Experiment – 1

Aim: To draw the operating characteristics of IDMT relay

Objective: *The aim of the experiment to investigate the operation, inverse characteristics and to determine the purpose of time and plug settings for over current relay in electrical supply system.*
By configuring these settings correctly, and by coordinately the operations of the relays, it is possible to isolate the smallest section of the system in the shortest time possible, thereby minimizing unnecessary disruption to other consumers whilst preventing damage the equipment within the fault section.
In the radial feeder configuration, supply from one end only, discrimination of faults can be achieved by incorporating time delays at each relay point. This enables the relay closest to the fault to trip, isolating the fault circuit without affecting the other non-faulty circuits. A disadvantage of this system is that for faults near the source, the fault current can be much greater than at the opposite end of the feeder due to the impedance. For a fault at point F in figure (1), the circuit breaker at point C opens before those at point A and B, leaving most of the feeder operational. The relays have a time grading of 0.5s (to allow for relay and circuit breaker operation plus error allowance), illustrating discrimination by time grading only.
The disadvantage can be overcome by employing relays with an inverse current / time characteristic – i.e. the time delays are reduced for higher currents. These relays are known as IDMT relays (Inverse Definite Minimum Time). A minimum time of operation is incorporated to ensure co-ordination between the relays when the fault level does not vary along the feeder.

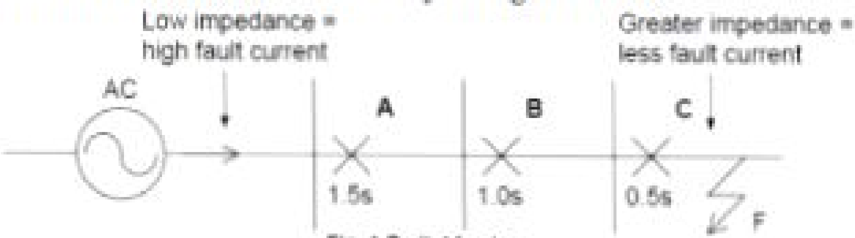
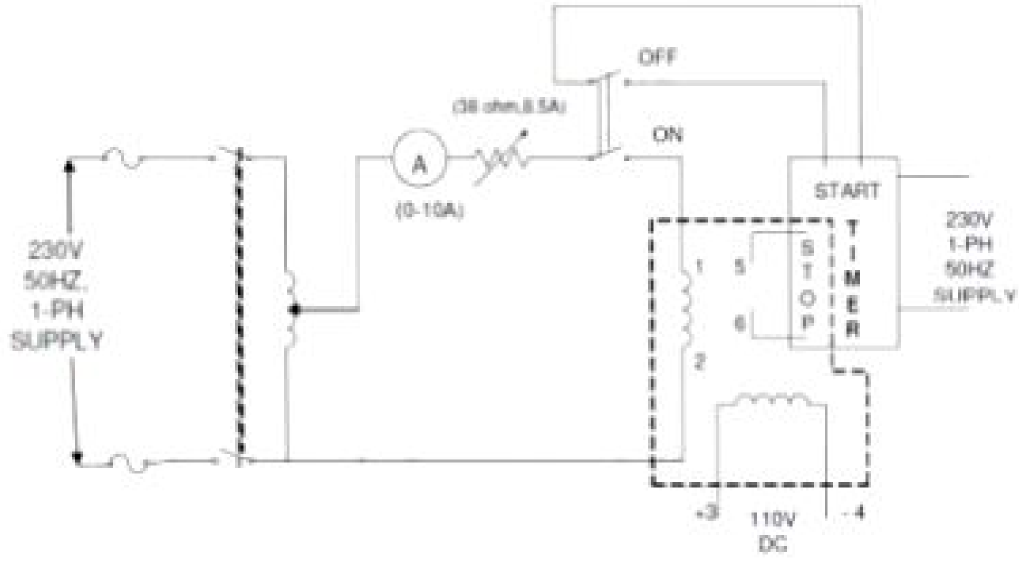


Fig. 1 Radial feeder

Apparatus Required:

1) Timer
2) IDMT relay (MODEL NO.ICM-21NP))
3) Auxiliary D.C. supplies = 110V
4) 1 phase Dimmer stat = 230V, 10A
5) Ammeter AC (0-15A)
6) Rheostat (38 ohm, 8.5 Amp)
7) Experiment Kit
8) Connecting wires

Circuit Diagram:



Procedure:

1. Make the connection as shown in the circuit diagram.
2. Select current setting (set phase trip) less than 100%, keeping phase TMS at maximum position.
3. Select any time setting.
4. Switch on variac and check power ON indication provided on relay front panel.
5. Vary dimmer stat and observe current value till Pick-Up will show 'Red' indication when current value exceeds set phase trip position.
6. Switch OFF dimmer stat without disturbing its position with the help of DPT switch. Also reset time.
7. Measure the relay time from timer by switching on DPT switch.
8. Now increase the fault current and note down timer time after switching 'OFF' and 'DPT' switch every time with same time setting.
9. Repeat same procedure for different time setting keeping current setting same.

Observation Table:

Sr. No.	Fault Current (A)	PSM	Timer time for TSM=	Timer time for TSM=	Timer time for TSM=

Result: For lower values of current the "time current " characteristics are inverse and for higher value for current observed times are constant

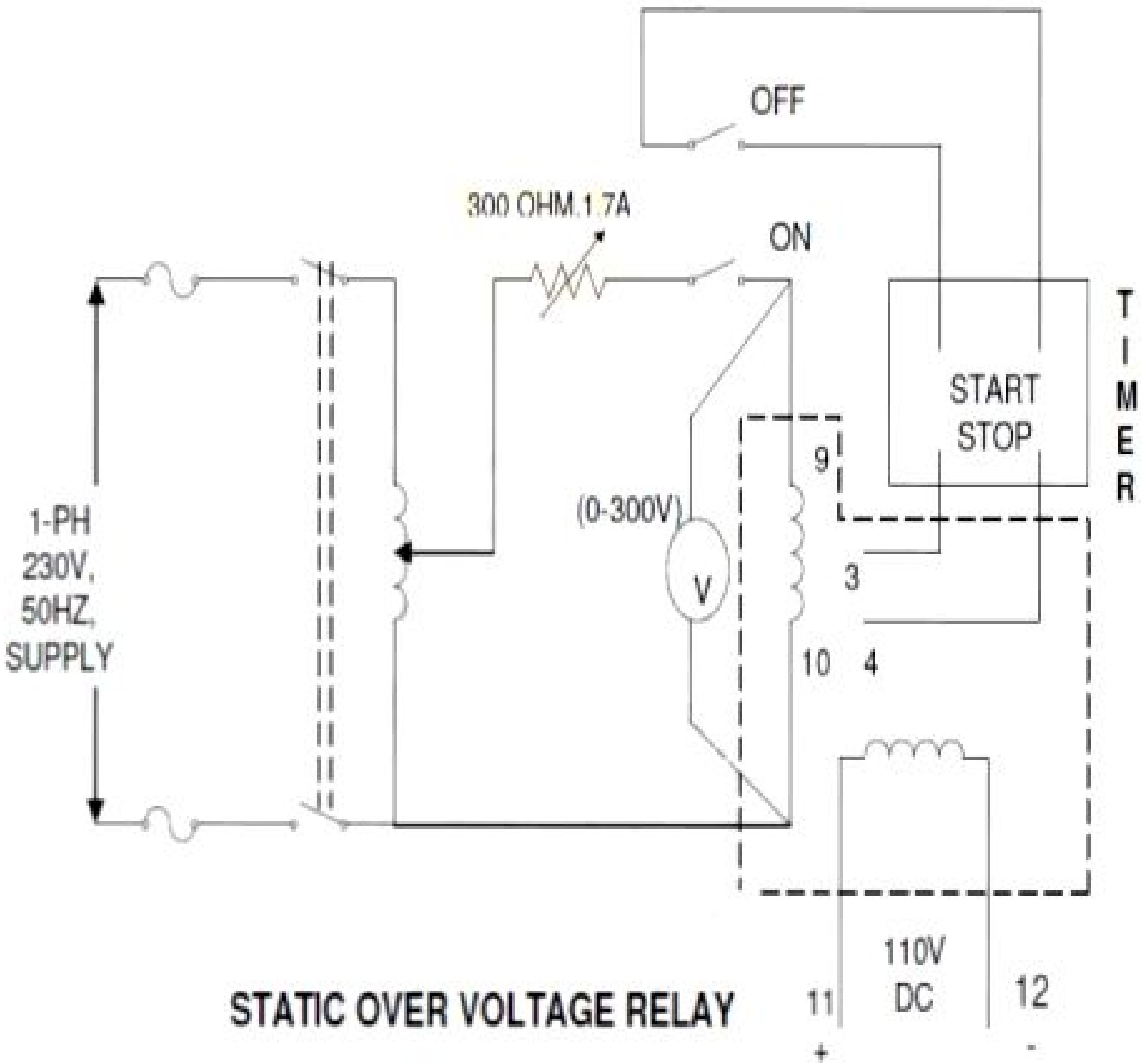
Experiment – 3

Aim: To study the performance of an over voltage relay.

