DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Power and Switchgear Lab

Course code: EEC377

Location of the Lab: Room No: 018 & 019, New Academic Building

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DEPARTMENT OF ELECTRICAL ENGINEERING

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Experiment No.: 01

<u>STUDY OF VARIOUS SYSTEM FAULTS USING A DC ANALYZER</u>

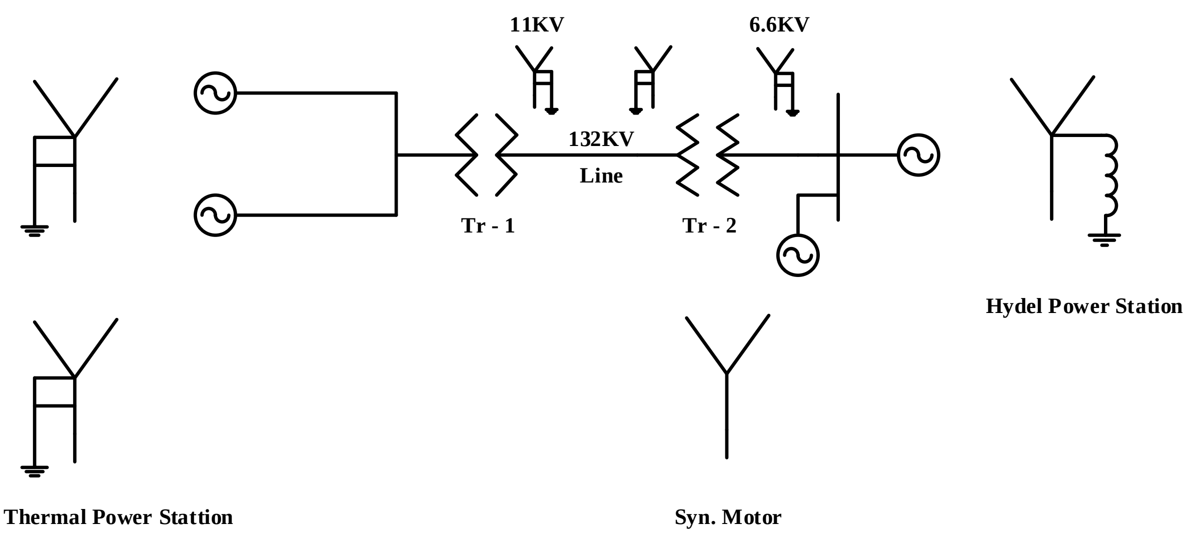
TITLE: Study of various system faults using a DC analyzer.

OBJECTIVE: To simulate the following system in a DC network analyzer and calculate the fault current in different parts of the system for i) 3-phase fault ii) S.L.G fault iii) L.L fault iv) D.L.G fault.

Apparatus List:

SI No.	ITEM	QTY	RANGE / RATING	MAKER'S NAME	MAKER'S NO
1.	Network Analyzer Board	2	0 - 25 - 50 V		
2.	DC Multi-meter (true RMS)	1	i) Used as DC voltmeter 0 - 75 V		

System Diagram:



Turbo alternator: 50MVA, 11KV each
Positive sequence reactance = 5%
Negative sequence reactance = 2.5%
Zero sequence reactance = 2%
Water wheel generator 20MVA, 6.6KV
Positive sequence reactance = 4%
Negative sequence reactance =1%
Neutral reactance = 0.073 ohm
Synchronous Motor: 10MVA, 6.6KV

Step-up Transformer: 11/132KV, 100MVA
Step-down Transformer: 132/11KV, 100MVA
Leakage Reactance = 10%
(for both transformers)
132KV line length = 66Km
Positive sequence reactance = 0.132ohm/KV
Negative sequence reactance = 0.132ohm/KV
Zero sequence reactance = 1%

Positive sequence reactance = 5%

Positive sequence reactance = 2%

Zero sequence reactance = 1%

<u>Procedure:</u>

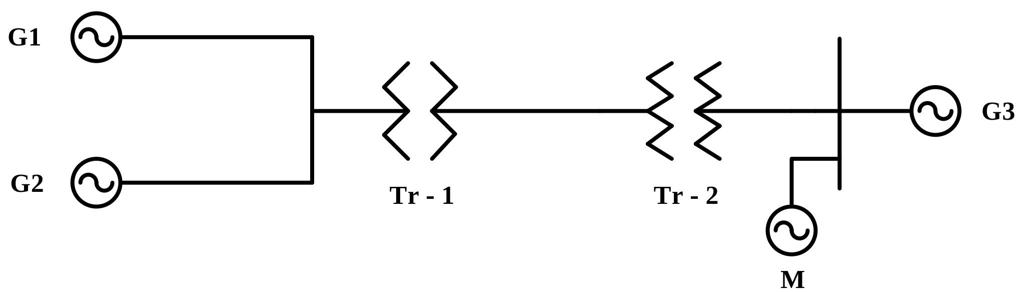
1. Convert all the data to per unit quantities choosing 100MVA base.
2. Draw sequence box connections for above faults, and check it with the help of teacher-in-charge.
3. Simulate the network with proper interconnection on the analyzer, taking a scale factor of

1 p.u volt = 10 volts

1 p.u Ohm = 1 KΩ Determine the scale factor for current.

4. Note the current value in p.u. in all parts of the system.

Single line diagram and their equivalent $Z_{p.u}$



The formulas used in the below calculations are:

$$Z_{p.u} = Z_{actual} * \left(\frac{S_{base}}{V_{base}^2}\right) = Z_{actual} * \frac{MVA}{KV^2}$$

$$Z_{p.u.new} = Z_{p.u.old} * \left(\frac{S_{base\ \ new}}{S_{base\ \ old}}\right) = Z_{p.u.old} * \left(\frac{(MVA)_{new}}{(MVA)_{old}}\right)$$

Base MVA = 100

Turbo Alternators (G1, G2): Base voltage = 11KV

+VE SEQUENCE: $Z_{p.u}$ = 0.05 x (100/50) = 0.1

-VE SEQUENCE: $Z_{p.u}$ = 0.025 x (100/50) = 0.05

ZERO SEQUENCE: $Z_{p.u}$ = 0.02 x (100/50) = 0.04

Transmission Line: Base voltage = 132KV

+VE SEQUENCE: $Z_{p.u}$ = (0.132 x 66) x (100/132^2) = 0.05

-VE SEQUENCE: $Z_{p.u}$ = (0.132 x 66) x (100/132^2) = 0.05

ZERO SEQUENCE: $Z_{p.u}$ = (0.264 x 66) x (100/132^2) = 0.1

Water wheel Generator (G3): Base voltage = 6.6KV

+VE SEQUENCE: $Z_{p.u}$ = 0.04 x (100/20) = 0.2

-VE SEQUENCE: $Z_{p.u}$ = 0.02 x (100/20) = 0.1

ZERO SEQUENCE: $Z_{p.u}$ = 0.01 x (100/20) = 0.05

Neutral grounding: $Z_{p.u}$ = (3 x 0.073) x (100/6.6^2) = 0.5

Synchronous Motor (M): Base Voltage = 6.6KV

+VE SEQUENCE: $Z_{p.u}$ = 0.05*(100/10) = 0.5

-VE SEQUENCE: $Z_{p.u}$ = 0.02*(100/10) = 0.2

ZERO SEQUENCE: $Z_{p.u}$ = 0.01*(100/10) = 0.1

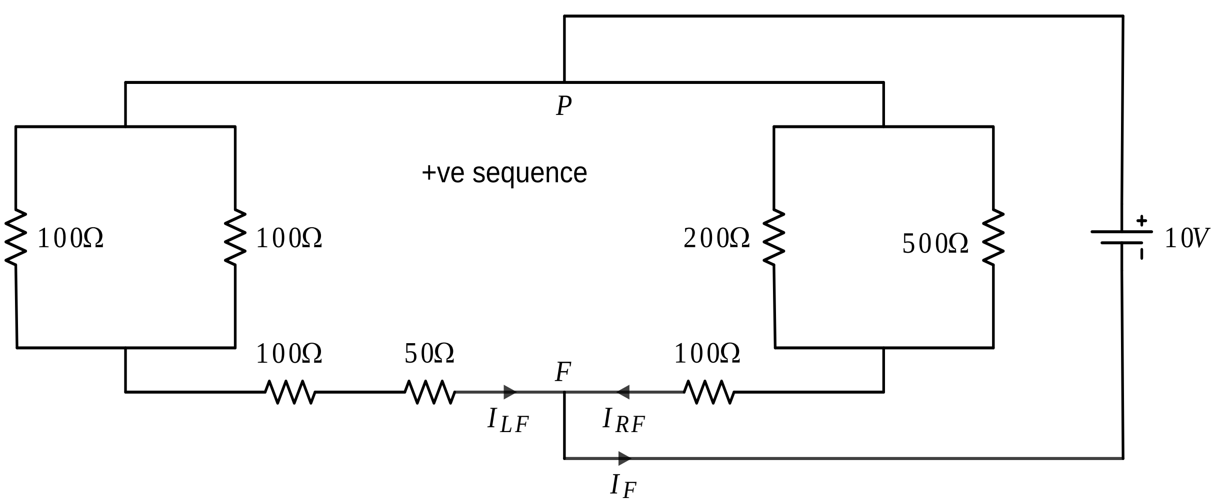
Transformer (T1 & T2):

+VE SEQUENCE, -VE SEQUENCE and ZERO SEQUENCE p.u. reactance: 0.1

1. 3 Phase (3-ø) Fault

$$V_a = V_b = V_c = (I_a + I_b + I_c)Z_f$$

$$I_f = I_a + I_b + I_c = E_a / (Z^1 + Z_f)$$



Observation Table: -

Observation Table 1. 3 Phase (3-ø) Fault

Sl No.	Fault Point	Resistance (Ω)	Voltage (V)	Current (mA)		% Error
				Theoretical	Measured	
1	F_1	50		50.00		
2	F_1	100		41.18		
			Total I_F	**91.18**		

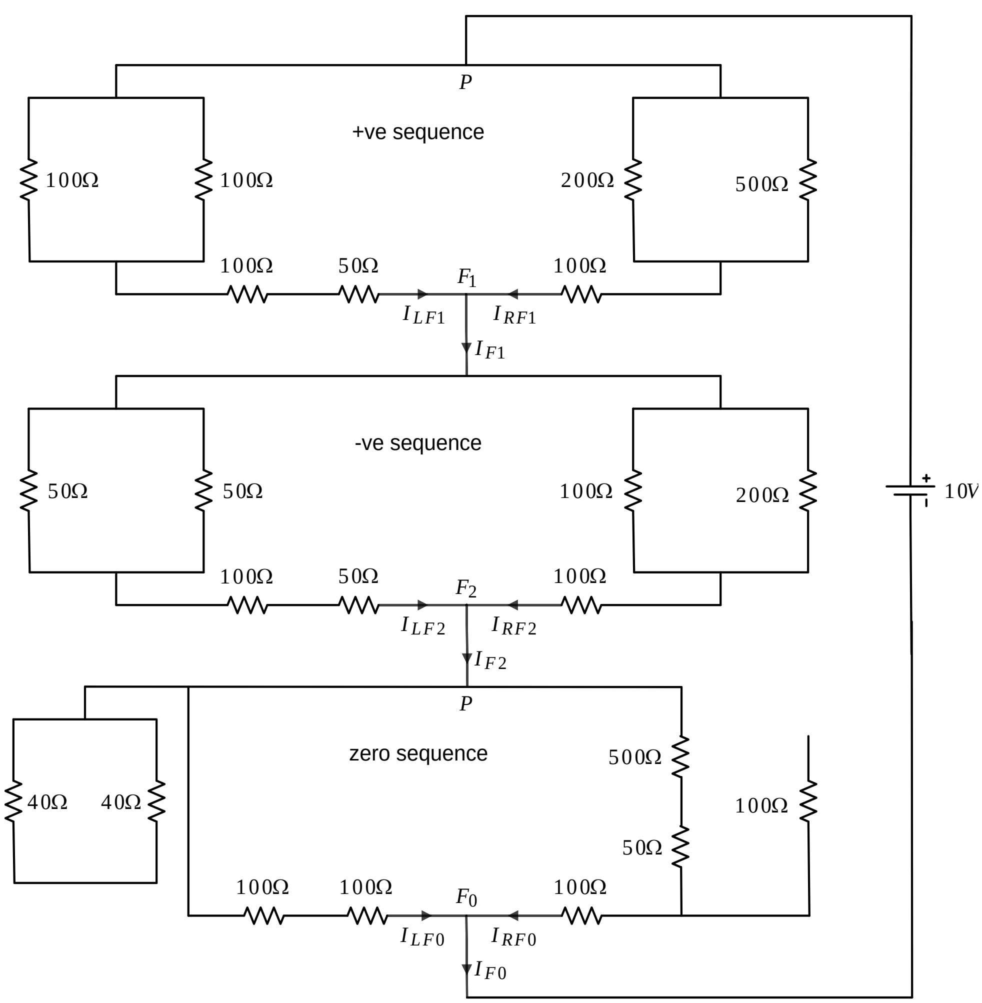
$I_f = I_L + I_R = 91.18mA$

2. Single Line to Ground (SLG) Fault

$V_a = Z_f I_a, \quad I_b = I_c = 0$

$I_a^1 = I_a^2 = I_a^0 = E_a / (Z^1 + Z^2 + Z^0 + 3Z_f)$

$I_f = I_a = 3I_a^1$



Observation Table: -

Observation Table 2. Single Line to Ground (SLG) Fault

Sl No.	Fault Point	Resistance (Ω)	Voltage (V)	Current (mA)		% Error
				Theoretical	Measured	
1	F_1	50		15.76		
2	F_1	100		12.98		
			Total I_{F1}	**28.74**		
3	F_2	50		14.02		
4	F_2	100		14.72		
			Total I_{F2}	**28.74**		
5	F_0	100		21.98		
6	F_0	100		06.76		
			Total I_{F0}	**28.74**		

