SESHADRIRAO GUDLAVALLERU ENGINEERING COLLEGE

SESHADRIRAOKNOWLEDGEVILLAGE::GUDLAVALLERU

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

R20

POWER SYSTEMS LAB MANUAL

Student Details :

Roll Number :

Name of the Student:

Academic Year : **2024-25**

Class & Semester : **IV B.Tech I Semester**

Section :

SESHADRIRAO

GUDLAVALLERU ENGINEERING COLLEGE

(An Autonomous Institute with Permanent Affiliation to JNTU, Kakinada)

Seshadri Rao Knowledge Village, Gudlavalleru

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

Vision:

To be a pioneer in electrical and electronics engineering education and research, preparing students for higher levels of intellectual attainment, and making significant contributions to profession and society.

Mission:

- To impart quality education in electrical and electronics engineering in dynamic learning environment and strive continuously for the interest of stake holders, industry and society.
- To create an environment conducive to student-centered learning and collaborative research.
- To provide students with knowledge, technical skills, and values to excel as engineers and leaders in their profession.

Program Educational Objectives (PEOs):

PEO1: Graduates will have technical knowledge, skills and competence to identify, comprehend and solve problems of industry and society.

PEO2: Graduates learn and adapt themselves to the constantly evolving technology to pursue higher studies and undertake research.

PEO3: Graduates will engage in lifelong learning and work successfully in teams with professional, ethical and administrative acumen to handle critical situations.

Program Outcomes (POs):

Graduates of the Electrical and Electronics Engineering Program will

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

Program Specific Outcomes (PSOs):

1. Apply the knowledge of circuit design, analog & digital electronics to the field of electrical and electronics systems.
2. Analyze, design and develop control systems, industrial drives and power systems using modern tools.

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

POWER SYSTEMS LAB

LIST OF EXPERIMENTS AS PER AUTONOMOUS SYLLABUS

Any 10 experiments from the following list are required to be conducted:

1. Characteristics of Static Negative Sequence Relay.
2. Characteristics of Microprocessor based Over Voltage Relay.
3. Simulation of 220KV Transmission line model.

i) Ferranti Effect ii) Transmission line constants

4. Determination of I-V and P-V characteristics of PV module with varying radiation.
5. Characteristics of Induction Motor Protection relays.
6. Determination of I-V and P-V characteristics of series and parallel combination of PV module.
7. Determination of Sub-Transient Reactance of a Salient Pole Machine.
8. Characteristics of impedance relay.
9. Testing of Buchholz relay.

Simulation Lab experiments

10. Obtain the Ybus for the given power system network.
11. Obtain the load flow solution for a given power system by using Gauss Seidel algorithm.
12. Load frequency control of single area system with and without integral controller.

Additional Experiments:

1. To study the differential Protection of a three phase delta-delta connected Transformer (Virtual lab experiment).
2. To determine the sub-transient (xd 3), transient (xd 2) and steady state reactance (xd) of a synchronous machine (Virtual lab experiment).

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DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

POWER SYSTEMS LAB

CO – PO & PSO Mapping (R20)

	PO 1	PO 2	PO 3	PO 4	PO 5	PO 6	PO 7	PO 8	PO 9	PO 10	PO 11	PO 12	PSO 1	PSO 2
CO1: Determine the sub transient reactance of a Salient Pole Machine.	3	2		2					2	2			2	2
CO2: Verify the characteristics of the over voltage and over current relay.	3	2		2					2	2			2	2
CO3: Plot the characteristics of PV Module in the laboratory environment.	2	2		2					2	2			2	2
CO4: Analyze the load flow for a given power system by using Gauss seidel method.	3	2		2					2	2			2	2
CO5 :Verify the load frequency control of single area system with and without controller.	3	2		2					2	2				

Experiments –CO mapping

Experiment Name	CO 1	CO 2	CO 3	CO 4	CO 5
1. Characteristics of Static Negative Sequence Relay.		3			
2. Characteristics of Microprocessor based Over Voltage Relay.		3			
3. Simulation of 220KV Transmission line model. i) Ferranti Effect ii) Transmission line constants.		1			
4. Determination of I-V and P-V characteristics of PV module with varying radiation.			3		
5. Characteristics of Induction Motor Protection relays		3			
6. Determination of I-V and P-V characteristics of series and parallel combination of PV module.			3		
7. Determination of Sub-Transient Reactance of a Salient Pole Machine.	3				
8. Characteristics of impedance relay.		3			
9. Transformer Oil Testing and testing of Buchholtz relay.		3			
10. Obtain the Ybus for the given power system network.				3	
11. Obtain the load flow solution for a given power system by using Gauss Seidel algorithm.				3	
12. Load frequency control of single area system with and without integral controller.					3
1. To study the differential Protection of a three phase delta-delta connected Transformer (Virtual lab experiment).		3			
2. To determine the sub-transient (xd 3), transient (xd 2) and steady state reactance (xd) of a synchronous machine (Virtual lab experiment).	3				

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S.No	Date	Name of the Experiment	Page No.	Marks [5M]	Faculty Signature
Total Marks					
Signature of the Faculty					

CHARACTERISTICS OF STATIC NEGATIVE SEQUENCE RELAY

CHARACTERISTICS OF STATIC NEGATIVE SEQUENCE RELAY

Aim: To conduct a test on solid state negative phase sequence current relay and study its operating characteristics**.**

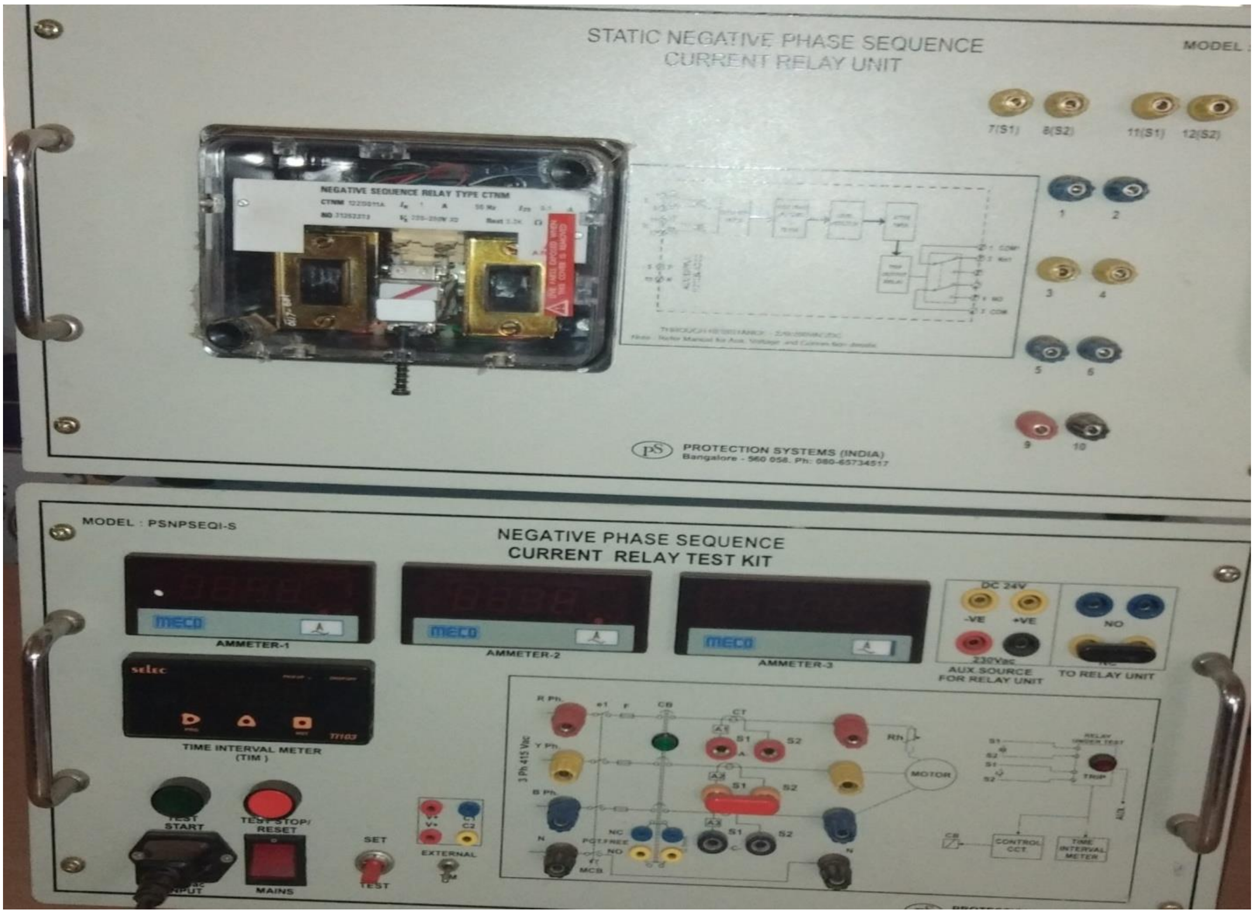
Apparatus:

1) Solid state negative phase sequence relay kit
2) Induction motor
3) Patch cards

Theory: Whenever there is an unbalance in circuit, the unbalanced currents will have a negative phase sequence component. A negative phase sequence (or phase unbalance) relay is essentially provided for the protection of generators and motors against unbalanced loading that may arise due to phase-to-phase faults. Such relay has a filter circuit, which is responsive only to the negative sequence components. Since small magnitude over-current can cause dangerous conditions, it becomes necessary to have low setting of such relays. An earth relay can also provide the desired protection but only in case when there is a fault between any phase and earth. For phase-to-phase faults an earth relay cannot provide necessary protection and hence negative phase sequence relay is required.

Procedure:

1. Connect as per diagram.
2. Connect Auxiliary power cord.
3. Connect three phase input. (415V, 3ph)
4. Mains switch ON(Rocker)
5. Push CB ON button. – CB on indicator will glow.
   i) CB on indicator will glow.
   ii) If motor connected, it starts running. Note down the ammeter readings.(Rheostat should be in zero(cut) position.)
6. Adjust the rheostat to create the Negative sequence(unbalance)
7. Negative relay sequence relay gets “TRIP”.
8. Push CB OFF / RESET.
9. Without disturbing the rheostat switch on the CB ON and note down the ammeter reading and trip timing.



Note: 9,10 – 230VAC

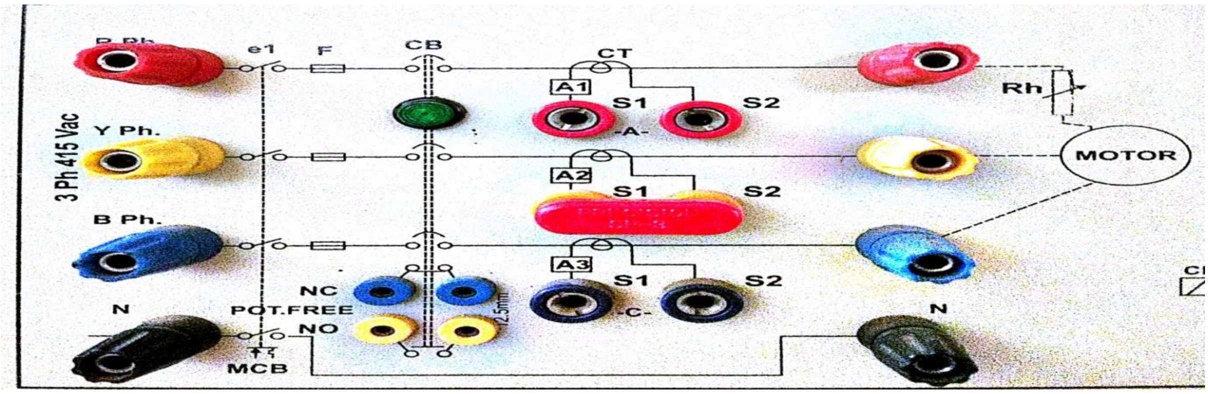
NO – 1,2 NC – Short

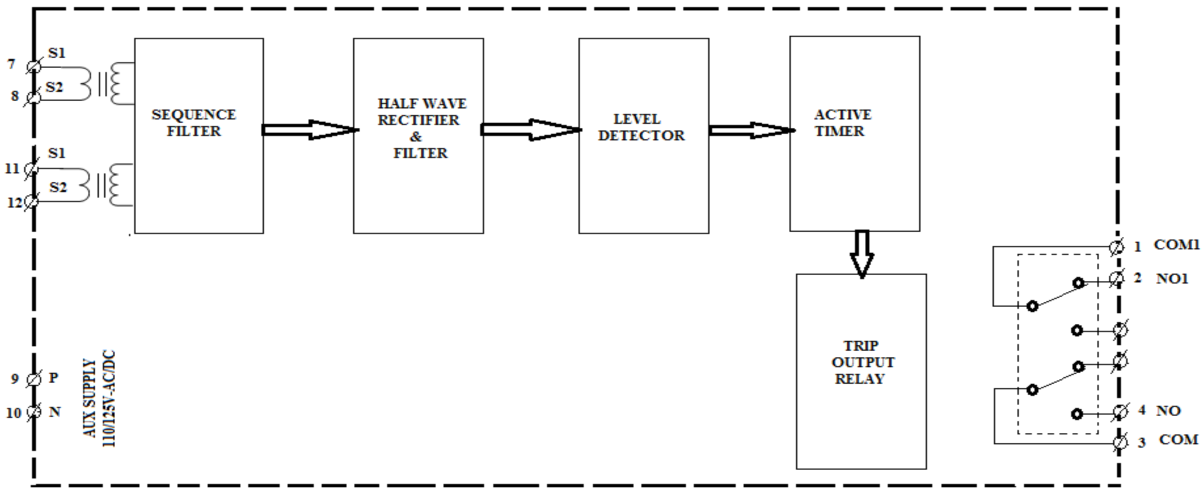
7,8 - CT 1 (Current Transformer) (RED TERMINALS)

SHORT - CT 2 (Current Transformer) (YELLOW TERMINALS)

11,12- CT 3 (Current Transformer) (BLOCK TERMINALS)

Circuit Diagram:





Observations: Balanced Condition: Table 1

S.NO	Current Phase (R)	Current Phase (Y)	Current Phase (B)	Time In Seconds
1				

Un Balanced Condition: Table 2

S.NO	Current Phase (R)	Current Phase (Y)	Current Phase (B)	Time In Seconds
1				
2				
3				

Result:

CHARACTERISTICS OF MICROPROSSESOR BASED OVER VOLTAGE RELAY

CHARACTERISTICS OF MICROPROSSESOR BASED OVER VOLTAGE RELAY

Aim: To conduct a test on micro processor based over voltage relay and Study the characteristics between voltage and time.