Apparatus Required:-

1) Static over voltage relay (Model No.: -ASOV)
2) Auxiliary D.C. supplies 110V
3) Time interval meter
4) Single pole variac 230V, 4A
5) Voltmeter (0-300V) AC
6) Rheostat (400 ohm, 1.7 Amp)
7) Connecting wires
8) Experiment Kit

Circuit Diagram:



STATIC OVER VOLTAGE RELAY

Procedure:

1. Connect the ckt as shown in fig procedure is done & time is noted.
2. Set current and time setting of relays as per requirement.
3. Connect Auxiliary D.C. Supply (110) to pin 11 & 12 of relay and pin no. 3&4 to the time interval meter.

4. Switch on the D.C. supply & make sure that relay is on Glowing of LED on the front panel of the relay.
5. Switch on power supply from dimmer as well as to time interval meter.
6. Adjust the voltage setting of the relay.
7. Adjust the time setting of relay.
8. Now by making DPDT switch on, increase the value of voltage by dimmer stat up to the point at which the relay trip. Trip can be observed by glowing of trip LED on front panel of relay.
9. Switch is made off and relay is reset.
10. Now Switch is made on & time interval meter reading is noted.
11. For the same voltage setting , time setting is changed & same procedure is repeated until all the time setting are covered.
12. Again voltage setting is changed & same procedure is repeated.

Result: The static over-voltage relay is studied

Experiment – 9

Aim: To study the performance of adifferential over current relay

Theory: Relays are of many types. SomeDepend on the operation of an armature by some form of electromagnet. A verylarge numbers of relays operate on the induction principle. When a relay operates itcloses contacts in the trip circuit which is normally connected across 110 V D.C.supplyfrom a battery. The passage of current in the coil of the trip circuit actuatesthe plunger, which causes operation of the circuit breaker, disconnecting the faultysystem. In the laboratory, a 3-phase contactor simulates the operation of the circuit breaker.The closure of the relay contacts short-circuits the 'no-volt ' coil of the contactor,which, in turn, disconnects the faulty system.The protective relaying which responds to a rise in current flowing through theprotected element over a pre-determined value is called 'overcurrent protection' andthe relays used for this purpose are known as ***over current relays.***
The operating time of all overcurrent relays tends to become asymptotic to a definiteminimum value with increase in the value of current. This is an inherent property of the electromagnetic relays due to saturation of the magnetic circuit. By varying thepoint of saturation, different characteristics can be obtained and these are

1. Definite time
2. Inverse Definite Minimum Time (IDMT)
3. Very Inverse
4. Extremely Inverse

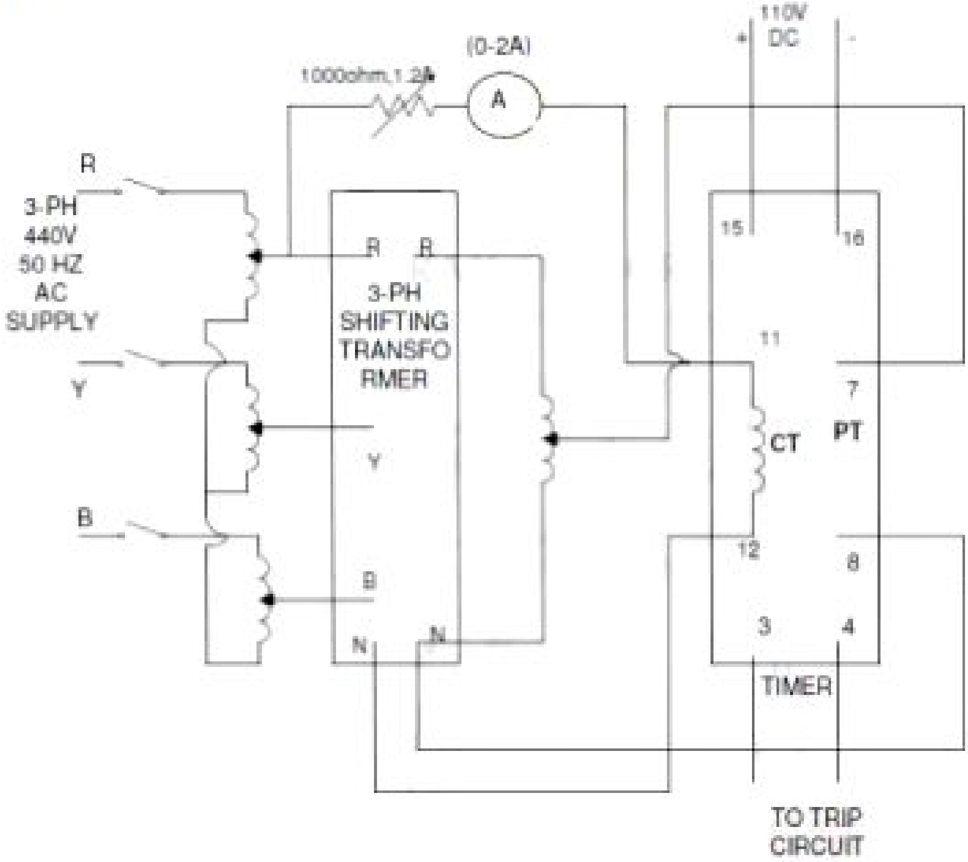
The torque of these relays is proportional to $\phi_1\phi_2 \sin\alpha$ where ϕ_1 and ϕ_1 are thetwo fluxes and α is the angle between them. Where both the fluxes are produced bythe same quantity (single quantity relays) as in the case of current or voltageoperated, the torque T is proportional to I_2. or $T = K I_2$. for coil current belowsaturation. If the core is made to saturate at very early stages such that with increaseof I_2, K decreases so that the time of operation remains the same over the workingrange. The time -current characteristic obtained is known as definite –timecharacteristic.If the core is made to saturate at a later stage, the characteristic obtained is known asIDMT. The time-current characteristic is inverseover some range and then aftersaturation assumes the definite time form. In order to ensure selectivity, it isessential that the time of operation of the relays should be dependent on the severityof the fault in such a way that more severe the fault, the less is the time to operate,this being called the inverse-time characteristic. This will also ensure that a relayshall not operate under normal overload conditions of short duration.It is essential also that there shall be a definite minimum time of operation, whichcan be adjusted to suit the requirements of the particular installation. At low valuesof operating current the shape of the curve is determined by the effect of therestraining force of the control spring, while at high values the effect of saturationpredominates. Different time settings can be obtained by moving a knurledclamping screw along a calibrated scale graduated from 0.1 to 1.0 in steps of 0.05.This arrangement is called Time Multiplier Setting and will vary the travel of thedisc required to close the contacts. This will shift the time-current characteristic ofthe relay parallel to itself.By delaying the saturation to a further point, the Very Inverse and Extremely VeryInverse time current characteristics can be obtained.