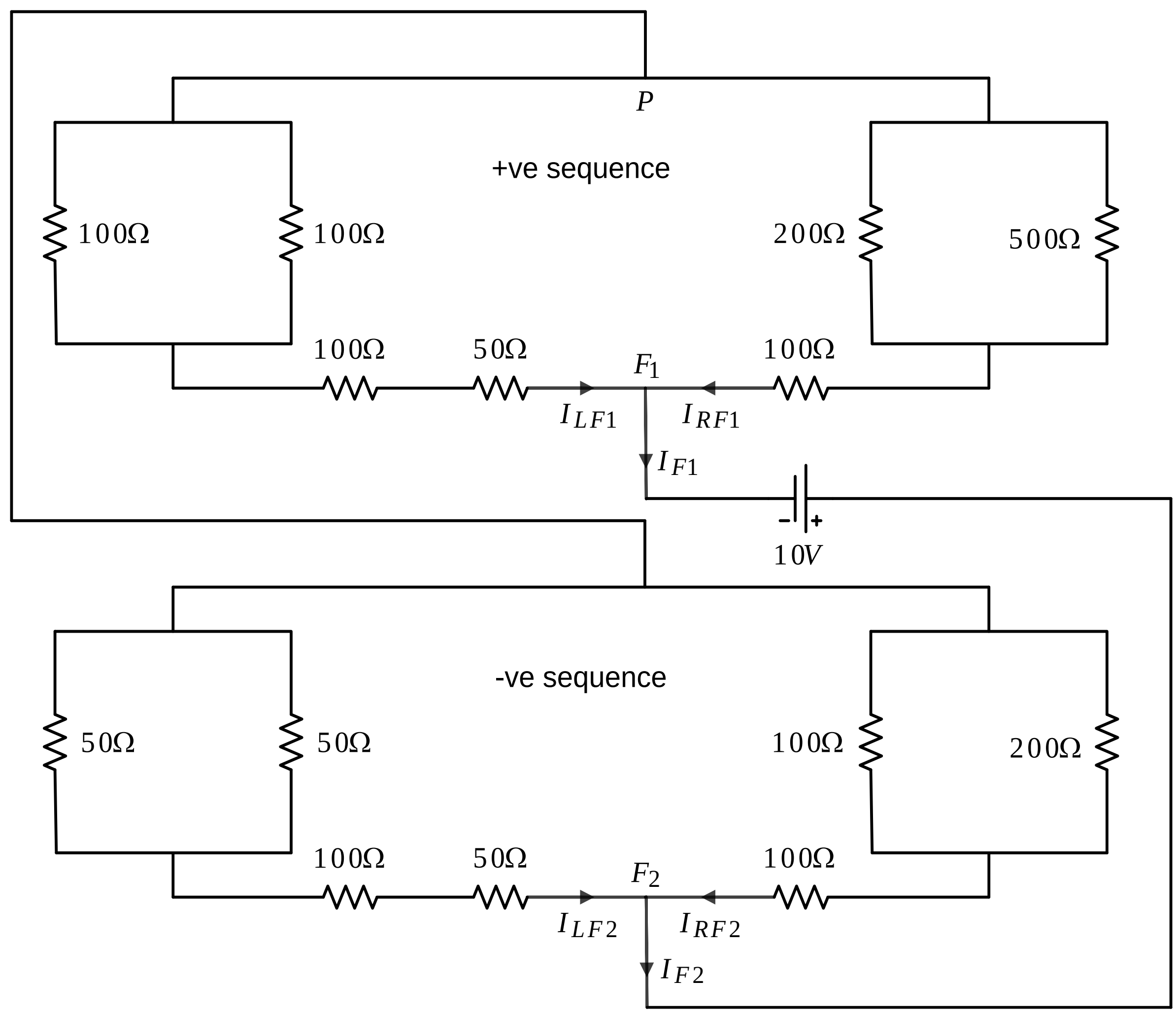
$$I_f = 3I_F^1 = 86.22mA$$

3. Line to Line (LL) Fault

$V_b - V_c = I_b Z_f$, $I_b + I_c = 0$, $I_a = 0$

$I_a^0 = 0$, $I_a^1 = -I_a^2 = E_a \big/ (Z^1 + Z^2 + Z_f)$

$$I_f = I_b = -I_c = (a^2 - a)I_a^1 = -j\sqrt{3}I_a^1$$



Observation Table: -

Observation Table 3. Line to Line (LL) Fault

Sl No.	Fault Point	Resistance (Ω)	Voltage (V)	Current (mA)		% Error
				Theoretical	Measured	
1	F_1	50		28.12		
2	F_1	100		23.15		
			Total I_{F1}	**51.27**		
3	F_2	50		-25.01		
4	F_2	100		-26.26		
			Total I_{F2}	**-51.27**		

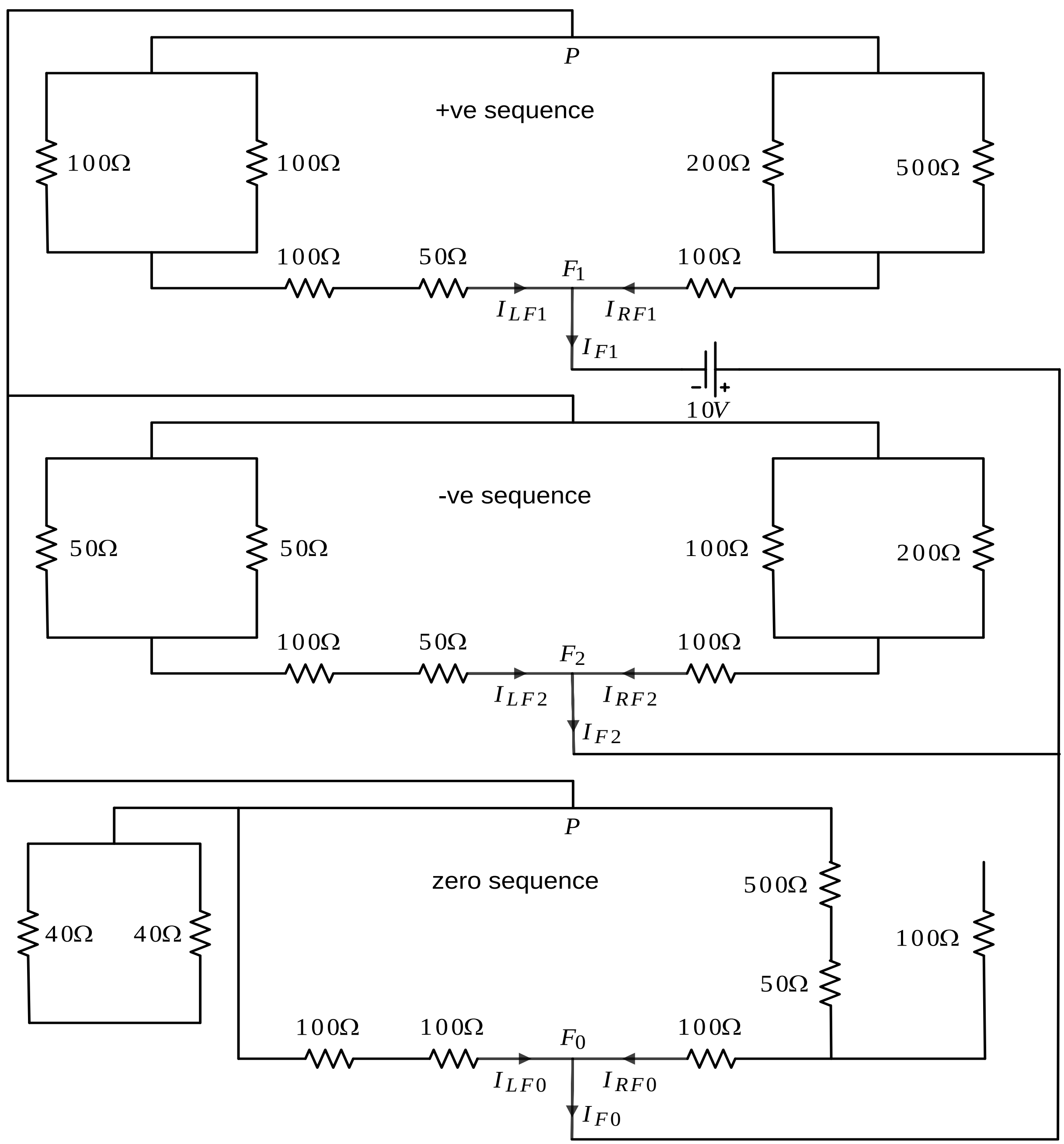
$$I_f = \sqrt{3} I_F^1 = 88.80 mA$$

4. Double Line to Ground (LLG) Fault

$V_b = V_c = (I_b + I_c)Z_f$, $I_a = I_a^1 + I_a^2 + I_a^0 = 0$

$V_a^1 = V_a^2$, $I_a^1 = E_a / \{Z_1 + \frac{Z^2(Z^0 + 3Z_f)}{Z^2 + Z^0 + 3Z_f}\}$, $I_a^2 = -\frac{E_a - I_a^1 Z^1}{Z^2}$, $I_a^0 = -\frac{E_a - I_a^1 Z^1}{Z^0 + 3Z_f}$

$I_f = I_b + I_c = 3I_a^0$



Observation Table: -

Observation Table 4. Double Line to Ground (LLG) Fault

Sl No.	Fault Point	Resistance (Ω)	Voltage (V)	Current (mA)		% Error
				Theoretical	Measured	
1	F_1	50		33.34		
2	F_1	100		27.46		
			Total I_{F1}	**60.80**		
3	F_2	50		-19.03		
4	F_2	100		-19.99		
			Total I_{F2}	**-39.02**		
5	F_0	100		-16.65		
6	F_0	100		-5.13		
			Total I_{F0}	**-21.78**		

$I_f = 3I_F^0 = 65.34mA$

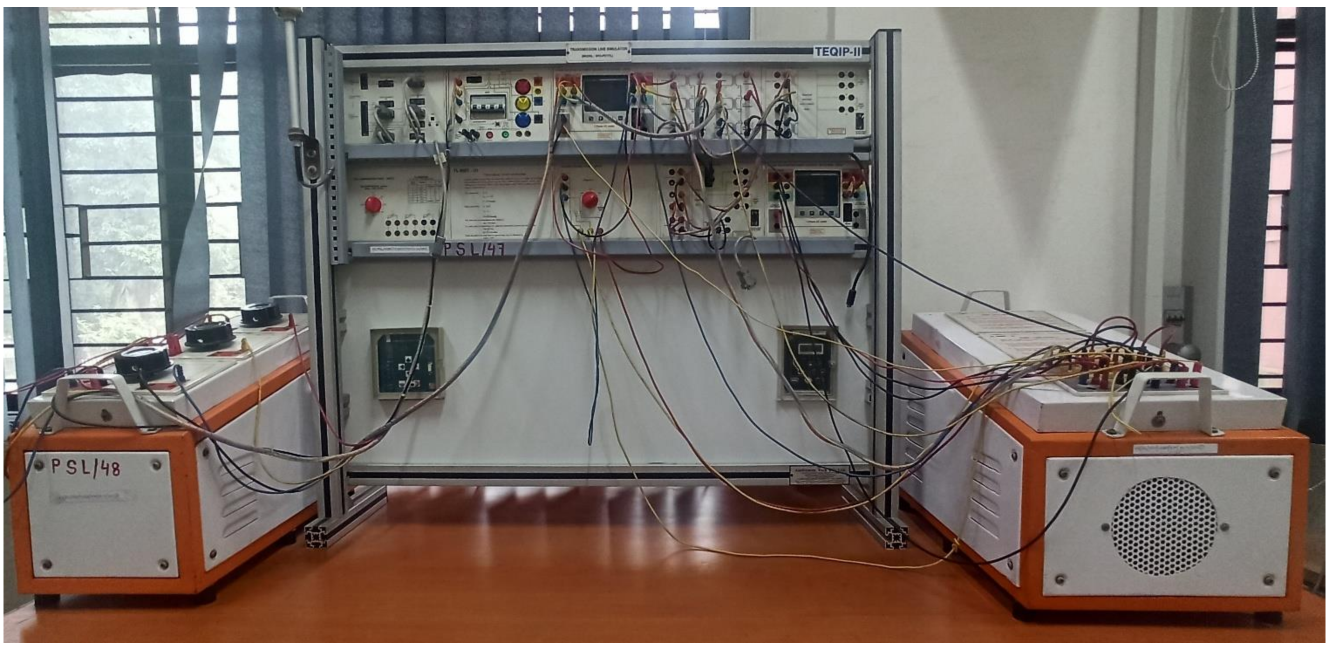
DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Power and Switchgear Lab

Course code: EEC377

Experiment No.: 02

SYMMETRIC & ASYMMETRIC FAULTS IN TRANSMISSION LINE



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Title: Study of the symmetric & asymmetric faults in transmission line.

Objective: To study the symmetrical and asymmetrical faults on the transmission line 'T 'model and understand the concept of symmetrical and asymmetrical faults:

1) Line to ground (L-G) fault

2) Line to Line (L-L) fault

3) Double line to ground (L-L-G) fault

4) Three phase fault (L-L-L)

5) Three phase to ground (L-L-L-G) fault

Apparatus used:

1) Three phase supply, 440volt, three phase, 50 Hz

2) Direct online starter

3) Reversing phase panel

4) Three phase AC voltmeter and ammeter

5) Transmission line simulator

6) Current transformer

7) Variac/Dimmer

Theory: Power systems are designed to be symmetrical or balanced i.e. in a three-phase system, the three line to neutral, voltages have same magnitude and differ in phase by 120 degree & line currents have same magnitude & differ in phase by 120 degree.

The most extreme but also common, series fault in the open circuit, this occur for example, when a circuit breaker or isolator is opened or when a line is broken (but does not touch the ground).

Short circuit faults are ordered by occurrence are classified into:

1) Single-line-to-ground (L-G) fault: Unsymmetrical fault between one phase and ground. The phase magnitudes will be no longer identical.

2) Line-to-line (L-L) fault: Unsymmetrical fault between two phases.

3) Double-line-to-ground or line-to-line-to-ground (L-L-G) fault: Unsymmetrical fault between two phases and ground.

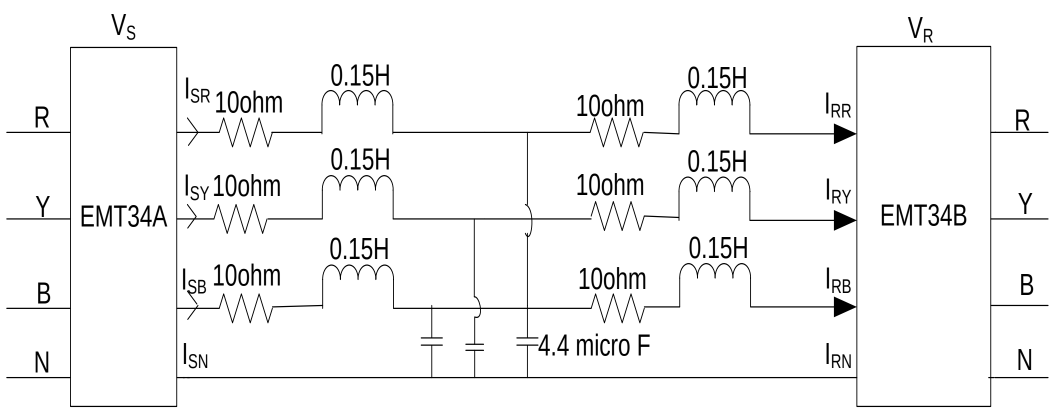
4) Three phase short circuit (L-L-L) fault: It is symmetrical fault that affects the three phases of the power system. This is the most severe short circuit fault.

