction makes installation and maintenance very easy.
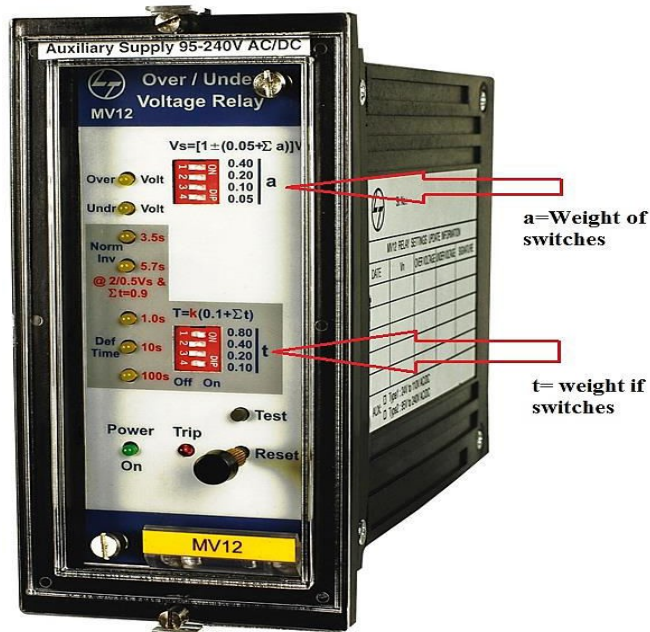
Details of L&T Under voltage/Over voltage relay:

Fig 1: Under/Over Voltage Relay

Technical Specifications of the relay are:

1.0	Rated Voltage (Vn)	110V
2.0	Rated Frequency	50Hz
3.0	Auxiliary Power Supply	230VAC
4.0	Relay Settings:	
	Pick up voltage(Vs)	
	Over Voltage Mode	105% to 180% of Vn in steps of 5% Under
	Voltage mode	95% to 20% of Vn in steps of 5%
	Time Multiplier TMS	0.1 to 1.6 in steps of0.1

5.0   Operating Characteristics

Time /Current characteristics Normal Inverse 3.5 sec in O/V mode
                              Normal Inverse 5.7 sec in U/V mode
                              Definite time 1, 10, 100sec

Pick up voltage   Same as set voltage Vs

Reset Voltage   (90% to 95%)of set voltage Vs
                     for Overvoltage

(105% to 110%) of set voltage Vs for Under voltage

Circuit Diagram:
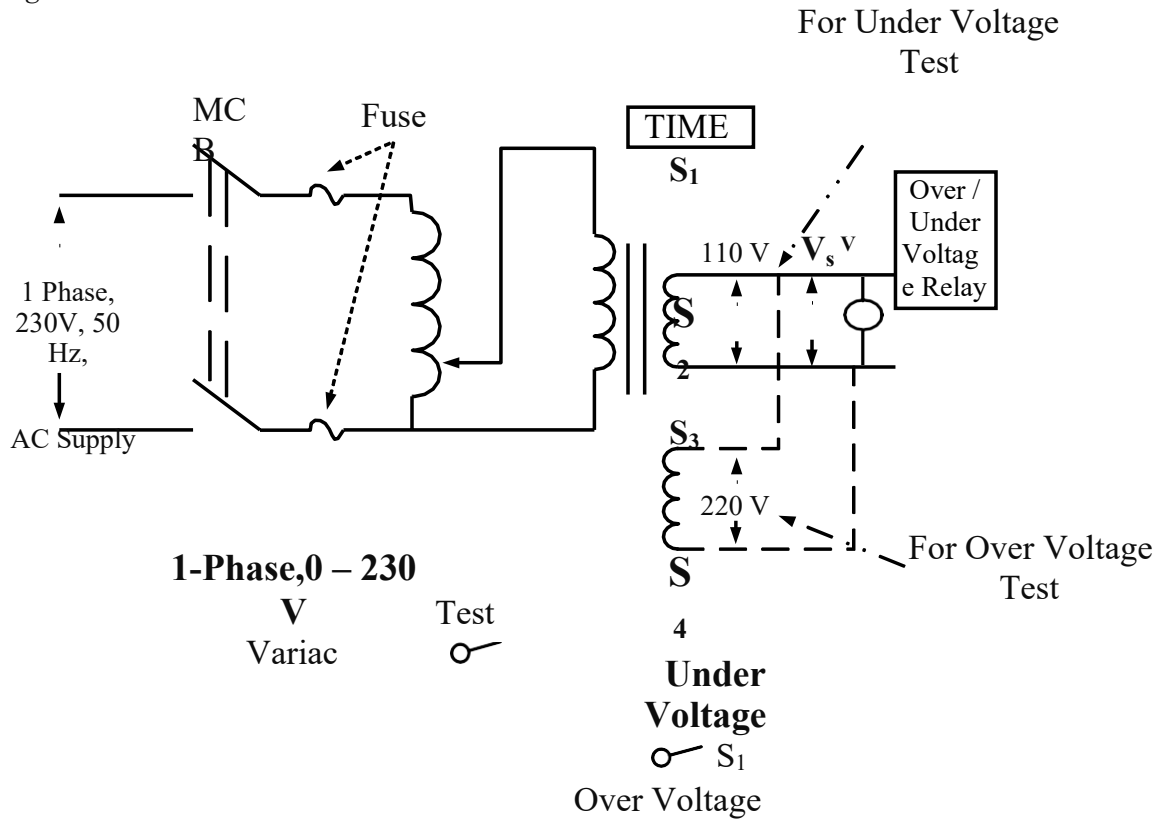
Calculations:
The following are the calculations for voltage and TMS settings:

Voltage setting on the secondary side of the transformer:

The calculated voltage Vs is given by equation
$V_s \square [1 \pm (0.05 \sum a)]V_n$ …………………………………………..(1)
+ is for over voltage
-is for under voltage

a= weight of switches {0.05, 0.1, 0.2, 0.4} in ON position
V_n is P.T. rating i.e. 110V. T.M.S:

Trip time $T = K (0.1 + \sum t)$……………………………………..(2)

t = weight of switches {0.1, 0.2, 0.4, 0.8} in ON position

K = 3.5 for over voltage
K = 5.7 for under voltage

UNDER VOLTAGE TESTING:

1. Connect circuit as per the circuit diagram. Switch ON MCB.
2. Calculate V_s from equations (1) and (2) for different values of 'a' and 't' and tabulate the values in table 1 and table 2.

Table 1

a	Vs
0.05	99V
0.1	94V
0.2	83V
0.4	61V

Table 2 (value of K=5.7)

t	Vs
0.1	
0.2	
0.4	
0.8	

3. Ensure that the switch S_1 in the circuit diagram is in 'Under Voltage condition', variac is in zero position and the switch 'TEST' is OFF position.
4. Now apply a voltage from variac which is less than the calculated setting voltage$V_s$for a=0.05 in order to test the operating condition of relay. Observe the relay indication and tripping. The setup will be in OFF condition.
5. Switch ON the 'TEST' mode, reset the timer
6. Switch ON the green button and note down the time in timer circuit for the applied under voltage Vs after tripping.
7. Repeat steps from 3 to 6 for three under voltage values.

OVER VOLTAGE TESTING:

1. Connect circuit as per the connection diagram. For over voltage condition, connect the relay to the terminals S_3 and S_4 which are present on the secondary side of the transformer. Switch ON MCB.
2. Calculate V_s from equations (1) and (2) for different values of 'a' and 't' and tabulate the values in table 3 and table 5.

Table 3

a	Vs
0.05	121V
0.1	126V
0.2	138V
0.4	140V

Table 2 (value of K=3.5)

t	T
0.1	
0.2	
0.4	
0.8	

3. Ensure that the switch S_1 in the circuit diagram is in 'Over Voltage condition', variac is in zero positon and the switch 'TEST' is OFF position.
4. Now apply a voltage from variac which is greater than the calculated setting voltage V_s for a=0.05 in order to test the operating condition of relay. Observe the relay indication and tripping. The setup will be in OFF condition.
5. Switch ON the 'TEST' mode, reset the timer
6. Switch ON the green button and note down the time in timer circuit for the applied under voltage Vs after tripping.
7. Repeat steps from 3 to 6 for three over voltage values.

UNDER VOLTAGE TESTING:

Vs =			Weight (a) =	
S.No	**T.M.S**	**Voltage Setting**	**Applied Voltage**	**Operating time**

OVER VOLTAGE TESTING :

Vs =			Weight (a) =	
S.No	**T.M.S**	**Voltage Setting**	**Applied Voltage**	**Operating time**

RESULT:

TESTING OF C.T AND P.T

AIM: To study the performance of current and potential Transformers.

APPARATUS:

| Sl.No	Apparatus	Range	Quantity
1.	Ammeters	0 – 20A	2
2.	Voltmeters	0 – 500V	2
3.	Connecting Wires	-	-
4.	C.T ranges	20/5A C.T	1
		10/5A C.T	1
5.	P.T ranges	400/100V P.T	1
		200/100V P.T	1

THEORY:

1. **Current transformers** reduce high voltage currents to a much lower value and provide a convenient way of safely monitoring the actual electrical current flowing in an AC transmission line using a standard ammeter. The principal of operation of a basic current transformer is slightly different from that of an ordinary voltage transformer. Current transformers can reduce or "step-down" current levels from thousands of amperes down to a standard output of a known ratio to either 5 Amps or 1 Amp for normal operation. Thus, small and accurate instruments and control devices can be used with CT's because they are insulated away from any high-voltage power lines. There are a variety of metering applications and uses for current transformers such as with Wattmeter's, power factor meters, watt-hour meters, protective relays, or as trip coils in magnetic circuit breakers, or MCB's.

2. **Potential transformer** or voltage transformer gets used in electrical power system for stepping down the system voltage to a safe value which can be fed to low ratings meters and relays. Commercially available relays and meters used for protection and metering, are designed for low voltage. This is a simplest form of potential transformer definition. Potential transformer theory is just like a theory of general purpose step down transformer. Primary of this transformer is connected across the phase and ground. Just like the transformer used for stepping down purpose, potential transformer i.e. PT has lower turns winding at its secondary.

    The system voltage is applied across the terminals of primary winding of that transformer, and then proportionate secondary voltage appears across the secondary terminals of the PT. The secondary voltage of the PT is generally 110 V. In an ideal potential transformer or voltage transformer, when rated burden gets connected across the secondary; the ratio of primary and secondary voltages of transformer is equal to the turns ratio and furthermore, the two terminal

voltages are in precise phase opposite to each other. But in actual transformer, there must be an error in the voltage ratio as well as in the phase angle between primary and secondary voltages.

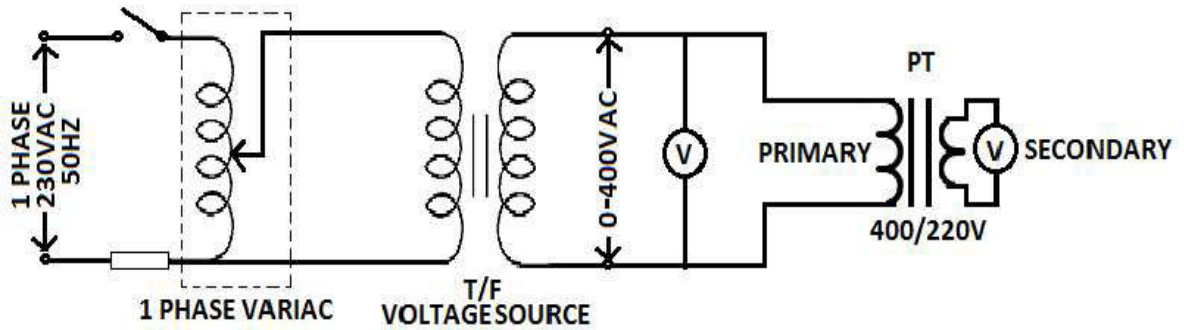*CIRCUIT DIAGRAM:*
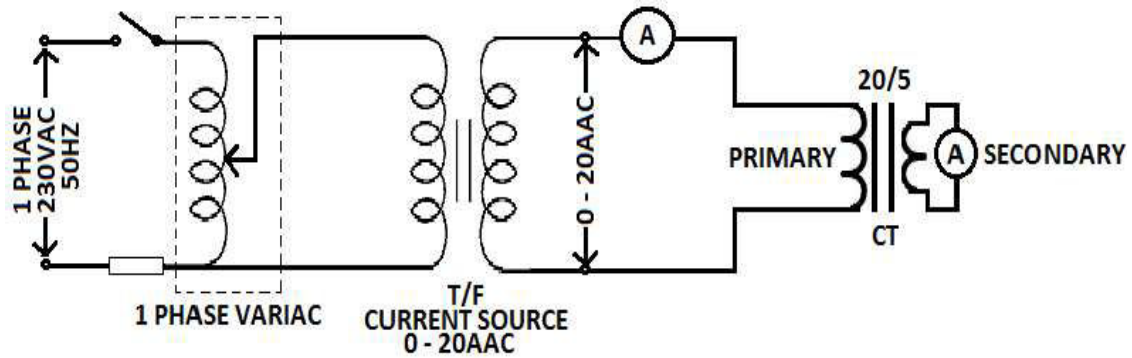
CURRENT TRANSFORMER CIRCUIT

PROCEDURE:

1. Give connections as per the circuit diagram.
2. Apply rated current to primary side of CT.
3. Note down ammeter readings.
4. Connect ammeter in secondary side of CT.
5. Note down the secondary ammeter readings.
6. Observe CT performance by doing above procedure.

TABULAR FORM:

S.No	C.T range	CT Primary (A)	CT Secondary (A)
1.	20/5A C.T		
2.	10/5A C.T		

CIRCUIT DIAGRAM:

POTENTIAL TRANSFORMER CIRCUIT

PROCEDURE:

1. Give connections as per the circuit diagram.
2. Apply rated voltage to primary side of PT.
3. Note down voltmeter readings.
4. Connect voltmeter in secondary side of PT.
5. Note down the secondary voltmeter readings.
6. Observe PT performance by doing above procedure.

TABULAR FORM:

S.No	P.T range	PT Primary (V)	PT Secondary (V)
1.	400/100V P.T		
2.	200/100V P.T		

RESULT:

TESTING OF STRING INSULATOR

AIM: To determine voltage distribution and string efficiency of suspension insulator with and without guard ring.

APPARATUS REQUIRED:

S.NO.	APPARATUS	RATING	QTY
1.	1-Phase Auto transformer.	100Volt/1Amp	01
2.	Digital Voltmeter.	300Volt	01
3.	MCB Protection.	20A	01
4.	Fuse Protection.	1A	01
5.	Capacitors. (C1)	2 micro Farad	03
6.	Capacitors.(C)	10 micro Farad	04
7.	Capacitors.(C2)	1 micro Farad	03
8.	Connecting wires.	---	As required

THEORY:

A string of suspension insulators consists of a number of porcelain discs connected in series through metallic links. Fig. 1 (i) shows string of suspension insulators. The porcelain portion of each disc is in between two metal links as shown in Fig. 1 (ii). Therefore, each disc forms a capacitor C as shown in Fig. 1 (iii). This is known as mutual capacitance or self-capacitance. However, in actual practice, capacitance also exists between metal fitting of each disc and tower or earth. This is known as shunt capacitance C_1. Due to shunt capacitance, charging current is not the same through all the discs of the string [See Fig. 1 (iii)]. Therefore, voltage across each disc will be different. Obviously, the disc nearest to the line conductor will have the maximum voltage. Thus referring to Fig. 1 (iii), V_1 will be much more than V_2 or V_3.
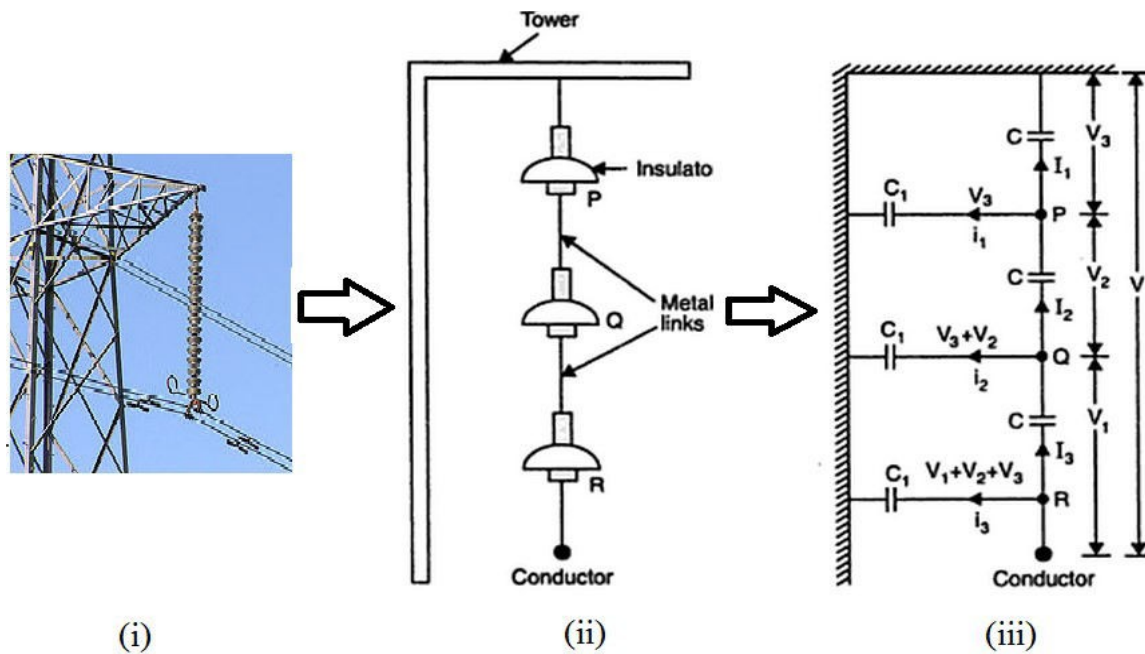
Fig. 1 String of Suspension insulators

The following points may be noted regarding the potential distribution over string of suspension insulators:

(i) The voltage impressed on a string of suspension insulators does not distribute itself uniformly across the individual discs due to the presence of shunt capacitance.

(ii) The disc nearest to the conductor has maximum voltage across it. As we move towards the Cross-arm, the voltage across each disc goes on decreasing.

(iii) The unit nearest to the conductor is under maximum electrical stress and is likely to be punctured. Therefore, means must be provided to equalize the potential across each unit.

(iv) If the voltage impressed across the string were d.c, then voltage across each unit would be the same. It is because insulator capacitances are ineffective for d.c.

STRING EFFICIENCY:

As stated above, the voltage applied across the string of suspension insulators is not uniformly distributed across various units or discs. The disc nearest to the conductor has much higher potential than the other discs. This unequal potential distribution is undesirable and is usually expressed in terms of string efficiency.

The ratio of voltage across the whole string to the product of number of discs and the voltage across the disc nearest to the conductor is known as string efficiency.

$$\text{String efficiency} = \frac{\text{Voltage across the string}}{n \times \text{Voltage across disc nearest to conductor}}$$

Where n = number of discs in the string.

String efficiency is an important consideration since it decides the potential distribution along the string. The greater the string efficiency, the more uniform is the voltage distribution. Thus 100%string efficiency is an ideal case for which the voltage across each disc will be exactly the same. Although it is impossible to achieve 100% string efficiency, yet efforts should be made to improve it as close to this value as possible.

METHODS OF IMPROVING STRING EFFICIENCY:

It has been seen above that potential distribution in a string of suspension insulators is not uniform. The maximum voltage appears across the insulator nearest to the line conductor and decreases progressively as the cross arm is approached. If the insulation of the highest stressed insulator (i.e. nearest to conductor) breaks down or flash overtakes place, the breakdown of other units will take place in succession. This necessitates equalizing the potential across the various units of the string i.e. to improve the string efficiency. The various methods for this purpose are:

(I) BY USING LONGER CROSS-ARMS. The value of string efficiency depends upon the value of K i.e., ratio of shunt capacitance to mutual capacitance. The lesser the value of K, the greater is the string efficiency and more uniform is the voltage distribution. The value of K can be decreased by reducing the shunt capacitance. In order to reduce shunt capacitance, the distance of conductor from tower must be increased i.e., longer cross-arms should be used. However, limitations of cost and strength of tower do not allow the use of very long cross-arms. In practice, K = 0·1is the limit that can be achieved by this method.

(II)BY GRADING THE INSULATORS. In this method, insulators of different dimensions are so chosen that each has a different capacitance. The insulators are capacitance graded i.e. they are assembled in the string in such a way that the top unit has the minimum capacitance, increasing progressively as the bottom unit (i.e., nearest to conductor) is reached. Since voltage is inversely proportional to capacitance, this method tends to equalize the potential distribution across the units in the string. This method has the disadvantage that a large number of different-sized insulators are required. However, good results can be obtained by using standard insulators for most of the string and larger units for that near to the line conductor.
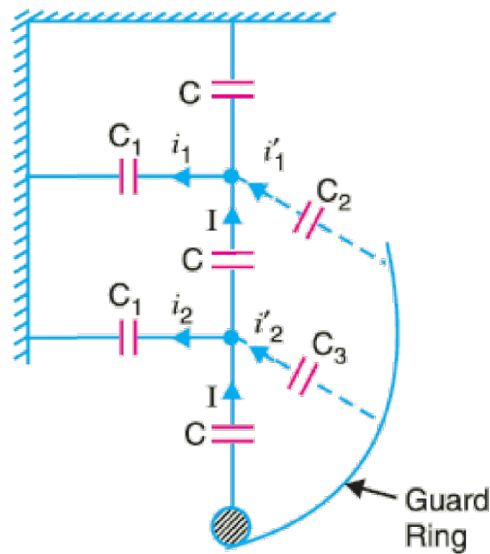
(III) BY USING A GUARD RING.