Apparatus Required:

1) Single pole directional O/C relay ACDR 11 HPD
2) Phase shifting transformer
3) Dimmerstat (3 phase , 440 volt, 50 Hz)

4) Ammeter (0-1 Amp)
5) Rheostate (300 ohm , 1.7 Amp)
6) Dimmerstat (1 phase , 230 volt, 4 Amp)
7) DC Power Supply (110 Volt)

Circuit Diagram:



Operation: Load current is continuously monitored and compared to set value and polarized with voltage for direction sensing. As soon as the current exceeds the set value and it is operating direction then N value (Time set value) is calculated and then the delay time count is started , two types of curves 10 times (N=10) current 3.0 sec . Delay and 1.3 sec delay can be provided. At the end of the time count if the current still exceeds the set value TRIP is exceeded. All the monitored current value is available at the front D is skeet's for external recording.

If the direction is reverse then the TRIP execution is (represented) restrained high fault setting is also provided (2N. 20 N) IF the current value exceeds the HF set value instant trip (i.e. 100 msec.) is executed, by passing the directional restraint.

Observation Table:

S. No.	Phase Angle	MTS = MAX torque setting		
		45 degree	60 degree	9^{th} Line
	0 degree			
	30 degree			
	60 degree			
	90 degree			
	120 degree			
	150 degree			
	180 degree			
	-150 degree			

Procedure:

1) Make the connections as shown in the fig.
2) Apply the voltage across the P.T of relay
3) The pick –up current through the relay coil.
4) Set current and time setting of relays as per requirement
5) Switch on the supply.
6) Find out the operating region and non-operating region of relay by changing angle using the phase shifting transformer.
7) Adjust the current to such a value, which is more than plug setting.
8) Change the shifter angle such that relay operates in that region.

Result: The static directional relay is studied and graph for different maximum________ torque setting is drawn.

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

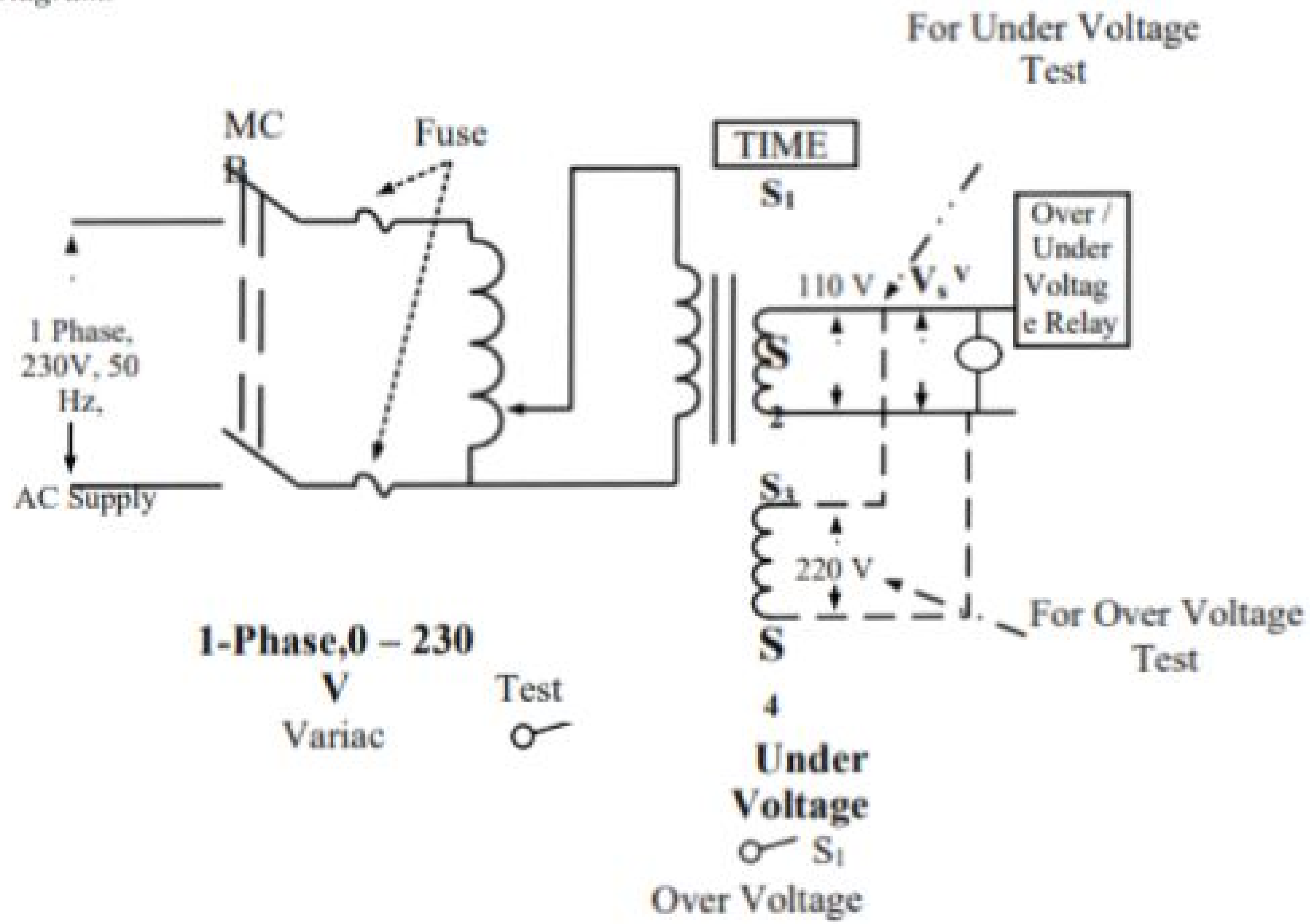
Definite time 1, 10, 100sec

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

PROCEDURE FOR UNDER VOLTAGE AND OVER VOLTAGE TESTING:

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.

Tabular Columns:

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:

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 :

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

* 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.

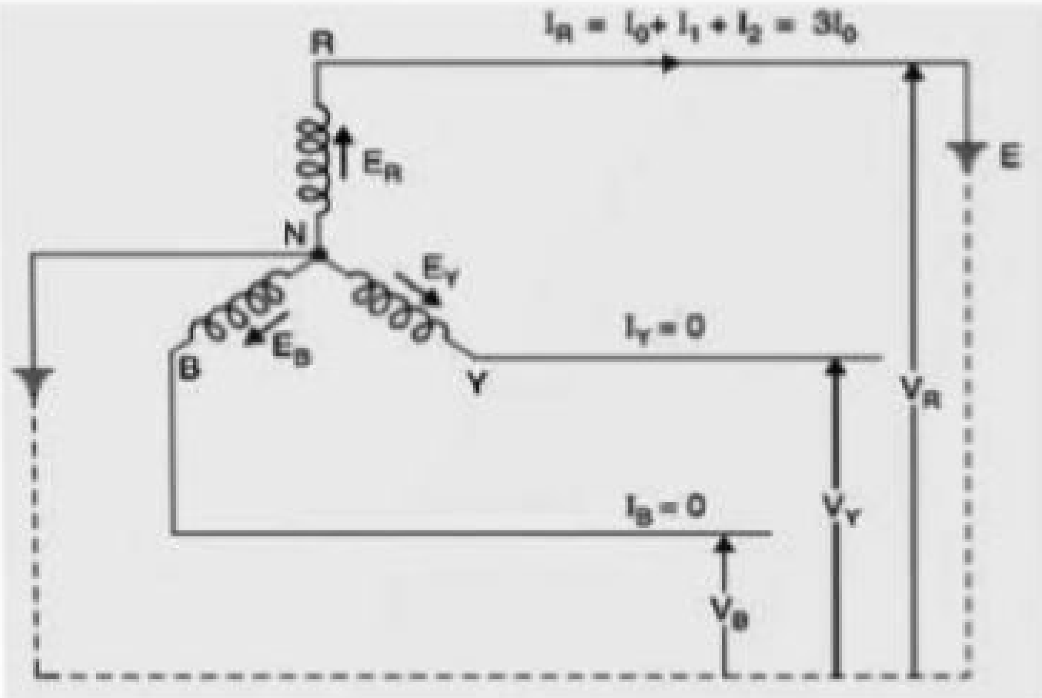
The sequence currents in the red phase in terms of line currents shall be