5) Three phase to ground (L-L-L-G) fault: It is symmetrical fault, all three phases are grounded.

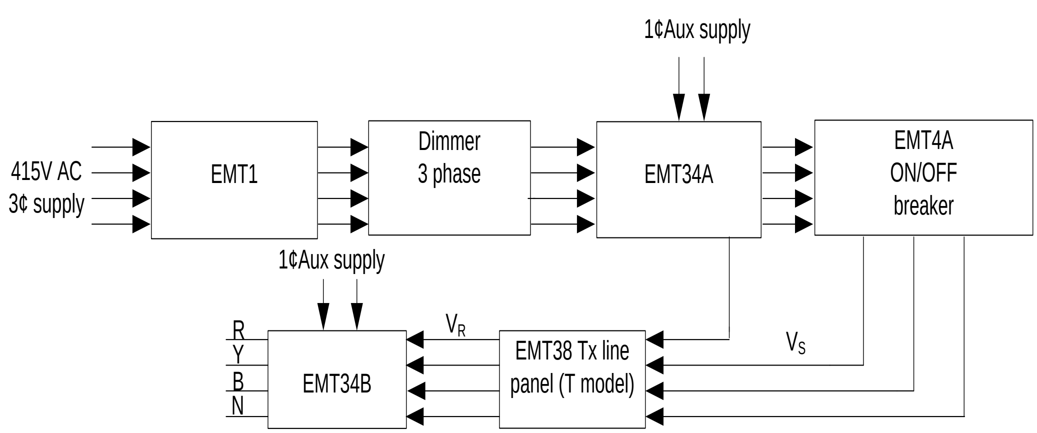
L-G, L-L & L-L-G are the unsymmetrical faults while L-L-L, L-L-L-G are symmetrical faults. In case of symmetrical faults, the system remains balanced even after the faults. For unsymmetrical faults the voltages and currents becomes unbalanced after the fault.

Procedure:

To create L-G, L-L, L-L-G, L-L-L & L-L-L-G faults on medium length transmission line T model.



(a) Circuit diagram for faults on T model



(b)Block diagram for faults on T model

Wiring sequence:

No.	From	To	No.	From	To
1	EMT1(1)	EMT20D/R(1)	2	EMT1(2)	EMT20D/Y(1)
3	EMT1(3)	EMT20D/B(1)	4	EMT1(4)	EMT20D/R(3)
5	EMT20D/R(4)	EMT20D/Y(3)	6	EMT20D/Y(4)	EMT20D/B(3)
7	EMT20D/R(5)	EMT34A(4)	8	EMT20D/R(7)	EMT34A(1)
9	EMT20D/Y(7)	EMT34A(2)	10	EMT20D/B(7)	EMT34A(3)
11	EMT34A(5)	EMT4A(1)	12	EMT34A(6)	EMT4A(2)
13	EMT34A(7)	EMT4A(3)	14	EMT4A(4)	EMT38(1)
15	EMT4A(5)	EMT38(9)	16	EMT4A(6)	EMT38(17)
17	EMT34A(8)	EMT38(2)	**18**	EMT38(3)	EMT38(7)
19	EMT38(11)	EMT38(15)	20	EMT38(19)	EMT38(23)
21	EMT38(4)	EMT38(6)	22	EMT38(8)	EMT38(16)
23	EMT38(14)	EMT38(12)	24	EMT38(10)	EMT38(18)
25	EMT38(20)	EMT38(22)	26	EMT38(5)	EMT38(1)
27	EMT38(13)	EMT38B(2)	28	EMT38(21)	EMT34B(3)
29	EMT38(24)	EMT34B(4)	30		

Wiring schedule for fault:

Sr. No.	Type of fault		From	To
1	L-G	R to G, B&Y open	EMT34B(5)	EMT34B(8)
2	L-L	R to Y, B open	EMT34B(5)	EMT34B(6)
3	L-L-G	R to Y to G, B open	EMT34B(5)	EMT34B(6)
			EMT34B(6)	EMT34B(8)
4	L-L-L	R to Y to B	EMT34B(5)	EMT34B(6)
			EMT34B(6)	EMT34B(7)
5	L-L-L-G	R to Y to B to G	EMT34B(5)	EMT34B(6)
			EMT34B(6)	EMT34B(7)
			EMT34B(7)	EMT34B(8)

1) Make the wiring connection as per wiring schedule for any fault say R to G (L-G). Keep the dimmer at minimum position & switch on EMT4A at FWD position.

2) Here EMT34A will read sending end voltage, current, power factor etc. and EMT34B will read receiving end voltage, current, power factor etc.

3) Here note that we have shorted R phase of transmission line to neutral at EMT34B.

4) Make on three phase supply and now increase dimmer slowly to 230volt AC observing voltage on EMT34A & monitoring current on EMT34B.

5) Now take the readings of sending and receiving end voltage & current as per table given below.

Observation table for faults on T model:

Sr. No.	Type of fault	Sending end (On EMT34A)						Receiving end (On EMT34B)					
		V_{SR}	V_{SY}	V_{SB}	I_{SR}	I_{SY}	I_{SB}	V_{RR}	V_{RY}	V_{RB}	I_{RR}	I_{RY}	I_{RB}
1	L-G												
2	L-L												
3	L-L-G												
4	L-L-L												
5	L-L-L-G												

Conclusion:

Based on above table of observation:

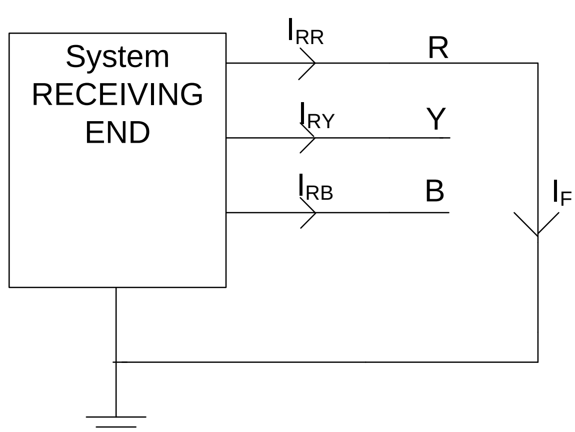
1) Answer following questions:

a) Which one do you thing is most severe fault? Why?

b) Which one of them will be the most severe for the network equipment?

c) How does the location (distance & impedance to source) of the fault increase/decrease the severity of the disturbance? Why?

2) Single line to ground fault (L-G):

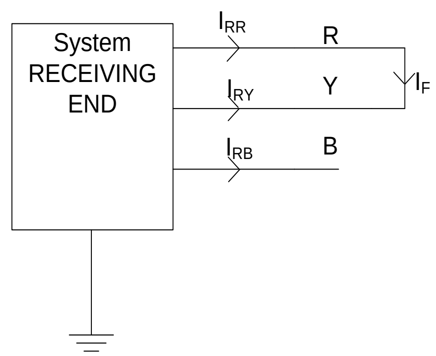


(a) Current in faulted phase R………

(b) Is the system balanced?

(c) What happens with the voltages at phases R, Y & B?

3) Line to line fault (L-L):

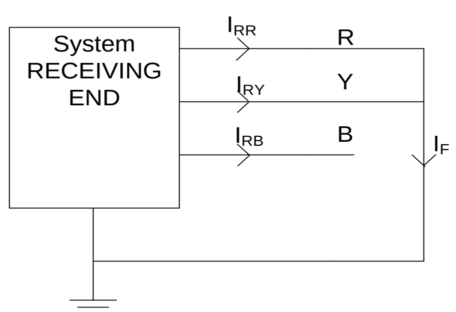


(a) Current in faulted phase R………

(b) Is the system balanced?

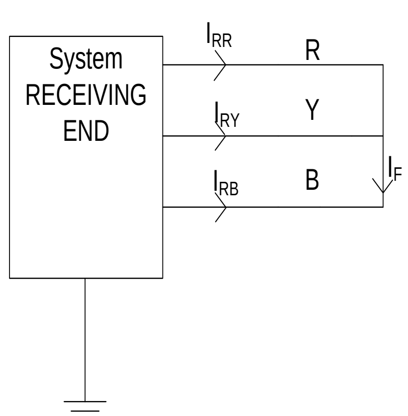
(c) What happens with the voltages at phases R, Y & B?

4) Double line to ground fault (L-L-G):



(a) Current in faulted phase R & Y.
(b) Is the system balanced?
(c) What happens with the voltages at phases R, Y & B?

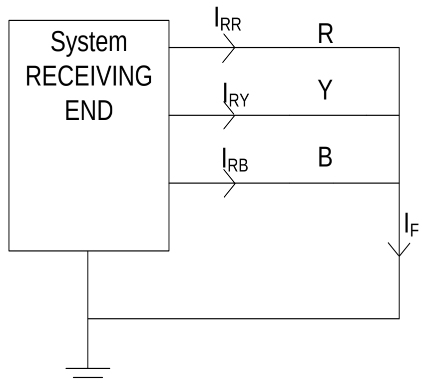
5) Three phase fault (L-L-L):



(a) Current in faulted phase R, Y & B.

(b) Is the system balanced?
(c) What happens with the voltages at phases R, Y & B?

(6) Three phase to ground fault (L-L-L-G):



(a) Current in faulted phase R, Y & B.
(b) Is the system balanced?
(c) What happens with the voltages at phases R, Y & B?

DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Power and Switchgear Lab

Course code: EEC377

Experiment No.: 03

<u>STUDY OF POWER TRANSFER THROUGH A TRANSMISSION SYSTEM</u>

TITLE: Study of power transfer through a transmission system.

List of Items:

	Apparatus	**Range**	**Maker**
1.	Ammeter	0-2 A	
2.	Voltmeter	0-150/300/600 V	
3.	Digital Phase-angle meter	(0-360°) 0-150/230 V, I (0-10) A	
4.	3-phase, 6-pole, 6 position rotary switch		
5.	Low Power Factor Wattmeter	0-150/300 V, 1A /2 A	
6.	Three pole ON/OFF switch		
7.	Single Phase Variac	0-250 V, 5 A	
8.	Isolation Transformer (3-phase)	110/110 V, 2 A	
9.	Power Supply Transformer (3- phase)	400-415 V/ 110-120 V (10 A), Star/ Delta	
10.	Single pole two way switch	230 V, 5 A	
11.	Indicating Lamps	0-230 V (AC)	
12.	0-2 A Fuses		
13.	Induction Motor type Phase Sequence Indicator		
14.	Single Pole two way Switch	230 V, 5 A	
15.	An Inductor (Linear air gap type) (It represents a short transmission system)	250/300/500 mh, 2 A	
16.	Sheet metal cubicle housing different equipments mentioned above		

OBJECT:

To plot the power angle diagram of a transmission system under steady state condition and to study the effect of resistance of the line on the power transfer characteristics.

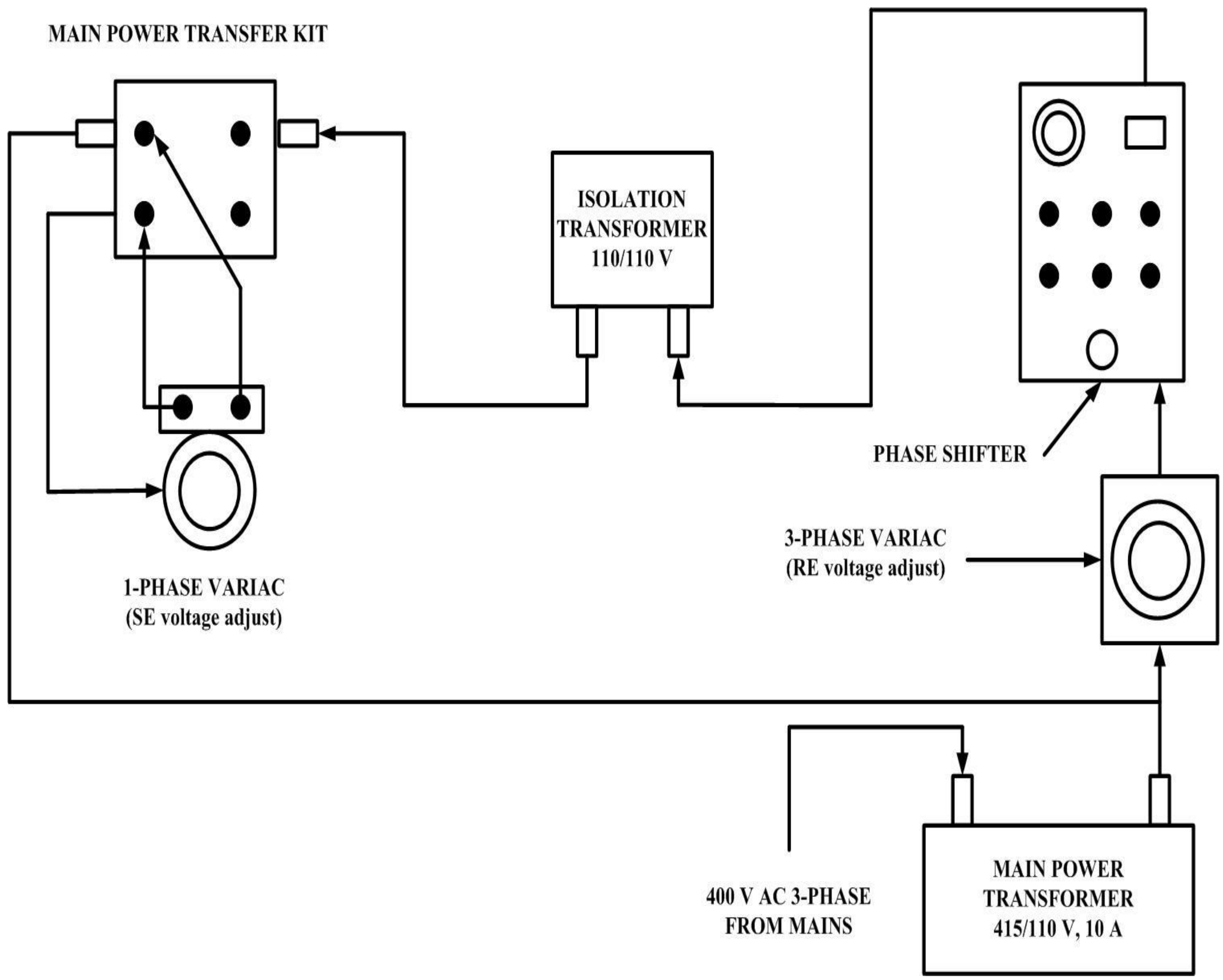


Fig.1 Connection diagram for power transfer experimental set-up

PROCEDURE:

The front view of the power transfer cubicles, and the detail circuit diagram and connection diagrams are shown in figure 1 and 2 respectively.

1) Connect the 3-phase power cable with neutral at the desired terminals provided in the power supply Transformer [i.e. 400-415/ 110-120 V (10A)] cubicle.