Apparatus Required:

1) Over Voltage Relay MV12
2) Voltage injection kit PSCI-S(μp)
3) Patch Cards

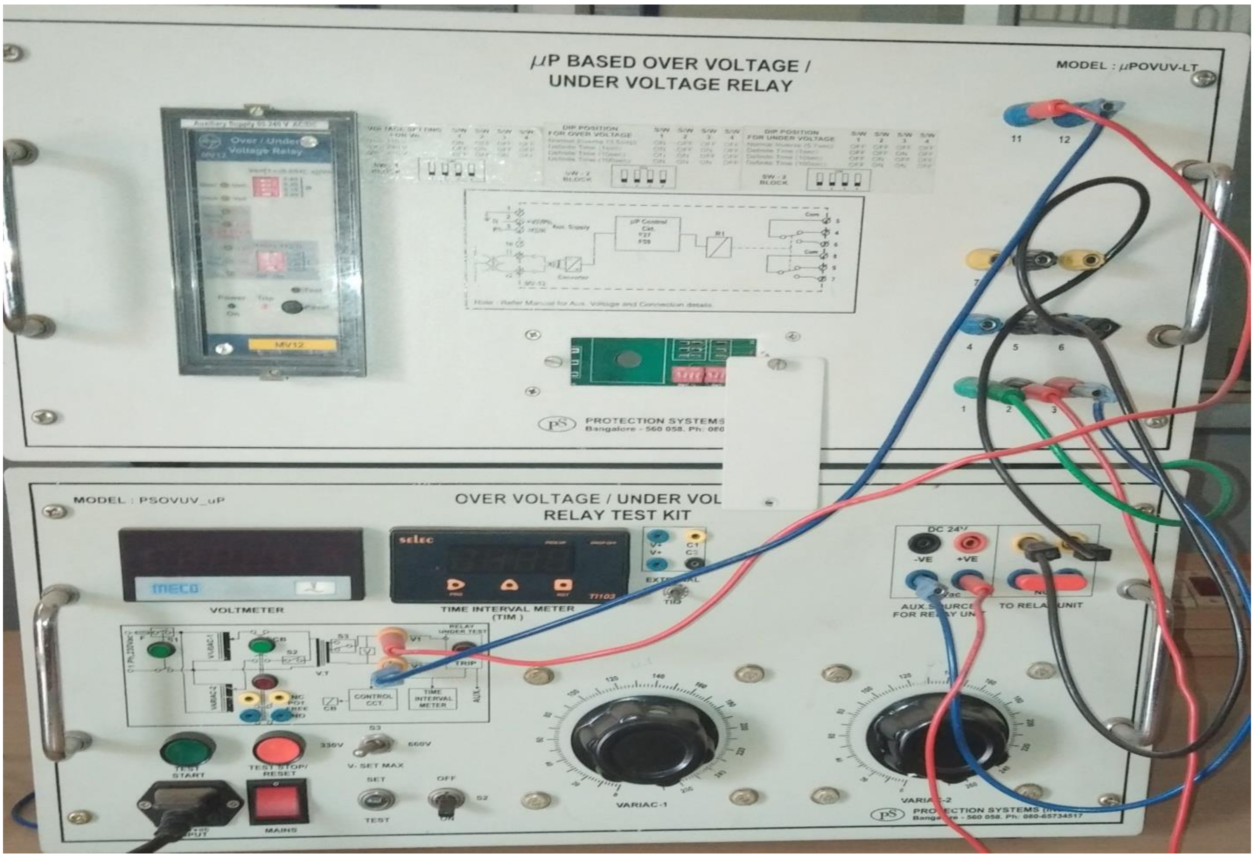
Theory:

There are several instruments in power system which may burn at over voltage like motor, transformer, capacitors etc. To protect these instruments from over voltage, the overvoltage relay is necessary. The several type of over voltage relays is available. One of the types from these relays is studying here. It is microprocessor based over voltage relay. The over voltage relay continuously monitor the system and give trip signal to circuit breaker or alarm signal whenever the operating voltage is exceeds the presetting value.

Procedure:

1. Connect as per interconnection daigram shown in fig 1.
2. Set the relay over voltage .
3. Set TMS (Time MultipliesSetting).
4. Ensure time interval meter selection switch in TIM position.
5. Ensure S2 switch is in ON position.
6. Bring both dimmers to zero position.
7. Connect the power card.
8. Put on the mains using mains ON switch (ROCKER). Results (mains on indicator, ammeter display, relay power and time display will glow.)
9. Bring Toggle switch to SET mode.
10. Push TEST START button, CB ON indicator will glow.
11. Adjust the dimmer2 to set the exact injection voltage.(with in 30 seconds otherwise protection timer will activate and circuit breaker will be off.)
12. Push TEST STOP/RESET button.

13. Don't disturb the dimmer's 1 & 2.
14. Bring toggle switch to SET mode.
15. Pust TEST START button. Note down the voltage (CB ON indicator will glow, time interval meter starts up counting, protection timer starts down counting, Over Voltage relay trip occurs TRIP indicator will glow at relay and injector unit also. If buzzer switch is on it gives the beep sound.)
16. Note down the Time interval meter reading.(pick up time)
17. Press the RESET button.
18. Repeat operation (10-18) by adjusting different voltage and TMS values.
19. Draw the graph trip time vs PSM (plug setting multiplier).



Note: 1- Ground, 2,3 – 230VAC
NO – 5,6 NC – Short
11,12 - V1,V2 (Potential Transformer)

CIRCUIT DIAGRAM:

Fig 1: Inter Connection diagram

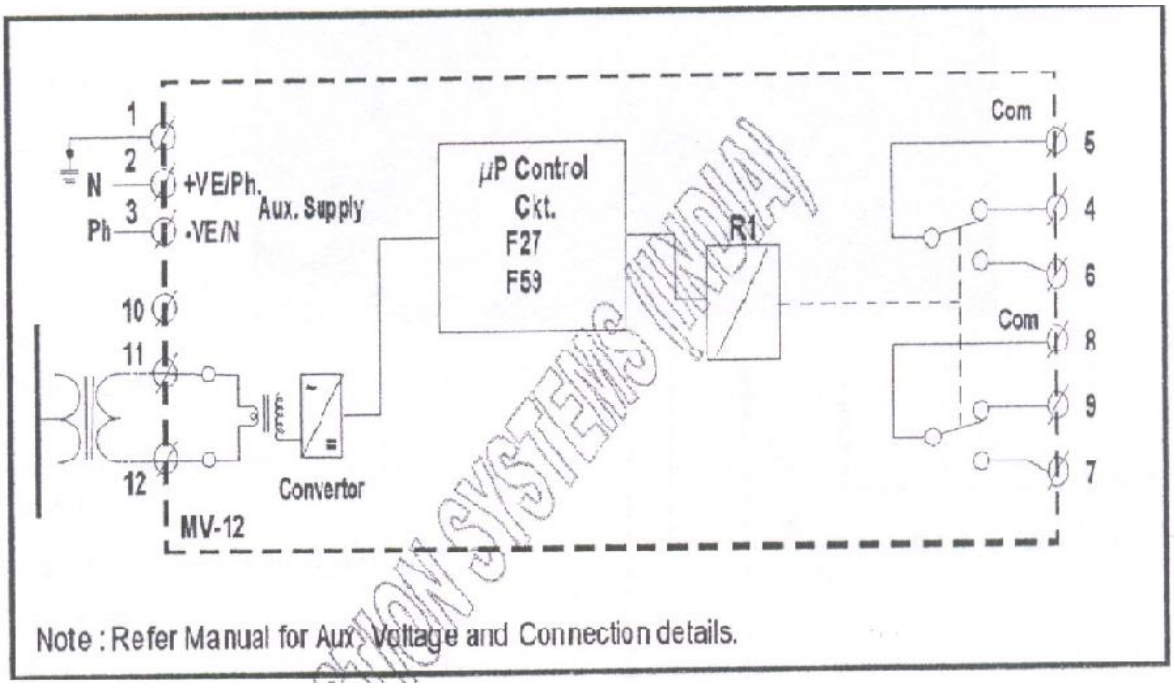
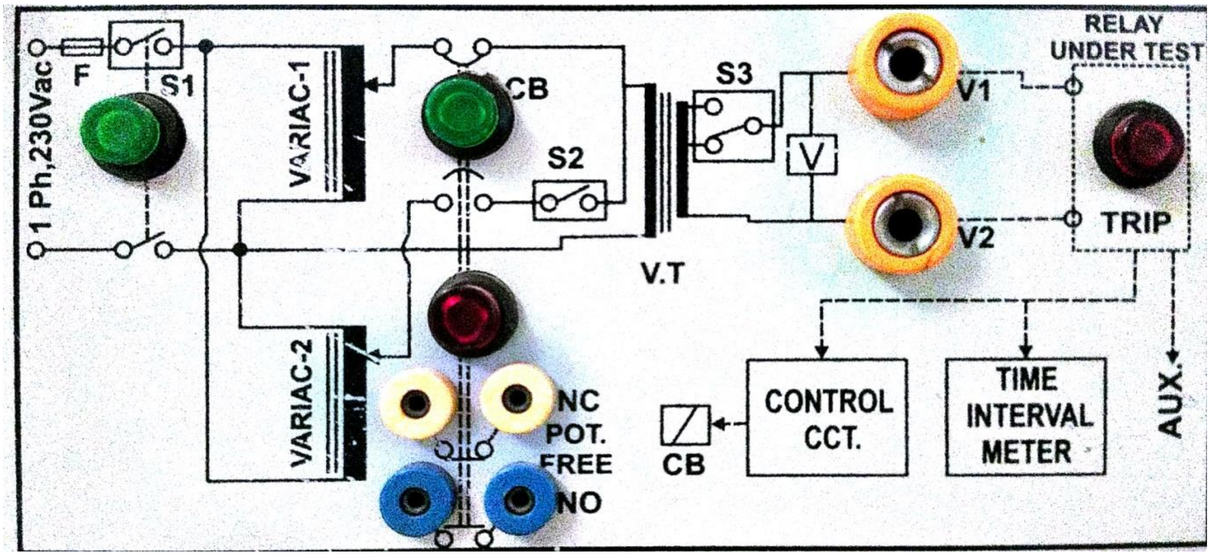
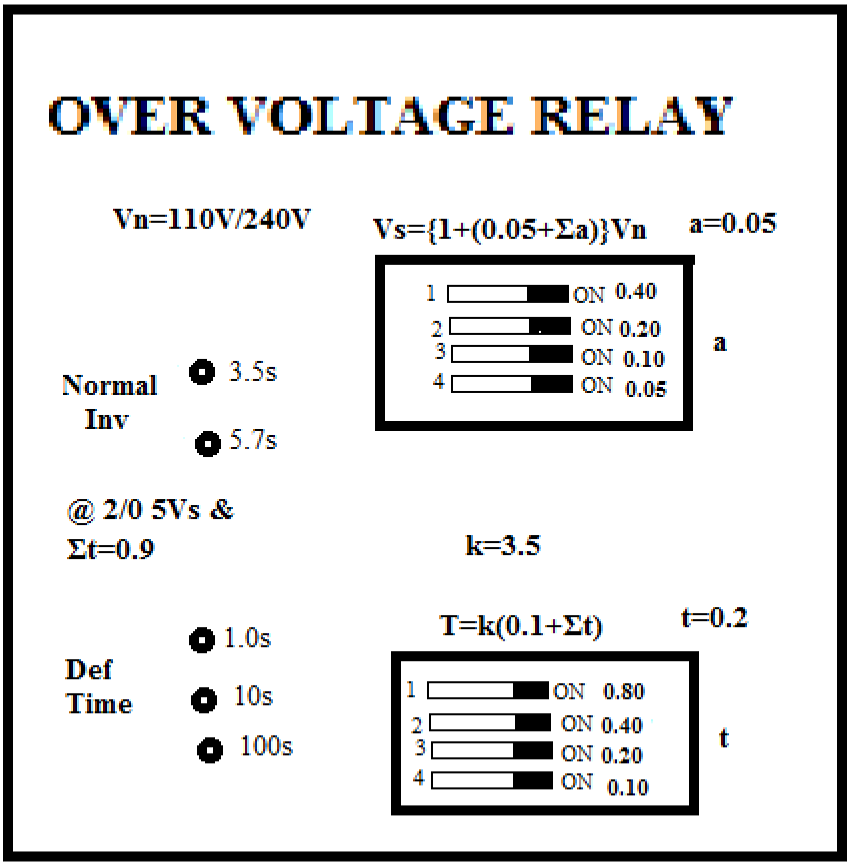


Fig2 :Connection Diagram Of Relay MV12





VOLTAGE SETTING FOR Vn	S/W (1)	S/W (2)	S/W (3)	S/W (4)
Vn= 110V	ON	OFF	OFF	OFF
Vn=240V	OFF	ON	OFF	OFF
Vn= 415V	OFF	OFF	ON	OFF

DIP POSITION FOR OVER VOLTAGE	S/W (1)	S/W (2)	S/W (3)	S/W (4)
Normal Inverse (3.5Sec)	ON	OFF	OFF	OFF
Definite Time (1sec)	ON	OFF	ON	OFF
Definite Time (10sec)	ON	ON	OFF	OFF
Definite Time (100sec)	ON	ON	ON	OFF

Observations: Vn = 110V , a = 0.05

Plug Setting multiplier (PSM) $= \frac{\textbf{Fault Voltage}}{\textbf{Plug Setting}}$

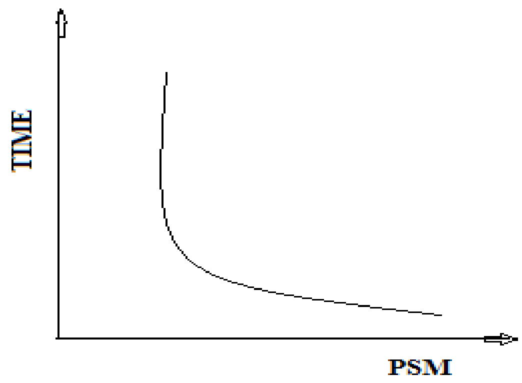
Normal Inverse Characteristics : Vs = {1+(0.05+∑a)}Vn

= { 1+(0.05+0.05)}110

= 121V

S. No	Plug Setting (Vs)	Fault Voltage	PSM	Operating Time in Sec
1				
2				
3				
4				
5				

Model Graph:



Similarly draw the graphs for different Time Multiplexer Setting(TMS) values, and follow the same procedure for different type of relays such as Inverse Definite Minimum Time (IDMT), Inverse, Very Inverse type relays.

Result:

SIMULATION OF 220KV TRANSMISSION LINE MODEL

Simulation of 220KV Transmission line model

i) Ferranti Effect ii) Transmission line parameter

Aim: To Simulate 220KV Transmission line model and

1) To determine the ABCD constants, characteristic impedance of long transmission line

2) To determine Ferranti effect on no load.

Apparatus: 1) Transmission line simulator

2) Patch cards

Theory:

Long lines cause special problems in power systems. The voltage at the receiving end may raise, on no load or light load, beyond permissible limits, Ferranti effect is an increase in voltage occurring at the receiving end of a long transmission line, relative to the voltage at the sending end. This occurs when the line is energized but there is a very light load or the load is disconnected, but on load the voltage may drop below normal. A transmission line demo panel comprises a line model per phase basis having the length 400KM & Voltage of 220 KV is designed for demonstration purposes. The lumped parameter line model with five cascaded networks each of them is designed for 80 KM parameters.

Since a transmission line is symmetrical, the measurement of the open circuit impedance is enough to determine the ABCD constants.