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

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

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

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



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,

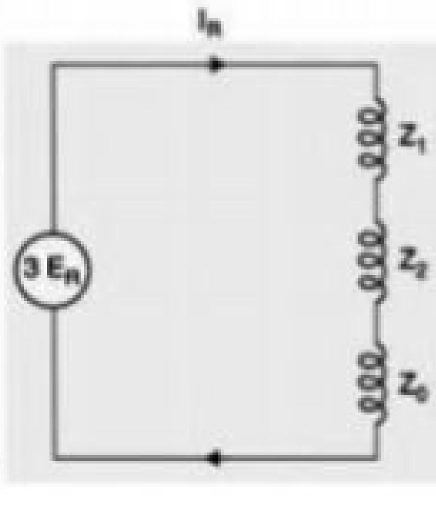
$$\vec{E_R} = \vec{I_1}\vec{Z_1} + \vec{I_2}\vec{Z_2} + \vec{I_0}\vec{Z_0} + \vec{V_R}$$

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

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

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

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



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

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

$$\vec{V_R} = 0$$

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

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

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 :

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

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

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

$\therefore$

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

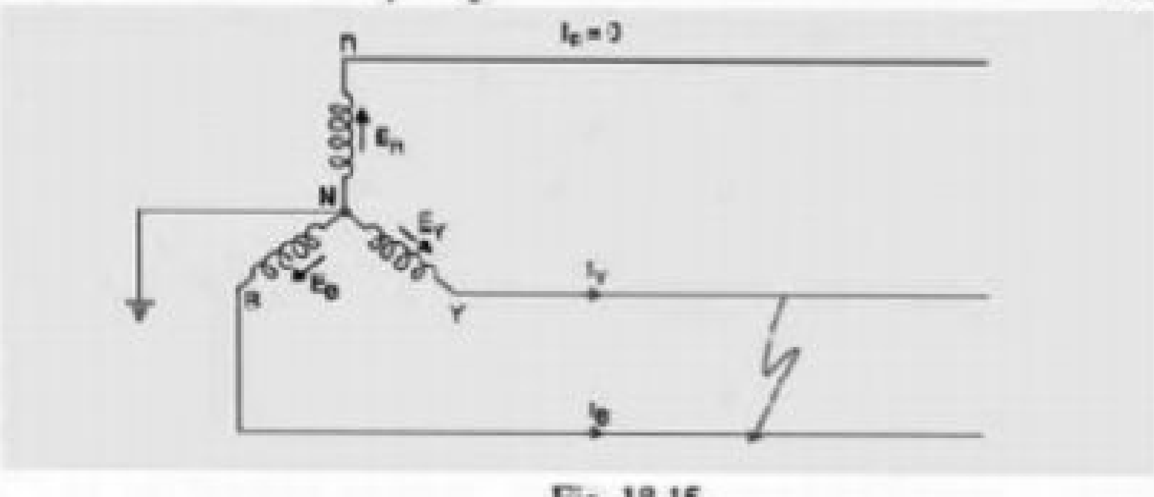


Fig. 18.15.

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

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

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

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

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 :

$$\vec{I_1} = -\vec{I_2} = \frac{\vec{E_R}}{\vec{Z_1} + \vec{Z_2}}$$

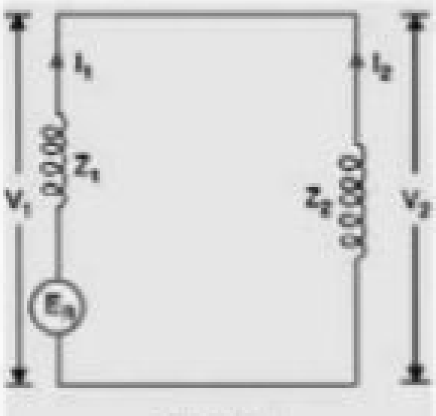


Fig. 18.16

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

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

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

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

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

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

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

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 :

$\vec{I}_R = 0 \;\; ; \;\; \vec{V}_Y = \vec{V}_B = 0$

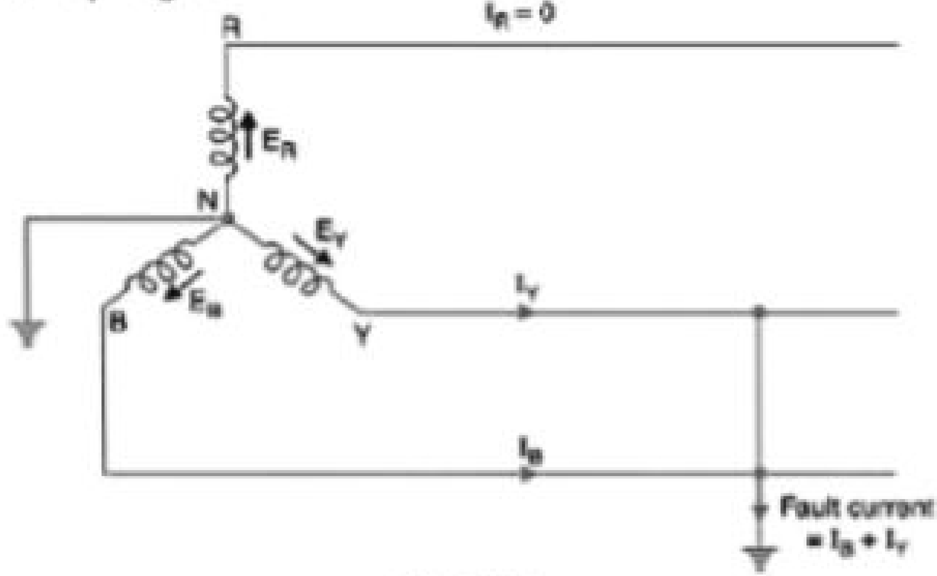


Fig. 18.17

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 $\vec{I}_R = \vec{I}_1 + \vec{I}_2 + \vec{I}_0 = 0$ *(given)* ...(*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 :

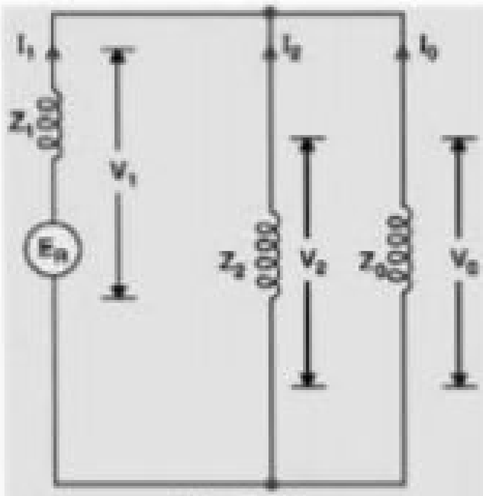


Fig. 18.18

$$\vec{I}_1 = \frac{\vec{E}_R}{\vec{Z}_1 + \frac{\vec{Z}_2\vec{Z}_0}{\vec{Z}_2 + \vec{Z}_0}}$$