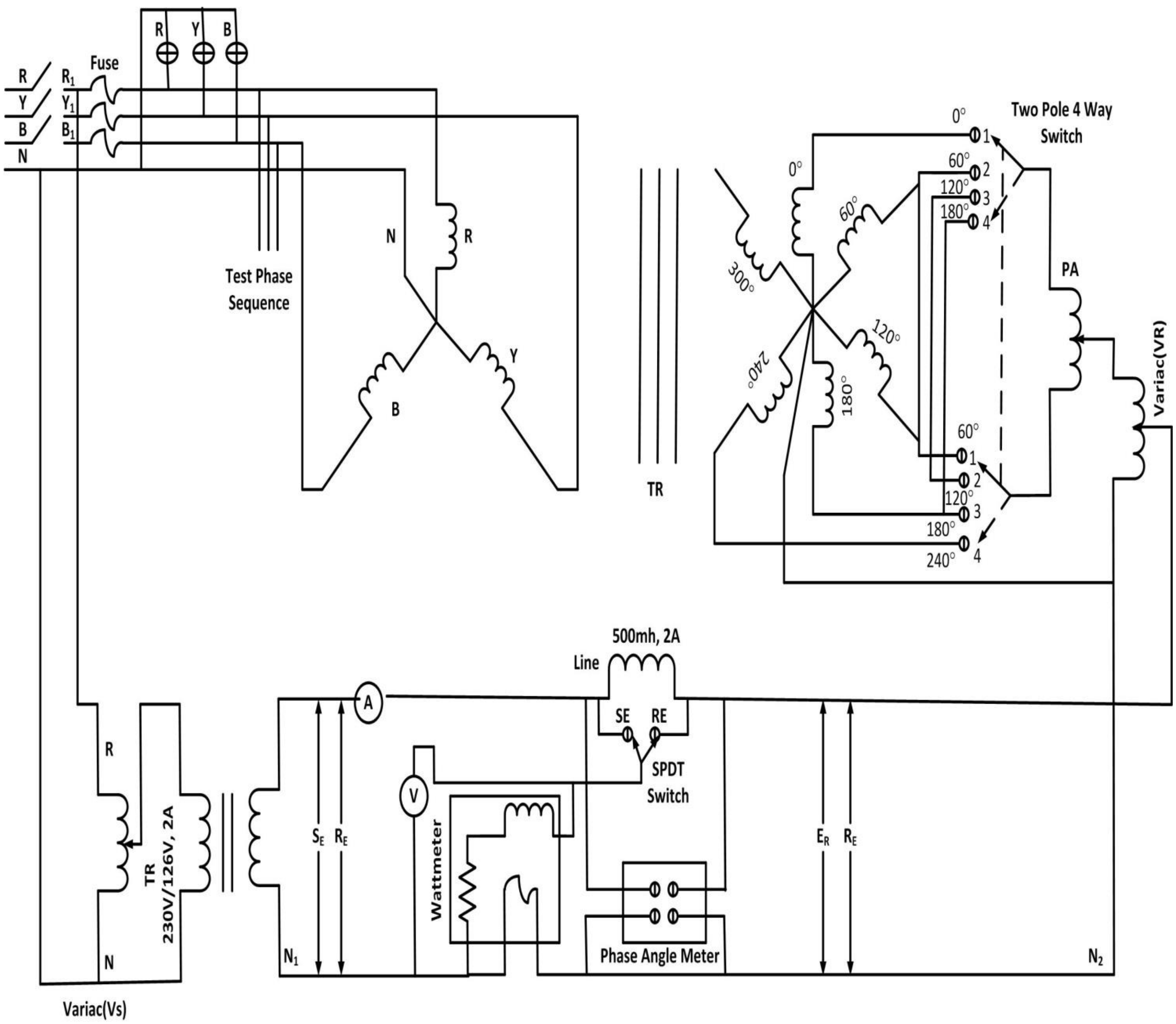


Fig.2 Power Transfer through Transmission System

2) Now connect the 110 or 120 V secondary to the 3-phase Variac and the main Power Transfer Kit Cubicle's left hand/ Sending End (SE) side through the cable entry grommet [110 V (line-to-line) single phase only].
3) Then connect the output of the Variac to the Phase Shifter input while connecting its output to the Isolation transformer [i.e. 110V/110V, 2A transformer].
4) Connect the output of the Isolation Transformer (single phase, the same phases as connected to the sending end only.) to the main Power Transfer Kit cubicle's right hand/Receiving End (RE) side through the cable entry grommet [110V (line-to-line) single phase on the RE side.]
5) Lastly connect the single phase Variac plug to the power plug socket present on the left hand side of the Main Power transfer cubicle while connecting the Variac outputs to the SE of the Main Power transfer cubicle.
6) Connect the Voltmeter, Ammeter, Wattmeter and the Phase-angle meters as shown in the diagram with the terminals on Main Power transfer cubicle.

7) Switch on the 3-phase, ON/OFF switch (on the Power Supply Transformer) to the 'ON' position and observe that the three indicator lamps glow.
8) Set SE voltage (E_S) and RE voltage (E_R) at a constant value of about 100V by the corresponding Variac. The AC voltages will show the actual value of E_S and E_R by throwing the single pole two way switch in either left-ward or right-ward directions.
9) Set the phase angle to zero degree by adjusting the Variac used for adjusting the phase angle. The 6-pole 6-way course phase shift adjust switch should be in POS-1.
10) Under that condition ammeter reading, wattmeter reading and phase angle meter reading should be zero.

RUN 1

Take ammeter and wattmeter readings at ends for E_S leading with respect to E_R from 0° to 180° in steps of 20° interval. This can be done by adjusting the phase shifter.

OBSERVATION TABLE

Sl. No.	Angle (°)	E_S(V)	E_R(V)	I_S(A)	W_S(W)	W_R(W)	Q_S(VAR)	Q_R(VAR)
							To be calculated	To be calculated

THEORY

To measure the active power transfer, we are keeping the sending and receiving end voltage constant while varying the phase angle to change the power output.

Known Parameters

1. Angle 'δ' in degrees
2. E_S – Sending end voltage
3. E_R – Receiving end voltage
4. I – Current magnitude in small transmission network in amps
5. W_S – Sending end power in watts
6. W_R – Receiving end power in watts

Unknown Parameters

1. Q_S – Sending end VAr
2. Q_R – Receiving end VAr
3. W_L – Line loss in Watts
4. Angle γ – of current I
5. $Z_S\angle\theta_S = r_s + jx_s$ – the value of the reactor

CALCULATION

Line loss = $W_S - W_R = I^2 r_s$ (1)

From equation (1),

$$r_s = \frac{W - W_R}{I^2}$$

$(\text{Volt Amp})^2 = (\text{Active Power})^2 + (\text{Reactive Power})^2$ (2)

$(E_S I)^2 = W_S^2 + Q_S^2$ (3)

Hence $|Q_S|$ is known for every observation.

Also,

$(E_R I)^2 = W_R^2 + Q_R^2$ (4)

Hence $|Q_R|$ is known for every observation.

Now,

$$I\angle\gamma = \frac{W_S - jQ_S}{E_S^*}$$

$$I\angle\gamma = \frac{W_S - jQ_S}{E_S}$$ (Taking E_S as a reference Phasor) (5)

From equation (5) $I\angle\gamma$ can be determined for every set of observation.

Again,

$$\frac{E_S\angle 0 - E_R\angle -\delta}{I\angle\gamma} = Z_S\angle\theta_S$$ (6)

From equation (6) $Z_S\angle\theta_S$ will be known for every set of observation.

Again,

$$Z_S\angle\theta_S = r_s + jx_s$$ (7)

From equation (7) $Z_S\angle\theta_S$ and r_s are known so x_s will be known for every set of observation.

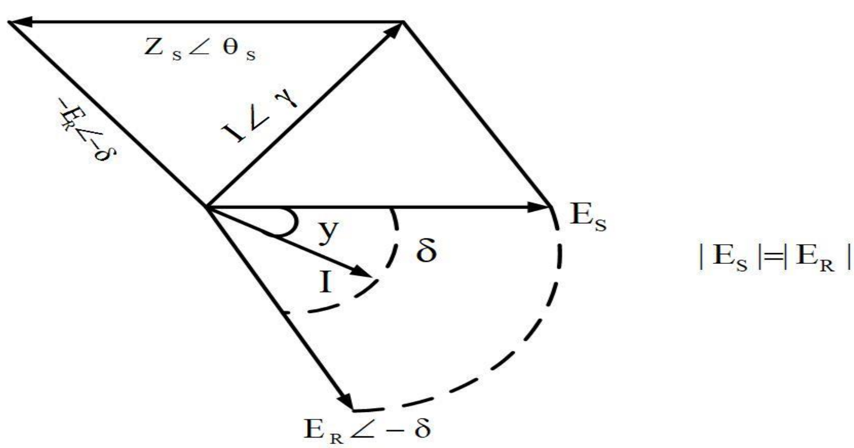


Fig. 3 Phasor diagram for RUN 1

DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Power and Switchgear Lab

Course code: EEC377

Experiment No.: 04

Study of power transfer through a transmission system

TITLE: Study of power transfer through a transmission system.

List of Items:

	Apparatus	Range	Maker
1.	Ammeter	0-2 A	
2.	Voltmeter	0-150/300/600 V	
3.	Digital Phase-angle meter	(0-360°) 0-150/230 V, I (0-10) A	
4.	3-phase, 6-pole, 6 position rotary switch		
5.	Low Power Factor Wattmeter	0-150/300 V, 1A /2 A	
6.	Three pole ON/OFF switch		
7.	Single Phase Variac	0-250 V, 5 A	
8.	Isolation Transformer (3-phase)	110/110 V, 2 A	
9.	Power Supply Transformer (3- phase)	400-415 V/ 110-120 V (10 A), Star/ Delta	
10.	Single pole two way switch	230 V, 5 A	
11.	Indicating Lamps	0-230 V (AC)	
12.	0-2 A Fuses		
13.	Induction Motor type Phase Sequence Indicator		
14.	Single Pole two way Switch	230 V, 5 A	
15.	An Inductor (Linear air gap type) (It represents a short transmission system)	250/300/500 mh, 2 A	
16.	Sheet metal cubicle housing different equipment mentioned above		

Objective:

To plot the power angle diagram of a transmission system under steady state condition and to study the effect of resistance of the line on the power transfer characteristics.

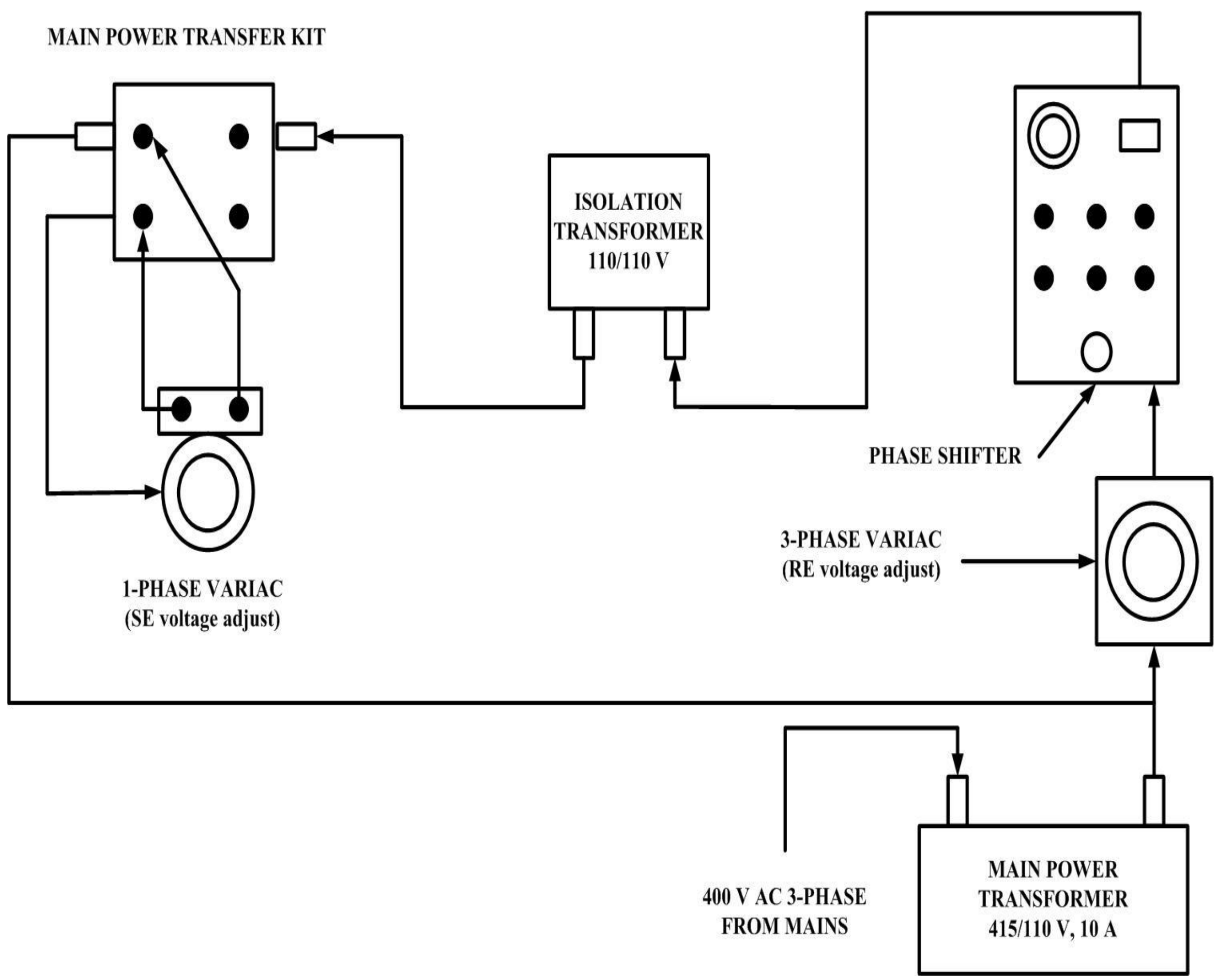
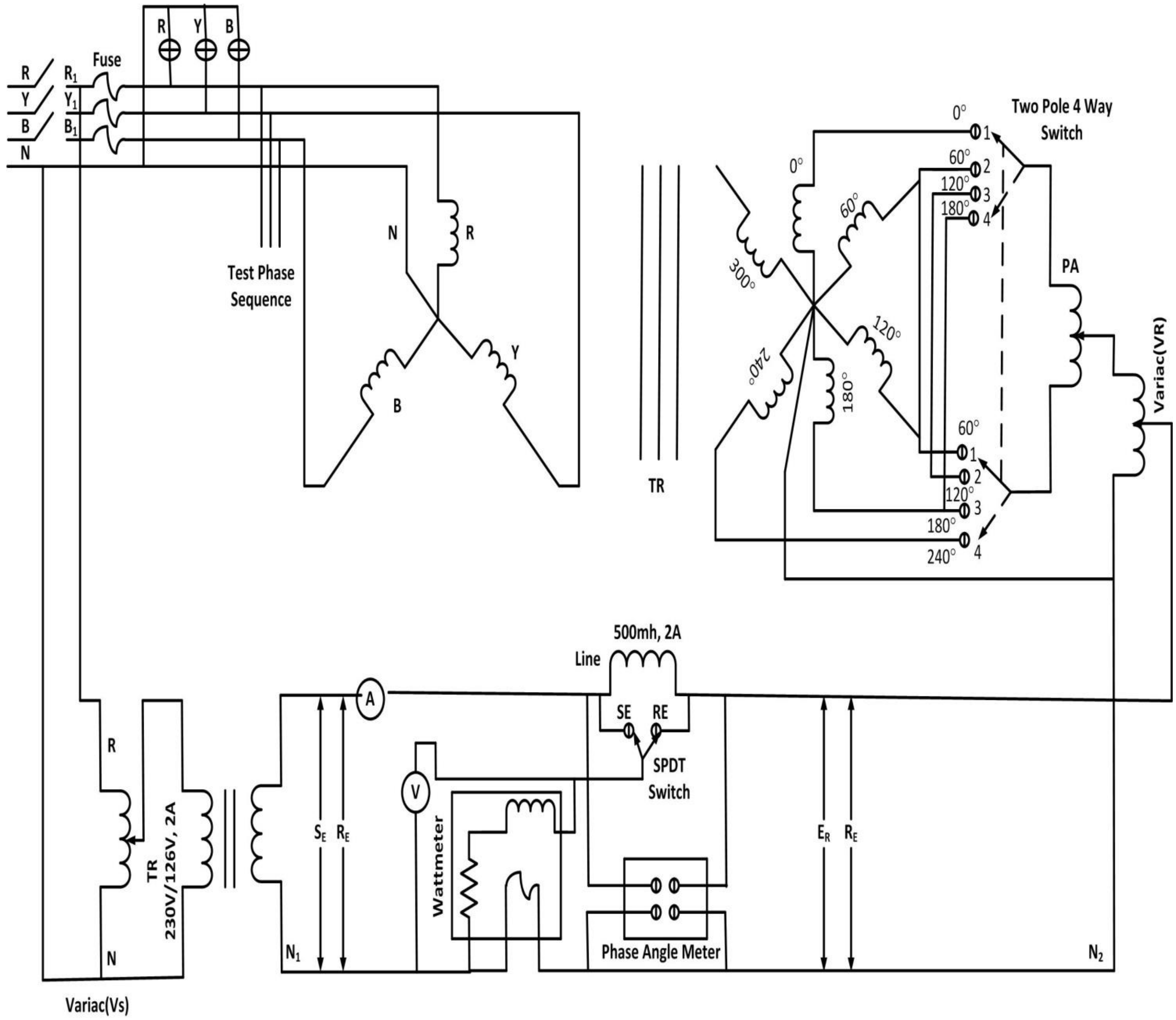