Fig. 2 String Insulators with Guard ring

The potential across each unit in a string can be equalized by using a guard ring which is a metal ring electrically connected to the conductor and surrounding the bottom insulator as shown in the Fig. 2. The guard ring introduces capacitance between metal fittings and the line conductor. The guard rings contoured in such a way that shunt capacitance currents i_1, i_2 etc. are equal to metal fitting line capacitance currents i'_1, i'_2 etc. The result is that same charging current I flows through each unit of string. Consequently, there will be uniform potential distribution across the units.
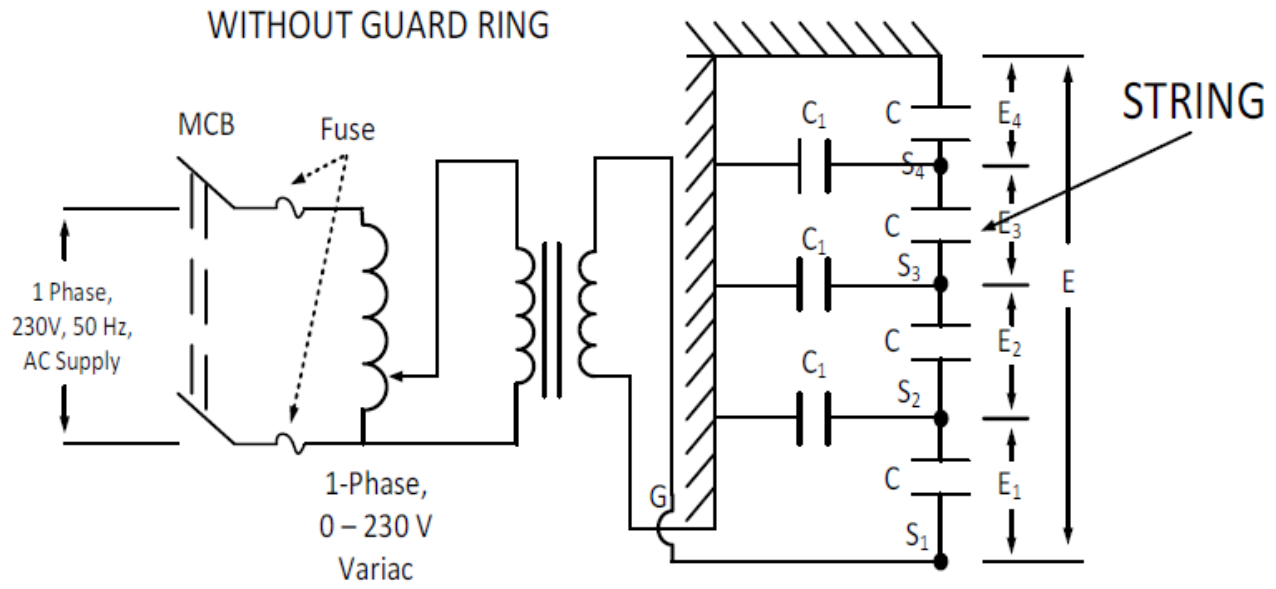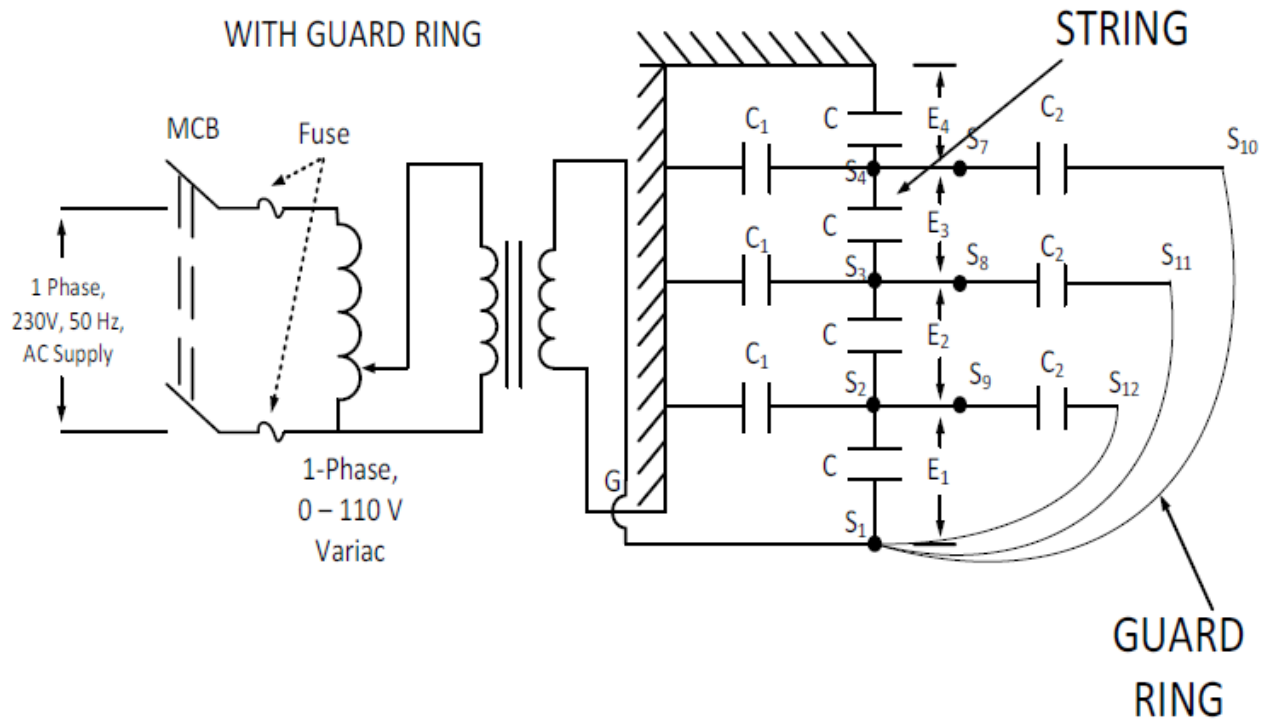
Fig 3: Without Guard Ring

Fig 4: With Guard Ring

PROCEDURE:

Without Guard Ring:

1. Connect the circuit as per the Fig. 3.From one of the Variac output terminals connect to terminals S_1 and other Variac output terminal to G as shown in Fig. 3.
2. Apply voltage from the Variac across the string in steps of 20V starting from 30V to 110V.
3. Measure the voltage across S_1 and S_2(which is to be noted as E_1); S_2 and S_3(which is to be noted as E_2); S_3 and S_4(which is to be noted as E_3) ; S_4 to G(which is to be noted as E_4)
4. Tabulate the voltages E_1 to E_4 in the tabular column 1.
5. Calculate the string efficiency without guard ring.

With Guard Ring:

1. Connect the circuit as per the Fig. 4.From one of the Variac output terminals connect to terminals S_1 and other Variac output terminal to G. To connect the guard ring to the string, connect the terminals S_4-S_7, S_3-S_8, S_2-S_9 and also make connections between S_1-S_{10}, S_1-S_{11} and S_1-S_{12}
2. Apply voltage from the Variac across the string in steps of 20V starting from 30V to 110V.
3. Measure the voltage across S_1 and S_2(which is to be noted as E_1); S_2 and S_3(which is to be noted as E_2); S_3 and S_4(which is to be noted as E_3) ; S_4 to G(which is to be noted as E_4)
4. Tabulate the voltages E_1 to E_4 in the tabular column 2.
5. Calculate the string efficiency with guard ring.

CALCULATIONS:

$$\textit{String Effciency} = \frac{\textit{Voltage across the string}}{\textit{number of units in the string} \times \textit{Voltage across the unit near the power conductor}}$$

TABULAR COLUMNS:

Without Guard Ring:

Table 1

E	E1	E2	E3	E4	Efficiency

With Guard Ring:

Table 2

E	E1	E2	E3	E4	Efficiency

RESULT:

DETERMINATION OF SEQUENCE IMPEDANCES OF A CYLINDRICAL ROTOR SYNCHRONOUS MACHINE

AIM: To determine the Positive, Negative and Zero sequence of impedances or sequence impedances of the given three phase alternator**.**

APPARATUS REQUIRED:

S.No	Apparatus	Type	Quantity
01.	DC motor coupled to alternator set	-----	01 No.
02.	Ammeters (0-2 amps DC)	Digital	01 No.
03.	Ammeters (0-20 amps DC)	Digital	01 No.
04.	Ammeters (0-5 amps AC)	Digital	01 No.
05.	Voltmeters (0-500 Volts, AC)	Digital	01 No.
06.	Rheostat 370 ohms/1.7 amps	Tubular type	01 No.
07.	Separate Excitation source(0-220V/2A DC)	-----	01 No.
08.	Connecting wires	-----	required

THEORY:

 (i) A balanced system of 3-phase currents having positive (or normal) phase sequence. These
are called *positive phase sequence components.*

(ii) A balanced system of 3-phase currents having the opposite or negative phase sequence. These are called *negative phase sequence components.*

(iii) A system of three currents equal in magnitude and having zero phase displacement. These are called *zero phase sequence components.*

The positive, negative and zero phase sequence components are called the *symmetrical components* of the original unbalanced system. The term 'symmetrical' is appropriate because the unbalanced3-phase system has been resolved into three sets of balanced (or symmetrical) components. The subscripts 1, 2 and 0 are generally used to indicate positive, negative and zero phase sequence components respectively. For instance, I_{R0} indicates the zero phase sequence component of the current in the red phase. Similarly, I_{Y1} implies the positive phase sequence component of current in the yellow phase. The positive phase sequence currents (I_{R1}, I_{Y1} and I_{B1}), negative phase sequence currents (I_{R2}, I_{Y2} and I_{B2}) and zero phase sequence currents

(I_{R0}, I_{Y0} and I_{B0}) separately from balanced system of currents. Hence, they are called symmetrical components of the unbalanced system. The symmetrical component theory applies equally tophase currents and voltages both phase and line values. The symmetrical components donot have separate existence. They are only mathematical components of unbalancedcurrents (or voltages) which a tually flow in the system. In a balanced 3-phase system, negative and zero phase sequence currents are zero.

Synchronous generators. The positive, negative and zero sequence impedances of rotating machines are generally different. The positive sequence impedance of a synchronous Generator is equal to the synchronous impedance of the machine. The negative sequence impedance is much less than the positive sequence impedance. The zero sequence impedance is a variable item and if its value is not given, it may be assumed to be equal to the positive sequence impedance.

In short:
Negative sequence impedance < Positive sequence impedance
Zero sequence impedance = Variable item
                        = may be taken equal to +ve sequence impedance if its value is
   not given
It may be worthwhile to mention here that any impedance Z_n in the earth connection of a star connected system has the effect to introduce an impedance of $3Z_n$per phase. It is because the three equal zero-sequence currents, being in phase, do not sum to zero at the star point, but they flow back along the neutral earth connection. Experimental set up to conduct OCC and SCC is made available. With the help of observations impedance can be calculated.

Synchronous
The –ve sequence impedance is much less than +ve Sequence impedance. The zero sequence impedance is a variable item and if its value is not given, it may be assumed to be equal to
the +ve sequence impedance. For Zero sequence impedance a separate model is used to conduct of experiment.

Sequence network of a 3-phase Alternator:
A three-phase synchronous generator, having a synchronous impedance of Z_s per phase, with its neutral grounded through a impedance Z_n is shown in Fig. The generator is supplying a balanced three phase load. The generator voltages E_a, E_b and E_c are balanced and hence treated
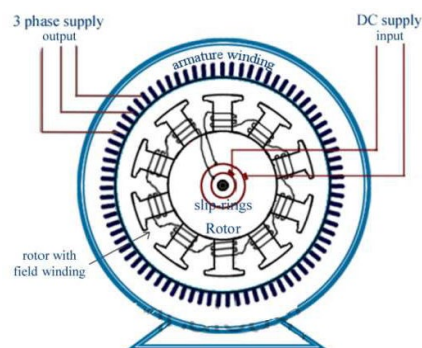
A. *Determination of Positive Sequence Impedance Z_1:*
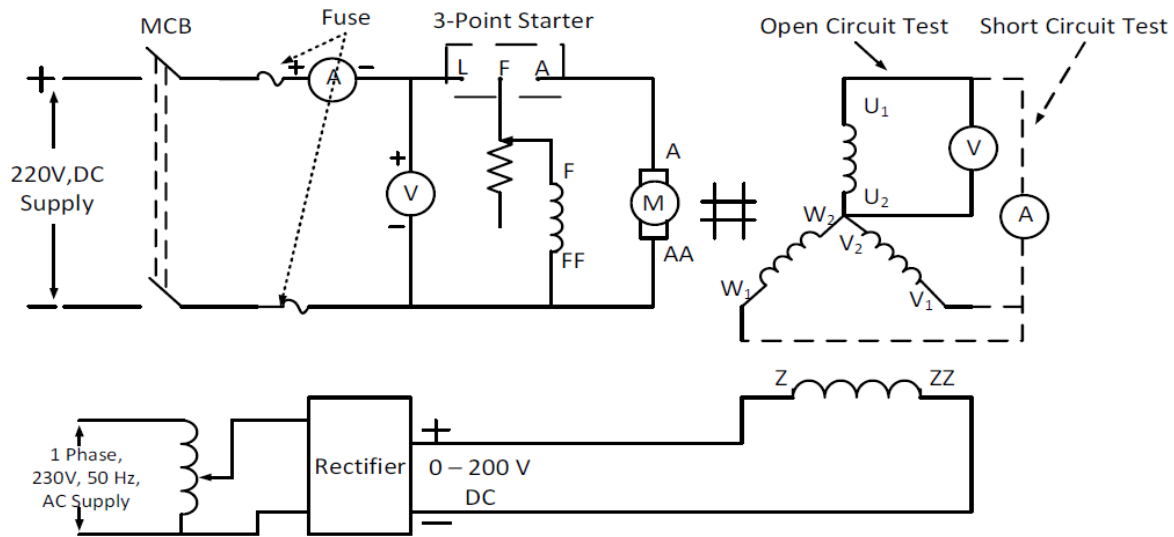
PROCEDURE:

In order to determine the positive sequence impedance, open circuit and short circuit tests are to be performed.
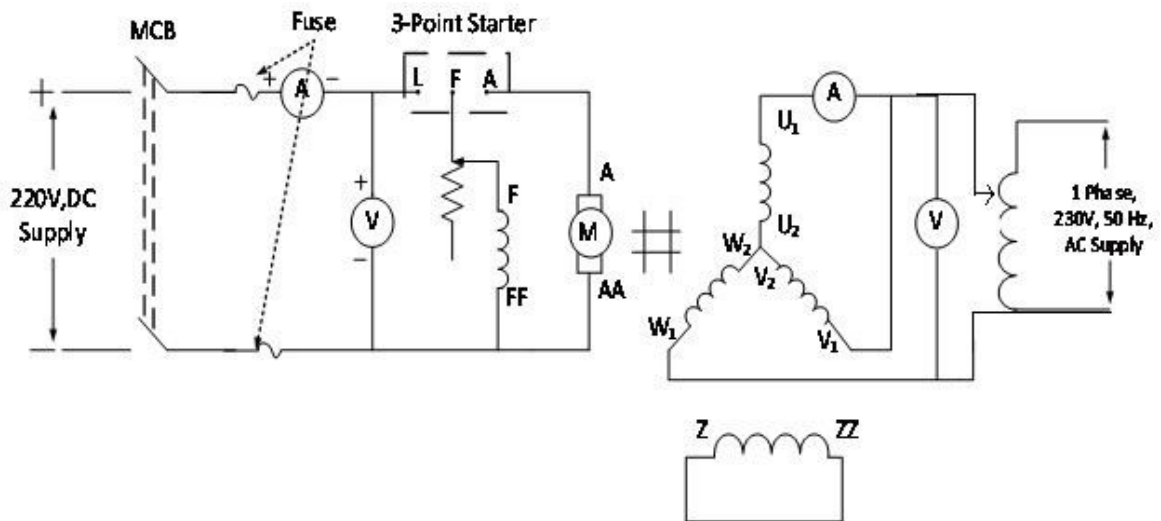
Open Circuit:

1. Connect the circuit as shown in the circuit diagram.
2. Field rheostat of the motor should be kept in minimum position and single phase variac should be in minimum output position.
3. Switch on the DC supply and start the motor-alternator set with the help of a three point starter.
4. Adjust the field rheostat of the motor to set motor-alternator set to the rated speed.
5. Slowly vary the Variac to increase the field excitation of the synchronous machine. Note down the value if I_f and V up to the rated voltage 415V.
6. Bring back the single phase Variac to the initial position, field rheostat to the minimum resistance position and switch off the MCB.

Short Circuit Test:

1. Connect the circuit as shown in the circuit diagram.
2. Field rheostat of the motor should be kept in minimum position and single phase variac should be in minimum output position.
3. Switch on the DC supply and start the motor-alternator set with the help of a three point starter.
4. Adjust the field rheostat of the motor to set motor-alternator set to the rated speed.
5. Slowly vary the variac such that the rated current flows through the alternator. Note down the field current and armature current.
6. Bring back the single phase variac to the initial position, field rheostat to the minimum resistance position and switch off the MCB.

B. *Determination of Negative Sequence Impedance Z_2 :*
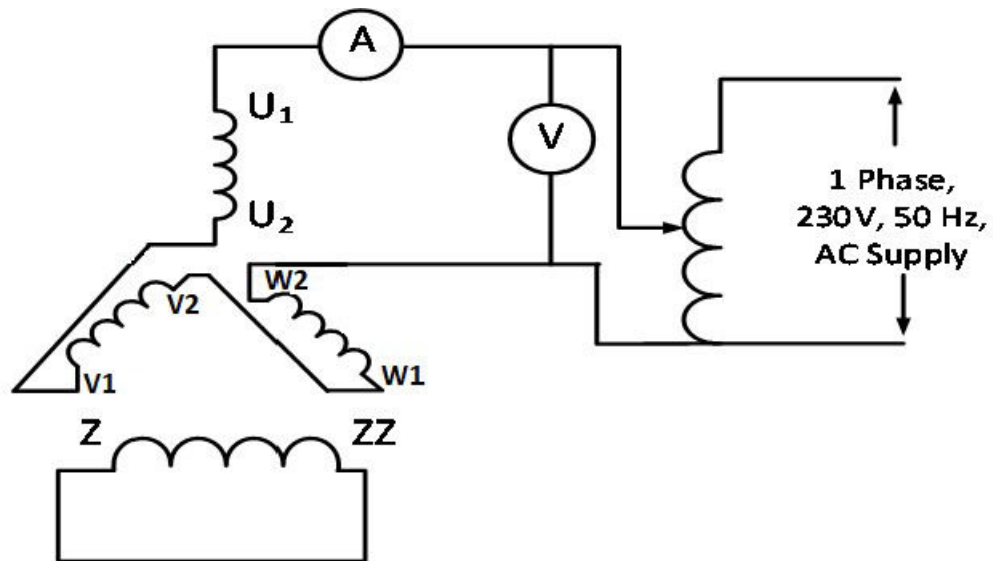
Circuit Diagram:

PROCEDURE:

1. Connect the circuit as per the circuit diagram.
2. Keep the armature resistance of the motor at maximum resistance position, field rheostat of the motor at minimum position and single phase variac at minimum output position.
3. Switch on MCB and start the motor-alternator set using 3 point starter.
4. Slowly apply the voltage and observe the fluctuations in voltmeter and ammeter of the alternator.
5. Adjust the armature rheostat of the motor to get slow oscillations.
6. Note down the minimum and maximum values of voltage and current.
7. Bring back all the rheostats and variac to the initial positions and switch off the supply.

C. *Determination of Zero Sequence Impedance Z_0 :*

Circuit Diagram:

PROCEDURE:

1. Connect the circuit as per the circuit diagram.
2. The three phase windings of the synchronous machine are connected in series.
3. Apply low voltage to the armature so that rated current flows in the series winding.
4. Note down the value of voltmeter and ammeter.
5. Reduce the voltage and switch off the supply.