$$\vec{I}_2 = -\vec{I}_1 \frac{\vec{Z}_0}{\vec{Z}_2 + \vec{Z}_0}$$

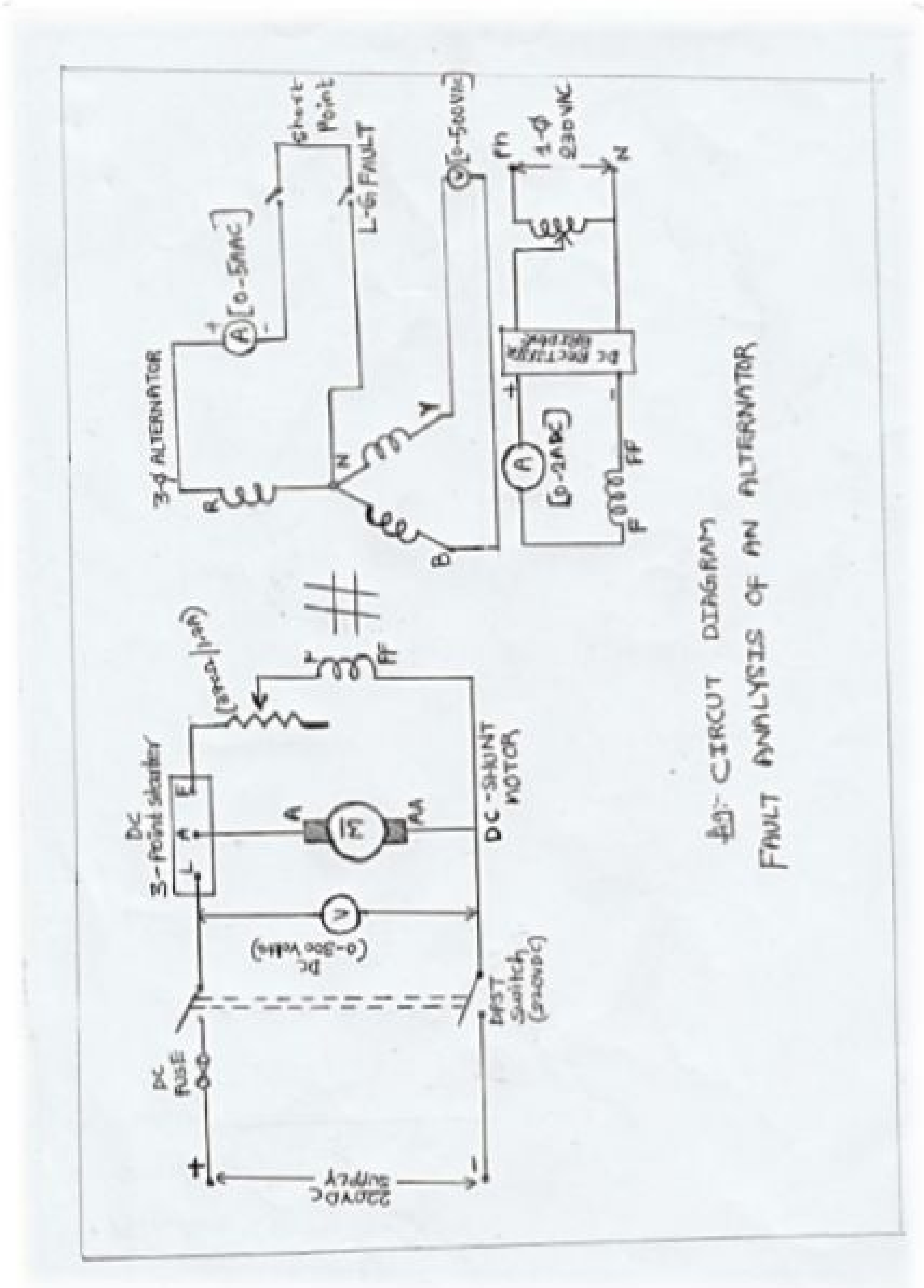
$$\vec{I}_0 = -\vec{I}_1 \frac{\vec{Z}_2}{\vec{Z}_2 + \vec{Z}_0}$$

Fault current, $\vec{I}_F = \vec{I}_Y + \vec{I}_B = 3\vec{I}_0 = 3\left(-\vec{I}_1 \frac{\vec{Z}_2}{\vec{Z}_2 + \vec{Z}_0}\right)$

$$= -\frac{3\vec{Z}_2}{\vec{Z}_2 + \vec{Z}_0} \times \frac{\vec{E}_R}{\vec{Z}_1 + \frac{\vec{Z}_2\vec{Z}_0}{\vec{Z}_2 + \vec{Z}_0}}$$

$$= -\frac{3\vec{Z}_2\vec{E}_R}{\vec{Z}_0\vec{Z}_1 + \vec{Z}_0\vec{Z}_2 + \vec{Z}_1\vec{Z}_2}$$

- **CIRCUIT DIAGRAM FOR L-G FAULT:**



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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_f in Volts
01.	4.16	

$Ia = 3Ef/(Z_1+Z_2+Z_0)$------------------------------------ (1)

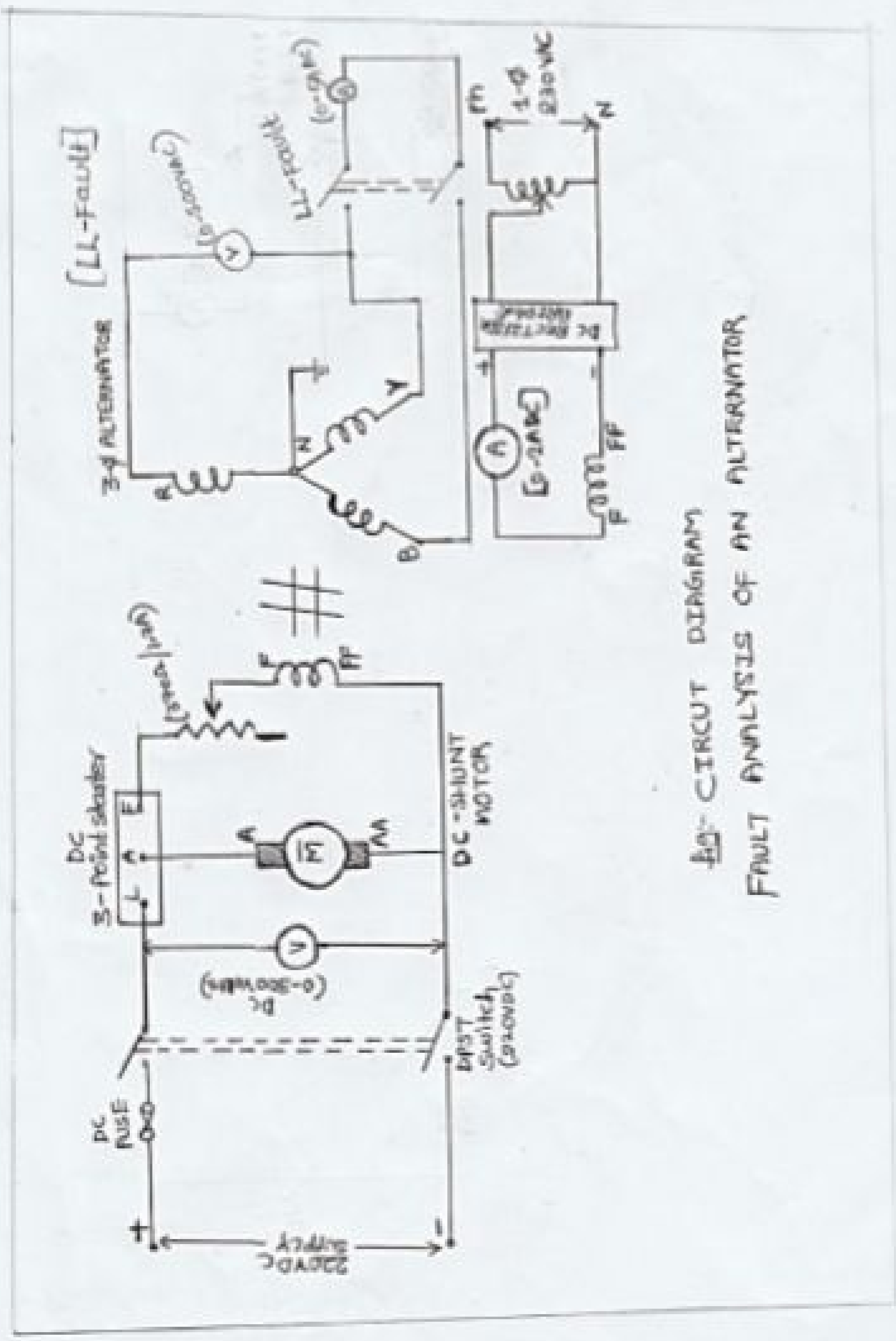
Where Ia is fault current

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):***



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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