Fig.1 Connection diagram for power transfer experimental set-up

Procedure:

The front view of the power transfer cubicles, and the detail circuit diagram and connection diagrams are shown in figure 1 and 2 respectively.

1) Connect the 3-phase power cable with neutral at the desired terminals provided in the power supply Transformer [i.e. 400-415/ 110-120 V (10A)] cubicle.



2)

3) Fig.2 Power Transfer through Transmission System

4) Now connect the 110 or 120 V secondary to the 3-phase Variac and the main Power Transfer Kit Cubicle's left hand/ Sending End (SE) side through the cable entry grommet
5) [110 V (line-to-line) single phase only].
6) Then connect the output of the Variac to the Phase Shifter input while connecting its output to the Isolation transformer [i.e. 110V/110V, 2A transformer].
7) Connect the output of the Isolation Transformer (single phase, the same phases as connected to the sending end only.) to the main Power Transfer Kit cubicle's right hand/Receiving End (RE) side through the cable entry grommet [110V (line-to-line) single phase on the RE side.]

8) Lastly connect the single phase Variac plug to the power plug socket present on the left hand side of the Main Power transfer cubicle while connecting the Variac outputs to the SE of the Main Power transfer cubicle.
9) Connect the Voltmeter, Ammeter, Wattmeter and the Phase-angle meters as shown in the diagram with the terminals on Main Power transfer cubicle.
10) Switch on the 3-phase, ON/OFF switch (on the Power Supply Transformer) to the 'ON' position and observe that the three indicator lamps glow.
11) Set SE voltage (E_S) and RE voltage (E_R) at a constant value of about 100V by the corresponding Variac. The AC voltages will show the actual value of E_S and E_R by throwing the single pole two way switch in either left-ward or right-ward directions.
12) Set the phase angle to zero degree by adjusting the Variac used for adjusting the phase angle. The 6-pole 6-way course phase shift adjust switch should be in POS-1.
13) Under that condition ammeter reading, wattmeter reading and phase angle meter reading should be zero.

RUN 2

The value of E_S from 30V to 100V in steps of 10V keeping E_R=50V and phase angle at 20° fixed and take ammeter and wattmeter readings.

OBSERVATION TABLE

Sl. No.	Angle (°)	E_S(V)	E_R(V)	I_S(A)	W_S(W)	W_R(W)	Q_S(VAR)	Q_R(VAR)
							To be calculated	To be calculated

THEORY

To measure the reactive power transfer, we are keeping receiving end voltage and phase angle constant while varying the sending end voltage to change the power output.

Known Parameters

7. Angle 'δ' in degrees
8. E_S – Sending end voltage

9. E_R – Receiving end voltage
10. I – Current magnitude in small transmission network in amps
11. W_S – Sending end power in watts
12. W_R – Receiving end power in watts

Unknown Parameters

6. Q_S – Sending end VAR
7. Q_R – Receiving end VAR
8. W_L – Line loss in Watts
9. Angle γ – of current I
10. $Z_S\angle\theta_S = r_s + jx_s$ – the value of the reactor

CALCULATION

Line loss = $W_S - W_R = I^2 r_s$ (1)

From equation (1),

$$r_s = \frac{W \ \ - W_R}{I^2}$$

$(\text{Volt Amp})^2 = (\text{Active Power})^2 + (\text{Reactive Power})^2$ (2)

$(E_S I)^2 = W_S^2 + Q_S^2$ (3)

Hence $|Q_S|$ is known for every observation.

Also,

$(E_R I)^2 = W_R^2 + Q_R^2$ (4)

Hence $|Q_R|$ is known for every observation.

Now,

$$I\angle\gamma = \frac{W_S - jQ_S}{E_S^{\ *}}$$

$$I\angle\gamma = \frac{W_S - jQ_S}{E_S} \quad \text{(Taking } E_S \text{ as a reference Phasor)} \qquad (5)$$

From equation (5) $I\angle\gamma$ can be determined for every set of observation.

Again,

$$\frac{E_S\angle 0 - E_R\angle -\delta}{I\angle\gamma} = Z_S\angle\theta_S \qquad (6)$$

From equation (6) $Z_S\angle\theta_S$ will be known for every set of observation.

Again,

$$Z_S\angle\theta_S = r_S + jx_S \qquad (7)$$

From equation (7) $Z_S\angle\theta_S$ and r_s are known so x_s will be known for every set of observation.

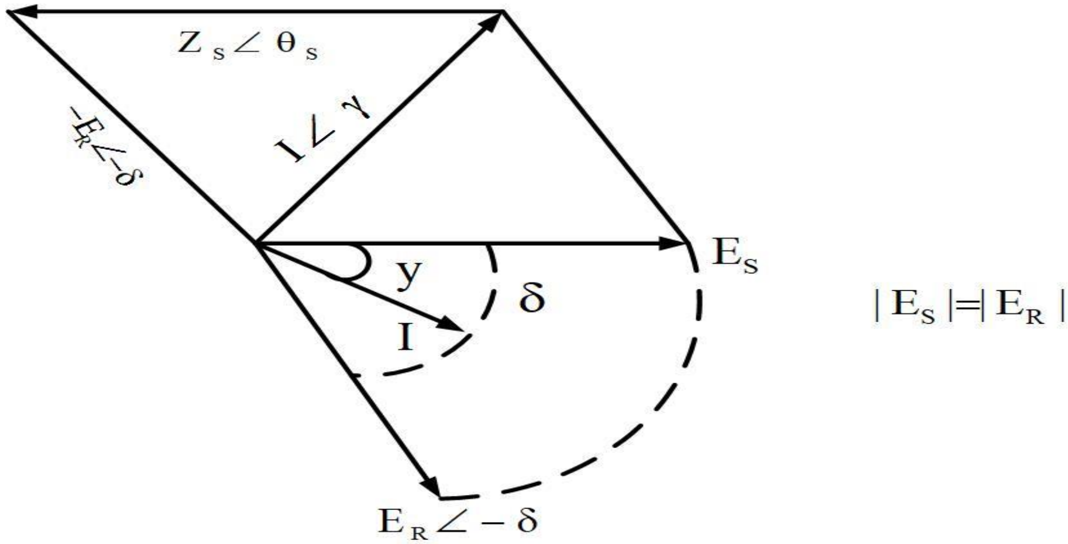


Fig. 3 Phasor diagram for RUN 1

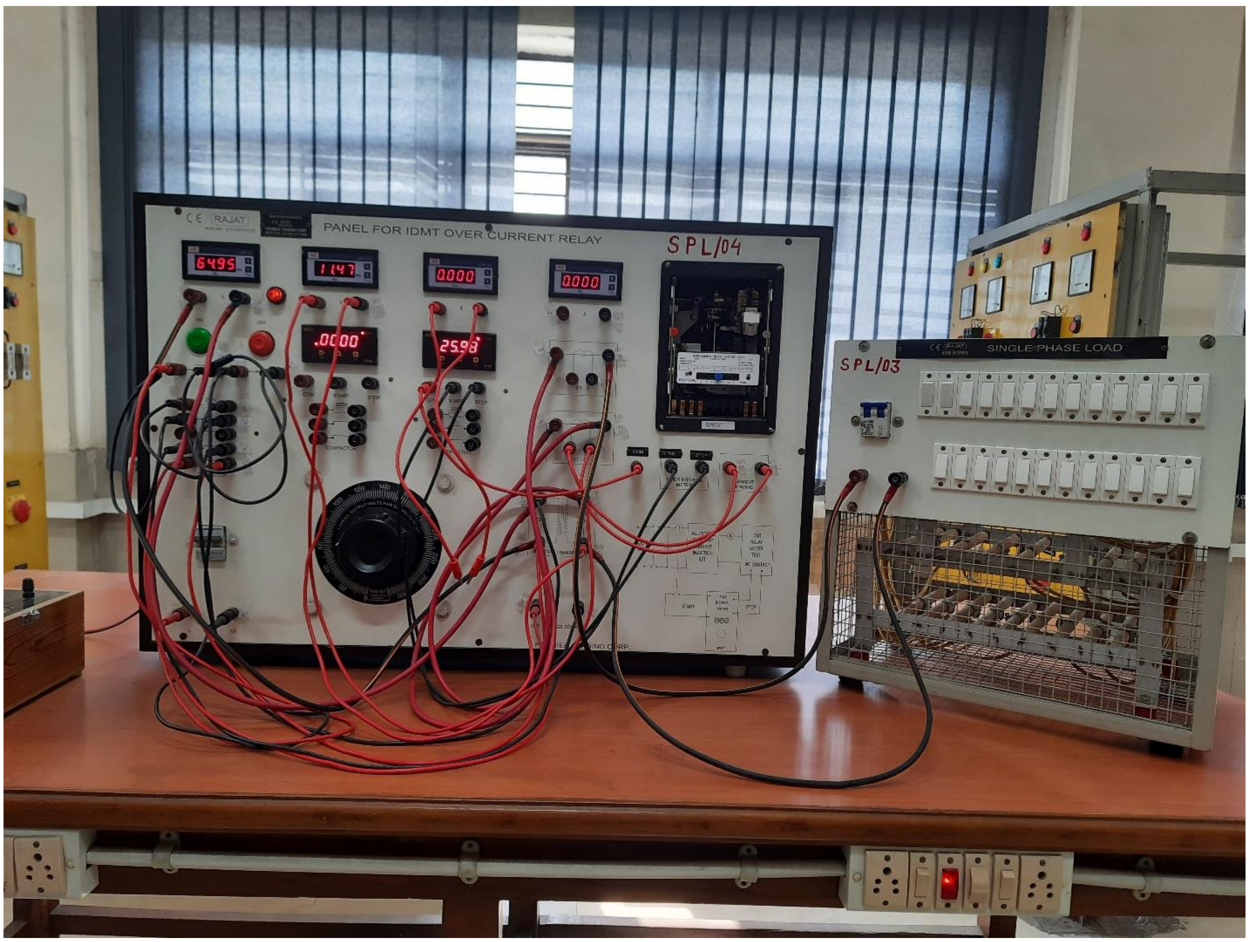
DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Power and Switchgear Lab

Course code: EEC377

Experiment No.: 05

STUDY OF IDMT OVER CURRENT RELAY



TITLE: Study of IDMT over current relay.

OBJECTIVE: To study the characteristics of IDMT over current relay experimentally.

APPARATUS USED:

Sl. No.	Name of the Equipment	Rating	Model No. of the Equipment	Makers Name
1. 2.				

THEORY:

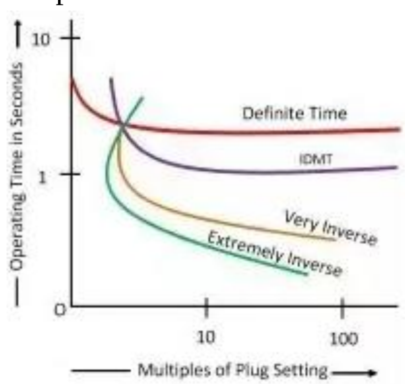
It finds its application from the fact that in the event of fault the current increases to a value several times greater than maximum load current. A relay that operates or picks up when its current exceeds a predetermined value (setting value) is called Over-current Relay. Over-current relay protects electrical power systems against excessive currents caused due to faults. Over-current relays can be used to protect practically any power system elements, i.e. transmission lines, transformers, generators, or motors. For feeder protection, there would be more than one over-current relay to protect different sections of the feeder. These over-current relays need to coordinate with each other such that the relay nearest to the fault operates first.

<u>Inverse Definite Minimum Time (IDMT) Over-current relay:</u>

The IDMT relay is widely used by the utilities in the field. Initially, the characteristics of the relay follows inverse law, and thereafter, when the current becomes very high, it follows definite minimum operating time pattern. This is because of the constant operating torque due to the saturation of flux at a high value of current in the electromechanical relay. The mathematical relation between the current and operating time of IDMT characteristics can be written as,

$$t_{op} = \frac{0.14\ (TMS)}{(PSM)^{0.02} - 1}$$

Where PSM is the plug-setting multiplier and TMS is the time multiplier setting of the relay.