Open-circuiting the load end of the line, the open circuit impedance is measured at sending end as

$$Z_{OC} = A/C \qquad (1)$$

Short circuiting the load end of the line, the short circuit impedance is measured at the sending end as

$$Z_{SC} = B/A \qquad (2)$$

For a symmetrical network,

$$A=D \qquad (3)$$

For a passive network,

AD-BC=1 (4)

Substituting equation (3) in equation (4)

$A^2 - BC = 1$ (5)

Using equation (1) and (5) we get

$A = \left(\frac{Z_{OC}}{Z_{OC} - Z_{SC}}\right)^{1/2}$ (6)

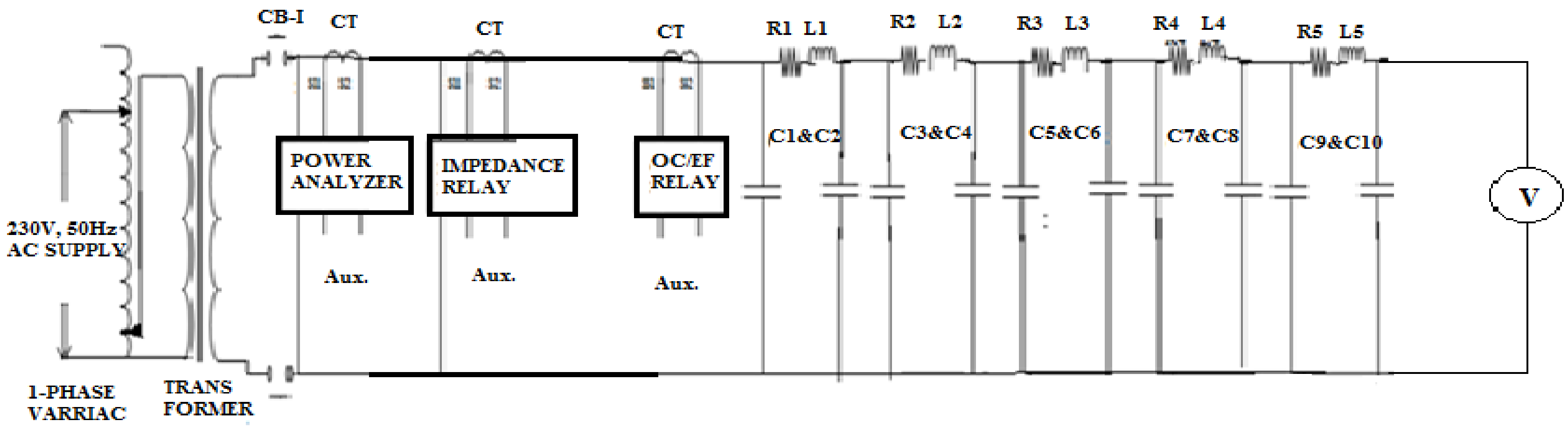
B= A.Zsc. (7)

C=A/Zoc (8)

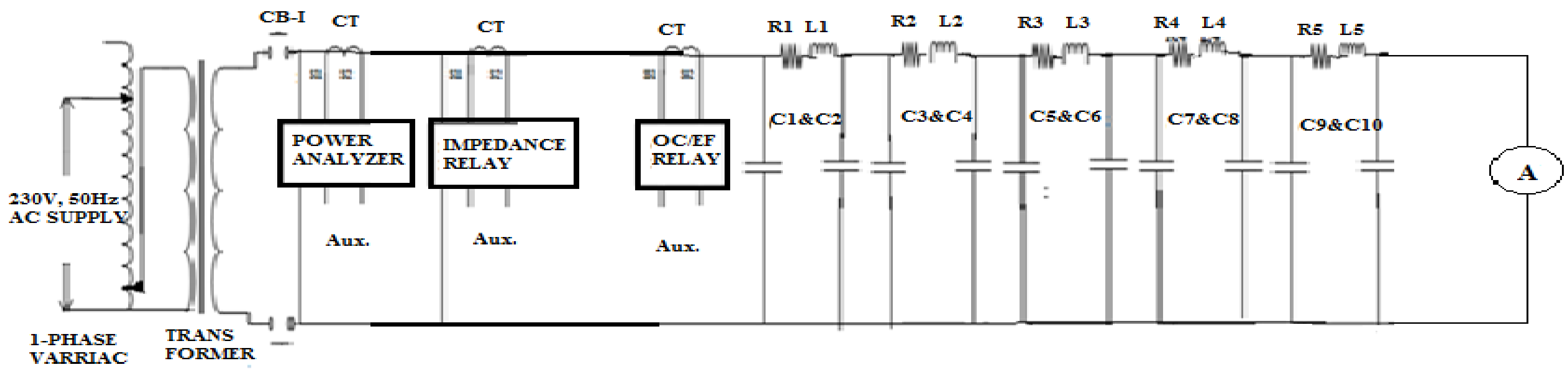
Note that all parameters A, B, C, D and the measured quantities Zoc and Zsc are complex numbers.

NOTE: OC TEST CONNECT VOLTMETER TO RECEIVING END
SC TEST CONNECT AMMETER TO RECEIVING END

OC TEST



SC TEST



Procedure to determine ABCD constants:

1) Connect the transmission line input terminal to transformer output terminals open receiving end.
2) Apply 220 V or less to measure Z_{OC}.

Zoc = Zoc-q (9)

$$Z_{OC} = \frac{V_S}{I_S} \quad (10)$$

$$COS\ \theta = \frac{W_S}{V_S * I_S} \quad (11)$$

Calculate Z_{OC} as a phasor.

3) For measuring Z_{SC}, short circuit receiving end with the help of switch 3 pass a current of 4.5 A or less calculate Z_{SC} as a phasor from equations similar to (9)-(11).
4) Calculate ABCD constants as phasors from equations (6)-(8).
5) Determine the surge impedance and propagation constant λl as phasors from the following equations.

$$Z_0 = (\frac{B}{C})^{1/2} \quad (12)$$

$$\lambda l = COSh^{-1}(A) \quad (13)$$

Procedure to determine Ferranti effect:

1. Open circuit the receiving end
2. Adjust the sending – end voltage to 220V. Note the receiving – end voltage.
3. The receiving end voltage is greater than sending end due to Ferranti effect.

Sample calculations

ABCD Parameters

1) Open circuit test

Open circuit voltage V_{oc} = 220V

Open circuit current I_{oc}= 1.12A

Open circuit power P_{oc} = 8W

$Z_{oc} = V_{oc} / I_{oc}$

$= 220/1.12$

$= 196.4\Omega$

$\cos\theta = W_s/(V_{oc}.I_{oc})$

$\theta = \cos^{-1} (W_s/(V_{oc}.I_{oc}))$

$= \cos^{-1}(0.1298)$

$= 82.53$

$Z_{oc} = Z_{oc}.\angle\theta$

$= 196 \angle -82.53$

=

Short circuit test

Short circuit voltage V_{sc} =

Short circuit current I_{sc}=

Short circuit power P_{sc} =

$Z_{sc} = V_{sc} / I_{sc}$

=

=

$\cos\theta = W_s/(V_{sc}.I_{sc})$

$\theta = \cos^{-1} (W_s/(V_{sc}.I_{sc}))$

=

$Z_{sc} = Z_{sc}.\angle\theta$

=

=

A = $\sqrt{\frac{Zoc}{Zoc - Zsc}}$

=

B = A.$\mathbf{Z_{sc}}$

=

C = A/$\mathbf{Z_{oc}}$

=

D = A

=

Surge impedance $\mathbf{Z_o}$ = $\sqrt{\frac{B}{C}}$

=

Propagation constant $\lambda l = COSh^{-1}(A)$

=

ABCD Parameters:

S.No.	Parameters	Theoretical	Practical
1	A		
2	B		
3	C		
4	D		

Ferranti effect:

Line capacitance	Sending end voltage	Receiving end voltage
14μfd	220V	232V

Result:

DETERMINATION OF I-V AND P-V CHARACTERISTICS OF PV MODULE WITH VARYING RADIATION

Determination of I-V and P-V characteristics of PV module with varying Radiation

Aim:ToDetermination of I-V and P-V characteristics of PV module with varying radiation.

Theory:

The PV module is characterized by its I-V and P-V characteristics. At a particular solar insolation andtemperature, module characteristic curves are shown in fig.

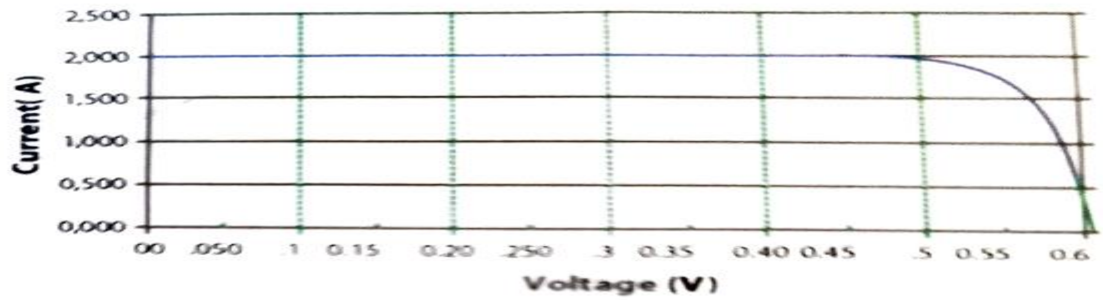


Fig. 1.1(a). I-V characteristic of PV module

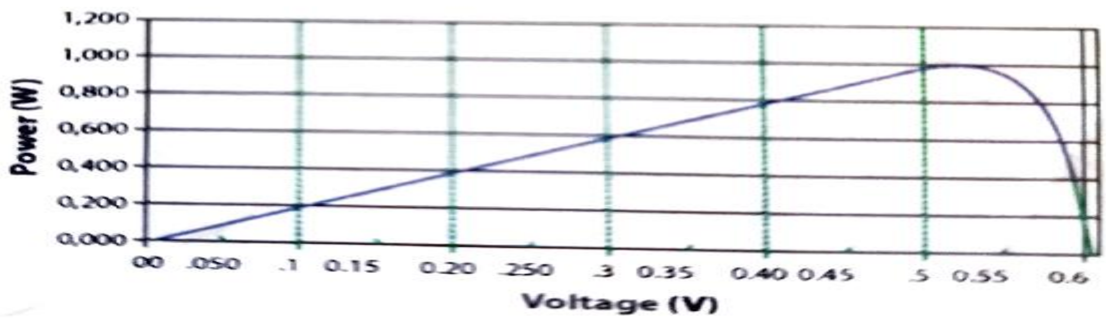


Fig. 1.1(b). P-V characteristic of PV module

Characteristic curves of solar cell:

In I-V characteristic maximum current at zero voltage is the short circuit current (I_{sc}) which can be measured by shorting the PV module and maximum voltage at zero current is the open circuit voltage (Voc). In P-V curve the maximum power is achieved only at a single point which called MPP (maximum power point) and the voltage and current corresponding to this point are referred as Vmp and Imp. On changing the solar insolation Isc of the module increases while the Voc increases very slightly as shown fig.1.3.

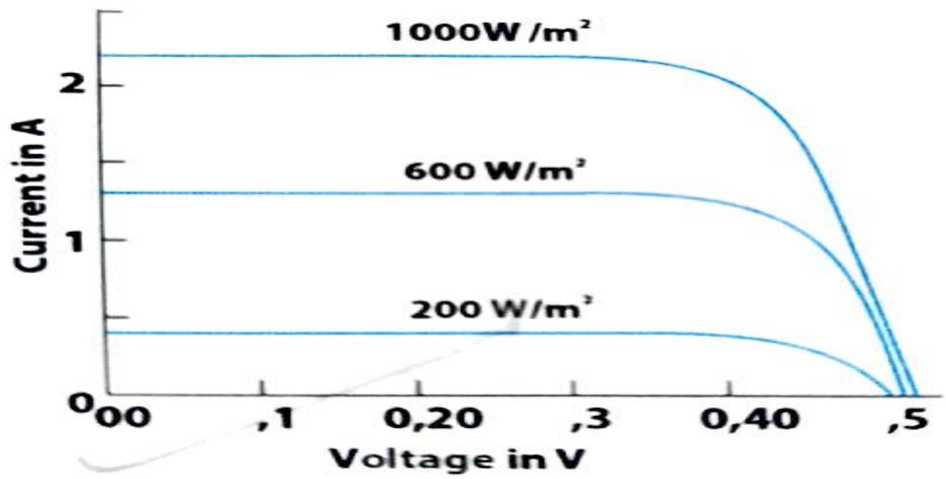


Fig. 1.3. Variation in I-V characteristic with insolation

CIRCUIT DIAGRAM:

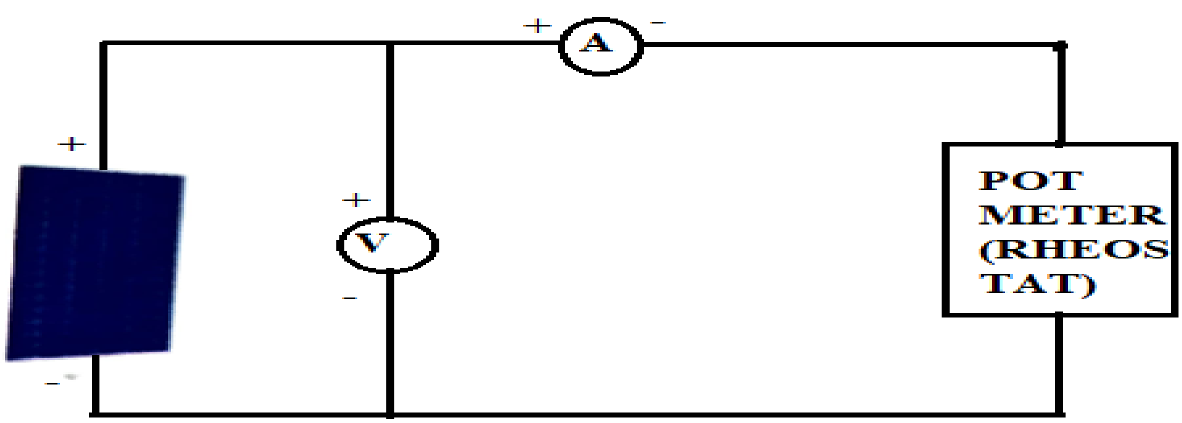


Fig. 1.5. Circuit diagram for evaluation of I-V and P-V characteristics

Experimental set-up(Procedure):

1. Connect the circuit diagram to evaluate I-V and P-V characteristics of a module as shown in connection diagram.
2. Form a PV system which includes PV module and a variable resistor (pot meter) with ammeter and voltmeter for measurement. Pot meter in this circuit works as a variable load for the module.
3. Vary the load on the module is by pot meter and note down the current and voltage of the module will change which shift the operating point on I-V and P-V characteristics.
4. Take I-V and P-V data from logger and plotter by connecting the logger plotter box with module output.
5. After taking the values of current and voltages from the data logger, plot the I-V curve can be at different radiation and temperature levels.

Fig. 2.4. Logger plotter box with power supply

Controller connections

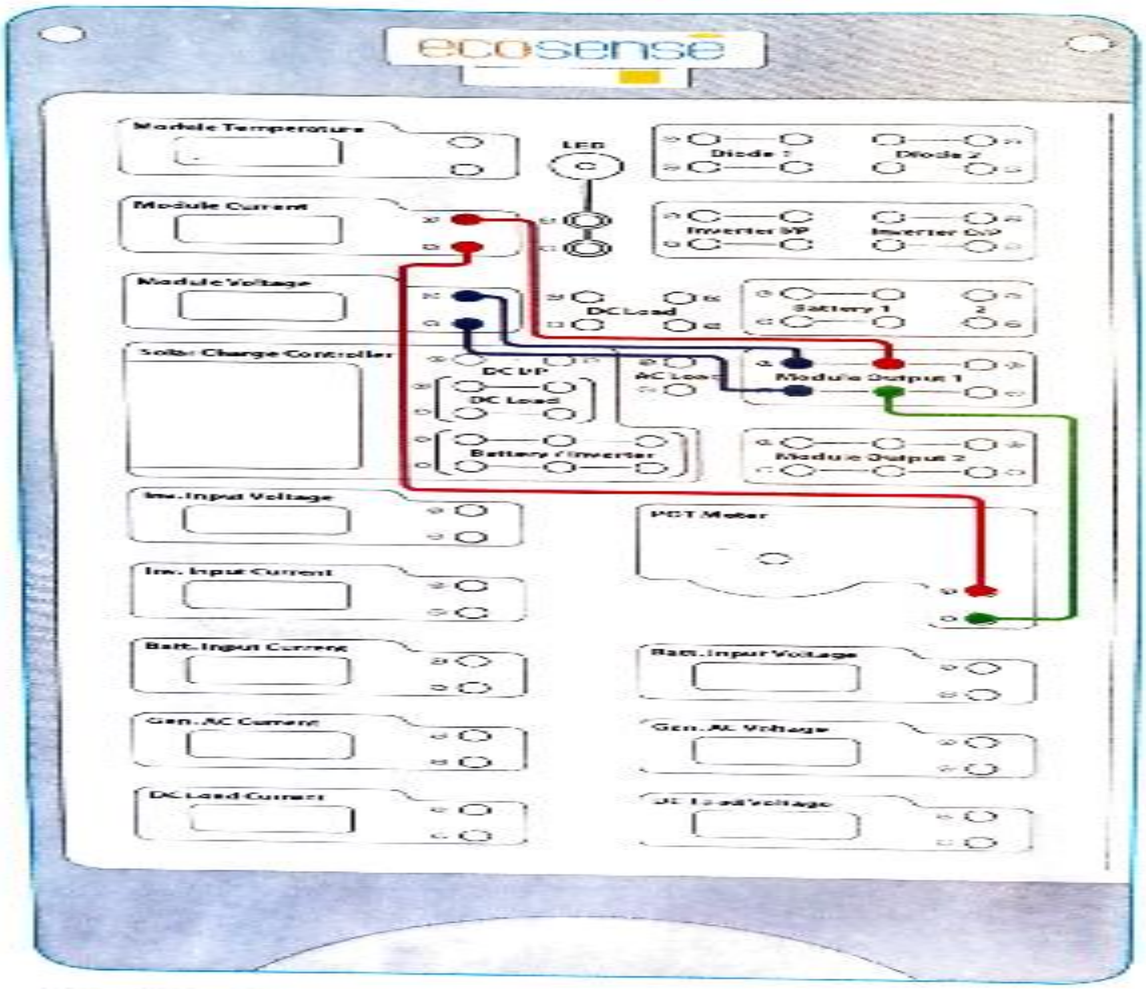


Fig. 1.6. Control board connections to get I-V and P-V characteristics

OBSERVATION TABLE:

I-V and P-V characteristics of PV modules:

S.No.	Radiation	V	I	P

S.No.	Radiation	V	I	P

S.No.	Radiation	V	I	P

Precautions:

1. Readings for one set should be taken within 1-2 minutes (for indoor exp.) otherwise temperature of the module may change as radiation source used is halogen lamp.
2. Halogen lamp position should not be changed during one set otherwise radiation on modules will change.
3. Connections should be tight.