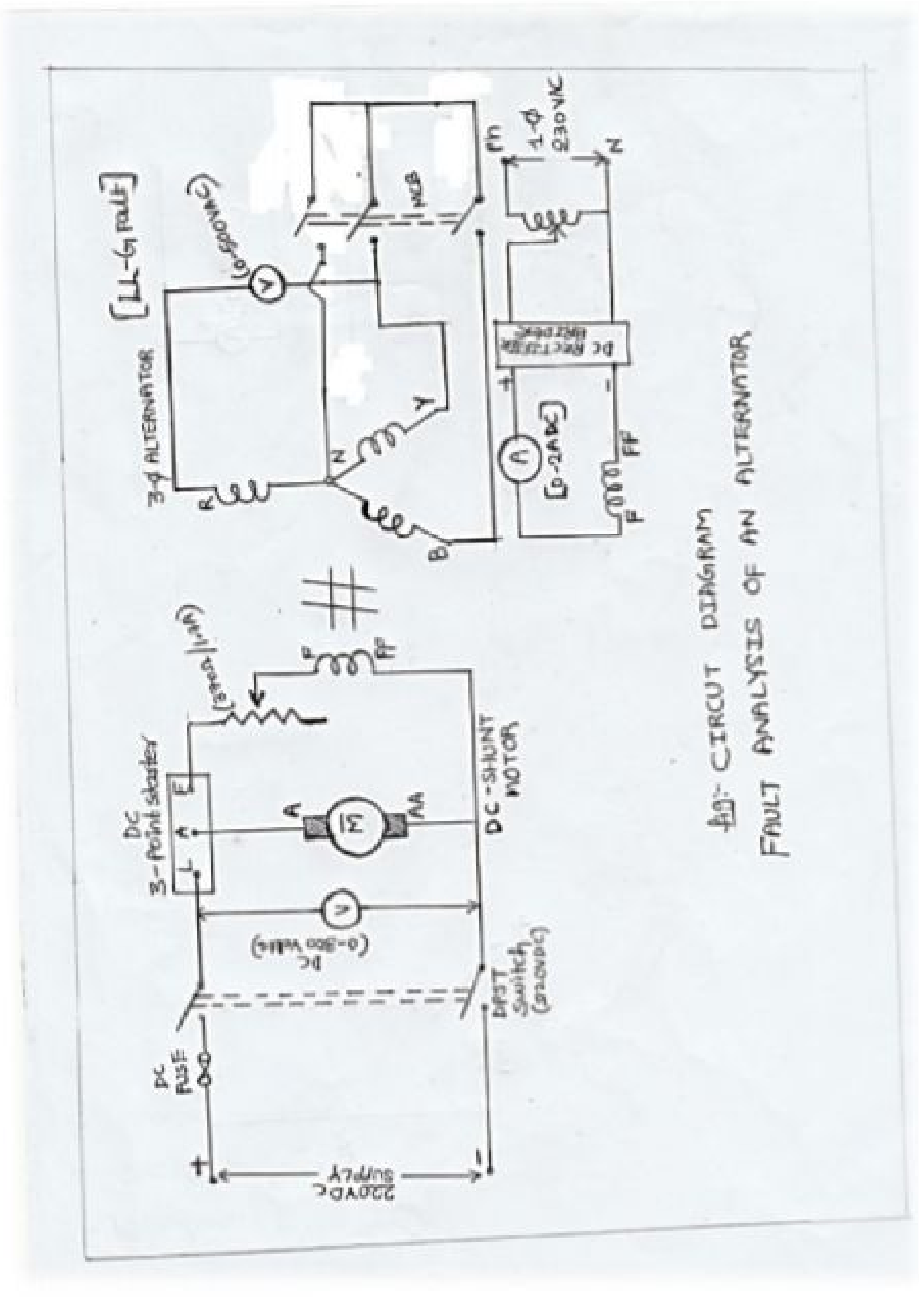
Sl.No.	I in Amps	E_f in Volts
01.	4.21	

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):*



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:

$V_{a1}=V_{a2}=V_{a0}=E_f-I_{a1}Z_1$

$I_{a1}=E_f/Z_1+(Z_2 \times Z_0/Z_2+Z_0)$ $I_{a2}=-V_{a2}/Z_2$; $I_{a0}=-V_{a0}/Z_0$
$I_b=a^2I_{a1}+a\,I_{a2}+I_{a0}$

Where $a^2=(-0.5+j0.866)$;
$a=(-0.5+j0.866)$ $I_n=3I_{a0}=I_b+I_C$
$I_c=-I_b=a\,I_{a1}-a^2I_{a1}$

Fault Analysis of an Alternator

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

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

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

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

$E_r = 108$ volts; $I = 4.2A$

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

∴ $I_R = 4.16$ Amps.

⇒ L-L Fault :- $(E_f = 184$ volts) (L-L)

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

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

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

$$a = (-0.5 - j0.866).$$

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

∴ $I_b = 4.46$ Amps.

3) L-L-G FAULT :- V = 155 volts. (L-LG)

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

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

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

$\therefore$ Fault Current $(I_R) = 3 \times I_0 = 3 \times (1.36)$

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

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

$\therefore Z_1 = 47\Omega$

$\therefore Z_2 = 24\Omega$

$\therefore Z_0 = 6.8\Omega$

EXPERIMENT

To study Zero sequence current 3phase Transformer

SEQUENCE IMPEDANCES OF TRANSFORMERS

Objective:

To determine the positive, negative and zero sequence impedances for the following transformer connections:

(i) Star-star, both neutrals solidly earthed.

(ii) Star-delta, neutral solidly earthed.

(iii) Star-star, one neutral earthed.

Theory:

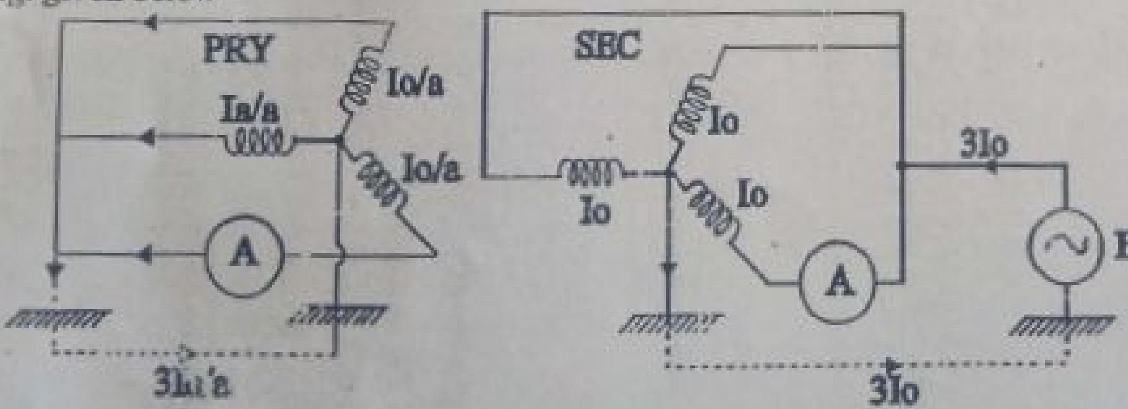
The positive sequence impedance of a transformer equals the leakage impedance. It may be obtained by the usual short-circuit test. Since the transformer is a static device, the leakage impedance does not change if the phase-sequence is altered from RYB to RBY. Therefore, the negative sequence impedance of a 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 and 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.

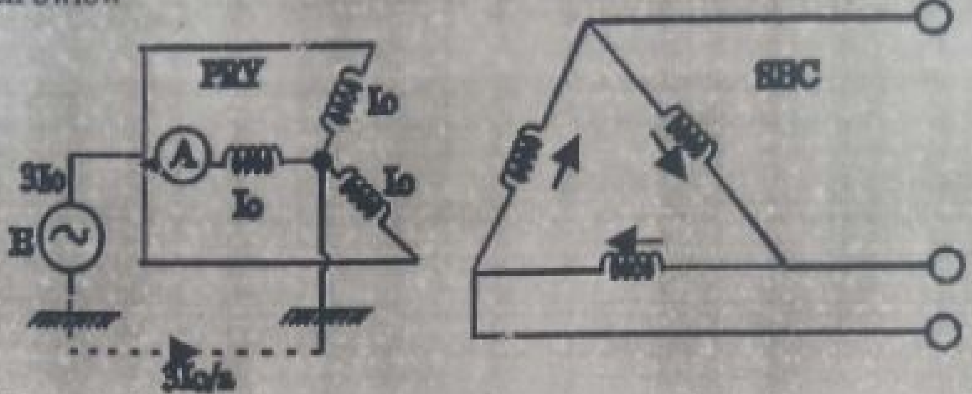
Procedure:

1. Connect the 3-phase transformer in star-star with both neutrals solidly earthed as shown in Fig. given below



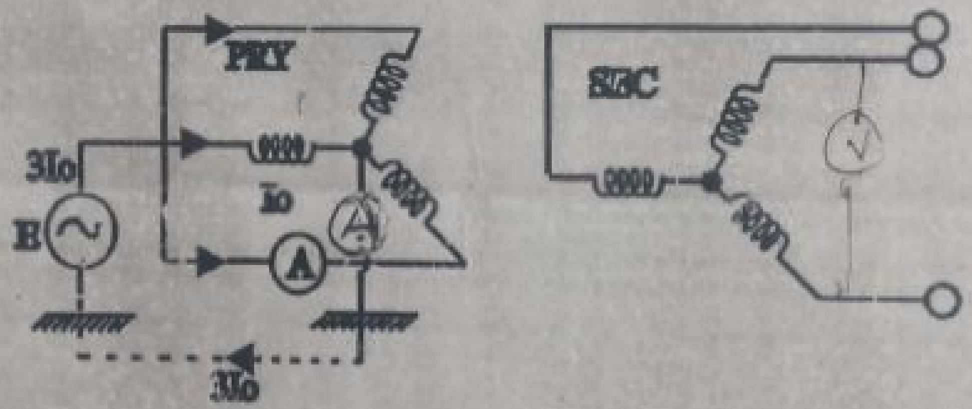
In this case the current is impeded only by the leakage impedance per phase. The zero sequence impedance Z_0 equals the leakage impedance. The p.u. zero sequence impedance has the same value, if measured from both sides (Note that the ohmic values on the two sides would be in the ratio a^2). Measure E, I_0 and I_0/a and calculate Z_0.

2. Connect the transformer in star delta with the neutral solidly earthed as shown in Fig given bwlow



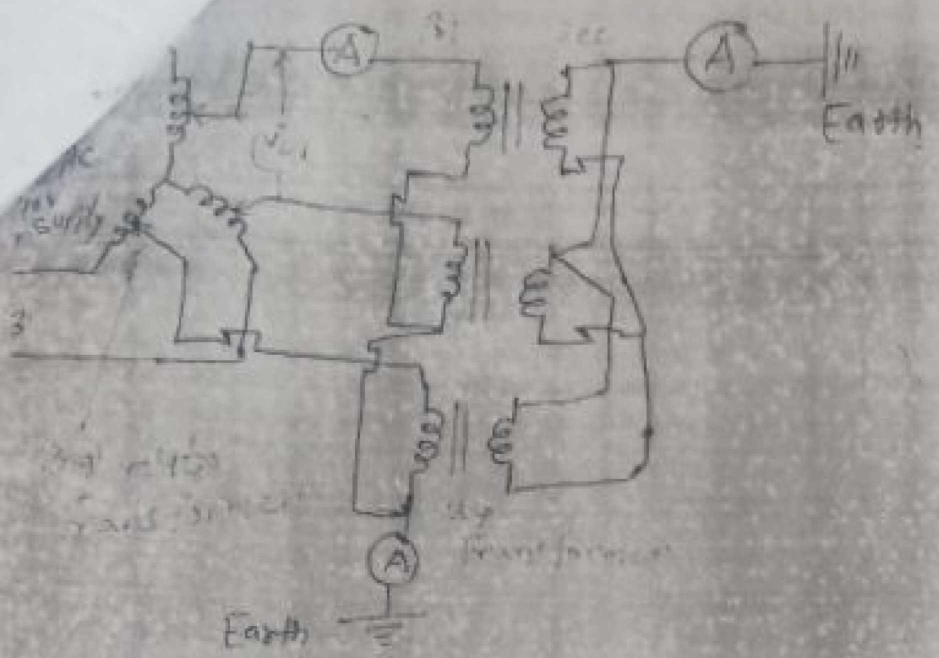
Measure E and I_0 and calculate the zero-sequence impedance which when measured from the star side equals the leakage impedance. Note that the zero-sequence currents cannot be injected into the delta terminals.

3. Connect the transformer in star-star, with one neutral earthed and the other neutral unearthed, as shown in Fig. given below:



Measure E and I_0 and calculate the zero sequence impedance which in this case is equal to magnetising impedance. From a zero sequence point of view, the secondary acts as an open-circuit, and therefore from the primary side we measure the magnetising impedance.

From the secondary side, the zero sequence currents face a total interruption. Note that the magnetising impedance is very large.



Here, V_L = Line Voltage, $V_{ph} = E$ = Phase Voltage

$I_{sc} = I_0$ = Line Current [OR Phase Current] or Short-ckt Current
= Rated Current of Transformer

So equivalent leakage Impedance per phase reffered to Primary Side

= Zero sequence Impedance $= Z_0 = \frac{V_{sc}}{I_{sc}} = \frac{E}{I_0}$

[illegible]lation :- BY Experiment, we get

$I_0 = 0.05$ Amp, $I_N = 0.15$ Amp, $V_1 = 426$ volt,

$W_1 = 12 \times 4 = 48$ watt, $W_2 = 1.5 \times 4 = 6$ watt

$\cos\phi_0 = ?$ R_{cl} (Core loss Resistance reffered to Primary winding $= ?$

X_{ml} = Magnetising Reactance = ?

$Z_m = Z_0$ = magnetising Impedance = ?

Zero sequence component: $\bar{I}_{R_0}$ [illegible]

$I_{R_0} = \frac{1}{3}\left[\bar{I}_R + \bar{I}_Y + \bar{I}_B\right] = \frac{1}{3}$ [illegible] current flowing in neutral wire

$= \frac{1}{3}$ [illegible]

NOW

$$R_{cl} = \frac{V_1}{I_c} = \frac{V_1}{I_0 \cos\phi_0} = \frac{V_1}{I_0 \cos\phi_0} \times \frac{V_1}{V_1}$$

$$= \frac{[V_1]^2}{V_1 I_0 \cos\phi_0} = \frac{(V_1)^2}{P_c} = \frac{(\text{Applied Voltage})^2}{\text{Per phase Power}}$$

Since $P_c = \frac{W_1 - W_2}{3} = \frac{48 - 6}{3} = \frac{42}{3} = 14$ watt.

So $R_{cL} = \frac{[426]^2}{14} = 12962\,\Omega$

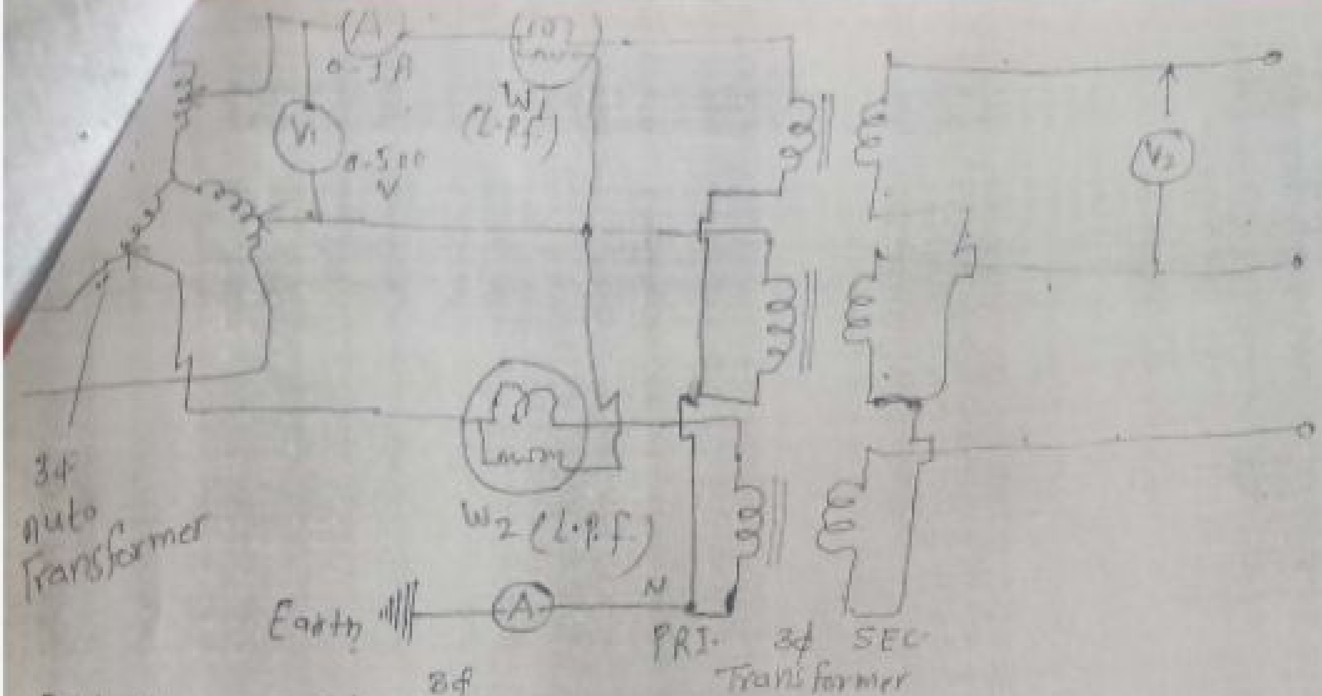
$\because \tan\phi_0 = \sqrt{3}\,\frac{W_1 - W_2}{W_1 + W_2}$

$X_{ml} = \frac{V_1}{I_m} = \frac{V_1}{I_0 \sin\phi_0}$

$= \sqrt{3}\,\frac{48 - 6}{48 + 6} = \sqrt{3} \times \frac{42}{54}$

OR $= \frac{426}{0.05 \times 0.802} = 10623\,\Omega$

$=$ [illegible]



Input Power supplied to 3φ Transformer $= W = W_1 - W_2$ (Difference of both watt-meter Reading)

Input Power per phase $= \frac{W}{3} = \frac{W_1 - W_2}{3} = V_{ph} I_{ph} \cos\phi_0$

For Y-connection, we know $V_{ph} = \frac{V_L}{\sqrt{3}}$ and $I_L = I_{ph}$

so again $\frac{W}{3} = V_{ph} I_{ph} \cos\phi_0 = \frac{V_L}{\sqrt{3}} \times I_L \times \cos\phi_0 = \frac{V_L I_L \cos\phi_0}{\sqrt{3}}$

OR $W = \sqrt{3} V_L I_L \cos\phi_0$

$\cos\phi_0 = \frac{W}{\sqrt{3} V_L I_L}$

(I_L : Ammeter Reading
V_L : Volt-meter Reading
W : Difference of both watt-meter Readings)

Core Loss Resistance $= R_{CL} = \frac{V_1}{I_0 \cos\phi_0} = \frac{V_1^2}{V_1 I_0 \cos\phi_0} = \frac{V_1^2}{\frac{W}{\sqrt{3}}} = \frac{V_1^2 \times \sqrt{3}}{W}$

$R_{CL} = \frac{[\text{Volt-meter Reading}]^2 \times \sqrt{3}}{\text{Difference of watt-meter Reading}}$

$\tan\phi_0 = \sqrt{3}\frac{W_1 - W_2}{W_1 + W_2}$

$\sin\phi_0 = ?$

W_1, W_2 = watt-meter Readings

Magnetising Reactance $X_{mL} = \frac{V_1}{I_0 \sin\phi_0} = \frac{V_1}{I_m}$

Finally, Magnetising Impedance, $Z_m = \sqrt{R_{CL}^2 + X_{mL}^2}$

Zero Sequence Components, $I_{R0} = I_{Y0} = I_{B0}$

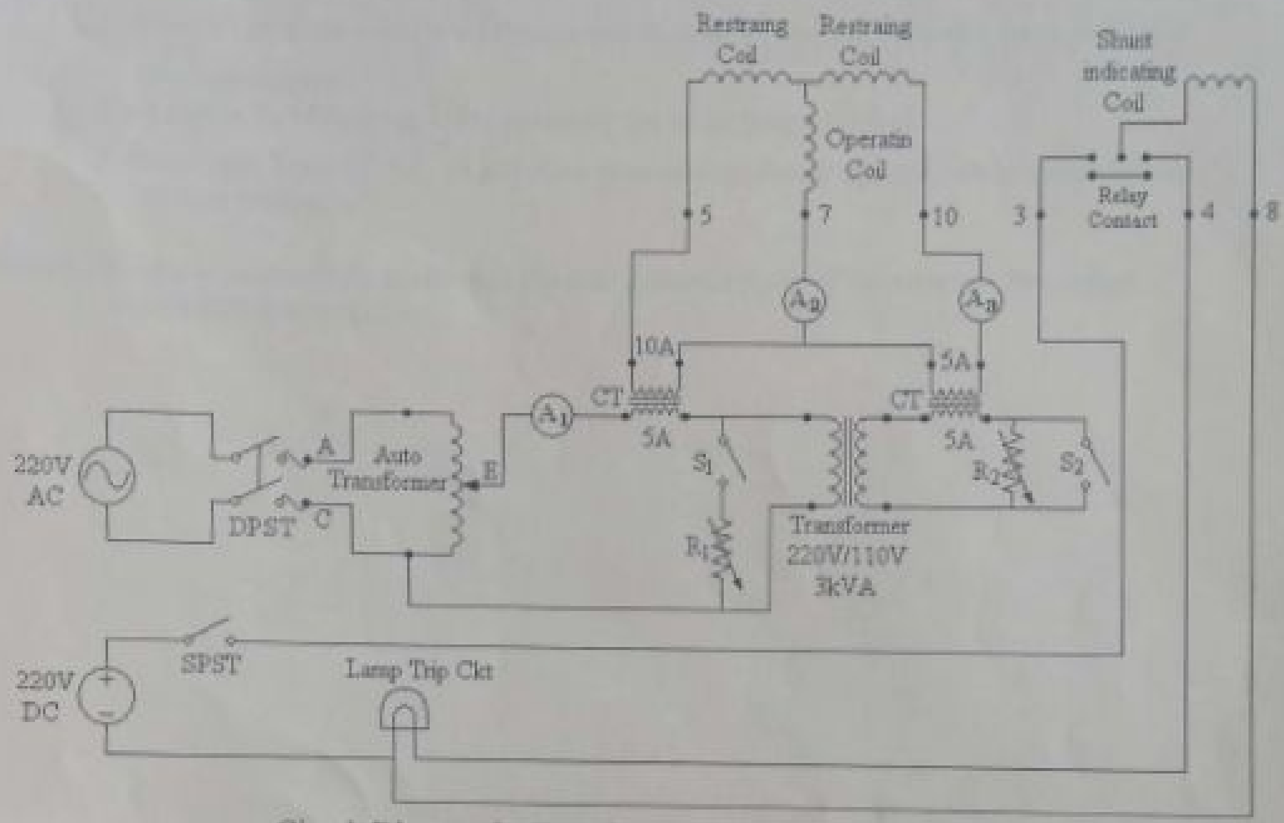
But $I_{R0} = \frac{1}{3}(\bar{I}_R + \bar{I}_Y + \bar{I}_B) = \frac{1}{3}$ [Current in neutral]

= Ammeter Reading

Zero Sequence Component = Ammeter Reading.

DIFFERENTIAL OVER CURRENT RELAY

Object: To determine the Operating characteristic of Transformer Percentage biased Differential Relay.



Circuit Diagram for Transformer Percentage Differential Relay.

Theory:

$I_2 \eta_o > I_3 \eta_r$. Where,

η_o = no of turns of Operating coil.

η_r = no of turns of Restraining coil

Procedure:

1. Chose a particular biasing (say 20%)
2. Close S_2. See that there is no relay operation (no current through A_2). If there is connect through A_2, reverse the connection of one of the CT secondary.
3. Switch OFF S_2.
4. Switch ON S_1, for a given value of A_3 (through current) adjust A_2 (relay operating current) to cause the relay to just operate.
5. Repeat for another bias setting.

Report:

1. Plot through current 'V' differential current.
2. Compare the curve with reference of the manufacturer

Discussion:

1. When switch 2 is closed, the relay does not operate. Why do we have such a scheme?
2. Current through R_2 represents for which current in the experiment?
3. What is the relation between the current through R_2 and the current I_2 for a particular through current?
4. At higher % of biasing, I_2 for operating the relay is more, why?
5. Other than Transformer, which other apparatus in Power system can be protected by differential relay?

Result- We have successfully performed Operating characteristic of Transformer Percentage biased Differential Relay.