The various important terms used in connection with over-current relays are as follows,

(i) **Pick-up current.** It is the minimum current in the relay coil at which the relay starts to operate. So long as the current in the relay is less than the pick-up value, the relay does not operate and the breaker controlled by it remains in the closed position. However, when the relay coil current is equal to or greater than the pickup value, the relay operates to energize the trip coil which opens the circuit breaker.

(ii) **Current setting.** It is often desirable to adjust the pick-up current to any required value. This is known as current setting and is usually achieved by the use of tappings on the relay operating coil. The taps are brought out to a plug bridge. The plug bridge permits to alter the number of turns on the relay coil. This changes the torque on the disc and hence the time of operation of the relay. The values assigned to each tap are expressed in terms of percentage full-load rating of C.T. with which the relay is associated and represents the value above which the disc commences to rotate and finally closes the trip circuit.

∴ Pick-up current = Rated secondary current of C.T. × Current setting

(iii) **Plug-setting multiplier (PSM).** It is the ratio of fault current in relay coil to the pick-up current i.e.

$$\text{P.S.M} = \frac{\text{Fault current in relay coil}}{\text{Pick} - \text{up current}}$$

(iv) **Time multiplier setting (TMS).** A relay is generally provided with control to adjust the time of operation. This adjustment is known as time-setting multiplier. The time-setting dial is calibrated from 0 to 1.

PROCEDURE:

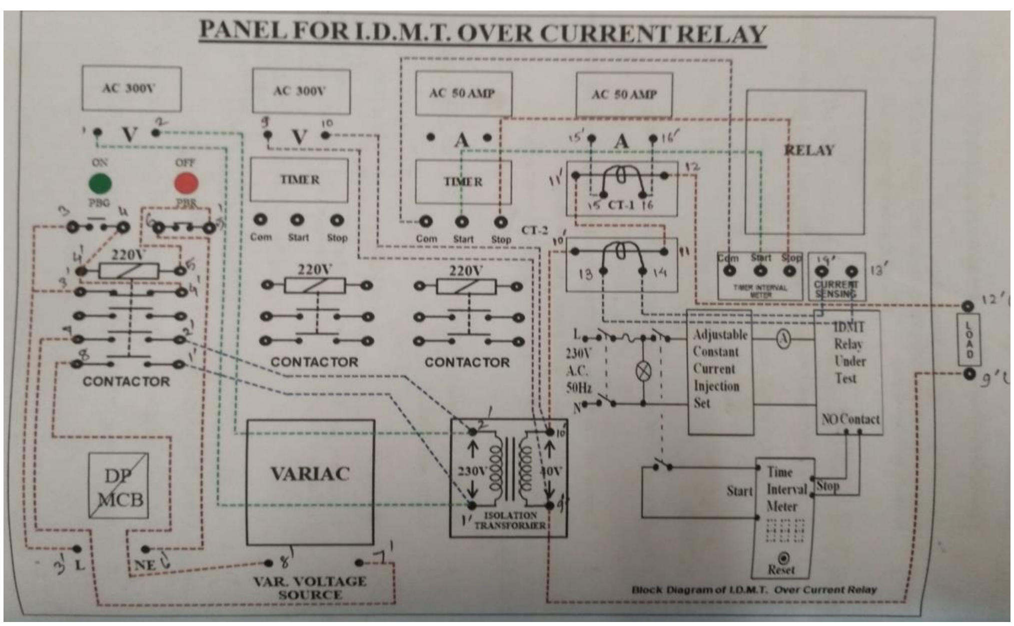


Fig. 1. Schematic diagram of the connected experimental kit.

1. According to the above figure make all the connections of the relay study kit.
2. Set the variac to 230 V.
3. Set PSM=1.
4. Set a particular TSM (=0.5) in the IDMT over current relay.
5. Switch on the green push button.
6. Increase the load.
7. Once the relay start operating note down the fault currents and relay tripping times.
8. Set other TSM (=0.9) in the IDMT over current relay.
9. Repeat step 6-7.
10. Plot the fault current (A) vs. operating time (s) curves for TSM=0.5 and TSM=0.9.

COMMENTS/ DISCUSSIONS:

Write your comments on the results obtained and discuss the discrepancies, if any.

PRECAUTIONS:

1) Turn off the power switch to equipment before making connections.
2) Don’t use broken connecting wires.
3) Maintain a work space clear of extraneous material such as books, papers, and clothes.
4) Don’t wear loose clothes.
5) Wear shoes that cover the feet.

DATA SHEET

Experiment No.: Date:

TITLE: Study of IDMT over current relay.

Name: ______________________________ SEM: ____________ Year: _________

Adm. No.: __________________

Experimental Data:-

Sl. No.	Plug setting (A)	Time setting multiplier (TMS)	Fault current (A)	Trip time (s)
1	1	0.5		
2				
3				
4				
5				
6				

Sl. No.	Plug setting (A)	Time setting multiplier (TMS)	Fault current (A)	Trip time (s)
1	1	0.9		
2				
3				
4				
5				
6				

____

(Signature of the teacher)

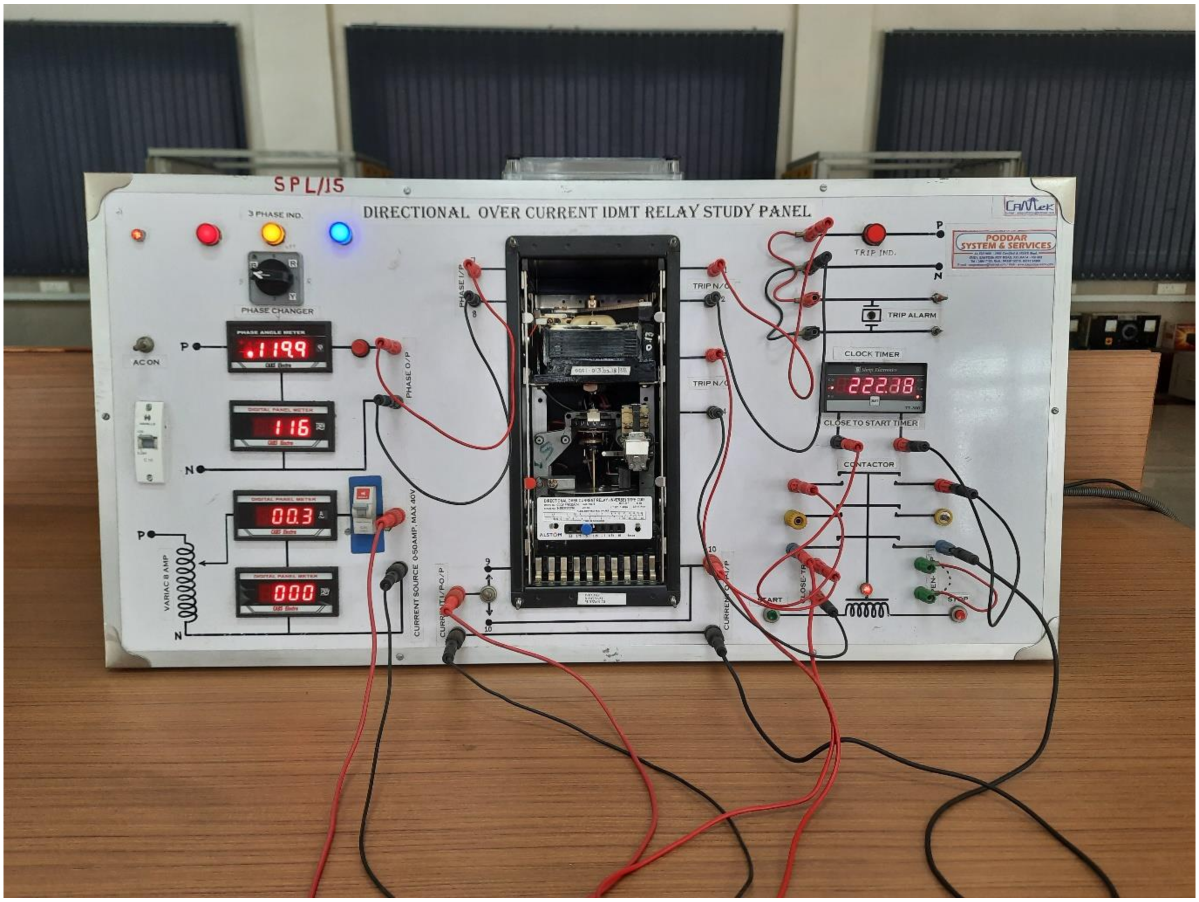
DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Power and Switchgear Lab

Course code: EEC377

Experiment No: 06

<u>STUDY OF DIRECTIONAL OVER CURRENT RELAY</u>



TITLE: Study of Directional Over Current Relay

OBJECTIVE: To study the directional over current relay experimentally.

APPARATUS USED:

Sl. No.	Name of the Equipment	Rating	Model No. of the Equipment	Makers Name
1.				
2.				

THEORY:

In plain radial feeder, the non-directional relays are used as they operate when the CT secondary current exceeds the threshold value of pickup setting in relays. Here, no directional features are used to avoid cost issues regarding both line current and bus voltage data extraction in directional relays. But to obtain fault zone discrimination in case of the protection of parallel feeders and ring main systems, the directional features are necessary. By introducing the directional features in relays, interrupted supply can be made possible at all load points connected in the parallel/ring system.

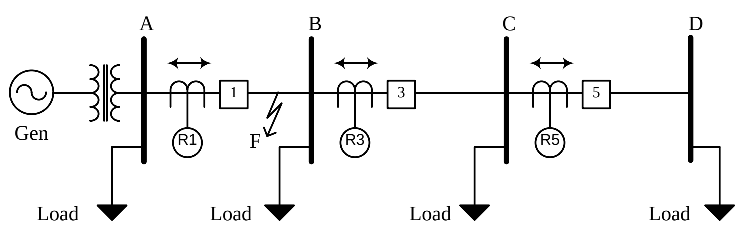


Fig. 1. Single line diagram of a radial system.

In the plain radial feeder shown in Fig. 1, if the breaker 1 trips because of any abnormalities in the section between bus A and bus B, it will interrupt the power supply at the buses B, C and D. Thus, because of the tripping of the first breaker, the load connected to the other buses will not receive any power supply. In case of the same radial feeder is fed from both the ends with the necessary modification in the protection scheme using the directional feature, at relay point R2, R3, R4 and R5 as shown in Fig. 2.

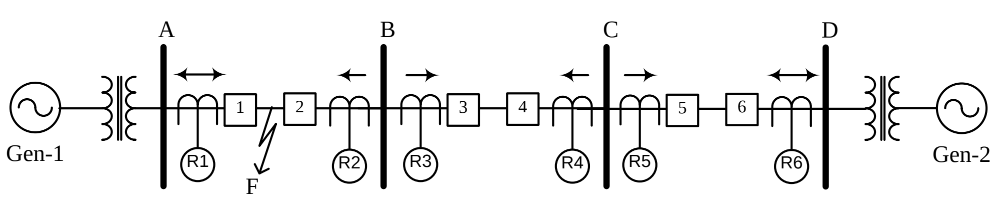


Fig. 2. Double-end feed radial feeder.

In the event of any abnormalities (e.g. faults) in the section between bus A and bus B, the breaker 1 and 2 will isolate the faulty section, without interrupting the supply to the load connected at the buses A, B, C and D. Hence, to discriminate the faulty section, the relay R2 should be direction sensitive so that it operate only in the direction indicated by the arrows as shown in Fig. 2. So the directional relays should operate when the current flows away from the bus where the relay is located and restrain if the current flows towards the bus.

Another power system network containing parallel feeders are shown in Fig. 3. In case a fault occurs on line 1 at point F, the fault is fed from both the buses (A and B) because line 2 is in healthy condition. If the directional feature is provided to the relay R3 (and R4), only relays R1 and R3 trip the respective breakers of line 1 for a fault at F. The relay R2 is graded with the relay R3 in such way the R2 provides backup to R3, if the relay R3 fails to clear the fault on line 1. Similarly, R1 is to be graded with the relay R4.

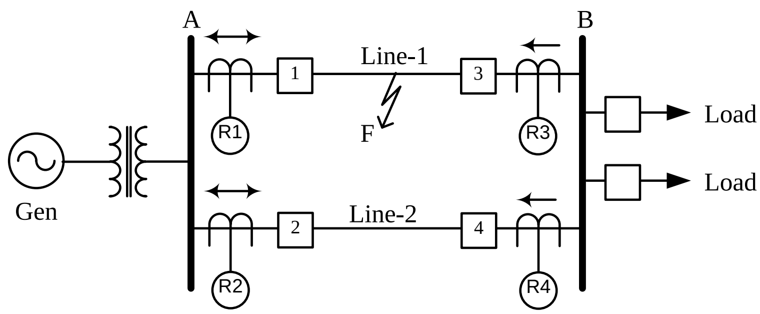


Fig. 3. Single-end feed parallel feeder.

CONNECTION DIAGRAM:

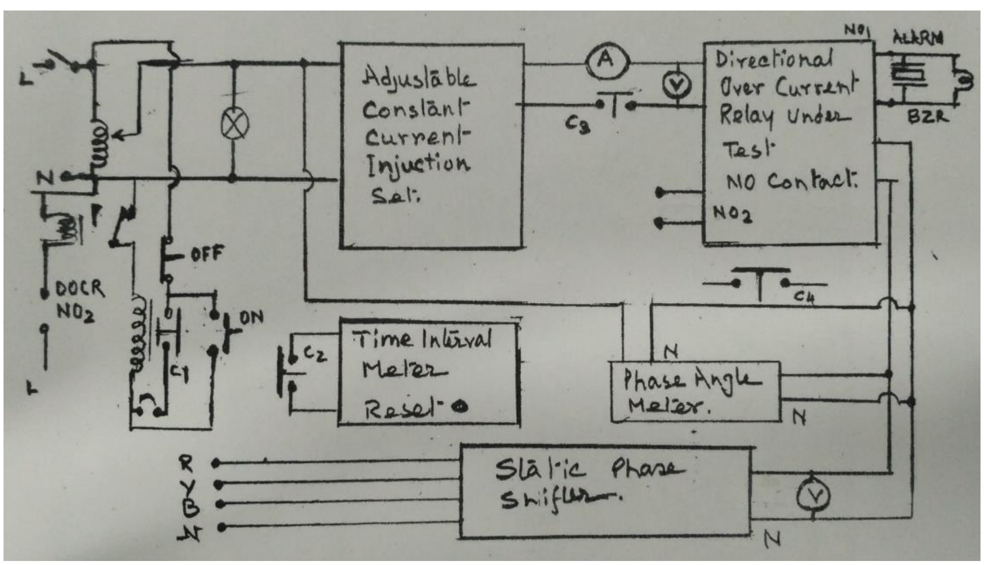


Fig. 4. Connection diagram of the experimental setup.