Tabular Columns:

A. Positive Sequence Impedance

OC test

I_f						
V						

SC test

I_{sc}			
I_f			

Plot OCC and SC characteristics and calculate the positive sequence impedance

$$Z = \frac{V_{OC}}{SC} \; \Omega \quad \text{For the same filed current.}$$

B. *Negative Sequence Impedance*

$$Z = \frac{V}{\sqrt{3}I} \; \Omega$$

C. Zero sequence impedance

V	I	$Z_O = \dfrac{V}{\sqrt{3}I} \; \Omega$

RESULT:

LG, L-L & LL-G FAULT ANALYSIS OF AN ALTERNATOR

AIM: To determine the fault currents on an unloaded synchronous generator for

1. Line to ground fault (L-G Fault)
2. Line to Line fault(L-L fault)
3. Double Line to ground fault(LL-G Fault)

APPARATUS REQUIRED:

Sl.No	Apparatus	Type	Quantity
01.	DC motor coupled to alternator set	-----	01 No.
02.	Ammeters (0-2 amps DC)	Digital	01 No.
03.	Ammeters (0-20 amps DC)	Digital	01 No.
04.	Ammeters (0-5 amps AC)	Digital	01 No.
05.	Voltmeters (0-500 Volts, AC)	Digital	01 No.
06.	Rheostat 370 ohms/1.7 amps	Tubular type	01 No.
07.	Separate Excitation source(0-220V/2A DC)	-----	01 No.
08.	Connecting wires	-----	required

THEORY:

SINGLE LINE-TO-GROUND FAULT:

Consider a 3-phase system with an earthed neutral. Let a single line-to-ground fault occur on the red phase as shown in Fig. 18.13. It is clear from this figure that :

$$^{*}\vec{V_R} = 0 \quad \text{and} \quad \vec{I_B} = \vec{I_Y} = 0$$

*   Note that V_R is the terminal potential of phase R i.e. p.d. between N and R. Under line-to-ground fault, it will obviously be zero.
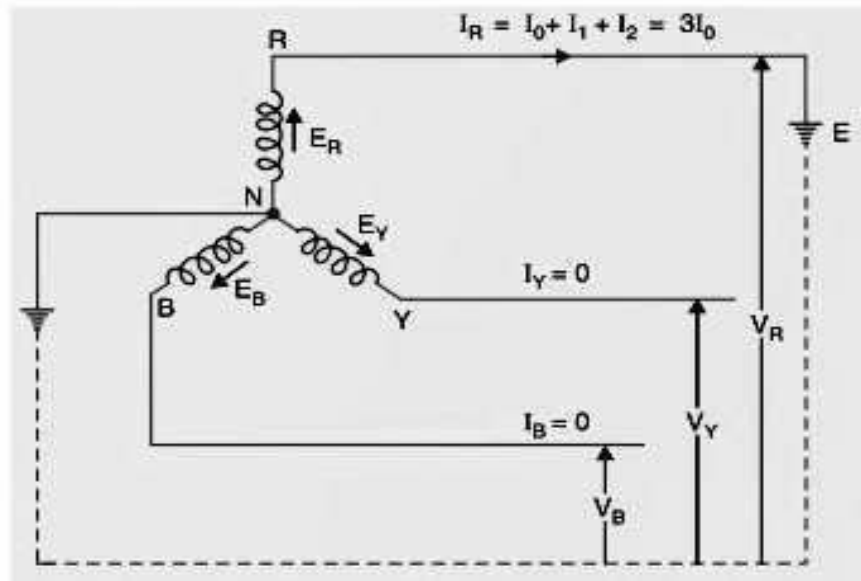
The sequence currents in the red phase in terms of line currents shall be

$$\vec{I_0} = \frac{1}{3}\left(\vec{I_R} + \vec{I_Y} + \vec{I_B}\right) = \frac{1}{3}\vec{I_R}$$

$$\vec{I_1} = \frac{1}{3}\left(\vec{I_R} + a\vec{I_Y} + a^2\vec{I_B}\right) = \frac{1}{3}\vec{I_R}$$

$$\vec{I_2} = \frac{1}{3}\left(\vec{I_R} + a^2\vec{I_Y} + a\vec{I_B}\right) = \frac{1}{3}\vec{I_R}$$

$$\vec{I_0} = \vec{I_1} = \vec{I_2} = \frac{1}{3}\vec{I_R}$$

Fault current. First of all expression for fault current $\vec{I_R}$ will be derived. Let $\vec{Z_1}$, $\vec{Z_2}$ and $\vec{Z_0}$ be the positive, negative and zero sequence impedances of the generator respectively. Consider the closed loop *NREN*. As the sequence currents produce voltage drops due only to their respective sequence impedances, therefore, we have,
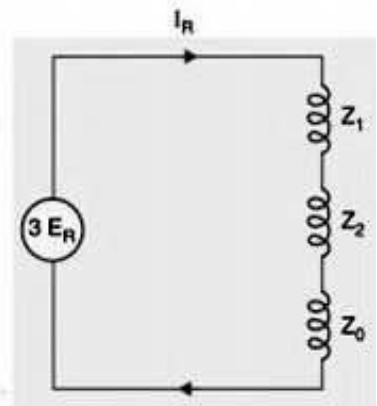
$$\vec{E_R} = \vec{I_1}\vec{Z_1} + \vec{I_2}\vec{Z_2} + \vec{I_0}\vec{Z_0} + \vec{V_R}$$

As $\qquad \vec{V_R} = 0 \quad \text{and} \quad \vec{I_1} = \vec{I_2} = \vec{I_0}$

$$\vec{E_R} = \vec{I_0}\left(\vec{Z_1} + \vec{Z_2} + \vec{Z_0}\right)$$

or $\qquad \vec{I_0} = \dfrac{\vec{E_R}}{\vec{Z_1} + \vec{Z_2} + \vec{Z_0}}$

Fault current, $\qquad \vec{I_R} = 3\vec{I_0} = \dfrac{3\vec{E_R}}{\vec{Z_1} + \vec{Z_2} + \vec{Z_0}} \quad ...(i)$

For line (R-phase)-to-ground fault :

$$\vec{I_R} = \text{Fault current} = \frac{3\vec{E_R}}{\vec{Z_1} + \vec{Z_2} + \vec{Z_0}} \quad ; \quad \vec{I_Y} = 0 \quad ; \quad \vec{I_B} = 0$$

$$\vec{V_R} = 0$$
$$\vec{V_Y} = \vec{V_0} + a^2\vec{V_1} + a\vec{V_2}$$
$$\vec{V_B} = \vec{V_0} + a\vec{V_1} + a^2\vec{V_2}$$

SINGLE LINE-TO-LINE FAULT:

Consider a line-to-line fault between the blue (B) and yellow (Y) lines as shown in Fig. 18.15. The conditions created by this fault lead to :

$$\vec{V_Y} = \vec{V_B} \quad ; \quad \vec{I_R} = 0 \quad \text{and} \quad \vec{I_Y} + \vec{I_B} = 0$$

Again taking R-phase as the reference, we have,

$$\vec{I_0} = \frac{1}{3}\left(\vec{I_R} + \vec{I_Y} + \vec{I_B}\right) = 0$$

Now
$$\vec{V_Y} = \vec{V_B}$$

Expressing in terms of sequence components of red line, we have,

$$\vec{V_0} + a^2\vec{V_1} + a\vec{V_2} = \vec{V_0} + a\vec{V_1} + a^2\vec{V_2}$$

or
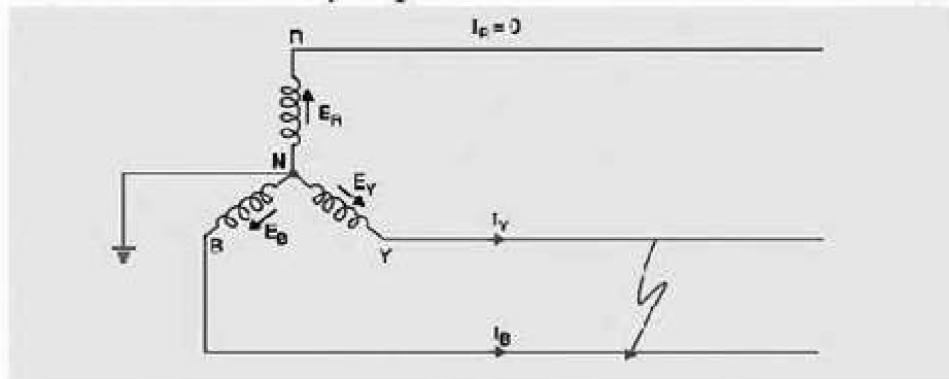$$\vec{V_1}(a^2 - a) = \vec{V_2}(a^2 - a)$$

$$\vec{V_1} = \vec{V_2} \qquad \qquad ...(i)$$

Fig. 18.15.

Also
$$\vec{I_Y} + \vec{I_B} = 0$$

or $\left(\vec{I_0} + a^2\,\vec{I_1} + a\,\vec{I_2}\right) + \left(\vec{I_0} + a\,\vec{I_1} + a^2\,\vec{I_2}\right) = 0$

or $\left(a^2 + a\right)\left(\vec{I_1} + \vec{I_2}\right) + 2\vec{I_0} = 0$

or $\vec{I_1} + \vec{I_2} = 0 \qquad [\because I_0 = 0] \qquad \ldots(ii)$

Fault current. Examination of exp. (*i*) and exp (*ii*) reveals that sequence impedances should be connected as shown in Fig. 18.16. It is clear from the figure that :
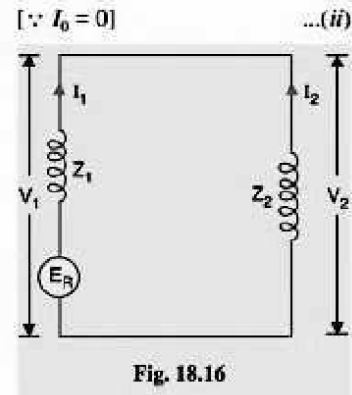
$$\vec{I_1} = -\vec{I_2} = \frac{\overline{E_R}}{\overline{Z_1} + \overline{Z_2}}$$

Fig. 18.16

Fault current, $\quad \vec{I_Y} = \vec{I_0} + a^2\,\vec{I_1} + a\,\vec{I_2}$

$$= 0 + a^2\left(\frac{\overline{E_R}}{\overline{Z_1} + \overline{Z_2}}\right) + a\left(\frac{-\overline{E_R}}{\overline{Z_1} + \overline{Z_2}}\right)$$

$$= (a^2 - a)\frac{\overline{E_R}}{\overline{Z_1} + \overline{Z_2}}$$

$$= \frac{-j\sqrt{3}\,\overline{E_R}}{\overline{Z_1} + \overline{Z_2}} = -\vec{I_B}$$

Summary of Results. For line-to-line fault (Blue and Yellow lines) :

(*i*) $\vec{I_R} = 0$; $\vec{I_Y} = -\vec{I_B} = \dfrac{-j\sqrt{3}\,\overline{E_R}}{\overline{Z_1} + \overline{Z_2}}$

(*ii*) $\vec{V_Y} = \vec{V_B} = -\dfrac{\overline{Z_2}}{\overline{Z_1} + \overline{Z_2}}\,\overline{E_R}$ and $\vec{V_R} = \dfrac{2\,\overline{Z_2}}{\overline{Z_1} + \overline{Z_2}}\,\overline{E_R}$

DOUBLE-TO-LINE-GROUND:

Consider the double line-to-ground fault involving Y–B lines and earth as shown in Fig. 18.17. Th conditions created by this fault lead to :
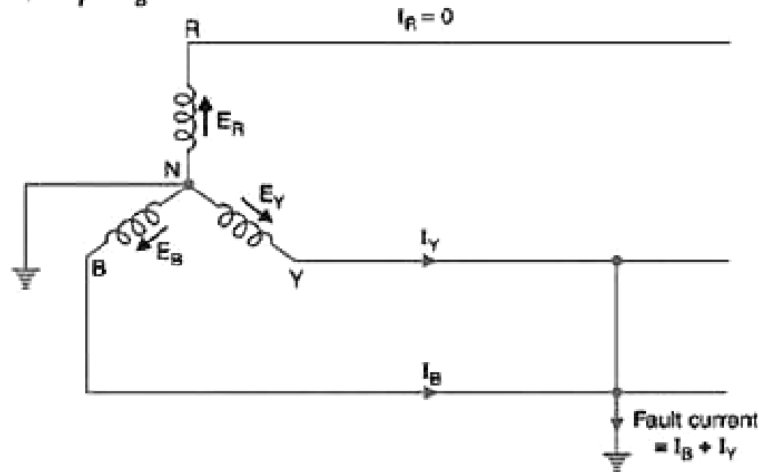
$$\vec{I_R} = 0 \quad ; \quad \vec{V_Y} = \vec{V_B} = 0$$

Fig. 18.17

Since $\vec{V_Y} = \vec{V_B} = 0$, it is implied that :

$$\vec{V_1} = \vec{V_2} = \vec{V_0} = \frac{1}{3} \vec{V_R} \qquad ...(i)$$

Also $\vec{I_R} = \vec{I_1} + \vec{I_2} + \vec{I_0} = 0 \quad (given) \qquad ...(ii)$

Fault current. Examination of exp. (i) and exp. (ii) reveals that sequence impedances should be *connected as shown in Fig. 18.18. It is clear that :

$$\vec{I_1} = \frac{\vec{E_R}}{\vec{Z_1} + \dfrac{\vec{Z_2}\,\vec{Z_0}}{\vec{Z_2} + \vec{Z_0}}}$$

$$\vec{I_2} = -\vec{I_1}\,\frac{\vec{Z_0}}{\vec{Z_2} + \vec{Z_0}}$$

$$\vec{I_0} = -\vec{I_1}\,\frac{\vec{Z_2}}{\vec{Z_2} + \vec{Z_0}}$$

Fig. 18.18

Fault current, $\vec{I_F} = \vec{I_Y} + \vec{I_B} = 3\vec{I_0} ** = 3\left(-\vec{I_1}\,\dfrac{\vec{Z_2}}{\vec{Z_2} + \vec{Z_0}}\right)$

$$= -\frac{3\,\vec{Z_2}}{\vec{Z_2} + \vec{Z_0}} \times \frac{\vec{E_R}}{\vec{Z_1} + \dfrac{\vec{Z_2}\vec{Z_0}}{\vec{Z_2} + \vec{Z_0}}}$$

$$= -\frac{3\,\vec{Z_2}\,\vec{E_R}}{\vec{Z_0}\,\vec{Z_1} + \vec{Z_0}\,\vec{Z_2} + \vec{Z_1}\,\vec{Z_2}}$$
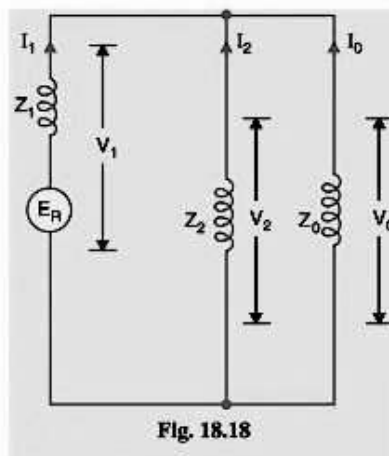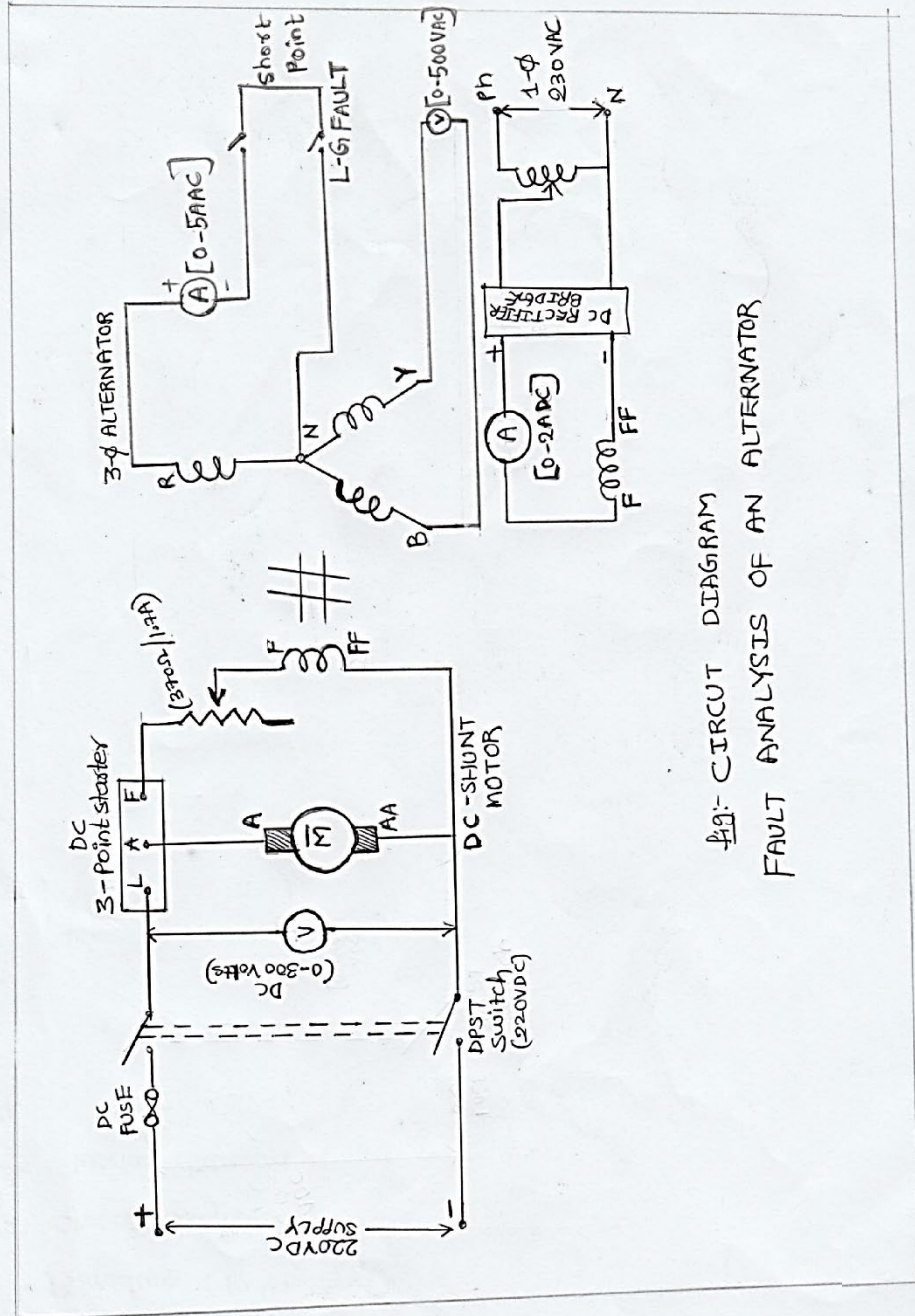
Fig:- CIRCUT DIAGRAM
FAULT ANALYSIS OF AN ALTERNATOR

PROCEDURE:

L-G FAULT:

1. Connect the circuit as per the circuit diagram for a line to ground fault on phase A.
2. Calculate the determinate value of the fault current from impedances (+ve, -ve, Zero sequences).
3. Run the generator rated speed.
4. Increase the field current of excitation so that terminal voltage is constant value.
5. Close the switch to create the L-G fault on Phase A.
6. Note the current and voltage in the ammeter and voltmeter.
7. Open the switch and remove the L-G fault on phase A.
8. Reduce the excitation and open the field circuit witch and switch of the prime mover.

Note: This voltage must be such that it does not cause the rated current of the machine to be exceeded.

TABULATION: For 3KVA alternator

Sl.No.	I in Amps	E_r in Volts
01.	4.16	

$I_a = 3E_r/(Z_1+Z_2+Z_0)$------------------------------- (1)

Where Ia is fault current

Ef is the voltage to which the machine is excited

Z1+Z2+Z0are the positive, negative and zero sequence impedances of the machine.

Verify the theoretical value calculated by using equation1 with the actual value noted by the ammeter.

- *CIRCUIT DIAGRAM FOR LINE TO LINE FAULT (L-L FAULT):*

Fig:- CIRCUIT DIAGRAM
FAULT ANALYSIS OF AN ALTERNATOR

PROCEDURE:

L-L FAULT:

1. Repeat the steps 1 to 6 from L-G Fault procedure for L-L and L-G faults.
2. Connect the respective circuit in step 1.
3. Generator is excited it's a certain voltage as mention in step 2 of the procedure.
4. This voltage must be such that it does not cause the rated current of the machine to be exceeded.

TABULATION: For 3KVA alternator

Sl.No.	I in Amps	E_f in Volts
01.	4.21	

$Ia1=Ef/Z1+Z2$

$Ib =a2Ia1+a\ Ia2;$
$Ia2=-Ia1$

Where a2= (-0.5-j0.866) a= (-0.5+j0.866)
Fault current calculated which must be verified with the actual value.