Result:

CHARACTERISTICS OF INDUCTION MOTOR PROTECTION RELAYS

CHARACTERISTICS OF INDUCTION MOTOR PROTECTION RELAYS

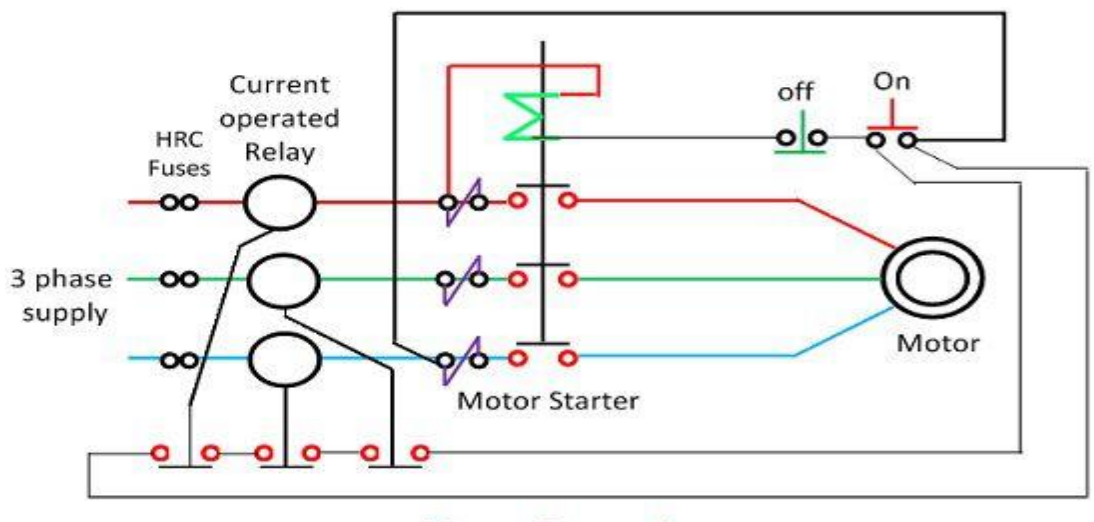
Aim: To test the induction motor protection relay under abnormal condition.

Apparatus:

1. Induction Motor Protection Relay kit
2. Induction Motor
3. Patch Cards

Theory:

The various types of the protective relays are available for protecting the motor from faults. These relays sense the abnormal operating condition and make the circuit breaker to trip. The motors provide protection against faults in windings and associated circuits, excessive overload and short circuits, under voltages, phase unbalances and single phasing, phase reversal and switching over voltages.



Motor Protection

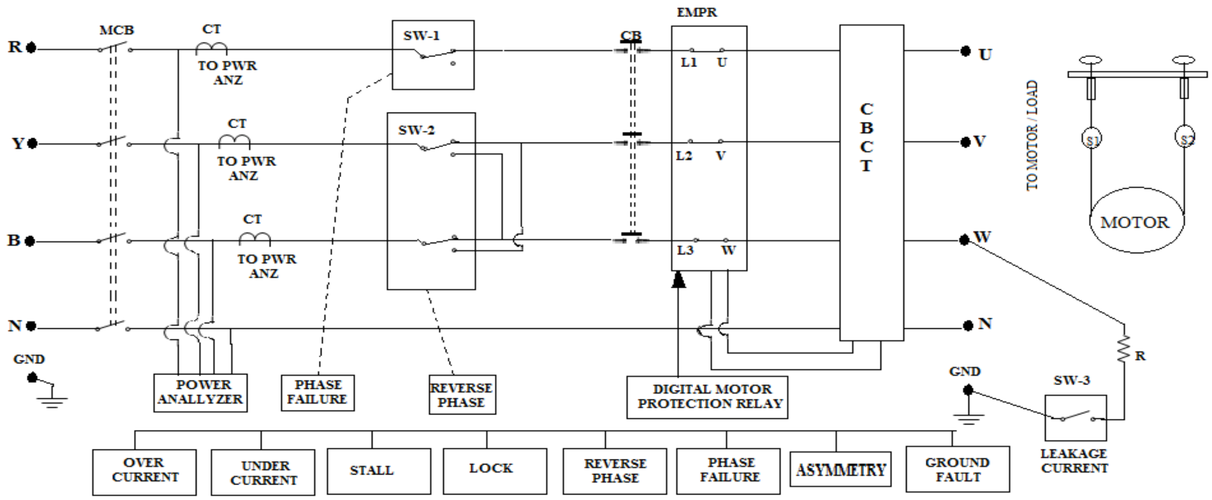
The main characteristic of the relay is to reduce the operating time with the increase in the magnitude of the fault current. The various types of motor protection schemes are explained below.

Unbalance and Single Phasing Protection – The unbalanced three phase supply causes the negative sequence current to flow in the motor which may cause overheating of the stator and rotor winding of the motor. The unbalanced condition provided to a motor should be such as to avoid the continuous unbalanced condition.

Reverse Phase Protection – The phase reversal is dangerous in some cases, such as in elevators, cranes, hoists, trams, etc. In such cases, the reverse phase protection must be provided. The phase reversal relay is based on the electromagnetic principle consists of a disc motor driven by the magnetic system.

For correct phase sequence, the disc experiences a torque in a positive direction and therefore keep the auxiliary contact closed. In the occurrence of phase reversal, the torque acting on the disc reverse and the disc start rotating in the opposite direction and hence open the auxiliary contact. Thus the magnetic coil of a starter can be de-energized, or circuit breaker can be tripped.

Circuit Diagram



Procedure:

1. Connect the Three phase power supply with Neutral and Ground.
2. Connect motor (Terminals provided at the top side of mimic).
3. Switch on power supply at source.
4. Switch on the MCB on the testing kit and look for power on indication (R,Y,B).
5. Trip indicator and buzzer will be ON, reset it.
6. Set the motor protection relay parameters.
   a. INVERSE / DEFINE ITE CHARACTERSTIC – DEFINE.
   b. DEFINITE TIME – 2SEC.
   c. REVERSE PHASE PROTECTION – ON.
   d. UNDER CURRENT PROTECTION – OFF.
   e. GROUND FAULT – 0.05SEC.
   f. STALL FUNCTION – ON.
   g. LSCK FUNCTION – ON – 200%.
   h. CT RATIO – 1.
   i. PHASE FAILURE – ON.
   j. STORE.
   k. CURRENT – 1.0A
7. Adjust the dimmer to 415V.
8. Push Motor ON button. Insuring that there is no load on the motor and observe the current and voltage of all the phases and record it.

PHASE FAILURE PROTECTION:

1. Ensure motor is off.
2. Bring the all the fault simulation to position 1.
3. Switch ON fault simulation single phase.
4. Ensure the EMPR settings.

a) INVERSE / DEFINE ITE CHARACTERSTIC – DEFINE.
b) DEFINITE TIME – 2SEC.
c) REVERSE PHASE PROTECTION – ON.
d) UNDER CURRENT PROTECTION – OFF.
e) GROUND FAULT – 0.05SEC.
f) STALL FUNCTION – ON.
g) LSCK FUNCTION – ON – 200%.
h) CT RATIO – 1.
i) PHASE FAILURE – ON.
j) STORE.
k) CURRENT – 1.0A

5. Switch on the Motor.
6. Note down the timer reading.
7. Relay trip scours-
   i) Motor will be stop
   ii) Relay display shows –P – F bar graph will be Turn ON.
   iii) Hooter will be on.
   iv) Fault indicator will be glow.
8. Now accept the fault by pressing the accept push button.
9. Reset the relay by pressing test / reset button.
10. Press the Reset button at control panel.
11. Bring SINGLE PHASEFAULT simulation switch to home position.

OBSERVATION TABLE:

	Ammeter reading (A)			Voltmeter reading (V)			PF	Phase Failure	Phase Reverse	Earth Leakage
	R	Y	B	R	Y	B		Trip Time (Sec)		
No-Load										

Result:

DETERMINATION OF I-V AND P-V CHARACTERISTICS OF SERIES AND PARALLEL COMBINATION OF PV MODULE

Determination of I-V and P-V characteristics of series and parallel combination of PV module

Aim: To Determination of I-V and P-V characteristics of series and parallel combination of PV module.

Theory:

The PV module is characterized by its I-V and P-V characteristics. At a particular level of solar insolation and temperature it will show a unique I-V and P-V characteristics. These characteristics can be altered as per requirement by connecting both modules in series or parallel to get higher voltage or higher current as shown in Fig.2.l(a) and 2.1(b) respectively.

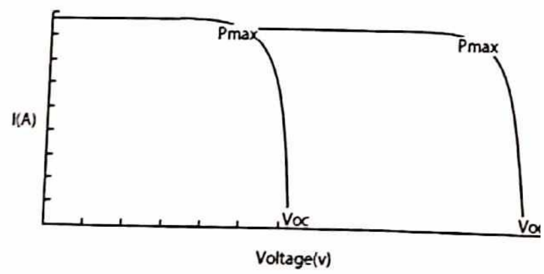


Fig. 2.1(a). I-V characteristic of series connected modules

On increasing the temperature, V_{oc}, of modules decrease while I_{sc} remains same which in turn reduces the power.

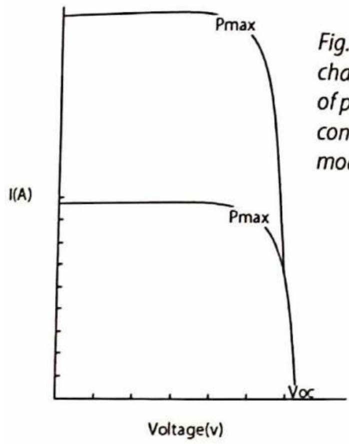


Fig. 2.1(b). I-V characteristic of parallel connected modules

Therefore, if modules are connected in series then power reduction is twice when connected in parallel.

On changing the solar insolation, I_{sc} of the module increases while the V_{oc} increases very slightly, therefore there is overall power increase. In parallel connection power increment is twice than when connected in series.

CIRCUIT DIAGRAM:

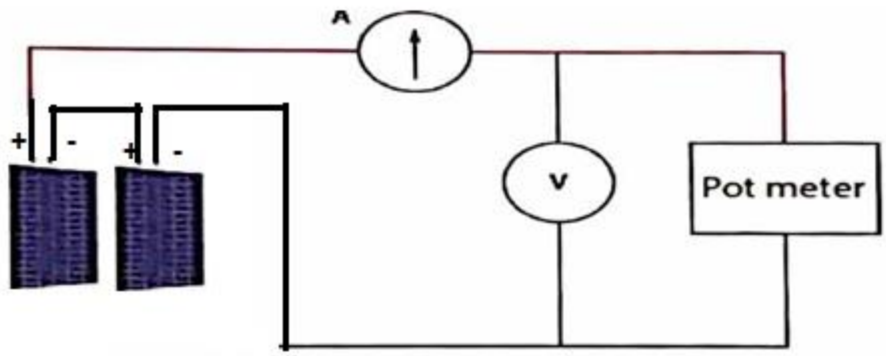


Fig. 2.2(a). Circuit diagram for evaluation of I-V and P-V characteristics of series connected modules

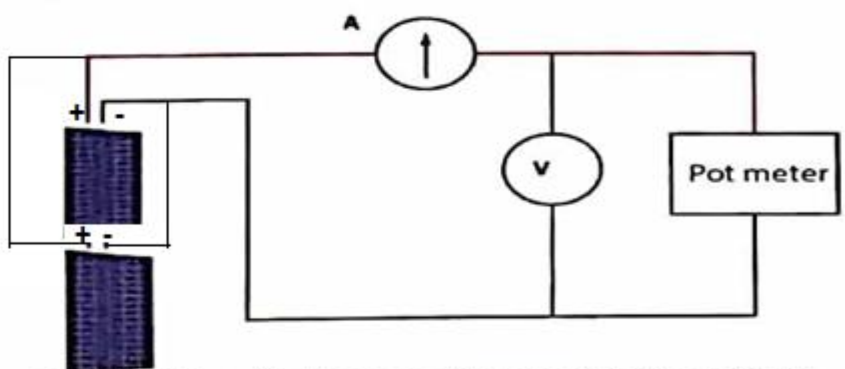


Fig. 2.2(b). Circuit diagram for evaluation of I-V and P-V characteristics of parallel connected modules

Experimental set-up (Procedure):

The circuit diagram to evaluate I-V and P-V characteristics of modules connected in series and parallel are shown in Fig.2.2(a) and 2.2(b) respectively.

Form a PV system with modules in either series or parallel and a variable resistor (Pot meter) with ammeter and voltmeter for measurement. Modules in series or parallel are connected to variable load (pot meter). The effect of load change on connected in series or parallel can be seen by varying load resistance (pot meter).

One can also take I-V and P-V data from logger and plotter by connecting the logger plotter box with module output.

Values of current and voltages can be taken from the data logger and then I-V curve can be plotted at different radiation and temperature levels.

One can also use real time plotter which will plot the curve of I-V and P-V.