PROCEDURE:

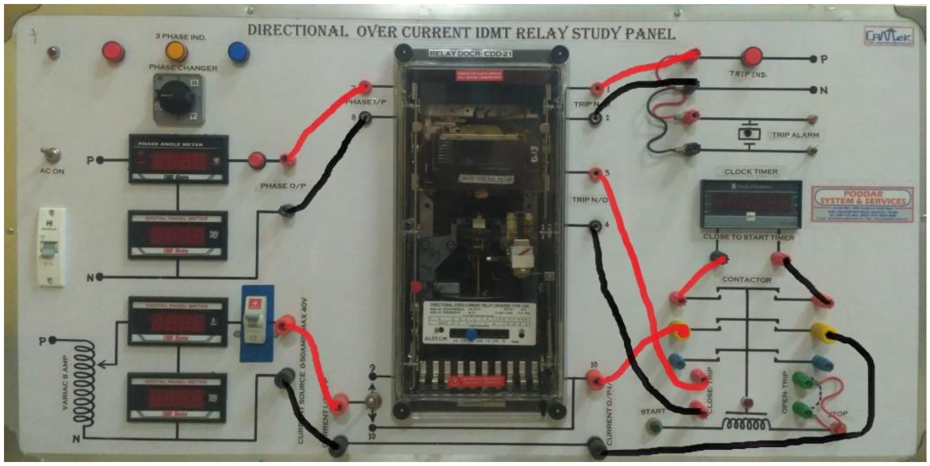


Fig. 5. Connected experimental kit.

1) According to the above figure make all the connections of the relay study kit.
2) Adjust the plug setting.
3) Before power switch on keep the variac in zero position.
4) Now make on the MCBs, AC switch.
5) Switch on green push button for contactor.
6) Rotate the variac and keep the set current value between 2 to 4 times of the plug setting value.
7) If it does not trips, no problem.
8) Now push the red push button, rotates the variac to zero.
9) Change the direction of current.
10) Follow step 5-6.
11) If trips push the red push button, keep the variac to previous position and again switch on green push button.
12) Note down the trip time.
13) Change the polarity.
14) Follow step 10-12.
15) Change the phase angle.
16) Follow step 10-12.

COMMENTS/ DISCUSSIONS:

Write your comments on the results obtained and discuss the discrepancies, if any.

PRECAUTIONS:

6) Turn off the power switch to equipment before making connections.
7) Don’t use broken connecting wires.
8) Maintain a work space clear of extraneous material such as books, papers, and clothes.
9) Don’t wear loose clothes.
10) Wear shoes that cover the feet.

DATA SHEET

Experiment No. Date:

TITLE: Study of Directional Over Current Relay

Name: ________________________________ SEM: _____________ Year: ___________

Adm. No. ____________________

Experimental Data:-

Case-I: Change in current direction

Sl. No.	Plug setting	Set current (A)	Phase angle (^{0})	Trip time (s)

Case-II: Change in polarity

Sl. No.	Plug setting	Set current (A)	Phase angle (^{0})	Trip time (s)

Case-III: Change in phase angle

Sl. No.	Plug setting	Set current (A)	Phase angle (^{0})	Trip time (s)

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(Signature of the teacher)

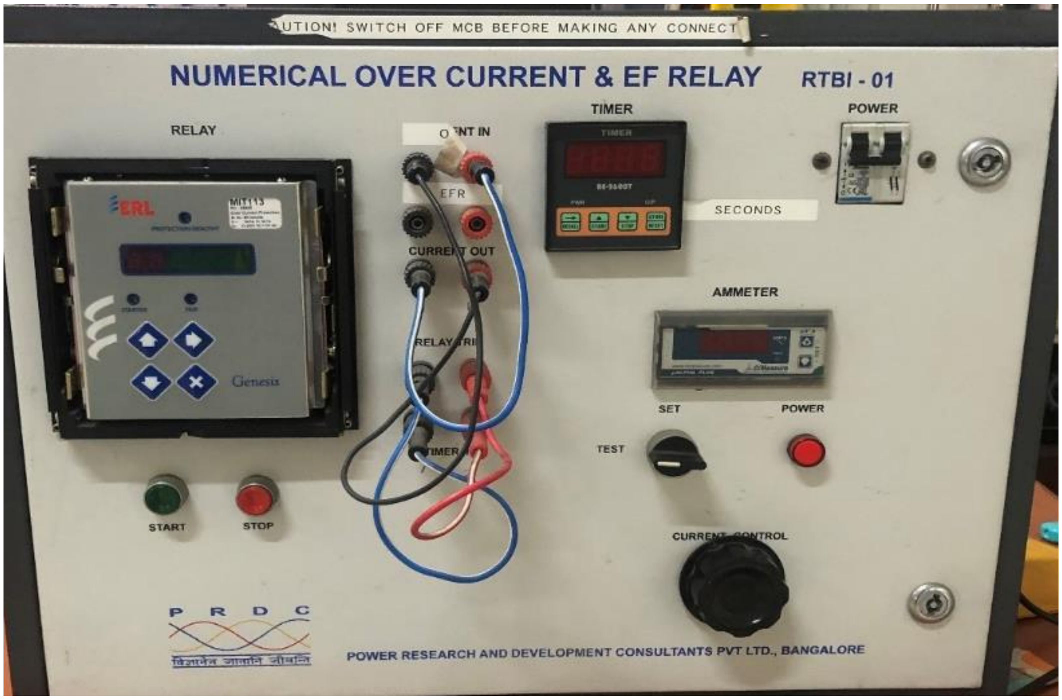
DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Power and Switchgear Lab

Course code: EEC377

Experiment No: 07

<u>STUDY AND APPLICATION OF NUMERICAL TYPE OVER CURRENT RELAY FOR DISTRIBUTION LINE PROTECTION</u>



TITLE: Study and application of numerical type over current relay for distribution line protection.

OBJECTIVE: To study the characteristics of numerical type over current relay and its application for protection of distribution lines experimentally.

APPARATUS USED:

Sl. No.	Name of the Equipment	Rating	Model No. of the Equipment	Makers Name
1.				
2.				

THEORY:

An over current relay has a current coil when normal current flows through it the magnetic field generated is not sufficient to move the restraining coil as restraining torque is greater than operating torque

In case of abnormal conditions fault current i.e. $I > I_{th}$, generated magnetic field effect produce deflecting torque which is greater than restraining coil torque hence change in constant position in relay.

Numerical over current relay is a microprocessor-based relay which follows certain inbuilt algorithm for its operating time by changing TSM as well as operating current by adjusting PSM.

$$TSM = \frac{Actual\ time\ of\ relay\ operation}{Time\ of\ operation\ time\ at\ (TSM = 1\ )}$$

$$t_{op} = \frac{80 * TMS}{\left[\left(\frac{Fault\ current}{Pick\ up\ Current}\right)^2 - 1\right]}$$

Where I_{th} = Current Threshold,
I = fault current,
t_{op} = operating time,
PSM = Plug setting multiplier ($\frac{Fault\ current}{Pick\ up\ current}$),
TMS = time multiplier setting.

CONNECTION DIAGRAM:

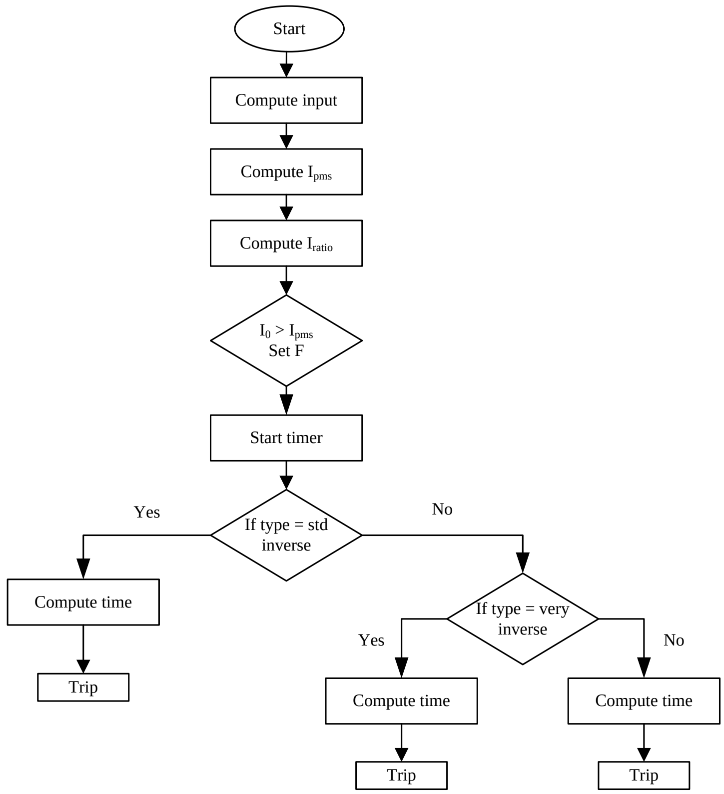


Fig. 4. Flow chart of the experimental setup.

PROCEDURE:

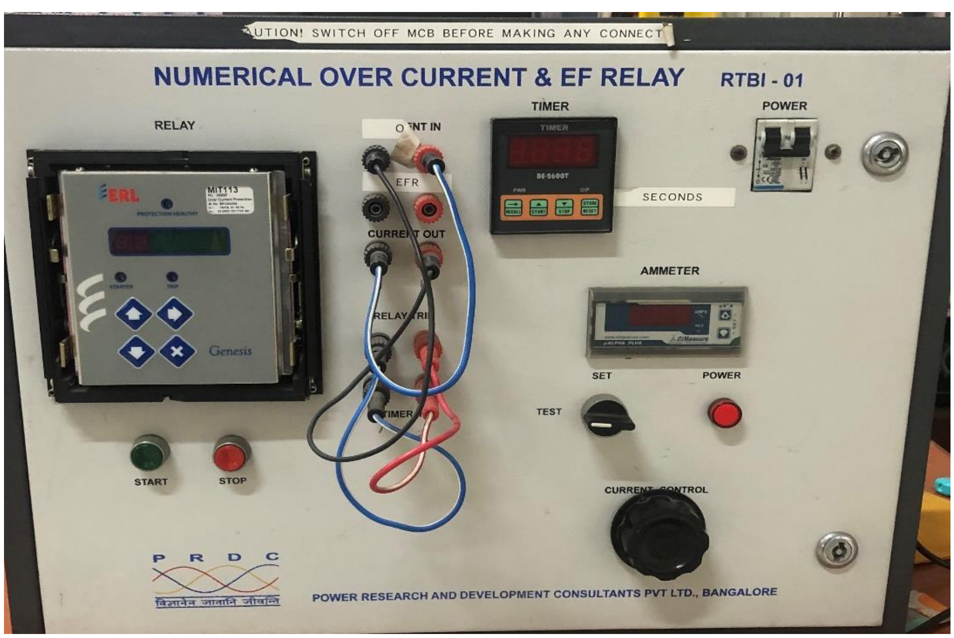


Fig. 5. Connected experimental kit.

1) According to the above figure make all the connections of the relay study kit.
2) Adjust the plug setting.
3) Before power switch on keep the variac in zero position.
4) Now make on the MCBs, AC switch.
5) Switch on green push button for contactor.
6) Rotate the variac and keep the set current value between 2 to 4 times of the plug setting value.
7) Note down the trip time.
8) Follow step 6-7.
9) Draw the graph for operating characteristics of over current

COMMENTS/ DISCUSSIONS:

Write your comments on the results obtained and discuss the discrepancies, if any.

PRECAUTIONS:

1) Turn off the power switch to equipment before making connections.
2) Don't use broken connecting wires.
3) Maintain a work space clear of extraneous material such as books, papers, and clothes.
4) Don't wear loose clothes.
5) Wear shoes that cover the feet.

Experimental setup of over-current relay-based distribution system feeder protection

DATA SHEET

Experiment No. Date:

TITLE: Study and application of numerical type over current relay for distribution line protection.

Name: ______________________ SEM: ____________ Year: __________

Adm. No. ____________________

Experimental Data:-

Case-I: Plug Setting = 120% = 1.2A (i) TMS = 0.5 sec

Sl. No.	Fault Current (V)	Operating Time (ms)	PSM

Case-II: Plug Setting = 120% = 1.2A (i) TMS = 1 sec

Sl. No.	Fault Voltage (V)	Operating Time (ms)	Calculated Time (ms)

Fault type	Fault location (km)	Fault current (A)	Fault type	Fault location (km)	Fault current (A)
A-G	120		A-B	120	
B-G			B-C		
C-G			C-A		
A-B-C			A-B-G		

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(Signature of the teacher)

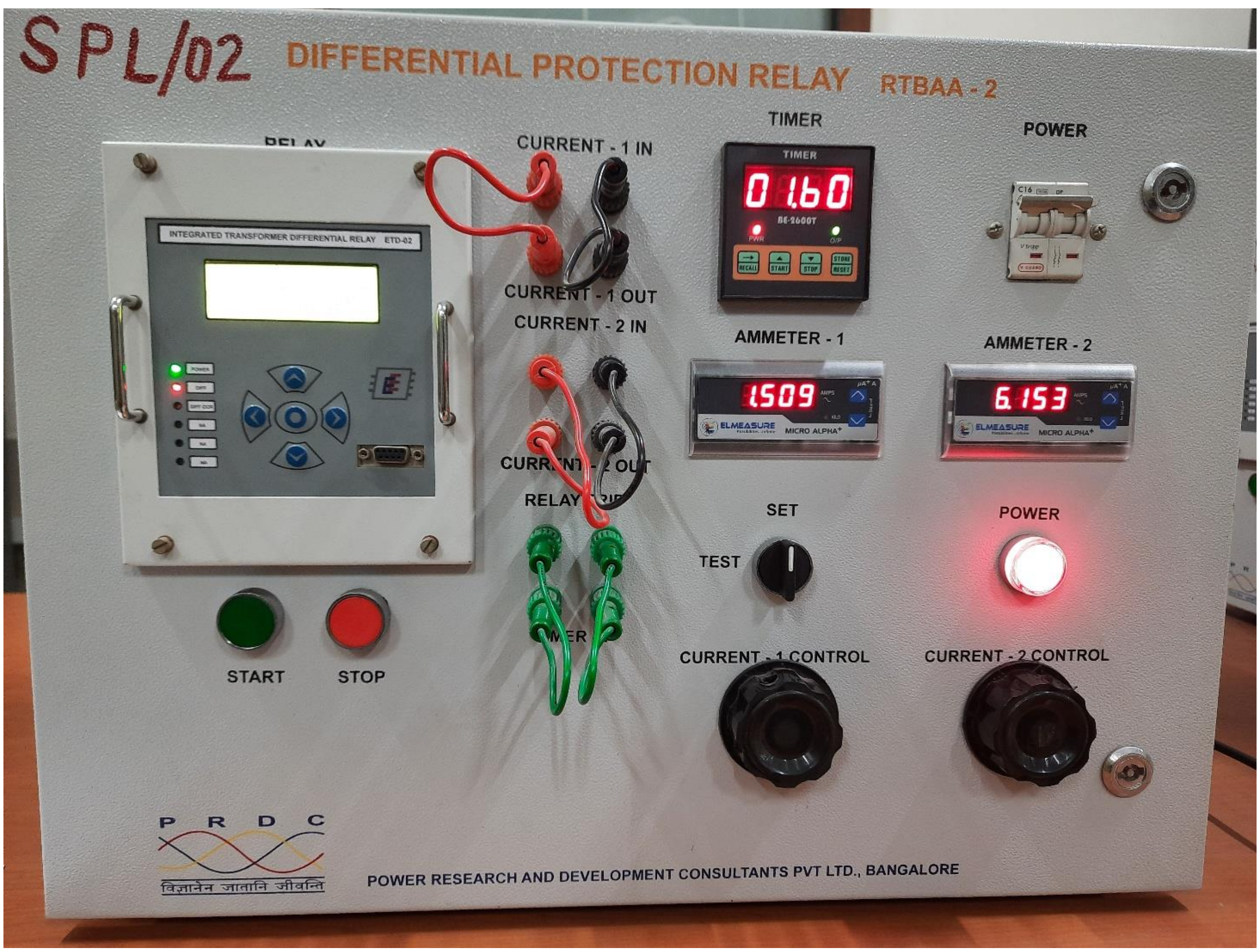
DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Power and Switchgear Lab

Course code: EEC377

Experiment No: 08

STUDY OF NUMERICAL TYPE DIFFERENTIAL RELAY



TITLE: Study of numerical type differential relay

OBJECTIVE: To determine the operating characteristic of a numerical differential protection scheme.

APPARATUS USED:

Serial No.	Name of the Equipment	Rating	Model No. of the Equipment	Makers Name
1.				
2.				

THEORY:

Differential protection is a method of protection in which an internal fault is identified by comparing the electrical conditions at the terminals of the electrical equipment to be protected. It is based on the fact that any internal fault in an electrical equipment would cause the current entering it to be different from that leaving it. Differential protection is one of the most sensitive and effective methods of protections of electrical equipment against internal faults. The differential protection is called unit protection because it is confined to protection of a particular equipment of a power system.

PERCENTAGE OR BIASED DIFFERENTIAL RELAY:

The schematic diagram of the percentage (biased) differential relay is shown in Figure 1. This relay has two coils. One coil is known as restraining coil or bias coil which restrains the operation of the relay. Another coil is the operating coil which produces the operating torque for the relay. When the operating torque exceeds the restraining torque, the relay operates. The operating coil is connected to the mid-point of the restraining coil as show in the Figure 1. N_r and N_0 are the total number of turns of the restraining coil and the operating coil, respectively. Since the restraining coil is tapped at the centre, it forms two sections with equal number of turns, $N_r/2$. The restraining coil is connected in the circulating current path in such a way that current I_{1s} flows through one section of $N_r/2$ turns and I_{2s} flows through the another section of $N_r/2$, so that the complete restraining coil of N_r turns receives the through fault current of $(I_{1s}+I_{2s})/2$. The operating coil, having N_0 number of turns, is connected in the difference path, so that it receives the differential current, $(I_{1s} - I_{2s})$.

The operating condition of the percentage differential relay can be derived as follows:

The relay operates if the operating torque produced by the operating coil is more that the restraining torque produced by the restraining coil. As the torque is proportional to the ampere-turns (AT), the relay will operate when the ampere-turns of the operating coil (AT_O), will be greater that ampere-turns of the restraining coil, (AT_R).

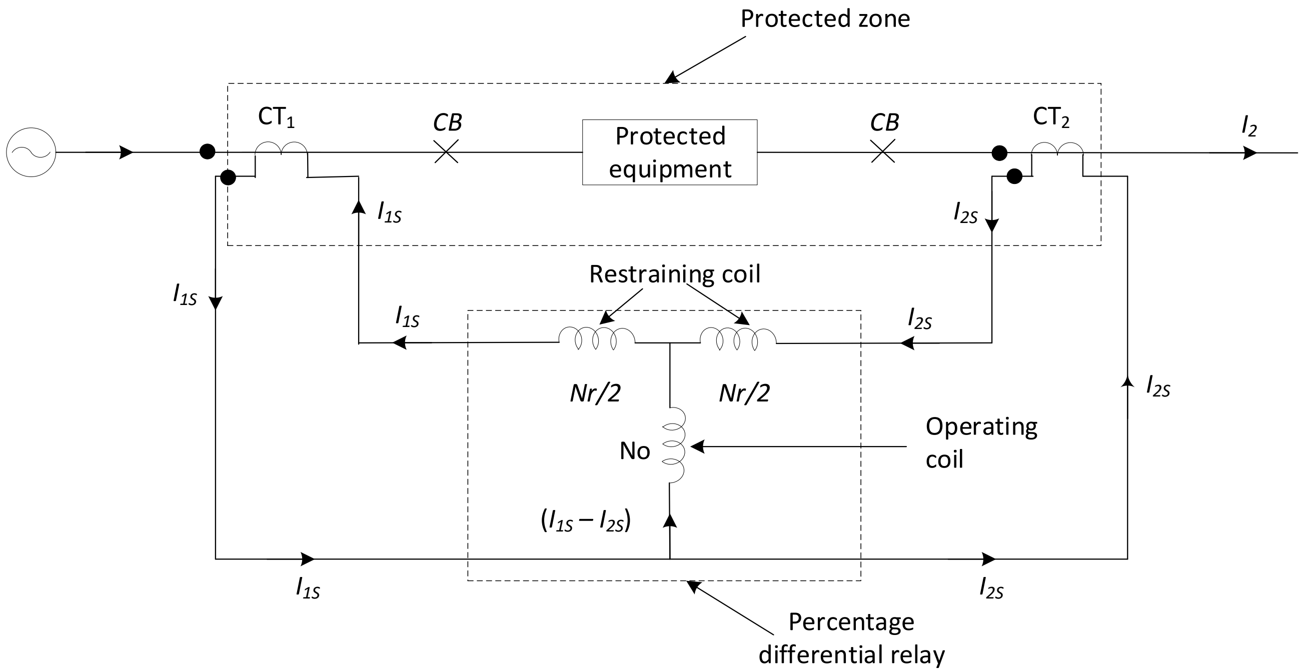


Figure 1. Percentage (biased) differential relay

Ampere-turns of the left-hand section of the restraining coil = $\frac{N_r}{2} I_{1S}$

Ampere-turns of the right-hand section of the restraining coil = $\frac{N_r}{2} I_{2S}$

Total ampere-turns of the restraining coil, $AT_R = \frac{N_r}{2}(I_{1S} + I_{2S})$

$$= N_r \frac{(I_{1S}+I_{2S})}{2}$$

Thus it can be assumed that the entire N_r turns of the restraining coil carries a current $(I_{1s}+I_{2s})/2$. The current $(I_{1s}+I_{2s})/2$ which is the average of the secondary currents of the CTs (CT_1 and CT_2) is known as the 'through current' or restraining current, I_R, Hence

$$I_R = (I_{1s}+I_{2s})/2$$

The ampere-turns of the operating coil, $AT_O = N_0\,(I_{1s} - I_{2s})$

Neglecting spring restraint, the relay will operate when,

$$AT_O > AT_R$$

Or $$N_0\,(I_{1s} - I_{2s}) > Nr\,(I_{1s}+I_{2s})/2$$

Or $$(I_{1s} - I_{2s}) > \frac{N_r}{N_0} \frac{(I_{1S}+I_{2S})}{2}$$

Or $$I_D > KI_R$$

Where, $I_D = (I_{1s} - I_{2s})$ is the differential current through the operating coil. Hence it is also called the differential operating current.

$I_R = (I_{1s} - I_{2s})/2$ is the restraining current or through current

And $K = \frac{N_r}{N_0}$ = Slope or Bias

K (Slope or Bias) is generally expressed as a percentage value.

The relay will be on the verge of operation when:

$$(I_{1s} - I_{2s}) = \frac{N_r}{N_0} \frac{(I_{1S}+I_{2S})}{2}$$

Or $$I_D > KI_R$$

Thus, at the threshold of operation of the relay, the ratio of the differential operating current (I_D) to the restraining current (I_R) is a fixed percentage; and for operation of the relay the differential operating current must be greater than this fixed percentage of the restraining (through fault) current. Hence, this relay is called 'percentage differential relay'. The percentage differential relay is also known as 'bias differential relay'. The operating characteristics of this relay is shown in Figure 2.

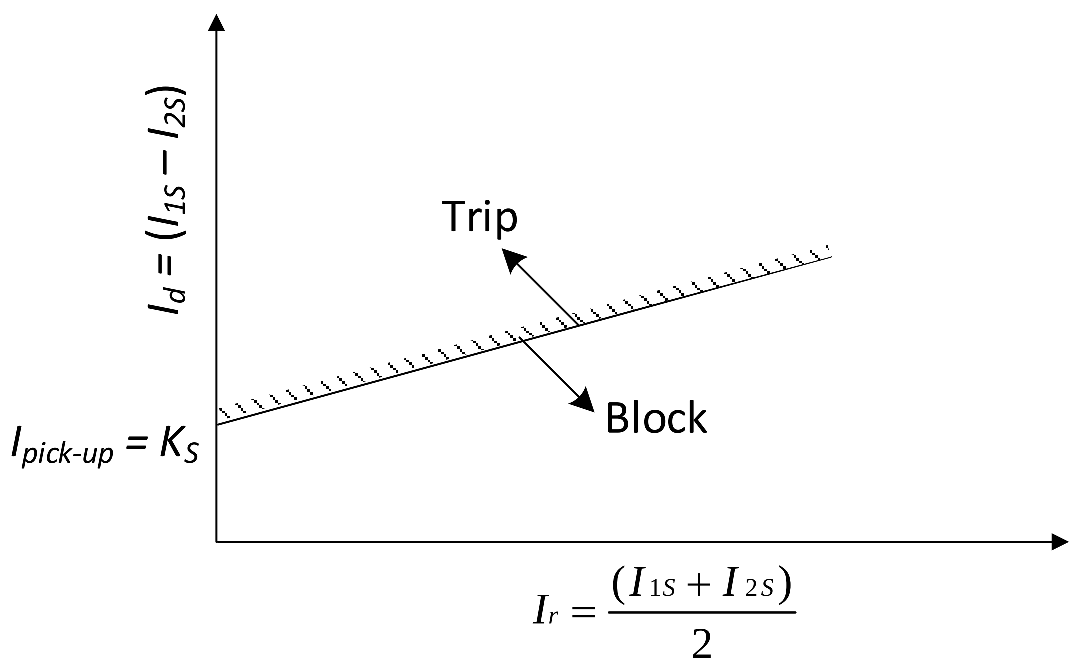


Figure 2. Operating characteristic of percentage differential relay

EXPERIMENTAL SETUP:

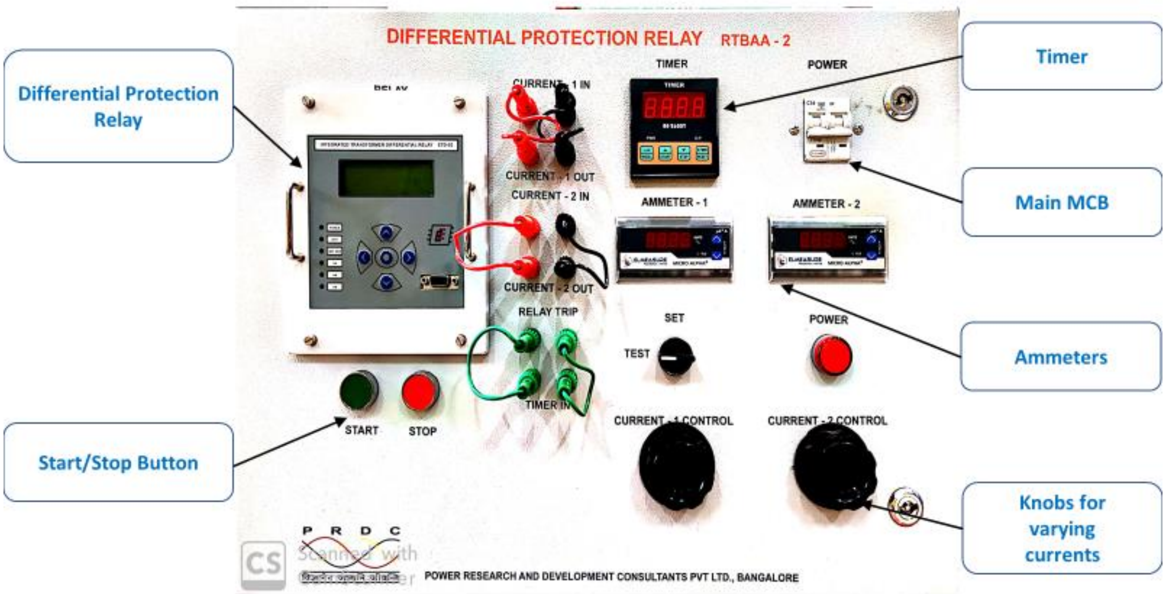


Figure 3. Experimental setup for percentage biased differential test kit.

PROCEDURE:

Procedure for testing the bias characteristics

1. Note the bias setting set in the relay.
2. Prepare the test kit and connect primary and secondary current to the relay.
3. Switch on the test kit.
4. Keep TEST/SET mode switch in SET mode.
5. Slowly increase both primary and secondary current equally so that sum is less than two amperes and relay should not pickup.
6. Slowly increase or decrease one of the currents till the required currents in source 1 and source 2 are obtained.
7. Note the primary, secondary and the differential current.
8. Repeat the above (from 3 to 6) for different values of currents.
9. Switch off the kit.
10. Tabulate the result and draw the graph.

The test points are calculated as follows:

$$I_D = I_1 - I_2,\ I_R = (I_1 + I_2)/2$$

COMMENTS/ DISCUSSIONS:

Write your comments on the results obtained and discuss the discrepancies, if any.

PRECAUTIONS:

1) The current must be maintained at minimum position.
2) Check the supply voltage.
3) Test kit must be grounded.
4) Use personal protective devices such as shoes, gloves before starting the experiments.
5) Proper fusing for incoming terminals.

<u>DATA SHEET</u>

Experiment No.: Date:

TITLE: Study of Numerical Type Differential Relay

Name: ______________________________ SEM: ____________ Year: _________

Adm. No. __________________

Experimental Data:-

Sl. No.	Test Points		I_1 (A)	I_2 (A)	Trip Status (Practical)	Trip Status (Theoretical)
	I_{diff} (A)	I_{bias} (A)				

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(Signature of the teacher)