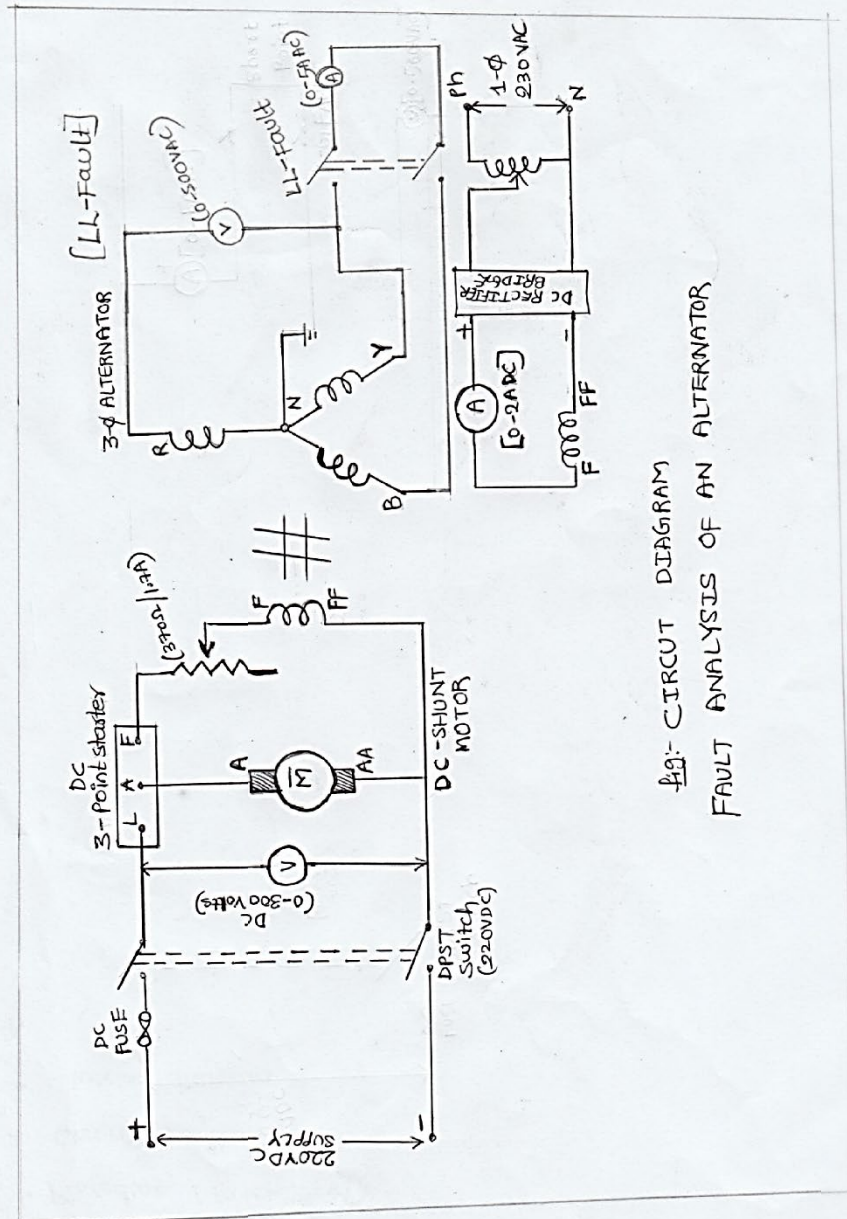• *CIRCUIT DIAGRAM FOR DOUBLE LINE TO GROUND FAULT (LL-G FAULT):*

Fig:- CIRCUT DIAGRAM

FAULT ANALYSIS OF AN ALTERNATOR

LL-G FAULT:

(1) Repeat the steps 1 to 6 from L-G Fault procedure for L-L and L-G faults.
(2) Connect the respective circuit in step 1.
(3) Generator is excited it's a certain voltage as mention in step 2 of the procedure.

TABULATION: For 3KVA alternator

Sl.No.	I in Amps	E𝑓 in Volts
01.	4.2	

E_f= **Short circuit Voltage at Fault condition.**

I = Rated Current of Alternator.

E_r = **armature Voltage of alternator.**

CALCULATIONS:

$Va1=Va2=Va0=Ef-Ia1Z1$

$Ia1=Ef/Z1+ (Z2 \times Z0/Z2+Z0)$ $Ia2=-Va2/Z2$; $Ia0= -Va0/Z0$
$Ib= a^2Ia1+a\ Ia2+Ia0$

Where $a^2= (-0.5+j0.866)$;
$a= (-0.5+j0.866)$ In $=3Ia0= Ib+IC$
$Ic= -Ib=a\ Ia1-a^2Ia1$

Fault Analysis of an Alternator

1) **L-G Fault :-**
$$E_r = \frac{187}{\sqrt{3}} = 108 \text{ volts} \quad (\text{L-G}).$$

∴ Positive seq. Impedance $(Z_1) = 47\,\Omega$.

∴ Negative seq. Impedance $(Z_2) = 24\,\Omega$.

∴ Zero seq. Impedance $(Z_0) = 6.8\,\Omega$.

$E_r = 108 \text{ volts}; \quad I = 4.2A$

$$\therefore I_R = 3 \times I_0 = \frac{3 \times E_R}{Z_1 + Z_2 + Z_0} = \frac{3 \times 108}{47 + 24 + 6.8} = 4.16\,A$$

$$\therefore I_R = 4.16 \text{ Amps}.$$

2) **L-L Fault :-**
$$(E_F = 184 \text{ Volts}).(\text{L-L})$$

$$\therefore I_{a_1} = \frac{E_F}{Z_1 + Z_2} = \frac{184}{47 + 24} = 2.6 \text{ Amps}.$$

$$\therefore I_b = a^2 I_{a_1} + a I_{a_2}$$

$$\Rightarrow a^2 = (-0.5 + j0.866)$$
$$a = (-0.5 - j0.866).$$

$$\Rightarrow 3.554 + 0.866 = 4.46 \text{ Amps}.$$

$$\therefore I_b = 4.46 \text{ Amps}.$$

3) **L-L-G FAULT :-** $\quad V = 155 \text{ volts. } (L-L-G).$

$$\therefore I_1 = \frac{E_R = 155}{Z_1 + \dfrac{Z_2 \times Z_0}{Z_2 + Z_0}} = 1.7 \text{ Amps.}$$

$$\therefore I_2 = -I_1 \frac{Z_0}{Z_2 + Z_0} = 0.385 \text{ Amps.}$$

$$\therefore I_0 = -I_1 \times \frac{Z_2}{Z_1 + Z_0} = +1.36 \text{ Amps.}$$

$$\therefore \text{Fault Current } (I_{fa}) = 3 \times I_0 = 3 \times (1.36)$$

$$= 4.08 \text{ Amps.}$$

$$\Rightarrow \frac{3 \times Z_2 \times E_R}{Z_0 Z_1 + Z_0 Z_2 + Z_1 Z_2} = 3.98 \text{ Amps.}$$

$$\therefore Z_1 = 47\Omega$$
$$\therefore Z_2 = 24\Omega$$
$$\therefore Z_0 = 6.8\Omega$$

RESULT:

ABCD CONSTANS & REGULATION OF A 3-Ph TRANSMISSION LINE MODEL

AIM: To calculate the efficiency and regulation of long transmission line with R and RL loads in power system simulator and also performing VAR compensation for RL load using capacitor banks.

APPARATUS REQUIRED:

S.NO.	APPARATUS	RATING	QUANTITY
1.	Digital Voltmeters.	0-500Volts AC	02
2.	Digital Ammeters.	0-20Amps AC	02
3.	Wattmeters	500V/5Amps	04
4.	MCB protection (3-pole type)	32 amps	01
5.	Inductor Coils. (air core type)	0.32milli Henry	60
6.	Capacitors (440Volts)	2 micro farad	60
7.	Load Bank (R-Load)	5 Amps	01
8.	Indication Lamps	(R, Y and B)	09
9.	Three Phase transformers	415/415 Volts, 7KVA	02
10.	Connecting Wires	-----	As required

THEORY:

Power System Simulator:
A power system simulator represents the total power system network consisting of generation, transmission and distribution systems in laboratory model. The schematic diagram of the power system simulator present in the power systems lab is given Fig1.

The supply to the power system simulator is from APSEB source.
  ➢ From AP State Electricity Board Supply
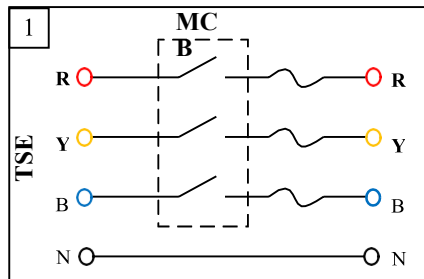
From the supply the power is transmitted to the load bank through different panels as listed.

> ➢ Sending End Panel
> ➢ Transmission line model
> ➢ Receiving End panel
> ➢ Load Bank panel

CIRCUIT DIAGRAM:

3-PHASE TRANSMISSION LINE MODEL

PROCEDURE: -   (For finding Efficiency and Regulation)

1. Make the connection as per the Circuit Diagram.
2. Switch ON supply and adjust rated voltage,
3. Note down voltage, no-load current readings.
4. Note down Current and power at sending end and receiving end at no load.
5. Now Switch ON some Load using R-load Bank provided.
6. Apply some Load like 3 amps in steps wise up to 5amps.
7. Note down all meter readings.
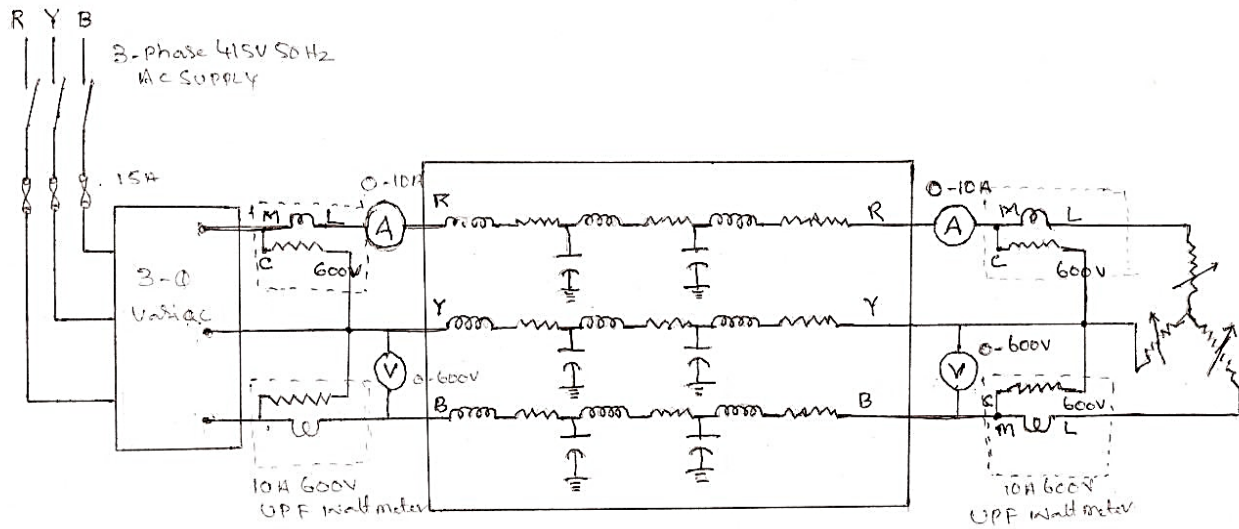8. Tabulate the readings in tabular columns.
9. Find out Efficiency and Regulation using formulas.
10. Repeat the same procedure for short and medium lines.
11. Observe all parameter readings in all conditions.
12. Note down the readings and tabulate it.

TABULAR COLUMNS:

R Load: - Loading Condition

Vs	Is	Ws	Vr	Ir	Wr	$\eta = \dfrac{Wr}{Ws} \times 100$	$Re\,g = \dfrac{Vs - Vr}{Vr} \times 100$

<u>**SAMPLE CALCULATIONS:**</u>

1. **Voltage Regulation Formula:**

   Voltage regulation of transmission line is defined as the ratio of difference between sending and receiving end voltage to receiving end voltage of a transmission line between conditions of no load and full load. It is also expressed in percentage.

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

2. Transmission efficiency is defined as the ration of receiving end power P_R to the sending end power P_S and it is expressed in percentage value.

$$\% \, \eta T = \frac{P_R}{P_S} \times 100 = \frac{V_R I_R \cos \theta_R}{V_S I_S \cos \theta_S} \times 100$$

PRECAUTION: -

> Keep the voltage at sending end constant throughout the experiment.
> Avoid loose connections.

RESULT:

DETERMINATION OF POSITIVE, NEGATIVE AND ZERO SEQUENCES OF A 3-PHASE TRANSFORMER

Aim: To determine the Positive, Negative and Zero sequence (sequence impedance) of given three phase transformer.

Apparatus required:

S.No	Apparatus	Type	Quantity
1	Voltmeters	0-500V,	1 No
2	Ammeter	20A	1 No
3	3-Phase Transformer	Shell type	1 No
4	Auto transformer	Closed type	1 No
5	Patch cords		As required

Theory:

Each element of power system will offer impedance to different phase sequence components of currentwhich may not be the same. For example, the impedance which any piece of equipment offers topositive sequence current will not necessarily be the same as offered to negative sequence current orzero sequence current. Therefore, in unsymmetrical fault calculations, each piece of equipment willhave three values of impedance—one corresponding to each sequence current *viz.*

(i) Positive sequence impedance ($Z1$)

(ii) Negative sequence impedance ($Z2$)

(iii) Zero sequence impedance ($Z0$)

The impedance offered by an equipment or circuit to positive sequence current is called positive

sequence impedance and is represented by $Z1$. Similarly, impedances offered by any circuit or equipment to negative and zero sequence currents are respectively called negative sequence impedance($Z2$) and zero sequence impedance ($Z0$).In a 3-phase

balanced system,each piece of equipment or circuit offers only one impedance–the one offered to positive or normal sequence current. This is expected because of theabsence of negative and zero sequence currents in the 3-phase balanced system.In a 3-phase unbalanced system, each piece of equipment or circuit will have three values ofimpedance *viz*. positive sequence impedance, negative sequence impedance and zero sequenceimpedance.The positive and negative sequence impedances of linear, symmetrical and static circuits (*e.g.* transmission lines, cables, transformers and static loads) are equal and are the same asthose used in the analysis of balanced conditions. This is due to the fact that impedance ofsuch circuits is independent of the phase order, provided the applied voltages are balanced.It may be noted that positive and negative sequence impedances of rotating machines (*e.g.* Synchronous and induction motors) are normally different.The zero sequence impedance depends upon the path taken by the zero sequence current.As this path is generally different from the path taken by the positive and negative sequencecurrents, therefore, zero sequence impedance is usually different from positive or negativesequence impedance.The positive sequence impedance of a transformer equals the leakage impedance. It may be obtained by the usual short-circuit test. Since the transformer is a static device, the leakage impedance does not change, if the phase sequence is altered from RYB to RBY. Therefore the negative sequence impedance of transformer is the same as the positive sequence impedance. The zero sequence impedance of the transformer depends on the winding type (star or delta) and also on the type of earth connection. The positive & negative sequence per unit impedances are independent of whether the sequence currents are injected into the primary or the secondary. However the zero sequence impedances will have different values, depending upon whether the sequence currents are injected into the primary or the secondary Since Transformers have the same impedance with reversed phase rotation, their +ve and –ve sequence impedances are equal. This value being equal to the impedance of the Transformer. However, Zero sequence impedance depends upon the Earth connection. If there is a through Circuit for the earth current, zero sequence impedance will be equal to the +ve sequence impedance otherwise it will be infinite. Lab experiment is planned to find out sequence impedances by creation of faults at secondary suitably and measure impedances. Proper care is taken to ensure readings would not damage the equipment.

In short,

Positive sequence impedance = Negative sequence impedance

= Impedance of Transformer

Zero sequence impedance = Positive sequence impedance, if there is circuit for earth current
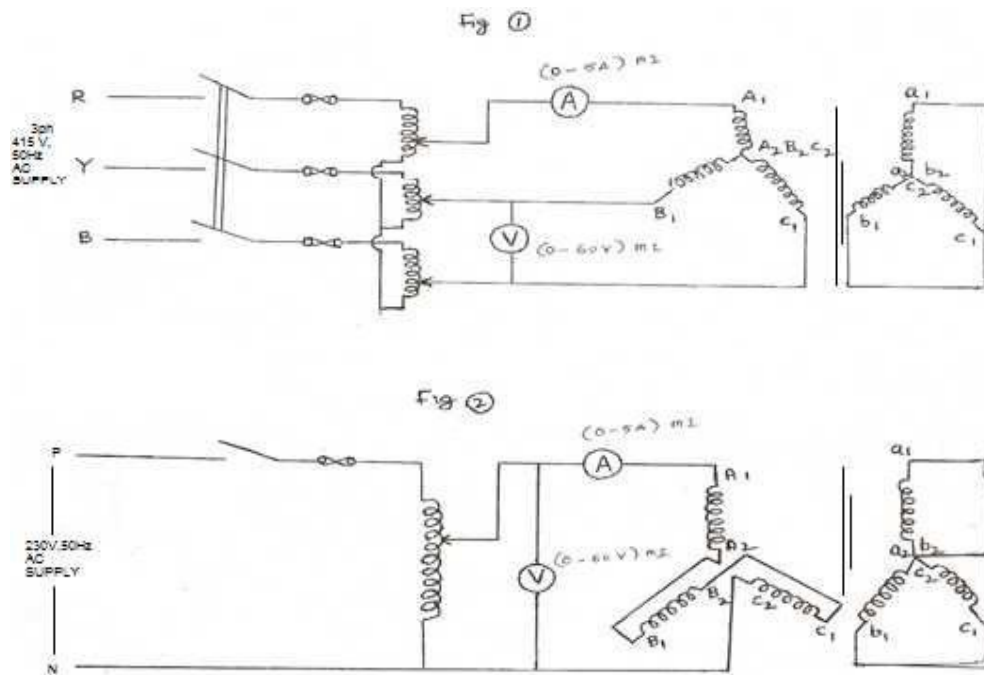
= Infinite, if there is no through circuit for earth current.

Formulae used:

$$Z_1 = Z_2 = V / \sqrt{3}I \, ;$$

$$Z_0 = V / 3I$$

Measurement of the positive and negative sequence impedances: Circuit Diagram:

- **Transformer Details :**

  ❖ **Rating : 1 KVA**
  ❖ **Voltage Rating: 400V/200V (L-L)**
  ❖ **Primary Current : 1.4A (Per Phase)**

Procedure:

7. Connect the transformer to the variable 3-phase supply (auto transformer) as shown in the figure. (1)
8. Connect active circuit on HV side (400V) and Short circuit on Low voltage side (200V).
9. Vary the 3-phase autotransformer so that the rated current (1.4) Amps flow through the HV side.
10. Note down the readings of wattmeter, voltmeter and Ammeter.

Readings and Tabular form:

V	I	$Z_1 = Z_2 = V / \sqrt{3}\ I$

Measurement of the Zero sequence impedance:

Procedure:

1. Connect the transformer to the variable 1-phase supply (auto transformer) as shown in the figure. (2)
2. Connect active circuit on HV side (400V) Short circuit on Low voltage side (200V).
3. Vary the 3-phase autotransformer so that the rated current (1.4) Amps flow through the HV side.
4. Note down the readings of wattmeter, voltmeter and Ammeter.

Readings and Tabular form:

V	I	$Z_0 = V / 3\ I$

RESULT:

ABCD Parameters of Transmission network

1. Aim: **To determine ABCD constants of 3-phase transmission line with**

   a) **Distributed Connection**

   b) **Nominal – T connection**

2. Apparatus:

   a) **For Open Circuit Test:**

      Voltmeter   - (0-300V) MI

      Ammeter   - (0-10A) MI

   b) **For Short Circuit Test**

      Voltmeter   - (0-30V) MI

      Ammeter   - (0-10A) MI

3. **Theory:**

   If a transmission line is erected, the constants are measured by conducting the OC&SC tests at the two ends of the line.

   Using equations

   $$V_s = AV_r + BI_s$$

   $$= CV_r + DI_r$$

Impedance measurement on the SE side: SE impedance with RE open circuitis

$$z_s - \frac{V}{I_s} = \frac{a}{c}(I_R = 0)$$

SE impedance with RE short circuited,

$$Z_{ss} = \frac{V_s}{I_s} = \frac{B}{D}V_r \quad = 0$$

Measurement of impedance on RE side using equations

$$V_r = DV_s - BI_r$$

$$= CV_s - A_s$$

While performing test, the current leaves the Network

$$I_s = I_s , I_r = I_r$$

$$V_r = DV_s - BI_s$$

$$-I_r = CV_s - A_s$$

$$_r = CV_s - AI_s$$

RE impedance with SE open circuited, Z_{ro}

$$Z_{ro} = \frac{V_r}{I_r} = \frac{D}{C} I_s = 0$$

RE impedance with SE short circuited, Z_{rs}

$$Z_{rs} = \frac{V_r}{I_r} = \frac{B}{A} I_{rs} = 0$$

$$Z_{ro} = Z_{rs} = \frac{D}{C} = \frac{B}{A} = \frac{1}{AC}$$

$$Z_{so} = \frac{Z_{so}}{Z_{ro} \quad Z_{rs}} = A^2$$

25

$$A = \sqrt{\frac{Z_{so}}{\left(Z_{ro} + Z_{rs}\right)}}$$

$$Z_{rs} = \frac{B}{A} \quad B = Z_{rs}A$$

$$B = Z_{rs}\sqrt{\frac{Z_{so}}{\left(Z_{ro} + Z_{rs}\right)}}$$

$$Z_{so} = \frac{A}{C} \quad C = \frac{A}{Z_{so}} = \frac{1}{Z_{so}}\sqrt{\frac{Z_{so}}{\left(Z_{ro} + Z_{rs}\right)}}$$

$$Z_{ro} = \frac{D}{C}$$

$$D = CZ_{ro} = \frac{Z_{ro}}{Z_{so}}\sqrt{\frac{Z_{so}}{\left(Z_{ro} + Z_{rs}\right)}}(Z_{ro} + Z_{so})$$

$$D = A$$

4. Circuit Diagram:
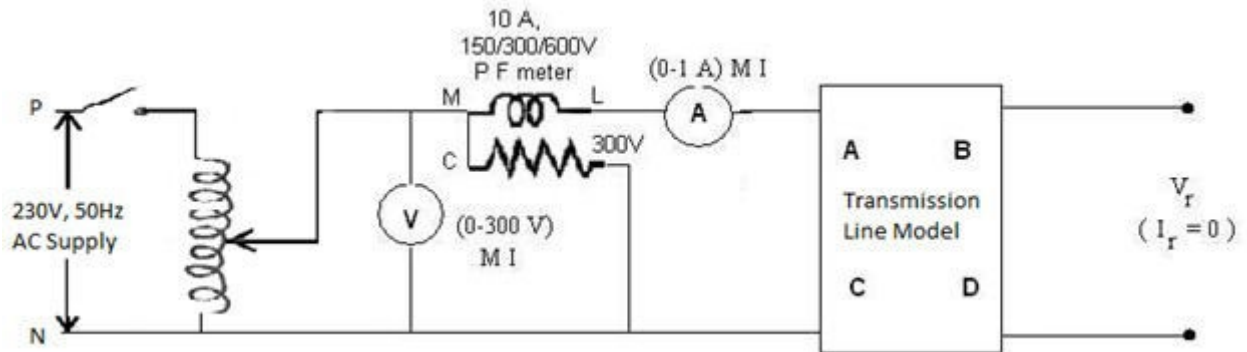
Fig-1 (OC test on SE side)
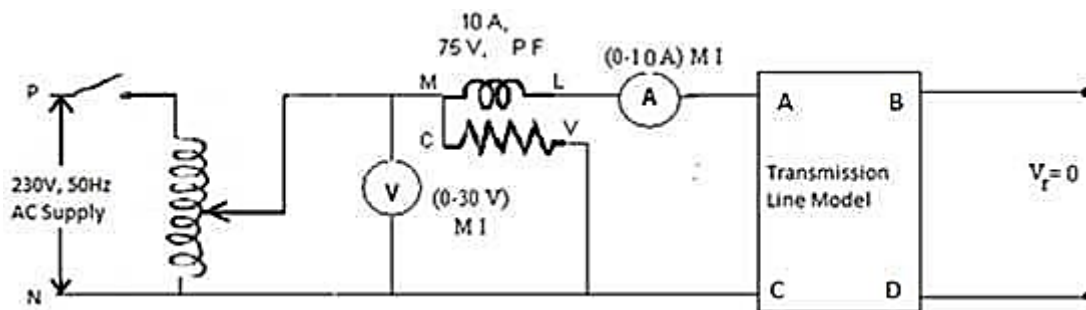
Fig-2 (SC test on SE)
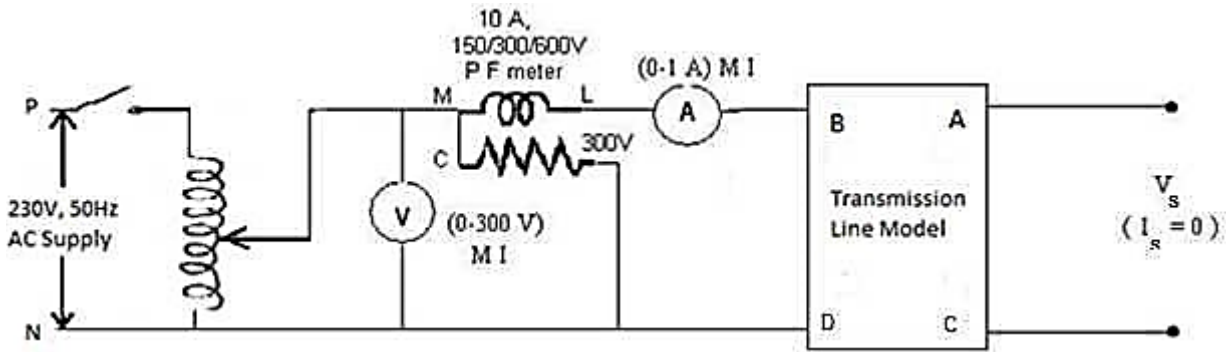
Fig-3 (OC test on RE side)
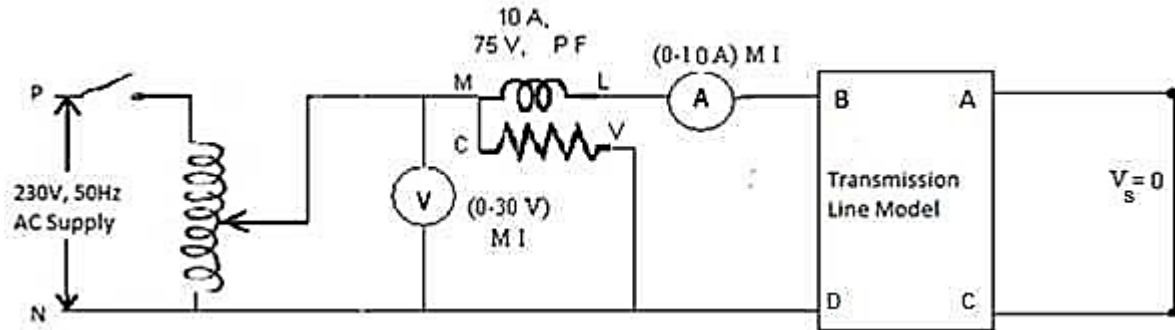
Fig.-4 (SC test on RE side)

5. Procedure: O.C & S.C. tests on SE side:

1. Connect the circuit as per fig.(1) for O.C. test on SE.

2. Set 230V on Voltmeter using variac and note V_s, I_s and p.f. meter reading.

3. Connect the circuit as per fig (2) for S.C. test on SE.

4. Set rated current of the line on Ammeter and note V_s, I_s and wattmeter readings.

28

6. **Procedure**: **O.C& S.C. tests on RE side:**

1. **Connect the circuit as per fig (3) for O.C test on RE.**
2. **Set 230V in Voltmeter & note V_r, I_r & p.f meter reading.**
3. **Connect the circuit as per fig (4) for SC test onRE.**
4. **Set rated current of the line in Ammeter & note V_r, I_r & Wattmeter reading.**

6. **Readings and Tabular forms**

O.C. & S.C. tests on SE side:

Test	V_s	I_s	p.f/Wattmeter
O.C(I_r=0)	230		
S.C(V_r=0)			

O.C. & SC tests of RE side

Test	V_r	I_r	p.f /Wattmeter
O.C(I_s=0)	230		
S.C(V_s=0)			

Calculations:

$$Z_{so} = \frac{V_s}{I_s} \left[I_r = 0 \right]$$

$$Z_{ss} = \frac{V_s}{I_s} \left[V_r = 0 \right]$$

$$Z_{ro} = \frac{V_r}{I_r} \left[I_s = 0 \right]$$

$$Z_{rs} = \frac{V_r}{I_r} \left[V_s = 0 \right]$$

$$A = \sqrt{\frac{Z_{so}}{\left(Z_{ro} - Z_{rs} \right)}}$$

$$B = Z_s \sqrt{\frac{Z_{so}}{\left(Z_{ro} - Z_{rs} \right)}}$$

$$C = \frac{1}{Z_{so}} \sqrt{\frac{Z_{so}}{\left(Z_{ro} - Z_{rs} \right)}}$$

$$D = A$$

Note: **Same 5. Procedure is repeated for Nominal – T Connection.**

7. Result:

1. DETERMINATION OF SEQUENCE IMPEDANCES OF CYLINDRICAL ROTOR SYNCHRONOUS MACHINE

Aim:-To determine experimentally Positive, Negative and Zero sequence reactance's of a cylindrical rotor synchronous machine.

Name Plate Details:-

S.No	Parameter	Alternator	DC Motor
1	Rated Voltage	415 V	220 V
2	Rated Current	4.2 A	20 A
3	Speed	1500 RPM	1500 RPM
4	Rating	3 KVA	5 HP
5	Power factor	0.8	-----
6	Frequency	50 Hz	-----
7	Excitation	220 V, 2 A	

Apparatus Required:-

S.No	Apparatus	Type	Range	Quantity
1	Ammeter			
2	Voltmeter			
3	Wattmeter			
4	Rheostat			
5	Tachometer			
6	Connecting Wires			

Procedure:-

(a) Determination of X_1 :-

(i) Open Circuit Test:-

1. Connect the circuit as per the given circuit diagram.

2. Ensure that the filed rheostat is kept in minimum resistance position.

3. Supply of 220V is given to dc motor, which is placed on the same shaft on which synchronous machine is placed and thus the synchronous machine is made to run at rated speed.

4. Voltmeter is connected across machine terminals and this meter is used to measure the voltage corresponding to the given field excitation and also the reading of the ammeter which is placed in the field winding.

5. Vary the field excitation, such that the voltmeter reads the rated voltage.

Circuit diagram for positive sequence reactance X_1:-

Circuit diagram for Negative sequence reactance X₂:-
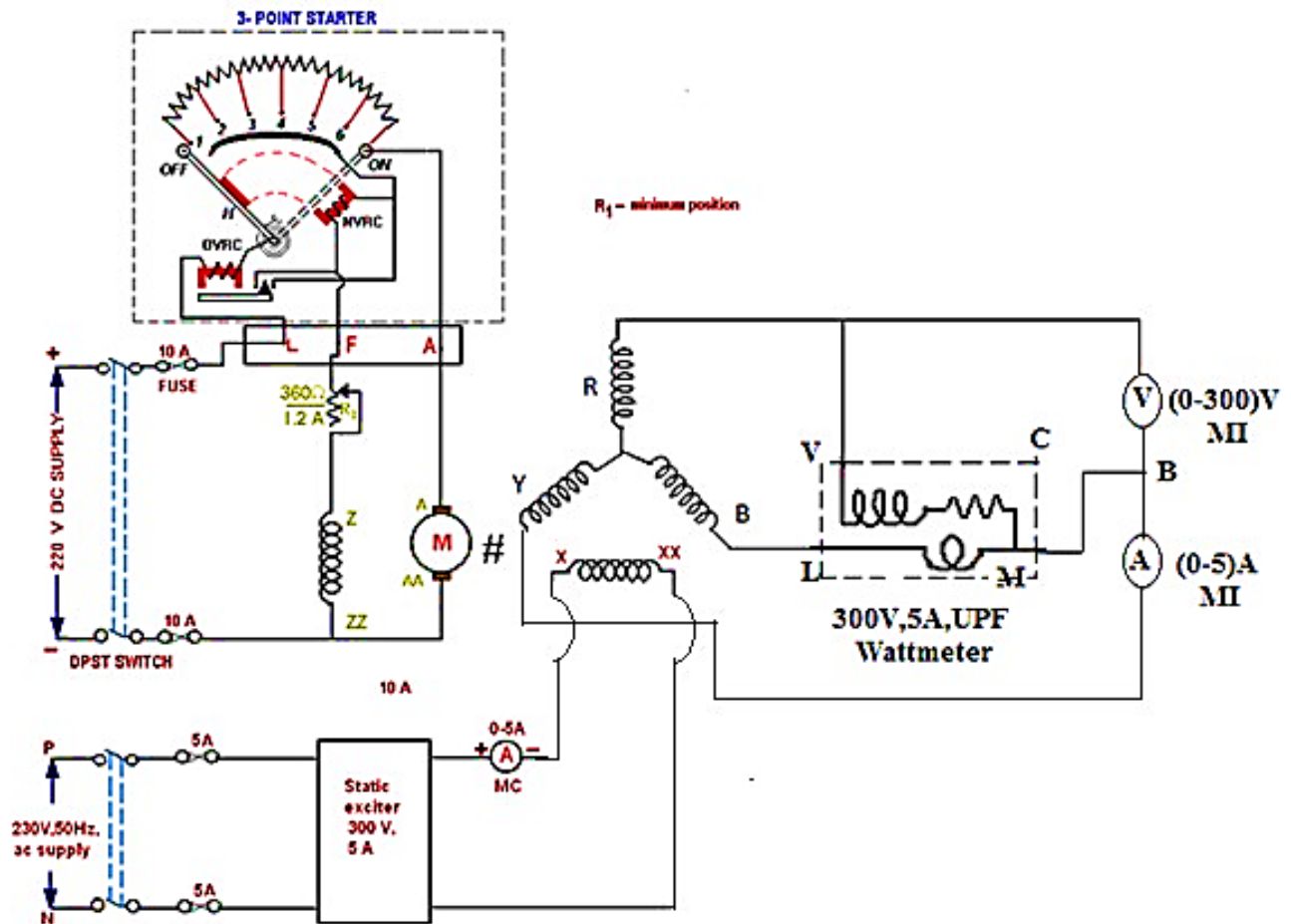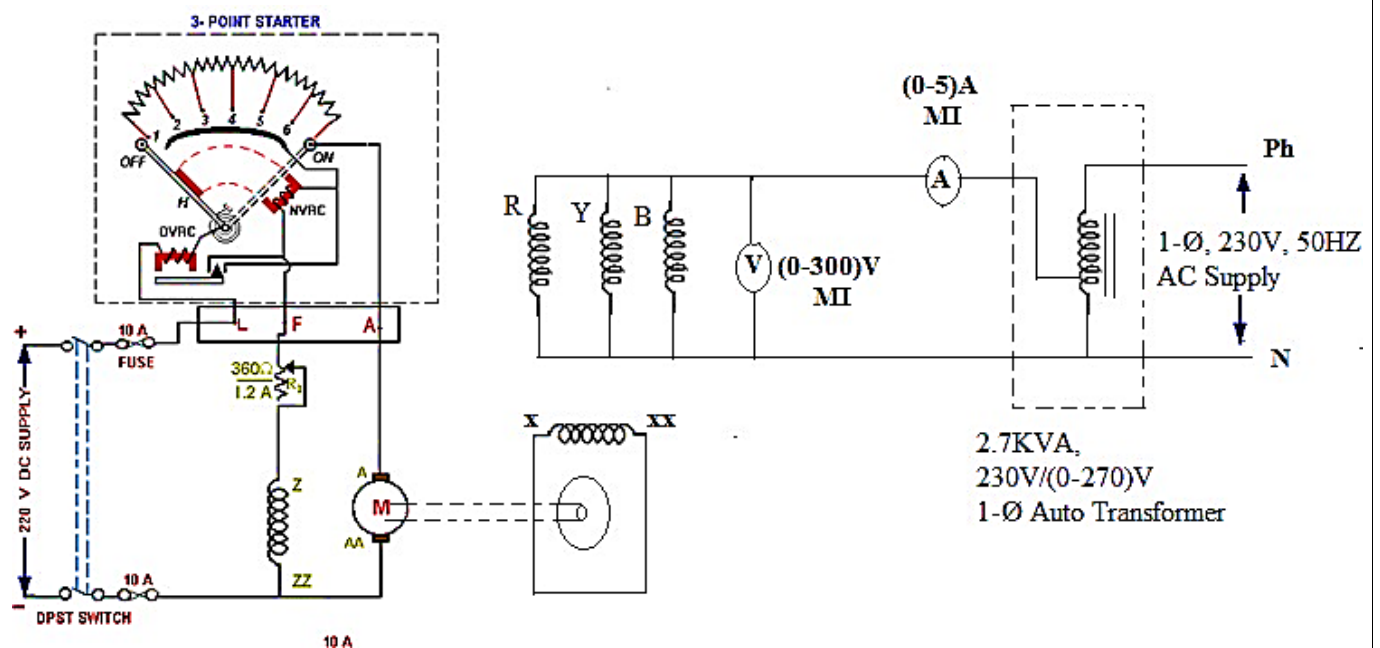

Circuit diagram for Zero sequence reactance X₀:-

(ii) Short Circuit Test:-

1. Connect the circuit as per the given circuit diagram.

2. Ensure that the filed rheostat is kept in minimum resistance position.

3. Supply of 220V is given to dc motor, which is placed on the same shaft on which synchronous machine is placed and thus the synchronous machine is made to run at rated speed.

4. Apply low voltage across the field circuit such that the rated current in the ammeter which connect the short circuit winding of the synchronous machine.

(b) Determination of X_2:-

1. Connect the circuit as per the given circuit diagram.

2. Ensure that the filed rheostat is kept in minimum resistance position.

3. Supply of 220V is given to dc motor, which is placed on the same shaft on which synchronous machine is placed and thus the synchronous machine is made to run at rated speed.

4. Short circuit the two phases of an alternator through an ammeter and the current coil of the wattmeter.

5. Connect the voltage coil of the wattmeter and voltmeter between the open phase and any short circuit phase.

6. Increase the Excitation gradually in step by step such that the short circuit current should not exceed the full load value.

(c) Determination of X_0:-

1. Connect the circuit as per the given circuit diagram.

2. Ensure that the filed rheostat is kept in minimum resistance position.

3. Supply of 220V is given to dc motor, which is placed on the same shaft on which synchronous machine is placed and thus the synchronous machine is made to run at rated speed.

4. Connect the armature winding in parallel.

5. Short circuit the field winding of an alternator.

6. Apply a low voltage of 1-Ø auto transformer and then taken the both the values of voltmeter and ammeter of an armature winding.

Tabular Column:-

(a) Determination of X_1 :-

(i) Open Circuit Test:-

Excitation Current I_f (A)	Open circuit voltage (V)

(ii) Short Circuit Test:-

Excitation Current I_f (A)	Short Circuit Current (A)

Positive sequence impedance $Z_1 = \dfrac{V_{OC}}{I_{SC}}$

Positive sequence reactance $X_1 = \sqrt{Z_1^2 - R_1^2}$

(b) Determination of X_2:-

Applied voltage (V)	Short circuit current (A)	Wattmeter reading (W)

Negative sequence impedance $Z_2 = \dfrac{V_{OC}}{I_{SC}}$

Power factor $Cos\,\phi = \dfrac{P}{\sqrt{3}\,VI_{SC}}$

Negative sequence reactance $X_2 = Z_2\,Sin\,\phi$

(c) Determination of X_0:-

Short circuit voltage (V)	Short circuit current (A)

Zero sequence reactance $X_0 = \dfrac{V_0}{I_0/3}$

Precautions:-

1. Avoid the loose connections.
2. Note down the readings without parallax error.
3. Keep the field rheostat in maximum resistance position.
4. Keep the variac of the static exciter in minimum voltage output position.

Result:-

Conclusion:-

EXP.NO: **DATE:**

Circuit diagram for L-G Fault:-

2. FAULT ANALYSIS – I

Aim:- To find the fault currents and fault voltages when a single line to ground (L-G) fault and line to line (L-L) faults occurred on unloaded alternator.

Name Plate Details:-

S.No	Parameter	Alternator	DC Motor
1	Rated Voltage	415 V	220 V
2	Rated Current	4.2 A	20 A
3	Speed	1500 RPM	1500 RPM
4	Rating	5 KVA	5 HP
5	Power factor	0.8	-----
6	Frequency	50 Hz	-----
7	Excitation	220V, 1A	220V, 1A

Apparatus Required:-

S.No	Apparatus	Type	Range	Quantity
1	Ammeter			
2	Voltmeter			
3	Rheostat			
4	Static Exciter			
5	Tachometer			
6	Connecting Wires			

Procedure:-
(a) LG Fault:-

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position and DPST switch in off position and give the supply to DC motor and then by varying field rheostat. Let, the motor runs at rated speed.
3. By varying the rheostat rated voltage in the voltmeter connected between the phase into be obtained with DPST switch in open stator.
4. At this instant note down all the voltmeter and ammeter readings.
5. Now close the DPST switch under fault condition. Note down the fault currents and fault voltages.