Fig. 2.4. Logger plotter box with power supply

OBSERVATION TABLE:

I-V and P-V characteristics of PV modules in Series:

S.No.	Temperature	V	I
1			
2			
3			
4			
5			

I-V and P-V characteristics of PV modules in Parallel:

S.No.	Temperature	V	I
1			
2			
3			
4			
5			

Series connected modules

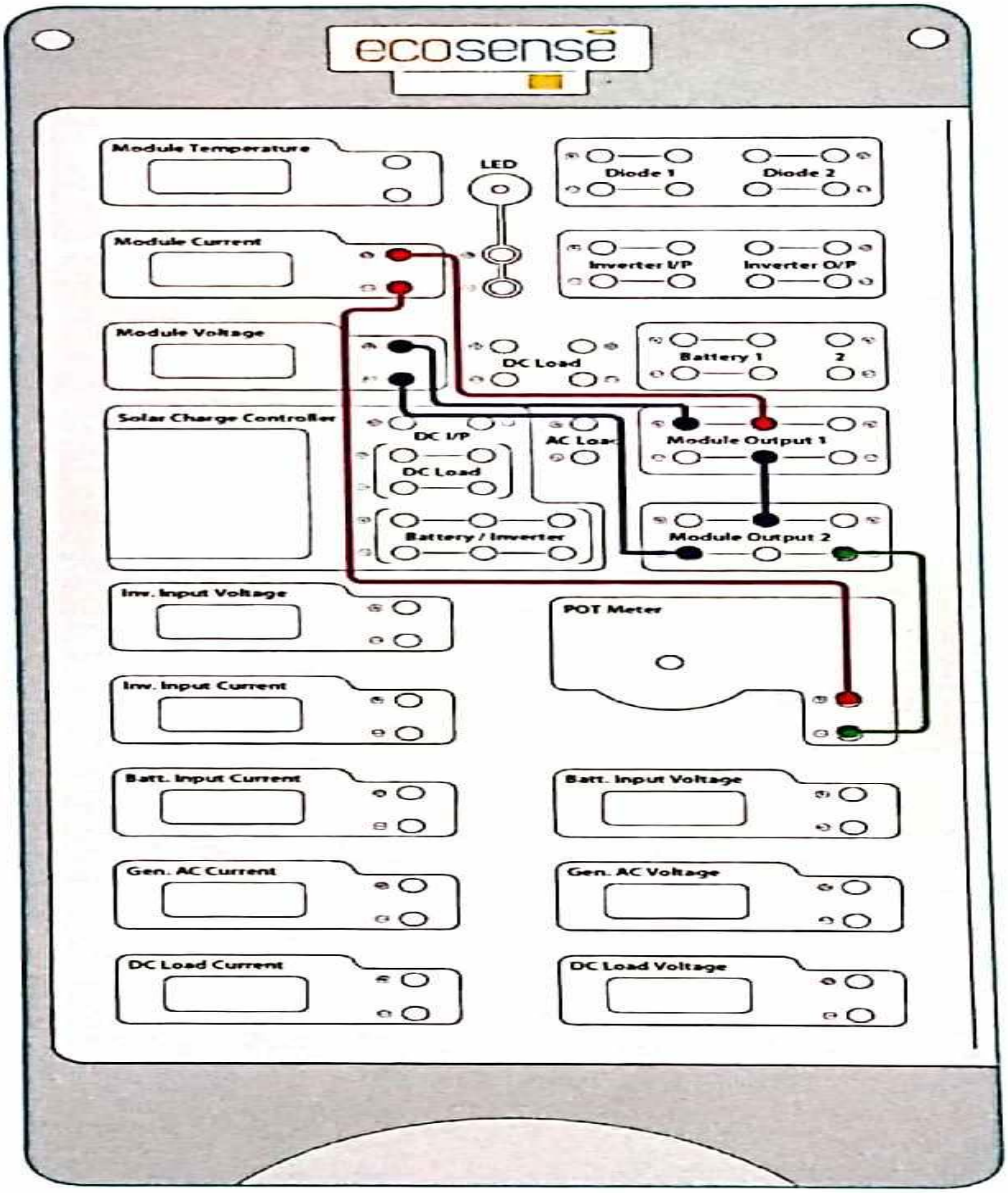


Fig. 2.3(a). Control board connections for modules connected in series

Parallel connected modules

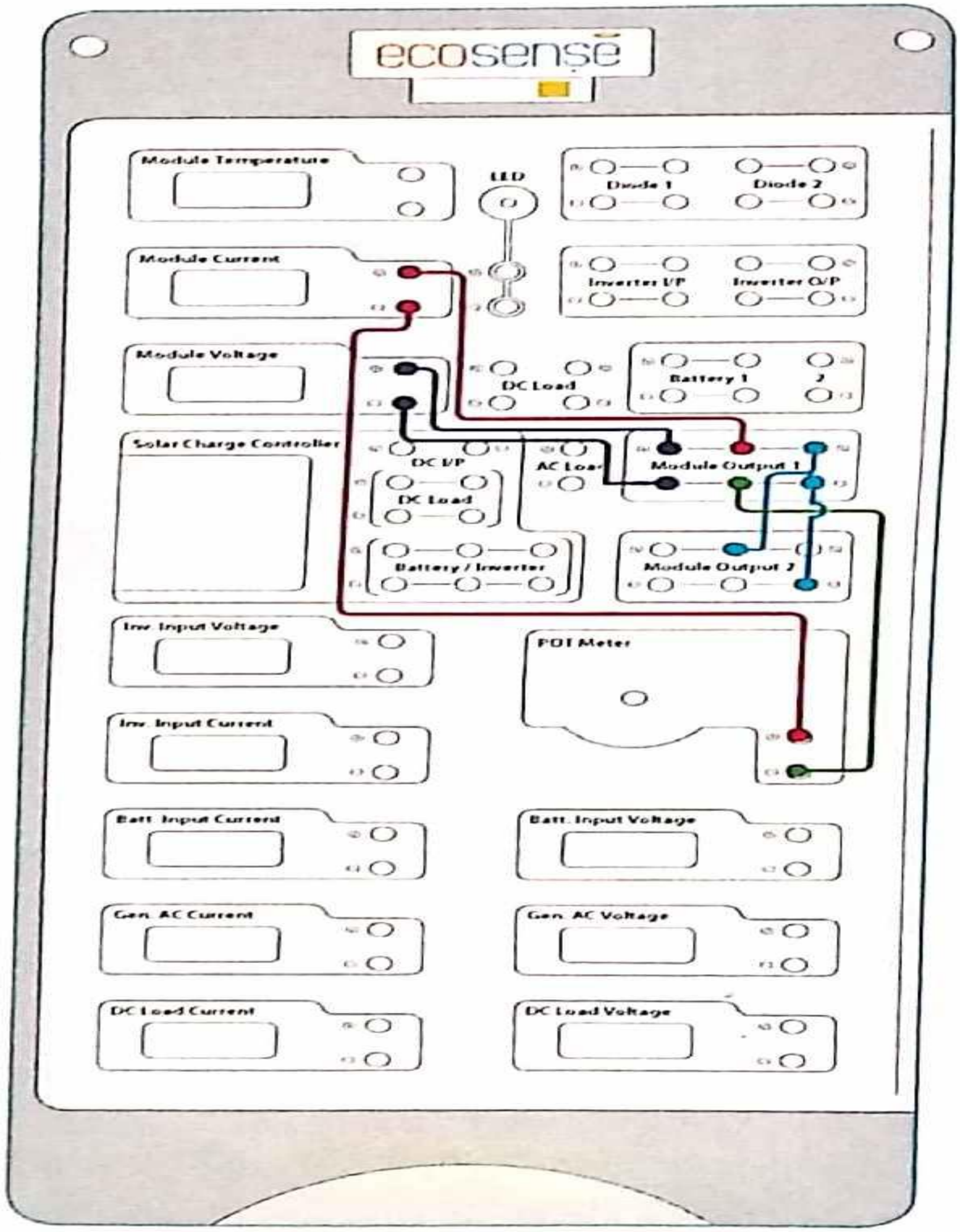


Fig. 2.3(b). Control board connections for parallel connected modules

Precautions:

1. Readings for one set should be taken within 1-2 minutes (for indoor exp.) otherwise temperature of the module may change as radiation source used is halogen lamp.
2. Halogen lamp position should not be changed during one set otherwise radiation on modules will change.
3. Connections should be tight.

Result:

1. Draw the I-V curves of all the sets on a single graph and show the characteristics at different radiation and temperatures levels (by using digital meters and data logger separately).
2. Draw the P-V curves of all the sets on a single graph and show the characteristics at different radiation and temperatures levels (by using digital meters and data logger separately).
3. Calculate the fill factor for the given module (by using digital meters and data logger separately).
4. Also get all above mentioned curves from the real time plotter.

Determination of Sub-Transient Reactance of a Salient Pole Machine

Determination of Sub-Transient Reactance of a Salient Pole Machine

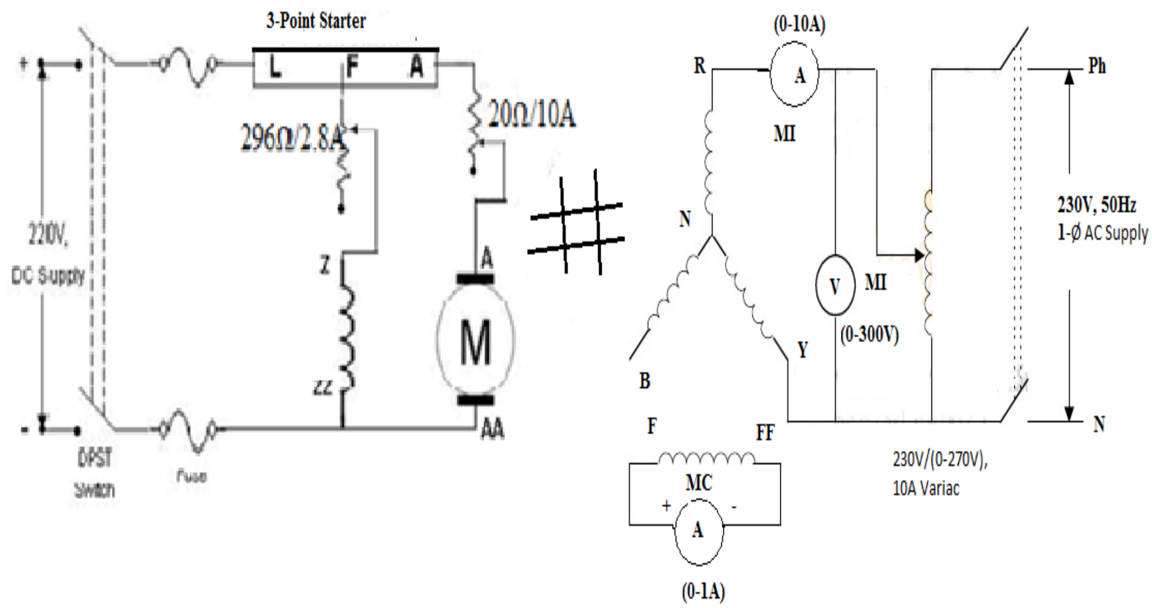
Aim: To conduct a test on salient pole synchronous machine to determine sub transient direct axis (X_d'') and quadratic axis(X_q'') synchronous reactance of alternator.

Apparatus:

Alternator: - 3 phase, 1KW, 4.2 A, 1500 RPM

S. No.	Apparatus	Type	Range	Quantity
1.	Voltmeter	MI	(0-300V)	1
2.	Ammeter	MI	(0-10A)	2
3.	Single phase variac	1-Ø	230V/(0-270V), 10A	1
4.	Rheostat	Wire Wound	20Ω/10A	1
5	Rheostat	Wire Wound	296Ω/2.8A	1

Circuit diagram:



Theory:

This theory is related to behavior of an alternator under transient conditions. In purely inductive closed circuit the total flux linkages cannot change suddenly at the time of any disturbance. Now if all the three phases of an unloaded alternator with normal excitation are suddenly short circuited there will be short circuit current flowing in the armature. As the resistance is assumed to be zero this current lag behind the excitation voltage by 90 degree and the mmf produced by this current will be in d- axis and the first conclusion is that , this current will be affected by d axis parameters $x_d, x_d^{'}$ and $x_q^{''}$ only. Further there will be demagnetizing effect of this current but as the flux linkages with field cannot change the effect of demagnetizing armature mmf must be counter balanced by a proportional increase in the field current, This additional induced component of field current gives rise to greater excitation , under transient state and results in more short circuit current at this time than the steady state short circuit. if field poles are provided with damper bars. Than at the instant three phase short-circuit the demagnetizing armature mmf induces current in damper bars which in turn produces field in the same direction as main field and hence and at this instant the excitation. Further increases in short circuit armature current. This is for a very short duration. Normally 5 to 4 cycles and this period is knows as sub-transient period. Since the field voltages are constant, there is no additional voltage to sustain these increased excitation during sub transient period or transient period. Consequently the effect of increased field current decrease with a time constant determined by the field and armature circuit parameter and accordingly the short circuit armature current also decays with the same time constant

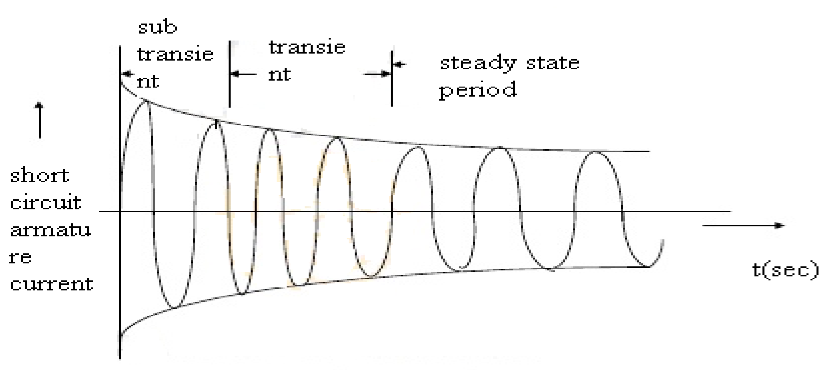


Fig. shows a symmetrical waveform for a armature short circuit for one phase of three phase alternator. The DC component is taken to be zero for this phase. The reactance's offered by the machine during sub transient periods are known as sub transient reactance. In direct axis it is $X_d^{''}$ and in quadrature axis it is x_q.

PROCEDURE:

1) Make the connections as shown in the circuit diagram

2) Set the dimmer stat output to zero and put on the supply

3) Gradually rotate the armature and see the field current and the armature current. Note the values of applied voltage and armature currents. When field current is maximum, and when minimum.

4) Repeat the step three for other applied voltage Take care that armature current does not go beyond its rated value during the experiment.

OBSERVATION TABLE:

S.No	Armature voltage (phase)	Armature voltage (phase)	Armature current		X_d'' (Ω)	X_q'' (Ω)	X_d'' (p.u)	X_q'' (p.u)
	V(Min)	V(Max)	I_f (Max)	I_f (Min)				
1								
2								
3								
4								

MODEL CALCULATIONS:

$$X_d'' = \frac{V(Max)}{I(Min)} = \frac{53.9}{1.7} = 31.70$$

$$X_q'' = \frac{V(Min)}{I(Max)} = \frac{53.7}{2.3} = 23.84$$

$$X_d''(pu) = \frac{X_d''}{Base\ impedence} = 0.920$$

$$X_q''(pu) = \frac{X_q''}{Base\ impedence} = 0.683$$

Base Impedance $= \frac{(BaseVoltage/K)^2}{BasemVA} = \frac{(0.415)^2}{(0.005)} = 34.45$

Result:

CHARACTERISTICS OF IMPEDANCE RELAY

CHARACTERISTICS OF IMPEDANCE RELAY

Aim: To test Impedance Relay under fault conditions and to observe it's response.

Apparatus: 1. Impedance Relay testing kit

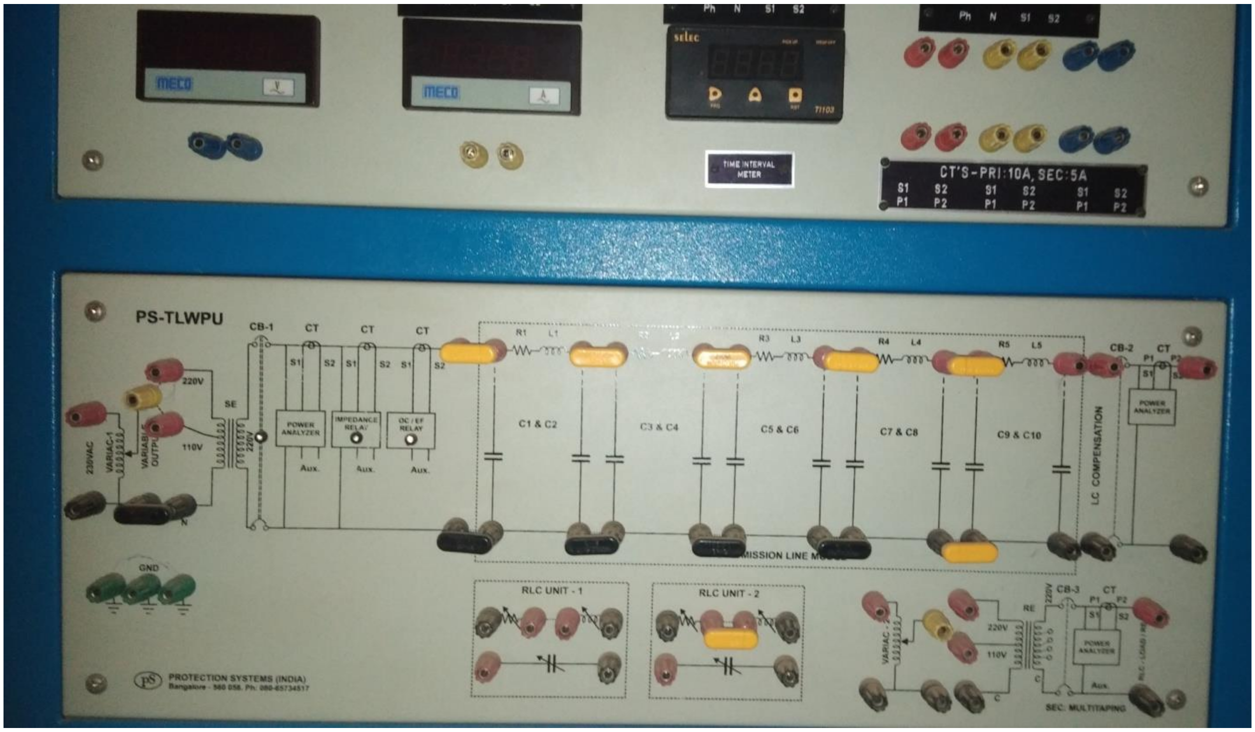
2. Patch Cards

Theory:

The **working principle of impedance relay** is very simple. There is one voltage element from potential transformer and a current element fed from current transformer of the system. The deflecting torque is produced by secondary current of CT and restoring torque is produced by voltage of potential transformer.

In normal operating condition, restoring torque is more than deflecting torque. Hence relay will not operate. But in faulty condition, the current becomes quite large whereas voltage becomes less. Consequently, deflecting torque becomes more than restoring torque and dynamic parts of the relay starts moving which ultimately close the No contact of relay. Hence clearly **operation or working principle of impedance relay** depends upon the ratio of system voltage and current. As the ratio of voltage to current is nothing but impedance so a distance relay is also known as impedance relay.

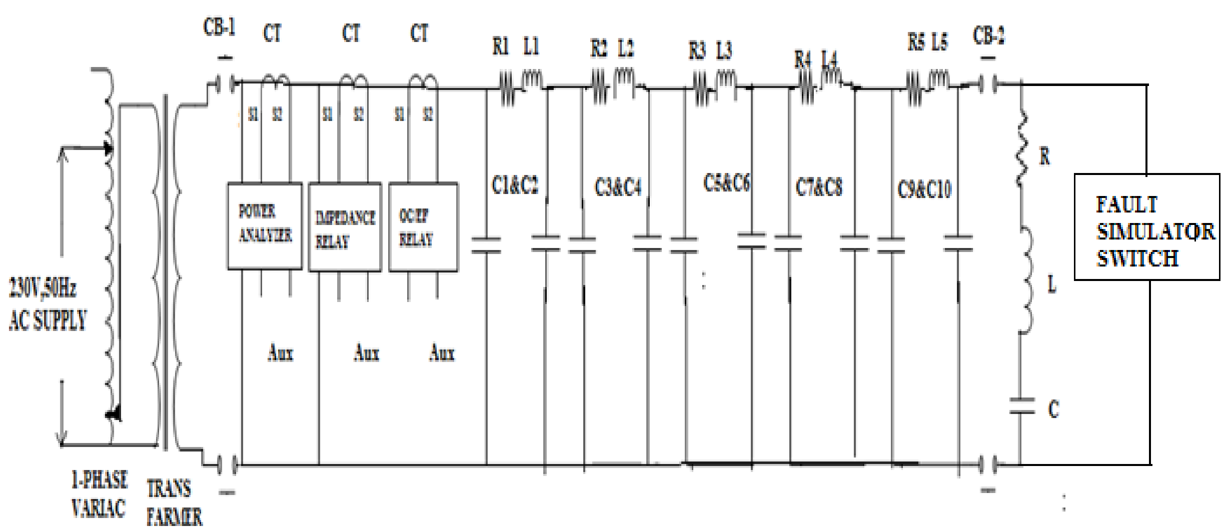
The operation of such relay depends upon the predetermined value of voltage to current ratio. This ratio is nothing but impedance. The relay will only operate when this voltage to current ratio becomes less than its predetermined value. Hence, it can be said that the relay will only operate when the impedance of the line becomes less than predetermined impedance (voltage / current). As the impedance of a transmission line is directly proportional to its length, it can easily be concluded that a distance relay can only operate if fault is occurred within a predetermined distance or length of line.



NOTE: Connect to RLC unit to Receiving End.

Connect Fault Simulator Switch to Receiving End.

Circuit Diagram:



Procedure:

1. Mains ON MCB's.
2. Impedance Relay Toggle switch to "healthy" position.
3. Make "Unhealthy" of Over current relay toggle switch.
4. Press "Set".
5. Select the "% impedance using by "HIGH/LOW" key.(1% to 200%)
6. Press "set" two times.
7. Select the K=100 (range 10-100).
8. Set impedance Z0=100%.
9. Kept the Fault simulator switch in "Position-1".
10. Connect the patch cord from receiving end to "Fault Simulator Input".
11. Connect the patch cord from receiving end to RLC UNIT-2, and kept the "Resistance 100W" ON position.(toggle switch down is ON/UP-OFF)
12. Push the "CB-1" ON.
13. Push the "CB-2" ON.
14. Press the "ENTER" key in impedance relay.
15. Turn the "Fault Simulator Switch" to Position-2.
16. Time interval meters starts counting, relay will read ~ 98 to 100%.
17. Relay may not operate, otherwise it will take more time to operate.
18. If relay tripped, then press the "Accept" push button, then press the reset button of the impedance relay, then "Fault/Reset" push button.
19. Turn the " Fault Simulator Switch" to Position-1.
20. Connect the patch cord from 320kms (4^{th} π section from sending end) to the " Fault Simulator Input"
21. Push the "CB-1" ON.
22. Press the "ENTER" key in impedance relay.
23. Turn the "Fault Simulator Switch" to Position-2.
24. Time interval meters starts counting, relay will be active and tripped after few seconds, display will read trip "Impedance, Voltage, Current." Note down the readings.
25. CB-1 will be OFF.
26. Timer will stop counting.
27. Note down the timer reading.
28. Repeat the same at 240km also. (from 11 to 26)
29. Observe the inverse characteristics of impedance relay.

OBSERVATION TABLE:

S.No	% Impedance (Z)		Impedance relay Voltage	Impedance relay Current	Trip time-sec	Fault at km (from sending end)
	Set	Actual				
1						
2						
3						
4						
5						

Trip Time calculated by

Z_0=Zset
Td=K*1/(Zset - Zactual) **or** T1= k/(Zdifference)
Where k = Time multiplier setting from (10-100) insteps of 10

Result:

BUCHHOLZ RELAY

BUCHHOLZ RELAY

Aim: To test Buchholz Relay for various faults and to observe the response of the relay.

Apparatus: Buchholz Relay demonstration kit

Theory:

Whenever a minor fault occurs inside the transformer, heat is produced by the fault currents. The produced heat causes decomposition of transformer oil and gas bubbles are produced. These gas bubbles flow in upward direction and get collected in the buchholz relay. The collected gas displaces the oil in buchholz relay and the displacement is equivalent to the volume of gas collected. The displacement of oil causes the upper float to close the upper mercury switch which is connected to an alarm circuit. Hence, when minor fault occurs, the connected alarm gets activated. The collected amount of gas indicates the severity of the fault occurred. During minor faults the production of gas is not enough to move the lower float. Hence, during minor faults, the lower float is unaffected.

During major faults, like phase to earth short circuit, the heat generated is high and a large amount of gas is produced. This large amount of gas will similarly flow upwards, but its motion is high enough to tilt the lower float in the buccholz relay. In this case, the lower float will cause the lower mercury switch which will trip the transformer from the supply, i.e. transformer is isolated from the supply.

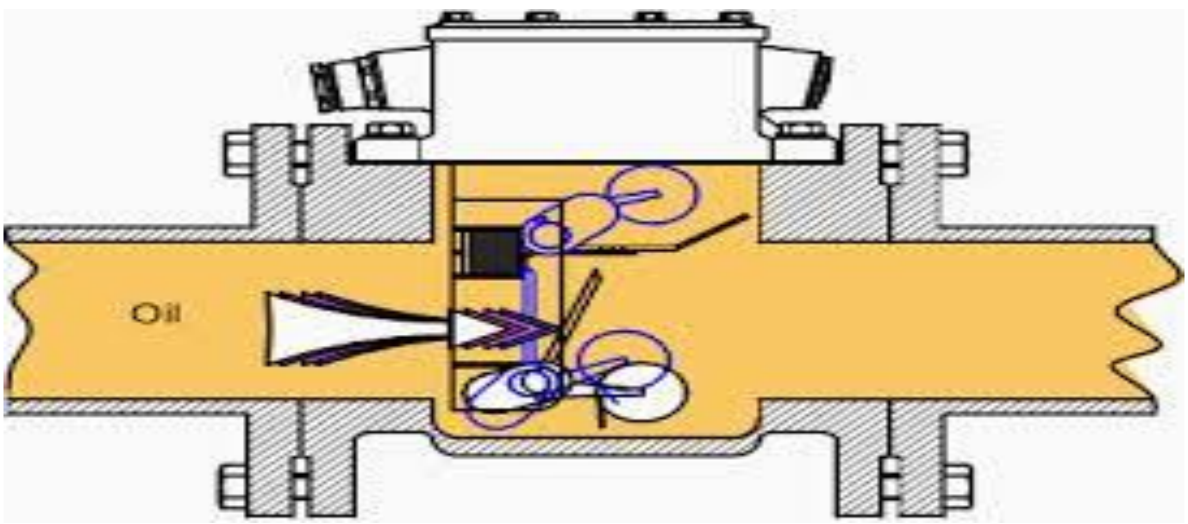
Advantages of Buchholz Relay

- Buchholz relay indicates the internal faults due to heating and it helps in avoiding the major faults.
- Severity of the fault can be determined without even dismantling the transformer.
- If a major fault occurs, the transformer can be isolated with the help of buchholz relay to prevent accidents.

Procedure:

1. Connect Buchholz Relay status unit.
2. Connect foot pump to the relay unit.
3. Fill the oil in Buchholz Relay green level.
4. Main on in the status unit.
5. Create the air bubbles using foot pump. (Slowly press the foot pump, results created the air bubbles.)
6. Oil level of the Buchholz Relay goes down due to gas. Results alarm will activate.
7. Release the Buchholz Relay air by using valve in relay.
8. Oil level should come in to the original level.
9. Apply the pressure suddenly, results trip indicator will glow.
10. Oil level of the Buchholz Relay goes down due to gas.
11. Release the Buchholz Relay air by using valve in relay.

12. Oil level should come in to the original level.



Insulating liquid flow:

Fault: A spontaneous incident generates a pressure wave moving in the direction of the conservator.

Response: The liquid flow reaches a damper arranged in the liquid flow. If the flow rate exceeds the operating threshold of the damper, the latter moves in flow direction. Due to this movement a switch contact is actuated so that the transformer is disconnected.

Result:

Y_{bus} formulation

FORMATION OF BUS ADMITTANCE MATRIX BY DIRECT INSPECTION METHOD

Aim:

To develop a computer program to form the bus admittance matrix, Y_{bus} of a power system.

Theory:

The Y_{bus} /Z_{bus} matrix constitutes the models of the passive portions of the power network. Y_{bus} matrix is often used in solving load flow problems. It has gained widespread applications owing to its simplicity of data preparation and the ease with which the bus admittance matrix can be formed and modified for network changes. Of course, sparsity is one of its greatest advantages a bit heavily reduces computer memory and time requirements. In short circuit analysis, the generator and transformer impedances must also 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 matrix formed by inspection method or by analytical method. The impedance matrix is a full matrix and is most useful for short circuit studies. Initially, the Y-bus matrix is formed by inspection method by considering line data only. After forming the Y-bus matrix, the modified Y-bus matrix is formed by adding the generator and transformer admittances to the respective diagonal elements and is inverted to form the Z-bus matrix.

The performance equation for a n-bus system in terms of admittance matrix can be written as,

$$I = Y_{bus}.V$$

$$Y_{bus} = \begin{bmatrix} Y_{11} & Y_{12} & - & Y_{1n} \\ Y_{21} & Y_{22} & - & Y_{2n} \\ - & - & - & - \\ Y_{n1} & Y_{n2} & - & y_{nn} \end{bmatrix}$$

The admittancesY_{11},$Y_{12,\ldots}$ Y_{1n} are called the self-admittances at the nodes and all other admittances are called the mutual admittances of the nodes.

Formulae Used:

Main diagonal element in Y-bus matrix = $\sum_{j=1}^{n} y_{ij} + B_{ij}$

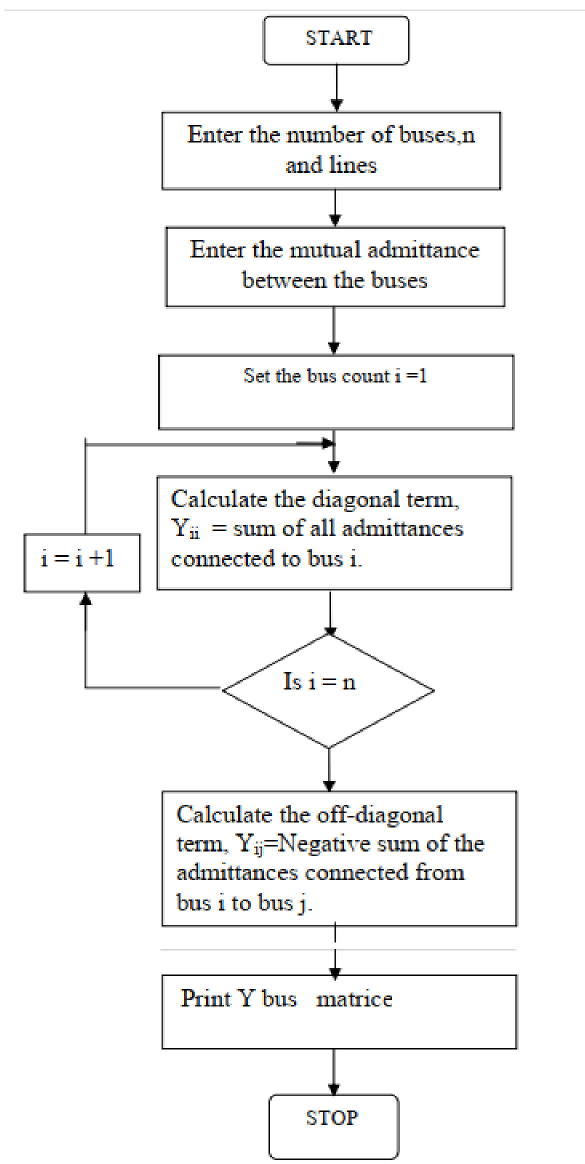
where B_{ij} is the half line shunt admittance in mho.

y_{ij} is the series admittance in mho.

Off-diagonal element in Y-bus matrix, $Y_{ij}=-y_{ij}$

where y_{ij} is the series admittance in mho.

Flowchart:



Algorithm:

Step1: Read the values of number of buses and the number of lines of the given system.

Step2: Read the self-admittance of each bus and the mutual admittance between the buses.

Step3: Calculate the diagonal element term called the bus driving point admittance, Y_{ij} which is the sum of the admittance connected to bus i.

Step4: The off-diagonal term called the transfer admittance, Y_{ij} which is the negative of the admittance connected from bus i to bus j.

Step5: Check for the end of bus count and print the computed Y-bus matrix

Step6: Stop the program and print the results.

MATLAB CODE:

```
clc;
n=input("enter no of buses=");
for i=1:n
   for j=1:n
       fprintf("enter the element of %d,%d =",i,j);
       z(i,j)=input('=');
       y(i,j)=1/z(i,j);
   end
end
Zmatrix=z
ymatrix=y
Y(n,n)=0;
for i=1:n
   for j=1:n
       if i==j
           for k=1:n
               Y(i,j)=Y(i,j)+y(i,k);
           end
       else
           Y(i,j)=-y(i,j);
       end
   end
end
Ybus=Y
```

Sample Problem:

The bus and branch data for a 3bus system is given in table below. Form Ybus matrix by inspection method.

Bus Code	Impedance	Bus Number	Admittance
1 -2	0.06 + j0.18	1	j0.05
1 – 3	0.02 + j0.06	2	j0.06
2 -3	0.04 + j0.12	3	j0.05

Solution:

Formation of Ybus:

$$Y_{bus} = \begin{bmatrix} \left(\frac{1}{0.06+j0.18}+\frac{1}{0.02+j0.06}+j0.05\right) & \frac{-1}{0.06+j0.18} & \frac{-1}{0.02+j0.06} \\ \frac{-1}{0.06+j0.18} & \left(\frac{1}{0.06+j0.18}+\frac{1}{0.04+j0.12}+j0.06\right) & \frac{-1}{0.04+j0.12} \\ \frac{-1}{0.02+j0.06} & \frac{-1}{0.04+j0.12} & \left(\frac{1}{0.04+j0.12}+j0.05+\frac{1}{0.02+j0.06}\right) \end{bmatrix}$$

Result:

POWER FLOW SOLUTION OF A POWER SYSTEM

POWER FLOW SOLUTION OF A POWER SYSTEM

AIM:

To solve the set of non linear load flow equations using Gauss seidal load flow algorithm using Matlab/Simulink.