Circuit diagram for L-L Fault:-
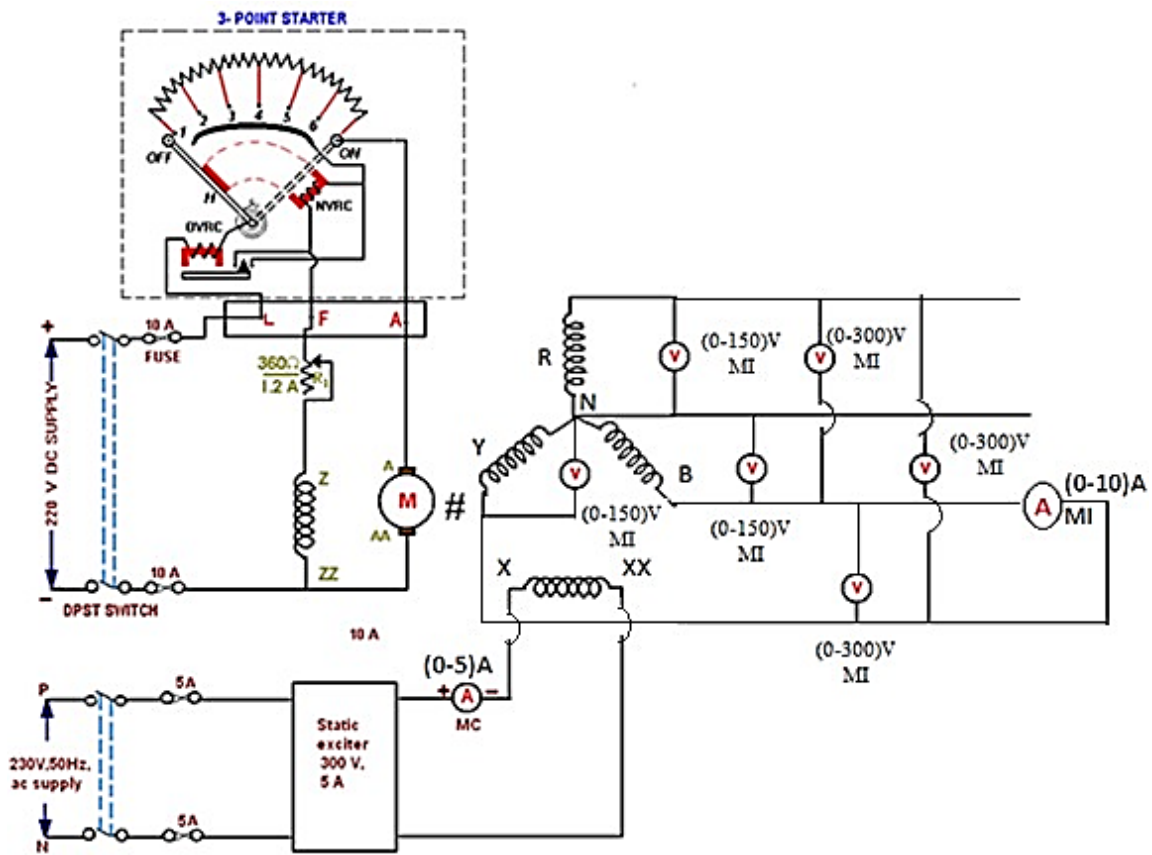
(b) LL Fault:-

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position and DPST switch in off position and give the supply to DC motor and then by varying field rheostat. Let, the motor runs at rated speed.
3. Vary the rated speed up to rated voltage in the voltmeter connected between the phasor with DPST Switch in open position.
4. Now create a fault between the phasor Y and B, take readings of voltmeter and Ammeter.
5. Calculate Fault current using sequence impedance method.

Tabular Column:-

(a) LG Fault:-

V_{RN} (V)	V_{YN} (V)	V_{BN} (V)	I_R (A)	V_{RY} (V)	V_{YB} (V)	V_{BR} (V)	I_F (A)

(b) LL Fault:-

V_{RN} (V)	V_{YN} (V)	V_{BN} (V)	I_R (A)	V_{RY} (V)	V_{YB} (V)	V_{BR} (V)	I_F (A)

Calculations:-

$\lambda \angle 1\angle 120^0, \lambda^2 \angle 1\angle 240^0$

$I_b = I_c = 0$ Amp

$$\begin{bmatrix} V_{a0} \\ V_{a1} \\ V_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \lambda & \lambda^2 \\ 1 & \lambda^2 & \lambda \end{bmatrix} \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix}$$

(i) For LG fault

$$V_{a0} = \frac{1}{3}\left[V_a + V_b + V_c\right]$$

$$V_{a1} = \frac{1}{3}\left[V_a + \lambda V_b + \lambda^2 V_c\right]$$

$$V_{a2} = \frac{1}{3}\left[V_a + \lambda^2 V_b + \lambda V_c\right]$$

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3}\begin{bmatrix} 1 & 1 & 1 \\ 1 & \lambda & \lambda^2 \\ 1 & \lambda^2 & \lambda \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$$I_{a0} = I_{a1} = I_{a2} = \frac{I_a}{3}$$

$$Z_0 = \frac{-V_{a0}}{I_{a0}}$$

$$Z_1 = \frac{E_a - V_{a1}}{I_{a1}}$$

$$Z_2 = \frac{-V_{a2}}{I_{a2}}$$

$$Z_f = \frac{V_{RN}}{I_R}$$

44

$$I_{fault} = \frac{3E_a}{Z_1 + Z_2 + Z_0 + 3Z_f}$$

(ii) For LL Fault

$I_a = 0$ Amp, $I_b + I_c = 0$

$\qquad I_c = - I_b$

$V_b = V_c$

$$\begin{bmatrix} I_{a0} \\ I_{a1} \\ I_{a2} \end{bmatrix} = \frac{1}{3} \begin{bmatrix} 1 & 1 & 1 \\ 1 & \lambda & \lambda^2 \\ 1 & \lambda^2 & \lambda \end{bmatrix} \begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix}$$

$I_{a0} \square 0$

$$I_{a1} \square \frac{1}{3} \left[\square \lambda^2 I_b \square \right] \square I_b$$

$$I_{a2} \square \frac{1}{3} \left[\lambda^2 \square \lambda I_b \square \right] \square I$$

$Z_f \square 0$

$$Z_1 \square Z_2 \square \frac{E}{I_{a1}} \square$$

$$I_{fault} \square \frac{\square j\sqrt{3}E}{Z_1 \square Z_2} \square$$

Precautions:-

1. Avoid the loose connections.
2. Note down the readings with out parallax error.
3. Keep the field rheostat in maximum resistance position.
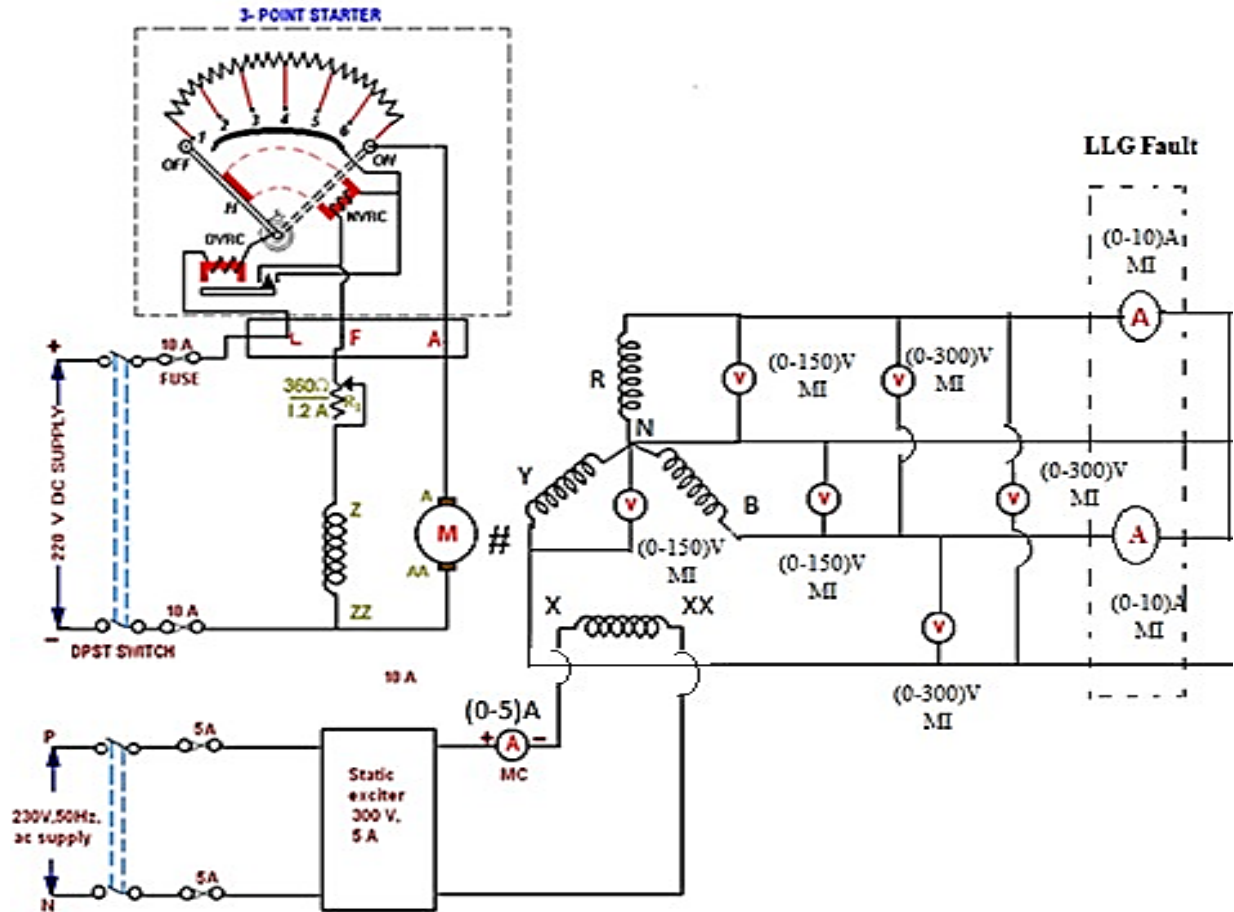4. Keep the variac of the static exciter in minimum voltage output position.

45

Result:-

Circuit diagram for LLG Fault:-

3. FAULT ANALYSIS – II

Aim:- To find the fault currents and fault voltages when a double line to ground (LLG) fault and Triple line to ground (LLLG) faults occurred on unloaded alternator.

Name Plate Details:-

S.No	Parameter	Alternator	DC Motor
1	Rated Voltage	415 V	220 V
2	Rated Current	4.2 A	20 A
3	Speed	1500 RPM	1500 RPM
4	Rating	3 KVA	5 HP
5	Power factor	0.8	-----
6	Frequency	50 Hz	-----
7	Excitation	220V 2A	220V 2A

Apparatus Required:-

S.No	Apparatus	Type	Range	Quantity
1	Ammeter			
2	Voltmeter			
3	Rheostat			
4	Static Exciter			
5	Tachometer			
6	Connecting Wires			

Procedure:-
(a) LLG Fault:-

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position and DPST switch in off position and give the supply to DC motor and then by varying field rheostat. Let, the motor runs at rated speed.
3. By varying the static exciter across the rotor of an alternator apply the rated voltage across V_{RN}, V_{YN}, V_{BN} and tabulate all readings.
4. Close the TPST switch and supply the load current and note down the readings of an voltmeter and ammeter readings.

Circuit diagram for LLLG Fault:-
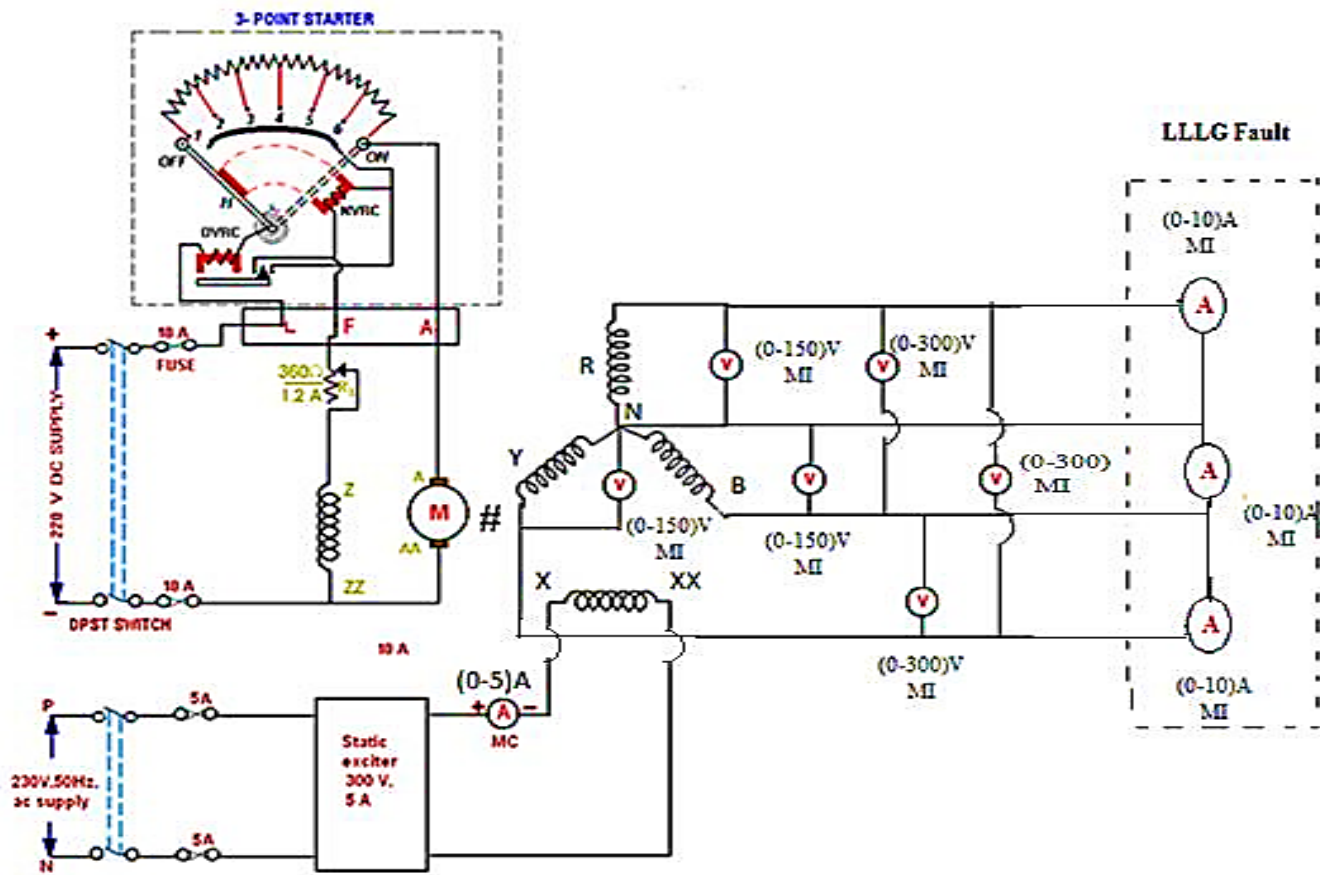
(b) LLLG Fault:-

1. Connect the circuit as per the given circuit diagram.
2. Ensure that the filed rheostat is kept in minimum resistance position and DPST switch in off position and give the supply to DC motor and then by varying field rheostat. Let, the motor runs at rated speed.
3. Apply the rated voltage across each phase and note down the readings of an 3-Ø alternator and tabulate them.
4. Close the TPST switch and supply the load current and note down the readings of an voltmeter and ammeter readings.

Tabular Column:-

(a) LLG Fault:-

V$_{RN}$ (V)	V$_{YN}$ (V)	V$_{BN}$ (V)	I$_R$ (A)	V$_{RY}$ (V)	V$_{YB}$ (V)	V$_{BR}$ (V)	I$_F$ (A)

(b) LLLG Fault:-

V$_{RN}$ (V)	V$_{YN}$ (V)	V$_{BN}$ (V)	I$_R$ (A)	V$_{RY}$ (V)	V$_{YB}$ (V)	V$_{BR}$ (V)	I$_F$ (A)

Calculations:-

Precautions:-

1. Avoid the loose connections.
2. Note down the readings with out parallax error.
3. Keep the field rheostat in maximum resistance position.
4. Keep the variac of the static exciter in minimum voltage output position.

Result:-

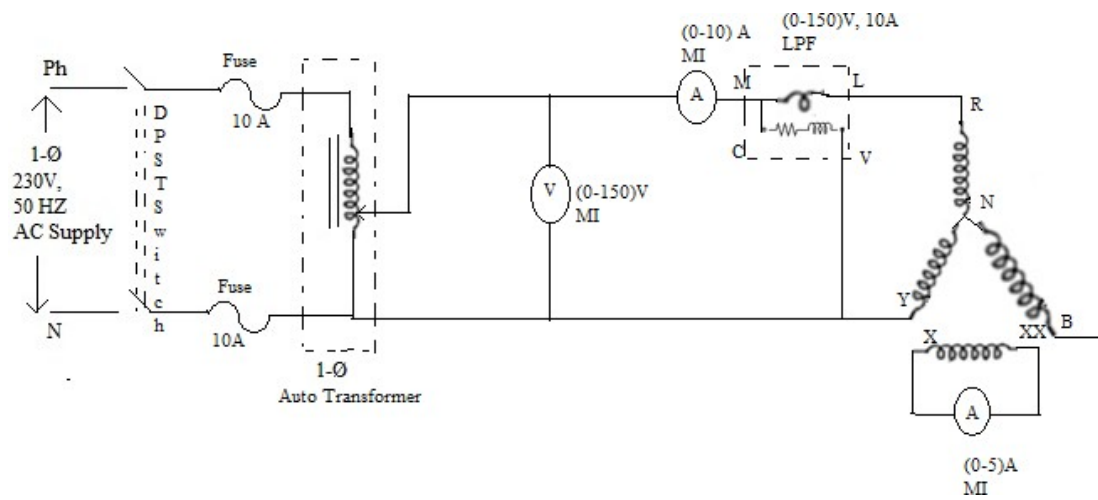## Conclusion:-

Circuit Diagram for sub transient reactance

Fig.4.1. Circuit diagram for determination of subtransient reactance of a salient pole synchronous machine

4. DETERMINATION OF SUBTRANSIENT REACTANCE OF A SALIENT POLE SYNCHRONOUS MACHINE

Aim:- To determine the subtransient direct axis reactance and quadrature axis reactance of a salient pole synchronous machine.

Name Plate Details:-

S.No	Parameter	Alternator	DC Motor
1	Rated Voltage	415 V	220 V
2	Rated Current	8A	27.2 A
3	Speed	1500 RPM	1500 RPM
4	Rating	5 KVA	5 HP
5	Power factor	0.8	-----
6	Frequency	50 Hz	-----
7	Excitation	220V 2A	

Apparatus Required:-

S.No	Apparatus	Type	Range	Quantity
1	Ammeter			
2	Voltmeter			
3	Wattmeter			
4	Auto Transformer			
5	Connecting Wires			

Procedure:-

1. Connect the circuit as per the given circuit diagram.
2. Intially the rotor is kept in standstill, then the auto transformer is varied and a nominal voltage is applied across the stator of the alternator. Thus the sufficient currents in the two series connected armature windings are passed.
3. The rotor position is adjusted with hand to get maximum deflection and minimum deflection values of armature.
4. The readings of ammeter, voltmeter and wattmeter are tabulated.
5. Calculate the $X_d^{\parallel}$ and $X_q^{\parallel}$ by using corresponding formulae's.

Tabular Column:-

(i) For Maximum field current

Field Current I_F (A)	Max. Armature Current I_a (A)	Excitation voltage (v)	Power (w)	Power factor COSØ	Subtransient impedance $Z_q^{\|}$ (Ω)	Subtransient reactance $X_q^{\|}$ (Ω)

Calculations:-

Power factor $COS\square_q \square \dfrac{P}{V_{min} I_{max}}$

$Sin\square_q \square \sqrt{1-(Cos\phi_q)^2}$

Subtransient impedance $Z_q^{\|}(\square) \underset{\square}{\quad} \dfrac{V_{min}}{2I_{max}}$

Subtransient Reactance $X_q^{\|}(\square) \square Z_q^{\|} Sin\square_q$

(ii) For Minimum field current

Field Current I_F (A)	Min. Armature Current I_a (A)	Excitation voltage (v) Max.	Power (w)	Power factor COSØ	Subtransient impedance $Z_d^{\|}$ (Ω)	Subtransient reactance $X_d^{\|}$ (Ω)

Calculations:-

Power factor $COS\phi_d = \dfrac{P}{V_{max}\,I_{min}}$

$Sin\phi_{d=} \sqrt{1-(Cos\phi_d)^2}$

Subtransient impedance $Z_d^{\|}(\square) = \dfrac{V_{max}}{2I_{min}}$

Subtransient Reactance $X_d^{\|}(\square) = Z_d^{\|}\,Sin\phi_d$

Precautions:-

1. Avoid the loose connections.
2. Note down the readings with out parallax error.

Result:-

Conclusion:-

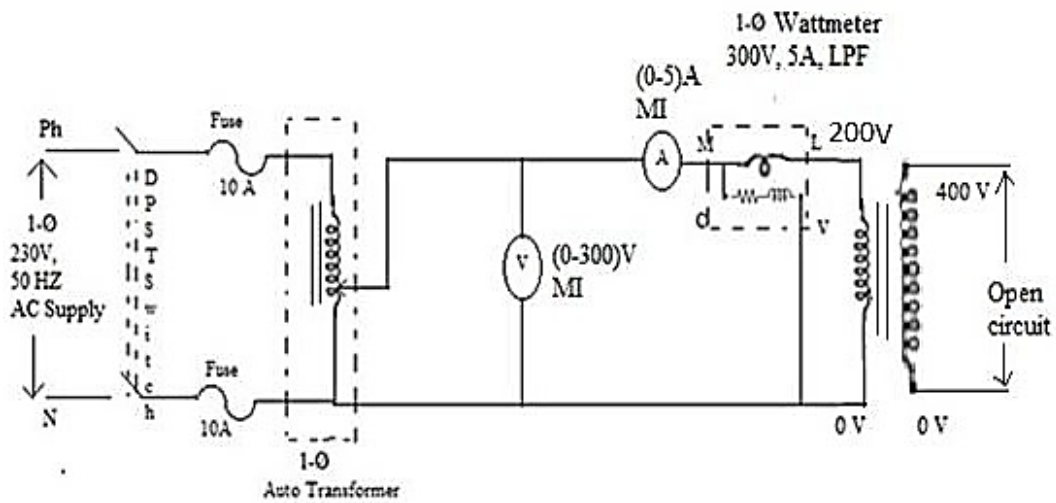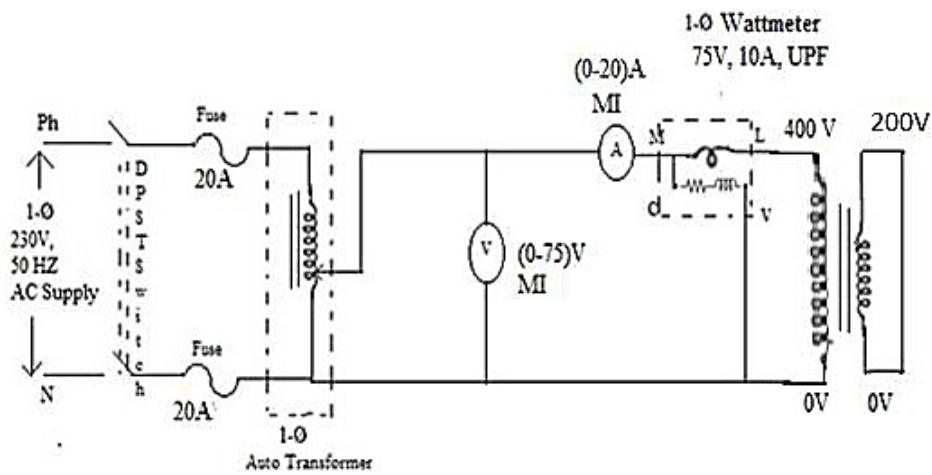Fig.5.1. Circuit diagram for Open Circuit Test

Fig.5.2. Circuit diagram for Short Circuit Test (For Z_{12})

56

5. Equivalent Circuit of a 3-Ø Three Winding Transformer

Aim:- To determine the equivalent circuit parameters of a 3-Ø three winding transformer.

Name Plate Details:-

S.No	Parameter	Primary	Secondary	Tertiary
1	Rated Voltage	400 V	200 V	80 V
2	Rated Current	1.83A	3.6 A	9.1 A
3	Rated Power	2.2 KVA	2.2 KVA	2.2 KVA
4	Phase	3-Ø	3-Ø	3-Ø

Apparatus Required:-

S.No	Apparatus	Type	Range	Quantity
1	Ammeter			
2	Voltmeter			
3	Wattmeter			
4	Auto Transformer			
5	3-Ø, 3 Winding Transformer			
6	Connecting Wires			

Procedure:-

(i) Open circuit test:-

1. Connect the circuit as per the given circuit diagram.

2. The auto transformer is kept in zero output voltage position.

3. Varying the auto transformer of variable knob and the rated voltage is applied across the low voltage winding of 3-Ø transformer.

4. The values of no-load current, no-load voltage and input power are noted.

5. The auto transformer is brought to zero output voltage position and the DPST switch is opened to disconnect the circuit.
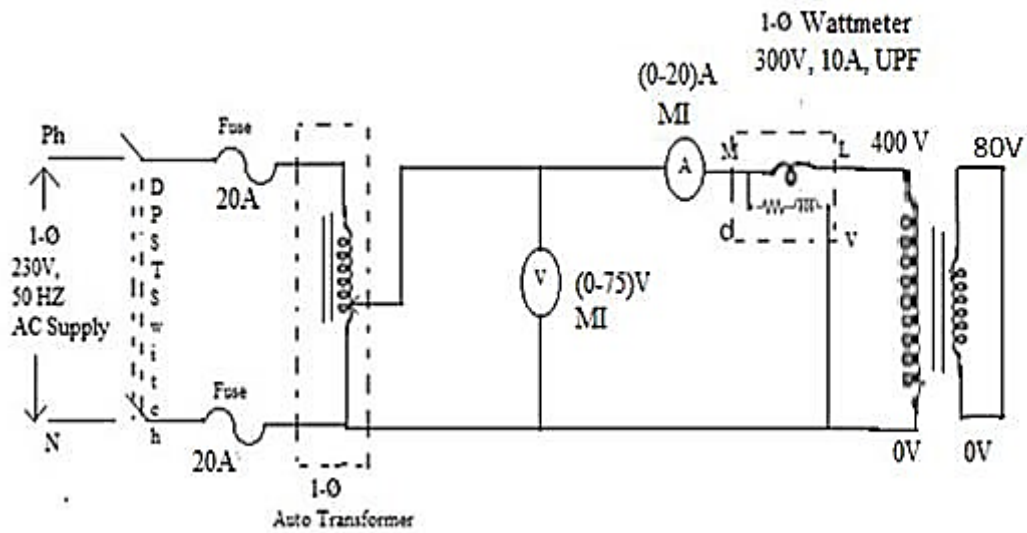
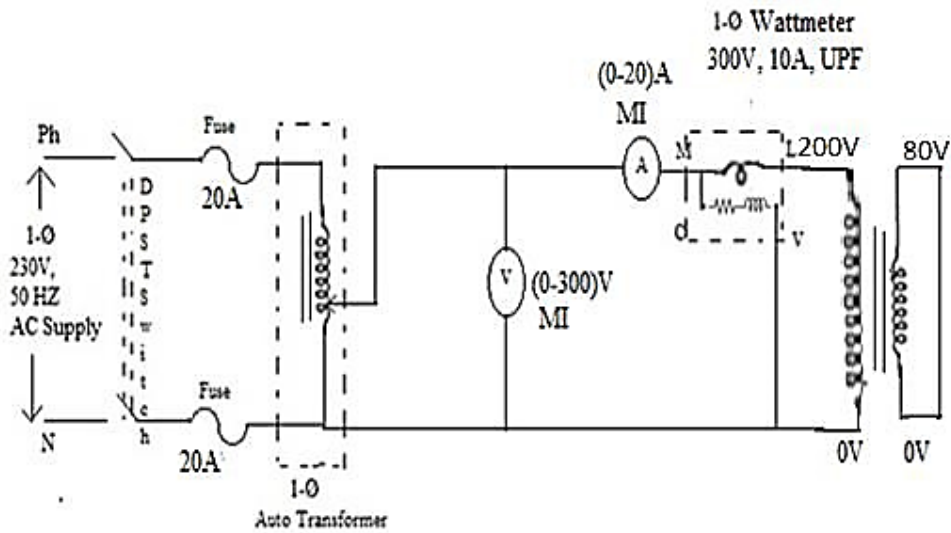Fig.5.3. Circuit diagram for Short Circuit Test (For Z_{13})

Fig.5.4. Circuit diagram for Short Circuit Test (For Z_{23})

(ii) Short circuit test:-

1. Connect the circuit as per the given circuit diagram.

2. The auto transformer is kept in zero output voltage position.

3. Varying the auto transformer of variable knob and allow the rated currents through the HV winding of 3-Ø transformer.

4. Note down the values of Short circuit voltage and input power.

5. The auto transformer is brought to zero output voltage position and the DPST switch is opened to disconnect the circuit.

Tabular Column:-

(i) Open circuit test:-

No-load voltage (V)	No-load current (A)	Power W_0 (w)

(ii) Short circuit test:-

	Short circuit current I_{SC} (A)	Short Circuit Voltage V_{sc} (V)	Input Power W_{sc} (w)
For Z_{12} For Z_{13} For Z_{23}			

Calculations:-

$$Z_{12} \square \frac{V_{sc}}{I_{sc}}, \quad Z_{13} \square \frac{V_{sc}}{I_{sc}}, \quad Z_{23} \square \frac{V_{sc}}{I_{sc}}$$

$$Z_1 \square \frac{1}{2} \square Z_{12} \square Z_{13} \square Z_{23} \square$$

$$Z_2 \square \frac{1}{2} \square Z_{23} \square Z_{12} \square Z_{13} \square$$

$$Z_3 \square \frac{1}{2} \square Z_{13} \square Z_{23} \square Z_{12} \square$$

Precautions:-

1. Avoid the loose connections.
2. Note down the readings with out parallax error.
3. Initially the auto transformer is kept in zero output voltage position.
4. Only one phase of the transformer is used to conduct the experiment.

Result:-

Conclusion:-

SOFTWARE PROGRAMS

FORMATION OF Y BUS MATRIX

EXERCISE 1

AIM

To compute bus admittance matrix for the given power system network using Mi – Power software package.

THEORY

Bus admittance matrix is often used in power system studies. In most of the power system studies, it is necessary to form Y-Bus matrix of the system by considering certain power system parameters depending upon the type of analysis.

For example, in load flow analysis, it is necessary to form Y-Bus matrix taking in to account only line data and not taking into account the generator impedance, transformer impedances or load impedances. In short circuit analysis, the generator transient reactance"s and transformer leakage impedances must be taken into account in addition to line data during the computation of Y-bus matrix.

In stability analysis, line data, the generator transient reactances, transformer leakage impedances and equivalent load impedances to ground must be taken into account in computing Y-bus matrix. Y-Bus may be computed by inspection method, only if there is negligible mutual coupling

between the lines. Every transmission line will be represented by the nominal $\square$ equivalent. Shunt admittances are added to the diagonal elements of Y-bus corresponding to the buses at which these are connected.

The off diagonal elements are unaffected by shunt admittances. The equivalent circuit of tap - changing transformer may be considered in forming Y-Bus matrix, if tap changing transformers are present in the system.

The dimension of the [Y-Bus] matrix is (n x n) where n is the total number of buses in the system other than reference bus which is the ground bus. In a power network, each bus is connected only to a few other buses. So, the [Y-Bus] of a large network is highly sparse. This property is not evident in small systems, but in systems with hundreds of buses, the sparsity is high. It may be as high as 99%. Hence, by applying sparsity technique, numerical computation time as well as computer storage requirement may be drastically reduced.

FORMATION OF Y-BUS MATRIX

$$\textbf{Generalized [Y-Bus]} = \begin{bmatrix} Y_{ii} & Y_{ij} \\ Y_{ji} & Y_{jj} \end{bmatrix}$$

Each diagonal term Y_{ii} (i = 1,2,.....n) is called the self admittance or driving point admittance of bus i and equals the sum of all admittances terminating on the particular bus.

Each off-diagonal term Y_{ij} (i, j = 1,2...n; j ≠ i) is the transfer admittance between buses i and j Y_{ij} = - y_{ij}, where y_{ij} is net admittance connected between buses i and j, n = total number of buses. Further, Y_{ij} = Y_{ji} on account of symmetry of Y-bus matrix.

ALGORITHM FOR FORMATION OF Y - BUS MATRIX

Step (1) :   Initialize [Y-Bus] matrix, that is replace all entries by zero $Y_{ij} = Y_{ij} -$

$y_{ij} = Y_{ji}$ = off diagonal element

Step (2) :   Compute

$$Y_{ii} = [\sum_{\substack{j \\ =1 \\ J \ne i}}^{n} y_{ij}] + y_{io} = \text{diagonal element}$$

Where y_{io} is the net bus to ground admittance connected at bus i.

FLOWCHART FOR FORMATION OF Y - BUS MATRIX

START

Read no of buses (NB), no of lines (NL) &
line Data

Initialize Y Bus Matrix

Consider Line $l = 1$

$i = sb\ (l); j = eb\ (l)$

$Y(i,i) + = y_{series}\ (l) + 0.5\ y_{sh}(l)$
$Y(j,j) + = y_{series}\ (l) + 0.5\ y_{sh}(l)$
$Y(i,j) + = -y_{series}\ (l)\ ;\ Y(j,i) = Y(i,j)$

No — Is $l = NL$? — Yes

$l = l + 1$

Print Y Bus

STOP
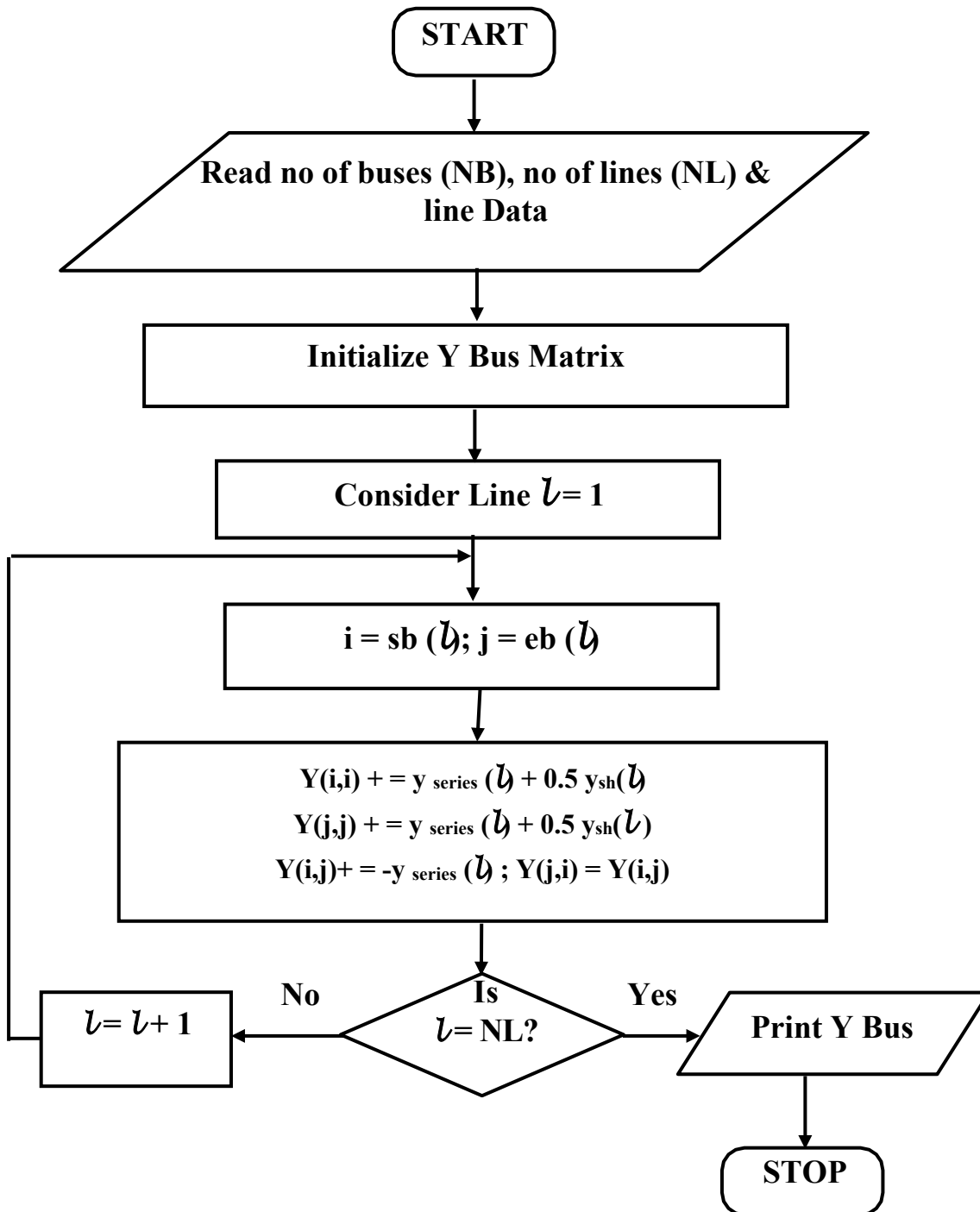
The [Y-Bus] matrix is formed by inspection method for a three-bus sample power system. The one line diagram and line data are given below.

5

SINGLE - LINE DIAGRAM
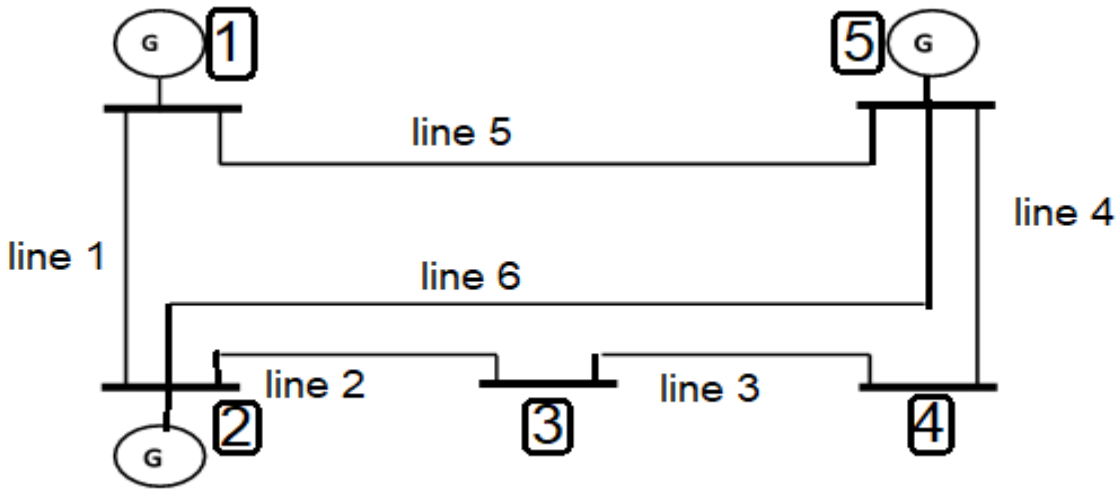
Line Specification

Line no.	Start bus	End bus	Series Impedance (P.U.)	Half-line charging admittance (P.U)	Rating (MW)
1	1	2	0.001 + j0.01	0.001	60
2	2	3	0.002+ j0.02	0.0005	40
3	3	4	0.004 + j0.03	0.0015	60
4	4	5	0.003 + j0.01	0.0001	60
5	5	1	0.004 + j0.03	0.0005	40
6	2	5	0.001 + j0.04	0.002	60

ybus.m (Program for the Y-BUS formation)

```
linedata = [1  1  2  0.001  0.01   0.001
            2  2  3  0.002  0.02   0.0005
            3  3  4  0.004  0.03   0.0015
            4  4  5  0.003  0.01   0.0001
            5  5  1  0.004  0.03   0.0005
            6  2  5  0.001  0.04   0.002];
fb = linedata(:,1); tb = linedata(:,2); r = linedata(:,3);
x = linedata(:,4);
b = linedata(:,5); z = r + i*x;
y = 1./z; b = i*b;


nbus = max(max(fb),max(tb)); nbranch = length(fb);
Y = zeros(nbus,nbus);

for k=1:nbranch
Y(fb(k),tb(k)) = Y(fb(k),tb(k))-y(k);
Y(tb(k),fb(k)) = Y(fb(k),tb(k)); end


for m =1:nbus
for n =1:nbranch
   if fb(n) == m
Y(m,m) = Y(m,m) + y(n)+ b(n);
   elseif tb(n) == m
Y(m,m) = Y(m,m) + y(n) + b(n);
   end
end
end
```

RESULT

Y =

```
0.0000 + 0.0100i  0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0000i
0.0000 + 0.0000i  0.2000 + 0.0600i  0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0000i -0.2000 + 0.0000i
0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0300i  0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0000i
0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0100i  0.0000 + 0.0000i  0.0000 + 0.0000i
0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0300i  0.0000 + 0.0000i
0.0000 + 0.0000i -0.2000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0000i  0.0000 + 0.0000i  0.2000 + 0.0400i
```

FORMATION OF Z BUS MATRIX

Aim: To obtain the bus impedance matrix Z – bus of the given power system network using Mi – Power package.

THEORY

Z - bus matrix is an important matrix used in different kinds of power system studies such as short circuit study, load flow study, etc

In short circuit analysis, the generator and transformer impedances must be taken into account. In contingency analysis, the shunt elements are neglected while forming the Z-bus matrix, which is used to compute the outage distribution factors.

Z-bus can be easily obtained by inverting the Y-bus formed by inspection method or by analytical method. Taking inverse of the Y-bus for large systems is time consuming; Moreover, modification in the system requires the whole process to be repeated to reflect the changes in the system. In such cases, the Z–bus is computed by Z–bus building algorithm.

ALGORITHM FOR FORMATION OF Z-BUS MATRIX

Step 1 : Read the values such as number of lines, number of buses and line data, Generator data and Transformer data.

Step 2 : Initialize Ybus matrix. Y-bus [i] [j] = complex (0.0,0.0) for all values of i and j

Step 3 :Compute Y- bus Matrix by considering only line data.

Step 4 : Modify the Ybus matrix by adding the combined transformer and the generator admittances to the respective diagonal elements of Y– bus matrix.
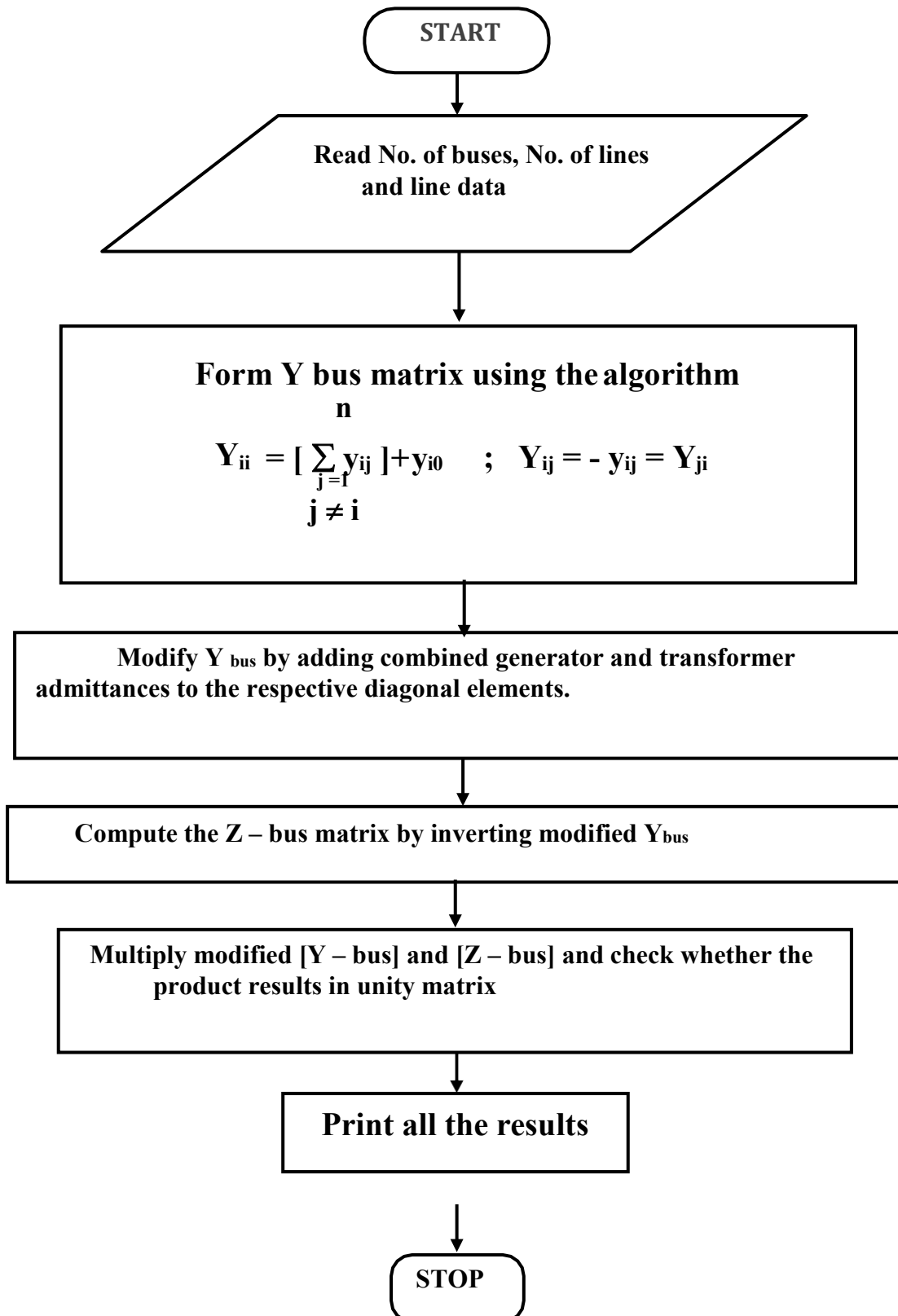
Step 5 : Compute the Z– bus matrix by inverting the modified Ybus matrix.

Step 6 : Check the inversion by multiplying modified Ybus and Z-bus matrices to see whether the resulting matrix is unity matrix or not. If it is unity matrix, the result is correct.

Step 7 :Print Z-bus matrix.

FLOWCHART FOR FORMATION OF Z-BUS MATRIX

START

Read No. of buses, No. of lines
and line data

Form Y bus matrix using the algorithm

$$Y_{ii} = [\sum_{\substack{j=1 \\ j \neq i}}^{n} y_{ij}] + y_{i0} \quad ; \quad Y_{ij} = - y_{ij} = Y_{ji}$$

Modify Y $_{bus}$ by adding combined generator and transformer admittances to the respective diagonal elements.

Compute the Z – bus matrix by inverting modified Y$_{bus}$

Multiply modified [Y – bus] and [Z – bus] and check whether the product results in unity matrix

Print all the results

STOP

THEORY

Z – bus matrix is an important matrix used in different kinds of power system studies such as short circuit study, load flow study, etc.

In short circuit analysis, the generator and transformer impedances must be taken into account. In contingency analysis, the shunt elements are neglected while forming the Z – bus matrix, which is used to compute the outage distribution factors.

This can be easily obtained by inverting the Y_{bus} formed by inspection method or by analytical method.

Taking inverse of the Y_{bus} for large systems is time consuming, more over, modification in the system requires the whole process to be repeated to reflect the changes in the system. In such cases, the Z – bus is computed by Z- bus building algorithm.

SIMULATION

In this exercise, Z-bus for the system is developed by first forming the Y_{bus} and then inverting it to get the Z-bus matrix. The generator and transformer impedances are taken into account while forming the Y-bus matrix. Note that all loads should be neglected

Y-$_{bus}$ is a sparse matrix, Z-bus is a full matrix, i.e. zero elements of Y_{bus} become non– zero values in the corresponding Z-bus elements. The bus impedance matrix is most useful for short circuit studies.
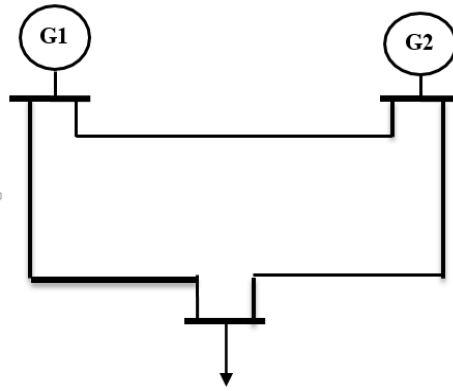
Line Specification

Line no.	Start bus	End bus	Series impedance (P.U.)	Half-line charging admittance (P.U.)	Rating MW
1	1	2	0.001 + j 0.015	0.001	60
2	2	3	0.002 + j 0.021	0.005	40
3	3	1	0.004 + j 0.046	0.0015	65

Shunt element Details

Bus	MVAR
3	50

zbus.m (Program for Z-bus formation)

```
linedata = [1      1      2      0.001 0.015 0.001
            2      2      3      0.002 0.021 0.0005
            3      3      1      0.004 0.046 0.0015 ];
fb = linedata(:,1);
tb = linedata(:,2);
r = linedata(:,3);
x = linedata(:,4);
b = linedata(:,5);
z = r + i*x;
y = 1./z; b = i*b;

nbus = max(max(fb),max(tb));
nbranch = length(fb);
Y = zeros(nbus,nbus);

for k=1:nbranch
Y(fb(k),tb(k)) = Y(fb(k),tb(k))-y(k);
Y(tb(k),fb(k)) = Y(fb(k),tb(k));
end


for m =1:nbus
for n =1:nbranch
   if fb(n) == m
Y(m,m) = Y(m,m) + y(n)+ b(n);
   elseif tb(n) == m
Y(m,m) = Y(m,m) + y(n) + b(n);
   end
end
end
Y
zbus = inv(Y)
```

Y =

$$0.0000 + 0.0150i \quad 0.0000 + 0.0000i \quad 0.0000 + 0.0000i$$
$$0.0000 + 0.0000i \quad 0.0000 + 0.0210i \quad 0.0000 + 0.0000i$$
$$0.0000 + 0.0000i \quad 0.0000 + 0.0000i \quad 0.0000 + 0.0460i$$

zbus =

$$0.0000 - 66.6667i \quad 0.0000 + 0.0000i \quad 0.0000 + 0.0000i$$
$$0.0000 + 0.0000i \quad 0.0000 - 47.6190i \quad 0.0000 + 0.0000i$$
$$0.0000 + 0.0000i \quad 0.0000 + 0.0000i \quad 0.0000 - 21.7391i$$

RESULT

Thus for a given system bus impedance matrix was formulated using MATLAB package.

Guass siedal method:

1. Gauss-Seidel Load Flow Analysis.
2. Keep all 5 the files in the same directory.
3. There are some assumptions used.
a. Bus number 1 is considered as the Slack bus in loadflow. ("gaussppg.m")
b. The first row in busdata matrix, corresponds to slack bus. ("busdata6.m")

4. For computing Admittance or Impedance Matrix, just we need to run "ybusppg.m" only.

5. For computing Bus Voltage and Angles, just we need to run "gaussppg.m" only.

Aim: to find solution using guass siedal method   for 3 machine and 9 bus system
Software used: Matlab2015a
Program:

% Bus data for Load Flow Analysis.

function busdata = busdata6()   % Returns busdata.

```
%        |Bus|Type| Vsp |theta |PGi |QGi | PLi | QLi | Qmin | Qmax |
busdata = [ 1    1   1.05   0   0.0  0   0    0    0    0;
            2    2   1.05   0   0.5  0   0    0   -0.5  1.0;
            3    2   1.07   0   0.6  0   0    0   -0.5  1.5;
            4    3   1.0    0   0.0  0   0.7  0.7  0    0;
            5    3   1.0    0   0.0  0   0.7  0.7  0    0;
            6    3   1.0    0   0.0  0   0.7  0.7  0    0 ];
```

        % Program for Gauss - Seidel Load Flow Analysis
% Praviraj P G, MTech I Year, EE Dept., IIT Roorkee, India, Email :pravirajpg@gmail.com

% Assumption, Bus 1 is considered as Slack bus.

```
ybus = ybusppg();          % Calling program "ybusppg.m" to get Y-Bus.
busdata = busdata6();       % Calling "busdata6.m" for bus data.

bus = busdata(:,1);         % Bus number.
type = busdata(:,2);        % Type of Bus 1-Slack, 2-PV, 3-PQ.
V = busdata(:,3);           % Initial Bus Voltages.
th = busdata(:,4);          % Initial Bus Voltage Angles.
GenMW = busdata(:,5);       % PGi, Real Power injected into the buses.
GenMVAR = busdata(:,6);     % QGi, Reactive Power injected into the buses.
LoadMW = busdata(:,7);      % PLi, Real Power Drawn from the buses.
LoadMVAR = busdata(:,8);    % QLi, Reactive Power Drawn from the buses.
Qmin = busdata(:,9);        % Minimum Reactive Power Limit
```

```matlab
Qmax = busdata(:,10);       % Maximum Reactive Power Limit
nbus = max(bus);            % To get no. of buses
P = GenMW - LoadMW;         % Pi = PGi - PLi, Real Power at the buses.
Q = GenMVAR - LoadMVAR;     % Qi = QGi - QLi, Reactive Power at the buses.
Vprev = V;
toler = 1;                  % Tolerence.
iteration = 1;              % iteration starting
while (toler > 0.00001)     % Start of while loop
   for i = 2:nbus
      sumyv = 0;
      for k = 1:nbus
         if i ~= k
            sumyv = sumyv + ybus(i,k)* V(k);  % Vk * Yik
         end
      end
      if type(i) == 2     % Computing Qi for PV bus
         Q(i) = -imag(conj(V(i))*(sumyv + ybus(i,i)*V(i)));
         if (Q(i) > Qmax(i)) || (Q(i) < Qmin(i))  % Checking for Qi Violation.
            if Q(i) < Qmin(i)   % Whether violated the lower limit.
               Q(i) = Qmin(i);
            else    % No, violated the upper limit.
               Q(i) = Qmax(i);
            end
            type(i) = 3;  % If Violated, change PV bus to PQ bus.
         end
      end
      V(i) = (1/ybus(i,i))*((P(i)-j*Q(i))/conj(V(i)) - sumyv); % Compute Bus Voltages.
      if type(i) == 2 % For PV Buses, Voltage Magnitude remains same, but Angle changes.
         V(i) = pol2rect(abs(Vprev(i)), angle(V(i)));
      end
   end
   iteration = iteration + 1;     % Increment iteration count.
   toler = max(abs(abs(V) - abs(Vprev)));     % Calculate tolerance.
   Vprev = V; % Vprev is required for next iteration,  V(i) = pol2rect(abs(Vprev(i)), angle(V(i)));
end     % End of while loop / Iteration

iteration      % Total iterations.
V              % Bus Voltages in Complex form.
Vmag = abs(V)  % Final Bus Voltages.
Ang = 180/pi*angle(V)    % Final Bus Voltage Angles in Degree.

% Line Data for Y-Bus Formation.
```

Fast decoupled algorithm

3 machine and 9 bus data

https://in.mathworks.com/matlabcentral/fileexchange/39005-fast-decoupled-load-flow-solution

Aim: to find solution using fast decouled algorithm for 3 machine and 9 bus system

Software used: Matlab2015a

Program:

```
clc

clear
%-------------v-----del-----Pg-----Qg----Pd----Qd------------
bus = [ 1   1.04     0.00    0.00    0.00  0.00  0.00  0.00  0.00 1;
        2   1.02533 0.00    1.63    0.00  0.00  0.00  0.00  0.00 2;
        3   1.02536 0.00    0.85    0.00  0.00  0.00  0.00  0.00 2;
        4   1.00     0.00    0.00    0.00  0.00  0.00  0.00  0.00 3;
        5   1.00     0.00    0.00    0.00  0.90  0.30  0.00  0.00 3;
        6   1.00     0.00    0.00    0.00  0.00  0.00  0.00  0.00 3;
        7   1.00     0.00    0.00    0.00  1.00  0.35  0.00  0.00 3;
        8   1.00     0.00    0.00    0.00  0.00  0.00  0.00  0.00 3;
        9   1.00     0.00    0.00    0.00  1.25  0.50  0.00  0.00 3];


% formation of y bus for nominal tap ratio i.e. a=1
%----------------r-------x-----------b------------
line = [1 4     0.0     0.0576      0.      1. 0. ;
        4 5     0.017   0.092       0.158   1. 0. ;
        5 6     0.039   0.17        0.358   1. 0. ;
        3 6     0.0     0.0586      0.      1. 0. ;
        6 7     0.0119  0.1008      0.209   1. 0. ;
        7 8     0.0085  0.072       0.149   1. 0. ;
        8 2     0.0     0.0625      0.      1. 0. ;
        8 9     0.032   0.161       0.306   1. 0. ;
        9 4     0.01    0.085       0.176   1. 0. ];
r = size(line);
p = r(1);
w = line(:,2 );
buses = max(w);
% b=zeros(1,buses);
ybus = zeros(buses,buses);
y = zeros(buses,buses);
for k= 1:p                      % finding the elements of ybus
    l= line(k,1);
    m= line(k,2);

    y(l,m)  = 1/(line(k,3)+ 1i*line(k,4));
    y(m,l)  = y(l,m);
%     b(l)  = b(l)+(i*line(k,5))/2;
%     b(m)  = b(m)+(i*line(k,5))/2;


end
for i = 1:buses
    for j = 1:buses
```

```
        if i==j
            ybus(i,j) =  ybus(i,j)+sum(y(i,:)); %+ b(i);
        end

        if i~=j
            ybus(i,j) =  -1*y(i,j);
        end
    end
end
ybus;
b = -imag(ybus);
%formation of b' matrtix
b1=zeros(buses-1,buses-1);
for i = 1:buses-1
    for j = 1:buses-1
        b1(i,j) =b(i+1,j+1);
    end
end
b1;
%formation of b" matrtix
%assuming all the load buses are at last
b2=zeros(buses-3,buses-3);
for i = 1:buses-3
    for j = 1:buses-3
        b2(i,j) =b(i+3,j+3);
    end
end
b2
v = bus(:,2);
del = bus(:,3);
Pg = bus(:,4);
Qg = bus(:,5);
Pd = bus(:,6);
Qd = bus(:,7);
Pspec = Pg-Pd;
Qspec = Qg-Qd;
iter = 1;
slack = 1;
tolerance = .01;
flag=1
while flag==1;

    m = real(ybus);
    n = imag(ybus);
    P = zeros(buses,1);
    Q = zeros(buses,1);
    iter= iter+1;
for i=1:buses      %finding  bus real and reactive power
    for j=1:buses
        P(i) = P(i)+ (v(i)*v(j)*(m(i,j)*cos(del(i)-del(j))+n(i,j)*sin(del(i)-
del(j)))));
        Q(i) = Q(i)+ (v(i)*v(j)*(m(i,j)*sin(del(i)-del(j))-n(i,j)*cos(del(i)-
del(j)))));
    end
end
```

```
P
Q
%finding del P by v
for i=1:(buses-1)
    if(i<slack)
        delP(i,1)= Pspec(i)-P(i);
    else
        delP(i,1)=(Pspec(i+1)-P(i+1));

    end
    delPbyv(i,1)=delP(i,1)/v(i,1);
end
%finding del Q by v
c=0;
for i=1:buses
    if bus(i,10)==3
        c=c+1;
        delQ(c,1)= (Qspec(i)-Q(i));
        delQbyv(c,1)= delQ(c,1)/v(i,1);
    end
end
if max(abs(delP))>tolerance | max(abs(delQ))>tolerance
    flag=1;    % tolerance check
else
    flag=0;
end
%calc correction vector
deldel = inv(b1)*delPbyv;
delv = inv(b2)*delQbyv;
%updating values
for i=1:(buses-1)
    del(i+1,1)= del(i+1,1)+deldel(i,1);
end
c=0;
for i=1:buses
    if bus(i,10)==3
        c=c+1;
        v(i,1)=v(i,1)+delv(c,1);
    end
end
iter
v
del
end
```

Power System Fault Analysis

This is a package to perform power system fault analysis. It follows the traditional analysis methods using the Ybus and Zbus methods along with the symmetrical components method. Provision is also provided for various types of connections of transformers and grounding of generators.

Check whether the package consists of the folowing files:

1)faultmain.m
2)dataentry.m
3)threephfault.m
4)slgfault.m
5)llfault.m
6)llgfault.m
7)Ypositive.m
8)Yzero.m

The following set of files ate .txt files which are to be opened using wordpad for proper viewing benefits

1)faultdata.txt=the data in this columnwise are faultedbus, type of fault and fault impedance
2)transformerdata.txt=HV bus, connection type, LV bus, connection type, +seq impedance, zero seq impedance
3)linedata.txt=starting bus, ending bus, +seq imp, zero seq imp, real off nominal tap, imaginary off nominal tap
4) gendata.txt=generator bus, +seq imp, zero seq imp, grounding impedance
5) output.txt=this containf the formatted output

This package gives u the option to either enter the data al over again or make modifications in the text files and run the program.

ABCD transmission line

```
clc;
clear all;
L=input('Length of transmission line in km\n ');
Vl=input('receiving end voltage in kv\n ');
r=input('Per km resistance in ohm\n ');
l=input('Per km inductance in mH\n ');
S=input('Receiving power in MVA\n ');
Fi=input('Lagging power factor\n ');
S=S*(10^6);
Vl=Vl*(10^3);
l=l*(10^-3);
ind=L*(l);
R=r*(L);
Vr=Vl/sqrt(3);
Z=complex(R,2*pi*50*ind);
j=sqrt(-1);
if L <= 60
A=1;
B=Z;
C=0;
D=A;
elseif L > 60 && L <= 160
c=input('Per km capacitance in uF\n ');
c=c*(10^-6);
Y=2*pi*50*c*L*j;
A=(Y/2)*Z+1;
B=Z*((Y/4)*Z+1);
C=Y;
D=A;
else
c=input('Per km capacitance in uF\n ');
c=c*(10^-6);
Y=2*pi*50*c*L*j;
K=sqrt(Y*Z);
M=sqrt(Y/Z);
A=cosh(K);
B=sinh(K)/M;
C=M*sinh(K);
D=A;
end
Ir=S/((sqrt(3)*Vl));
IR =((Ir))*complex(cos(-acos(Fi)),sin(-acos(Fi)));
VS=A*Vr+B*IR;
IS=C*Vr+D*IR;
```

```matlab
Ps=3*real(VS*(conj(IS)));
VR=abs((((abs(VS)/abs(A))-abs(Vr))/abs(Vr)))*100;
Pr=S*0.8;
EF=(Pr/Ps)*100;
Qs=3*imag(VS*(conj(IS)));
F=cos(atan(Qs/Ps));
fprintf('\n')
disp('No load receiving end voltage');
disp(abs(Vr))
disp('No load sending end current');
disp(abs(IS))
disp('Sending end p.f.');
disp(F)
disp('Voltage Regulation of the line');
disp(VR)
disp('Transmission Efficiency of the line');
disp(EF)
```

This code solves the generator swing equation using the runge kutta 4th order numerical integration method. This code is basically written to help students learn the basics of the numerical integration and how these techniques are used to slove the equation involving derivatives.