APPARATUS REQUIRED:

1. PC.
2. Matlab/simulink software.

THEORY:

Load flow analysis is the most frequently performed system study by electric utilities. This analysis is performed on a symmetrical steady-state operating condition of a power system under 'normal' mode of operation and aims at obtaining bus voltages and line/transformer flows for a given load condition. This information is essential both for long term planning and next day Operational planning. In long term planning, load flow analysis helps in investigating the effectiveness of alternative plans and choosing the 'best' plan for system expansion to meet the Projected operating state. In operational planning, it helps in choosing the 'best' unit commitment plan and generation schedules to run the system efficiently for them next day's load Condition without violating the bus voltage and line flow operating limits.

The Gauss seidal method is an iterative algorithm for solving a set of non- linear algebraic equations. The relationship between network bus voltages and currents may be represented by either loop equations or node equations. Node equations are normally preferred because the number of independent node equation is smaller than the number of independent loop equations.

The network equations in terms of the bus admittance matrix can be written as

$$\bar{I}_{bus} = [Y_{bus}]\,\bar{V}_{bus}$$

For an *n* bus system, the above performance equation can be expanded as,

$$\begin{bmatrix} I_1 \\ I_2 \\ \vdots \\ \vdots \\ I_p \\ \vdots \\ I_n \end{bmatrix} = \begin{bmatrix} Y_{11} & Y_{12} & \dots & Y_{1p} & \cdots & Y_{1n} \\ Y_{12} & Y_{22} & \cdots & Y_{2p} & \cdots & Y_{2n} \\ \vdots & \vdots & & \vdots & & \vdots \\ \vdots & \vdots & & \vdots & & \vdots \\ Y_{p1} & Y_{p2} & \dots & Y_{pp} & & Y_{pn} \\ \vdots & \vdots & & \vdots & & \vdots \\ Y_{n1} & Y_{n2} & \dots & Y_{np} & & Y_{nn} \end{bmatrix} \begin{bmatrix} V_1 \\ V_2 \\ \vdots \\ \vdots \\ V_p \\ \vdots \\ V_n \end{bmatrix}$$

where *n* is the total number of nodes.

Vp is the phasor voltage to ground at node *p*.

I_p is the phasor current flowing into the network at node.

At the p[th]bus, current injection:

$$I_P = Y_{P1} V_1 + Y_{P2} V_2 + \cdots\cdots\cdots + Y_{PP} V_P + \cdots\cdots\cdots Y_{Pn} V_n$$

$$= \sum_{q=1}^{n} Y_{pq} V_q \qquad = Y_{PP} V_P + \sum_{\substack{q=1 \\ q \neq p}}^{n} Y_{Pq} V_q$$

$$V_p = \frac{1}{Y_{pp}} \left[I_p - \sum_{\substack{q=1 \\ q \neq p}}^{n} Y_{pq} V_q \right]; \quad p = 2, \ldots. n$$

At bus p, we can write $P_P - jQ_p = V^*{}_P \, I_P$

Hence, the current at any node p is related to P,Q and V as follows

$\therefore I_P = \frac{(P_P - jQ_P)}{V_P{}^*}$ (For any bus **p** except slack bus **S**)

$$V_p = \frac{1}{Y_{pp}} \left[\frac{P_p - jQ_p}{V_p^*} - \sum_{\substack{q=1 \\ q \neq p}}^{n} Y_{pq} V_q \right]; \; p = 2, \ldots. n$$

I_p has been substituted by the real and reactive powers because normally in a power system these quantities are specified

ALGORITHM:

Step 1: Read the input data.

Step 2: Find out the admittance matrix.

Step 3: Choose the flat voltage profile 1+j0 to all buses except slack bus.

Step 4: Set the iteration count p = 0 and bus count i = 1.

Step 5: Check the slack bus, if it is the generator bus then go to the next step otherwise go to next step

Step 6: Before the check for the slack bus if it is slack bus then go to step 11 otherwise go to next step.

Step 7: Check the reactive power of the generator bus within the given limit.

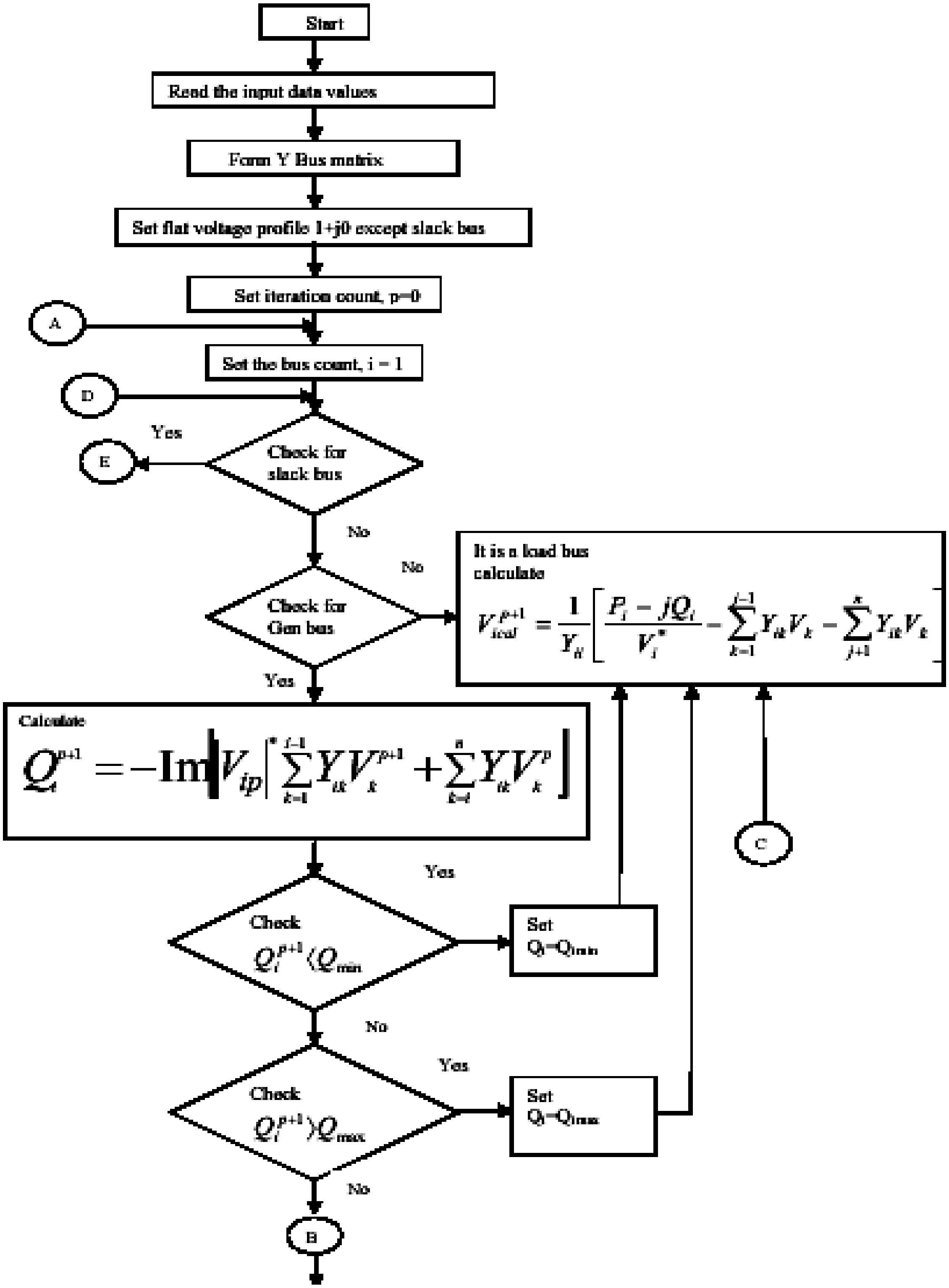
Step 8: If the reactive power violates a limit then treat the bus as load bus.

Step 9: Calculate the phase of the bus voltage on load bus.

Step 10: Calculate the change in bus voltage of the repeat step mentioned above until all the bus voltages are calculated.

Step 11: Stop the program and print the results.

FLOWCHART:


Start
Read the input data values
Form Y Bus matrix
Set flat voltage profile 1+j0 except slack bus
Set iteration count, p=0
A
Set the bus count, i = 1
D
Yes
E
Check for slack bus
No
No
Check for Gen bus
It is a load bus calculate
Yes
Calculate
Yes
Check
Set
No
Yes
Check
Set
No
B
C

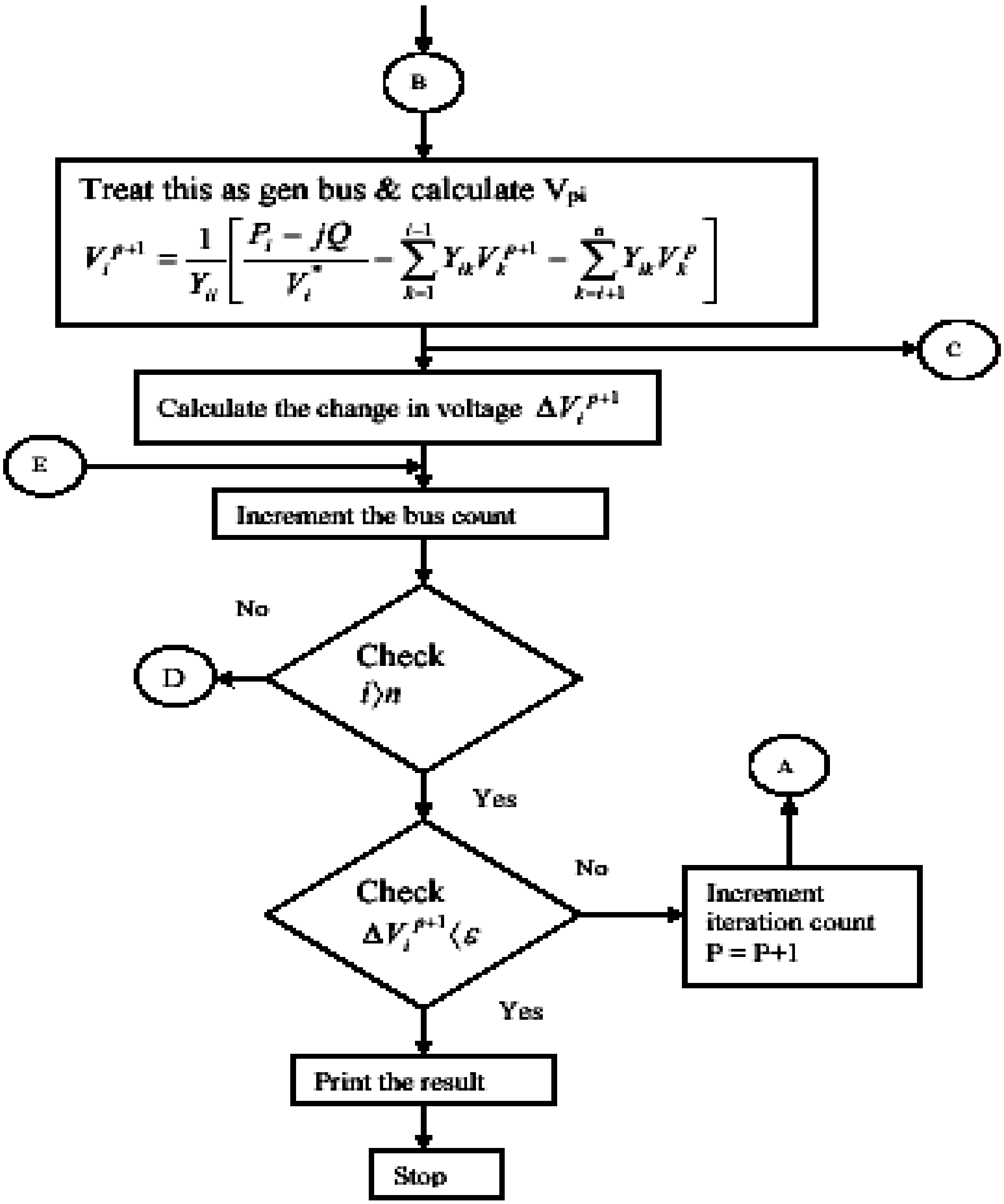

B
Treat this as gen bus & calculate V_{pi}
$V_i^{p+1} = \frac{1}{Y_{ii}}\left[\frac{P_i - jQ}{V_i^*} - \sum_{k=1}^{i-1} Y_{ik}V_k^{p+1} - \sum_{k=i+1}^{n} Y_{ik}V_k^p\right]$
C
Calculate the change in voltage ΔV_i^{p+1}
E
Increment the bus count
No
Check
$i \rangle n$
D
Yes
A
No
Check
$\Delta V_i^{p+1} \langle \varepsilon$
Increment
iteration count
P = P+1
Yes
Print the result
Stop

FIG.1

THEORETICAL CALCULATION FOR A PROBLEM:

Fig shows the one – line diagram of a simple three-bus power system with generators at buses 1 and 3. The magnitude of voltage at bus 1 is adjusted to 1.05 pu. Voltage magnitude at bus 3 is fixed at 1.04 pu with a real power generation of 200 MW. A load consisting of 400 MW and 250MVar is taken from bus 2.line impedances are marked in per unit on a 100 MVA base, and the line charging susceptances are neglected. Obtain the power flow solution by the gauss-seidel method including line flows and line losses.

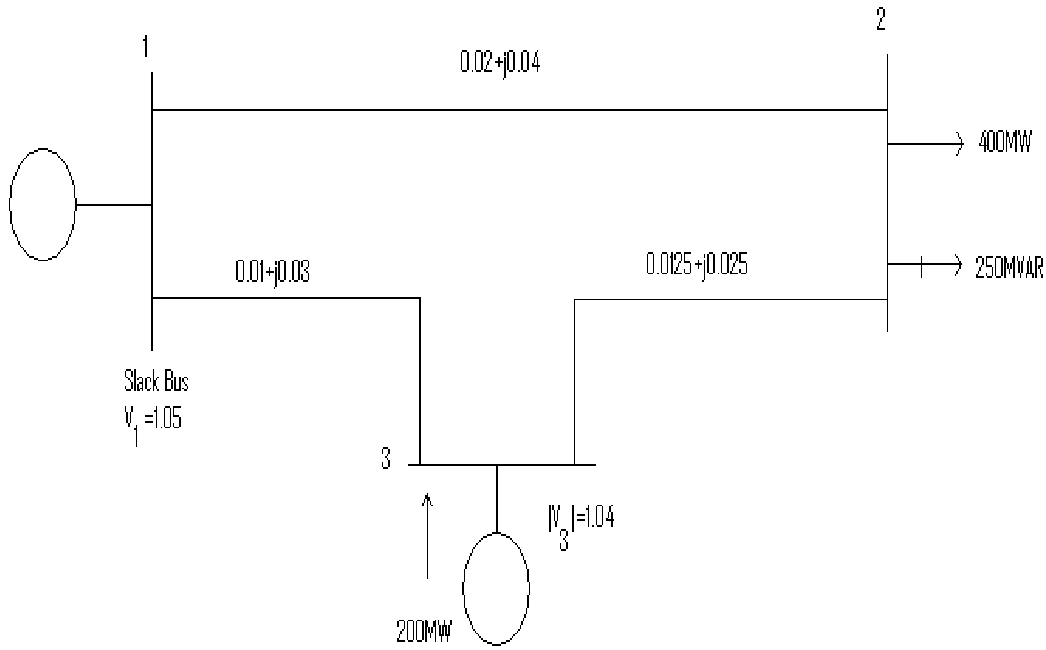


FIG.2

SOLUTION:

Line impedances converted to admittances are y_{12}=10-j20, y_{13}=10-j30 and y_{23}=16-j32.The load and generation expressed in per units are

$$S_2^{sch} = -\frac{(400 + j250)}{100} = -4.0 - j2.5\ p.u$$

$$P_3^{sch} = \frac{200}{100} = 2.0\ p.u$$

Bus 1 is taken as the reference bus (slack bus). Starting from an initial estimate of $V_2^{(0)}$=1.0+j0.0 and $V_3^{(0)}$=1.04+j0.0, V_2 and V_3 are computed as

$$V_2^{(1)} = \frac{\frac{P_2^{sch} - jQ_2^{sch}}{V_2^{*(0)}} + y_{12}V_1 + y_{23}V_3^{(0)}}{y_{12} + y_{23}} \quad = \frac{\frac{-4.0+j2.5}{1.0-j0} + (10-j20)(1.05+j0) + (16-j32)(1.04+j0)}{(26-j52)}$$

=0.97462-j0.042307

Bus 3 is a regulated bus where voltage magnitude and real power are specified. For the voltage controlled bus, first the reactive power is computed

$$Q_3^{(1)} = -Im\{V_3^{*(0)}[V_3^{(0)}(y_{13} + y_{23}) - y_{13}V_1 - y_{23}V_2^{(1)}$$

= - Im{(0.04-j0)[(1.04+j0)(26-j62)-(10-j30)(1.05+j0)-

(16-j32)(0.97462-j0.042307)]}

=1.16

The values of $Q_3^{(1)}$ is used as Q_3^{sch} for the computation of voltage at bus 3.The complex voltage at bus 3, denoted by $Vc_3^{(1)}$, is calculated as

$$V_{c3}^{(1)} = \frac{\frac{P_3^{sch} - jQ_3^{sch}}{V_3^{*(0)}} + y_{13}V_1 + y_{23}V_2^{(1)}}{y_{13} + y_{23}}$$

$$= \frac{\frac{2.0 - j1.16}{1.04 - j0} + (10 - j30)(1.05 + j0) + (16 - j32)(0.97462 - j0.042307)}{(26 - j62)}$$

= 1.03783-j0.005170

Since $|V_3|$is held constant at 1.04 p.u , only the imaginary part of $V_{c3}^{(1)}$ is retained, and its real part is obtained from

$$e_3^{(1)} = \sqrt{(1.04)^2 - (0.005170)^2} = 1.039987$$

Thus

$$V_3^{(1)} = 1.039987 - j0.005170$$

For the second iteration, we have

$$V_2^{(2)} = \frac{\frac{P_2^{sch} - jQ_2^{sch}}{V_2^{*(1)}} + y_{12}V_1 + y_{23}V_3^{(1)}}{y_{12} + y_{23}}$$

$$= \frac{\frac{-4.0 + j2.5}{.97462 + j.042307} + (10 - j20)(1.05) + (16 - j32)(1.039987 + j0.005170)}{(26 - j52)}$$

=0.971057-j0.043432

$$Q_3^{(2)} = -Im\{V_3^{*(1)}[V_3^{(1)}(y_{13}+y_{23}) - y_{13}V_1 - y_{23}V_2^{(2)}$$

= - Im {(1.039987+j0.005170)[(1.039987-j0.005170)(26-j62)-

(10- j30)(1.05+j0)-(16-j32)(0.971057-j0.043432)]}

= 1.38796

$$V_{c3}^{(2)} = \frac{\frac{P_3^{sch}-jQ_3^{sch}}{V_3^{*(1)}} + y_{13}V_1 + y_{23}V_2^{(2)}}{y_{13}+y_{23}}$$

$$= \frac{\frac{2.0-j1.38796}{1.039987+j0.00517}+(10-j30)(1.05)+(16-j32)(.971057-j0043432)}{(26-j62)}$$

= 1.03908-j0.00730

Since |V_3|is held constant at 1.04 p.u , only the imaginary part of $V_{c3}^{(2)}$ is retained, and its real part is obtained from

$$e_3^{(2)} = \sqrt{(1.04)^2 - (0.00730)^2} = 1.039987$$

$$V_3^{(2)} = 1.039974 - j0.00730$$

The process is continued and a solution is converged with an accuracy of 5 x 10^{-5} pu in seven iterations as given below.

$V_2^{(3)}$=0.97073-j 0.04479 $Q_3^{(3)}$=1.42904 $V_3^{(3)}$=1.03996-j 0.00833

$V_2^{(4)}$=0.97065-j 0.04533 $Q_3^{(4)}$=1.44833 $V_3^{(4)}$=1.03996-j 0.00873

$V_2^{(5)}$=0.97062-j 0.04555 $Q_3^{(5)}$=1.45621 $V_3^{(5)}$=1.03996-j 0.00893

$V_2^{(6)}$=0.97061-j 0.04565 $Q_3^{(6)}$=1.45947 $V_3^{(6)}$=1.03996-j 0.00900

$V_2^{(7)}$=0.97061-j 0.04569 $Q_3^{(7)}$=1.46082 $V_3^{(7)}$=1.03996-j 0.00903

The final solution is

$$V_2 = 0.97168\angle - 2.6948^o\ pu$$

S_3=2.0+j1.4617 pu

$$V_3 = 1.04\angle -.498^o\ pu$$

S_1=2.1842+j1.4085 pu

To find line flows, first the line currents are computed

$I_{12} = y_{12}(V_1-V_2) =(10-j20)[(1.05+j0)- 0.97168\angle -2.6948^o]=1.7076-j1.13$

$I_{21} =- I_{12} =-1.7076+j1.13$

$I_{13} = y_{13}(V_1-V_3) =(10-j30)[(1.05+j0)- 1.04\angle -.498^o]=0.3716-j0.2108$

$I_{31} =- I_{13} =-0.3716+j0.2108$

$I_{23} = y_{23}(V_2-V_3) =(16-j32)[(0.97168\angle -2.6948^o)-(1.04\angle -.498^o)]=-2.2823+j1.6330$

$I_{32} =- I_{23} =2.2823-j1.6330$

The line flows are

$S_{12}= V_1I_{12}^*=(1.05)(1.7076+j1.13)=179.3$ MW +j118.65 MVAR

$S_{21}= V_2I_{21}^*=(0.97168\angle -2.6948^o)(-1.7076-j1.13)=-170.90$ MW -j101.877 MVAR

$S_{13}= V_1I_{13}^*=(1.05)(0.3716+j0.2108)=39.02$ MW +j22.13 MVAR

$S_{31}= V_3I_{31}^*=(1.04\angle -.498^o)(-0.3716-j0.2108)=-38.84$ MW -j21.586 MVAR

$S_{23}= V_2I_{23}^*=(0.97168\angle -2.6948^o)(-2.2823-j1.6330)=-228.98$ MW -j148.07 MVAR

$S_{32}= V_3I_{32}^*=(1.04\angle -.498^o)(2.2823+j1.6330)=238.83$ MW +j167.763 MVAR

And the line losses are

$S_{L12}= S_{12}+ S_{21}=8.4$MW+j16.773MVAR

$S_{L13}= S_{13}+ S_{31}=0.18$ MW +j0.544 MVAR

$S_{L23}= S_{23}+ S_{32}=9.85$ MW +j19.693 MVAR

The power flow diagram is shown in figure where real power direction is indicated by and the reactive power direction

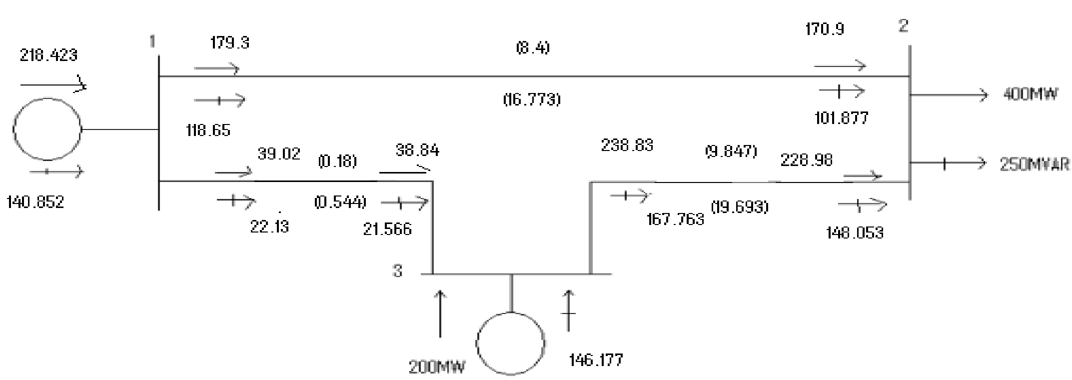


FIG.3

SIMULATION PROGRAM:

```
y12=10-j*20;
y13=10-j*30;
y23=16-j*32;
y33=y13+y23;
V1=1.05+j*0;
iter =0;
S2=-4.0-j*2.5;
P3 = 2;
V2=1+j*0;
Vm3=1.04;
V3=1.04+j*0;
for I=1:10;
iter=iter+1;
E2 = V2;
E3=V3;
V2 = (conj(S2)/conj(V2)+y12*V1+y23*V3)/(y12+y23);
Q3 = -imag(conj(V3)*(y33*V3-y13*V1-y23*V2));
S3 = P3 +j*Q3;
Vc3 = (conj(S3)/conj(V3)+y13*V1+y23*V2)/(y13+y23);
Vi3 = imag(Vc3);
Vr3= sqrt(Vm3^2 - Vi3^2);
V3 = Vr3 + j*Vi3;
end
format short
V2
```

```
V3
Q3
I12=y12*(V1-V2);
I21=-I12;
I13=y13*(V1-V3);
I31=-I13;
I23=y23*(V2-V3);
I32=-I23;
display('Lineflows')
S12=V1*conj(I12)*100
S21=V2*conj(I21)*100
S13=V1*conj(I13)*100
S31=V3*conj(I31)*100
S23=V2*conj(I23)*100
S32=V3*conj(I32)*100
display('Linelosses')
S1221=[S12+S21]
S1331=[S13+S31]
S2332=[ S23+S32]
```

OUTPUT:

V2 =   0.9706 - 0.0457i

V3 =   1.0400 - 0.0091i

Q3 =   1.4617

LINE FLOWS

S12 = 1.7936e+002 +1.1874e+002i

S21 = -1.7096e+002 -1.0195e+002i

S13 = 39.0563 +22.1191i

S31 = -38.8735 -21.5709i

S23 = -2.2903e+002 -1.4805e+002i

S32 = 2.3888e+002 +1.6775e+002i

LINELOSSES

S1221 = 8.3931 +16.7863i

S1331 = 0.1827 + 0.5482i

S2332 = 9.8466 +19.6932i

OBSERVATIONS:

S.NO	Parameter	Calculated	Simulated

APPLICATION:

1. short circuit fault analysis,
2. stability studies(transient& steady state),
3. unit commitment and economic load dispatch analysis

CONCLUSION:

From this experiment we can conclude that power flow and load floe studies are important for planning future expansion of power system as well as in determining magnitude and phase angle of the voltage at each bus, and real and reactive power flowing in each line

RESULT:

LOAD FREQUENCY CONTROL OF SINGLE AREA SYSTEM

LOAD FREQUENCY CONTROL OF SINGLE AREA SYSTEM

AIM: To become familiar with modelling and analysis of the frequency and tie-line flow dynamics of a power system without and with load frequency controllers (LFC) and to design better controllers for getting better responses.

THEORY:

Active power control is one of the important control actions to be perform to be normal operation of the system to match the system generation with the continuously changing system load in order to maintain the constancy of system frequency to a fine tolerance level. This is one of the foremost requirements in proving quality power supply. A change in system load cases a change in the speed of all rotating masses (Turbine – generator rotor systems) of the system leading to change in system frequency. The speed change form synchronous speed initiates the governor control (primary control) action result in all the participating generator – turbine units taking up the change in load, stabilizing system frequency. Restoration of frequency to nominal value requires secondary control action which adjust the load - reference set points of selected (regulating) generator – turbine units. The primary objectives of automatic generation control (AGC) are to regulate system frequency to the set nominal value and also to regulate the net interchange of each areas to the scheduled value by adjusting the outputs of the regulating units.This function is referred to as load – frequency control(LFC).

PROCEDURE:

1. Enter the command window of the MATLAB.

2. Create a new Model by selecting File - New – Model

3. Pick up the blocks from the simulink library browser and form a block diagram.

4. After forming the block diagram , save the block diagram.

5. Double click the scope and view the result.

EXERCISE:

1.An isolated power station has the following parameters

Turbine time constant t_T = 0.5sec

Governor time constant t_g = 0.2sec

Generator inertia constant H = 5sec

Governor speed regulation = R per unit

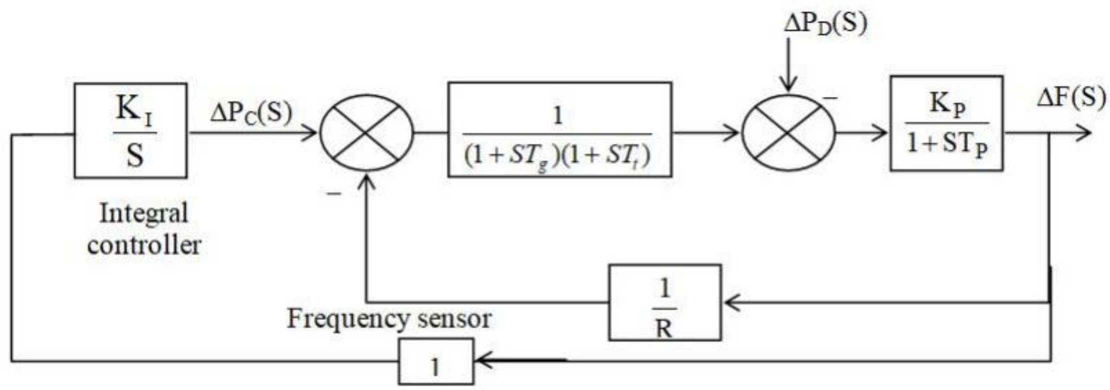
The load varies by 0.8 percent for a 1 percent change in frequency , i.e,D = 0.8

The governor speed regulation is set to R = 0.05 per unit.The turbine rated output is 250MW

at nominal frequency of 50Hz. A sudden load change of 50MW(P_L = 0.2 per unit) occurs.

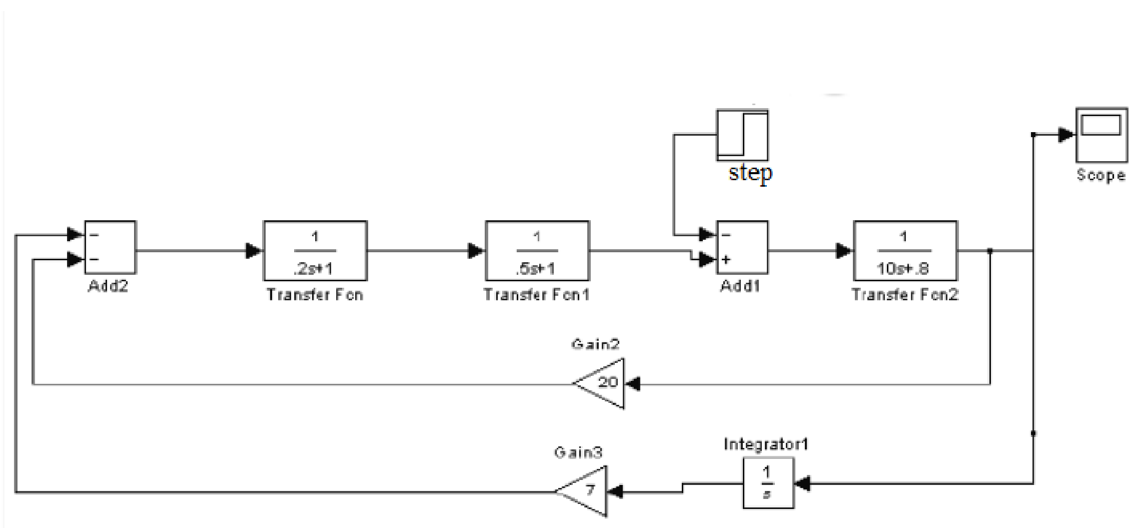
(i) Find the steady state frequency deviation in Hz.

(ii) Use MATLAB to obtain the time domain performance specifications and the frequency deviation step response



Block Diagram of LFC single area system with integral controller

Block diagram in MATLAB:



Result: