DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Advanced Power System Protection Lab

Course code: EEC514

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

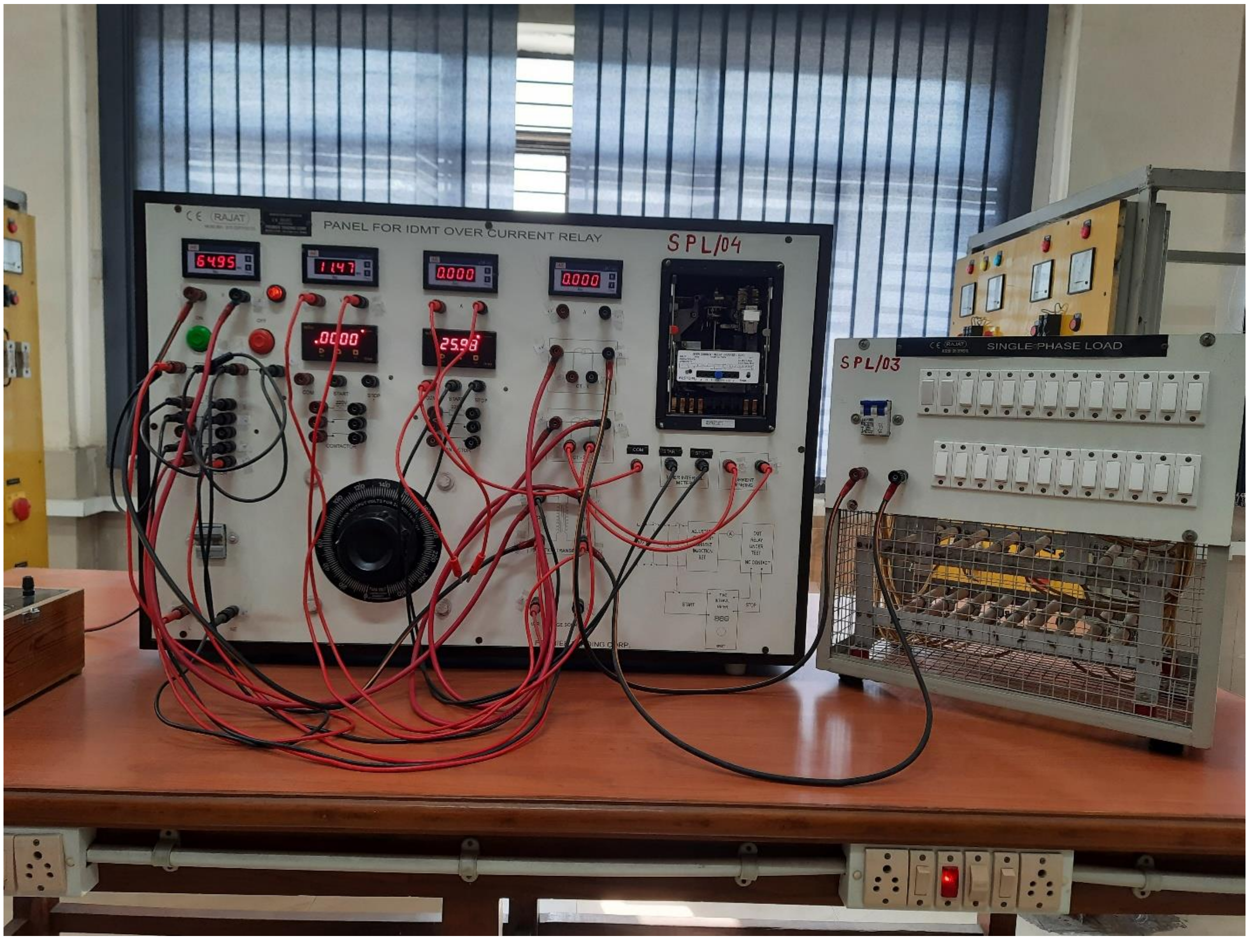
DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Advanced Power System Protection Lab

Course code: EEC514

Experiment No.: 01

A. STUDY OF IDMT OVER CURRENT RELAY



TITLE: Study of IDMT over current relay.

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

APPARATUS USED:

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

THEORY:

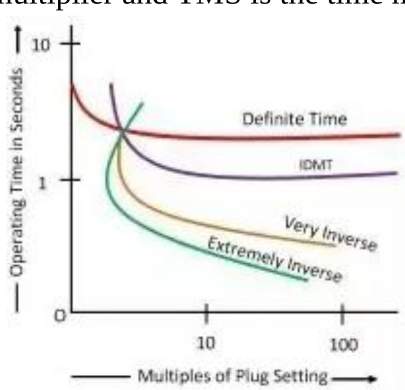
It finds its application from the fact that in the event of fault the current increases to a value several times greater than maximum load current. A relay that operates or picks up when its current exceeds a predetermined value (setting value) is called Over-current Relay. Over-current relay protects 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.

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

(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:

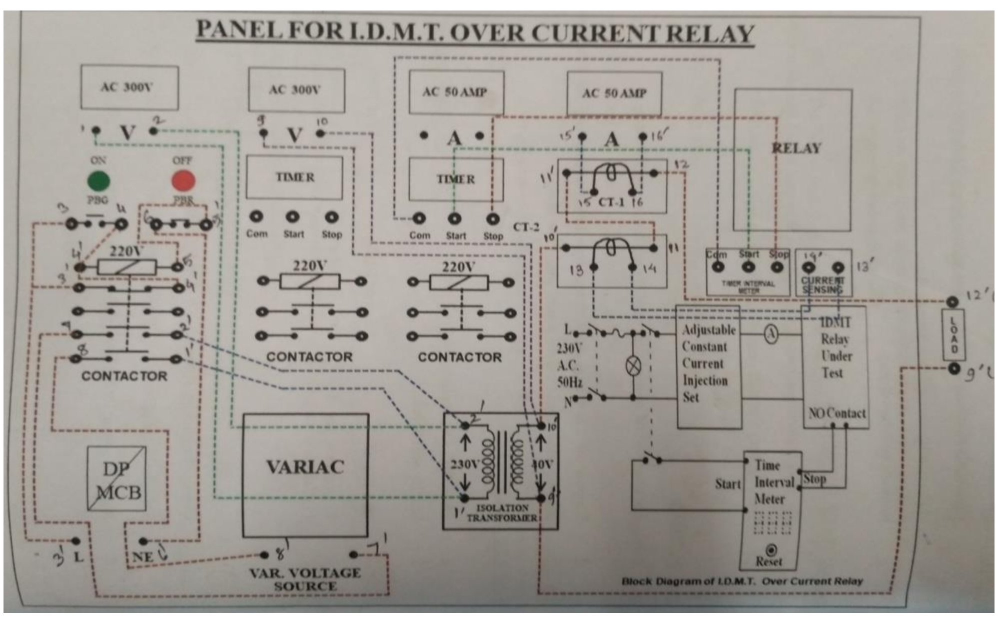


Fig. 1. Schematic diagram of the connected experimental kit.

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				

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(Signature of the teacher)

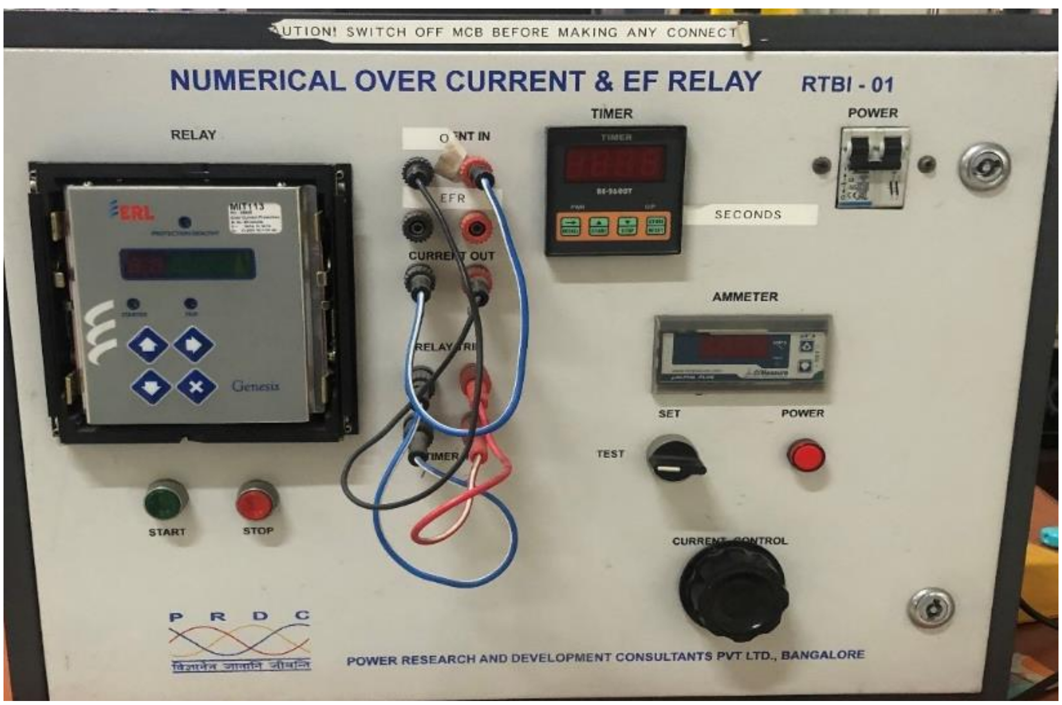
DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Advanced Power System Protection Lab

Course code: EEC514

<u>Experiment No.: 01</u>

B. <u>STUDY 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 through experiment.

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:

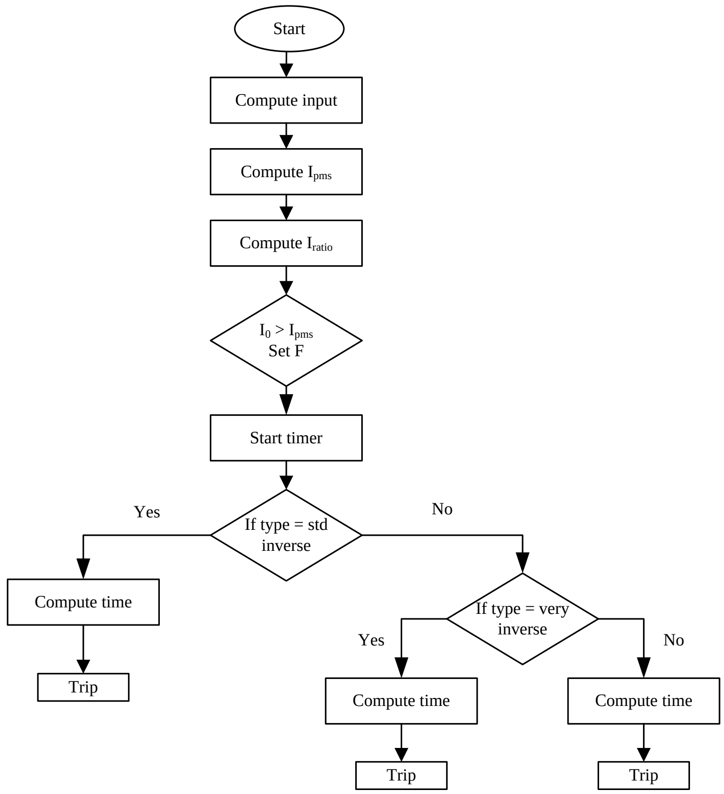


Fig. 4. Flow chart of the experimental setup.

PROCEDURE:

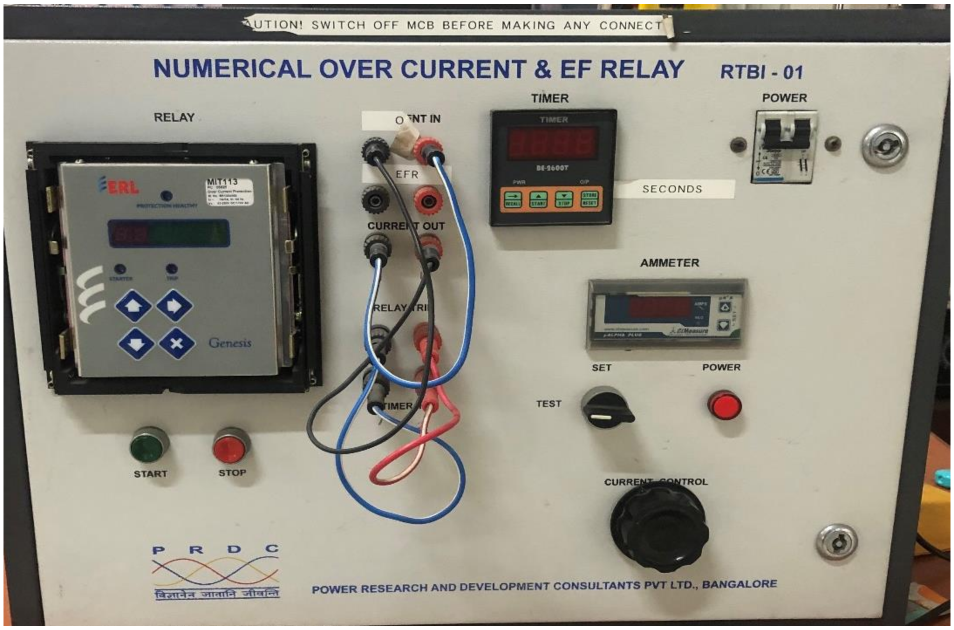


Fig. 5. Connected experimental kit.

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.

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)

<table>
<tr><th>Fault type</th><th>Fault location (km)</th><th>Fault current (A)</th><th>Fault type</th><th>Fault location (km)</th><th>Fault current (A)</th></tr>
<tr><td>A-G</td><td rowspan="4">120</td><td></td><td>A-B</td><td rowspan="4">120</td><td></td></tr>
<tr><td>B-G</td><td></td><td>B-C</td><td></td></tr>
<tr><td>C-G</td><td></td><td>C-A</td><td></td></tr>
<tr><td>A-B-C</td><td></td><td>A-B-G</td><td></td></tr>
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(Signature of the teacher)

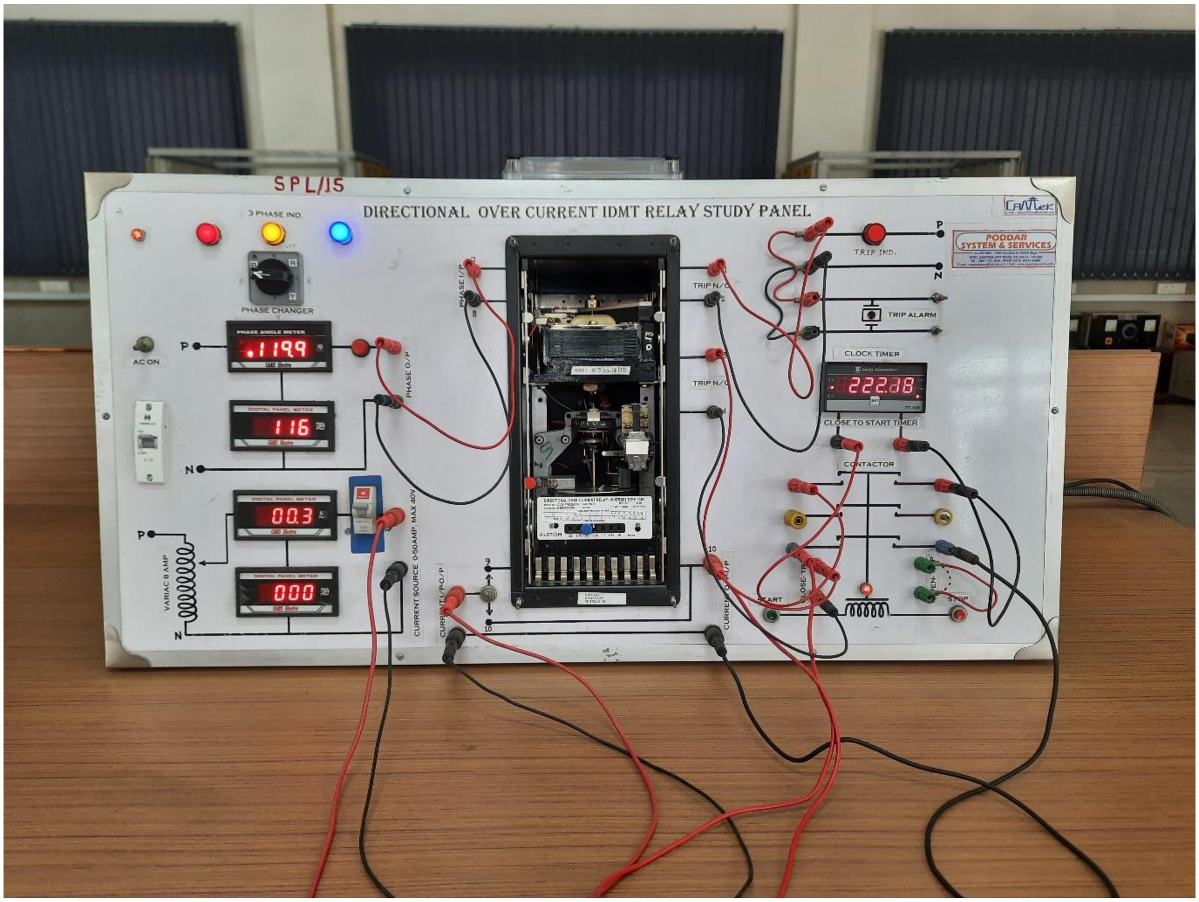
DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Advanced Power System Protection Lab

Course code: EEC514

Experiment No: 02

STUDY OF DIRECTIONAL OVER CURRENT RELAY



TITLE: Study of Directional Over Current Relay

OBJECTIVE: To study the directional over current relay through experiment.

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.

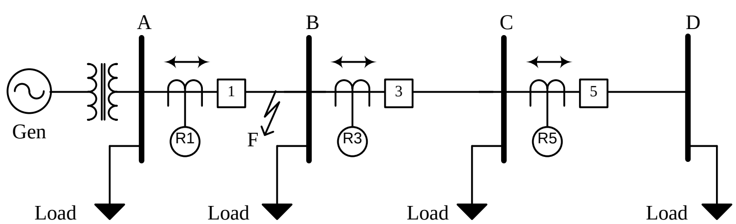


Fig. 1. Single line diagram of a radial system.

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.

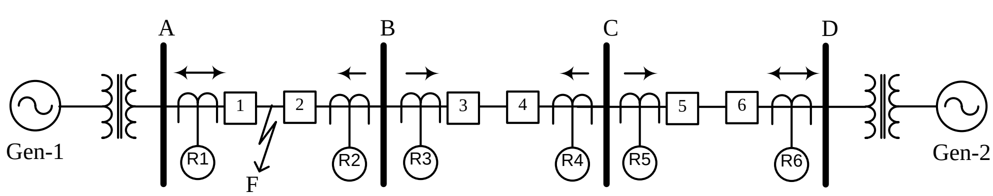


Fig. 2. Double-end feed radial feeder.

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 operates 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.

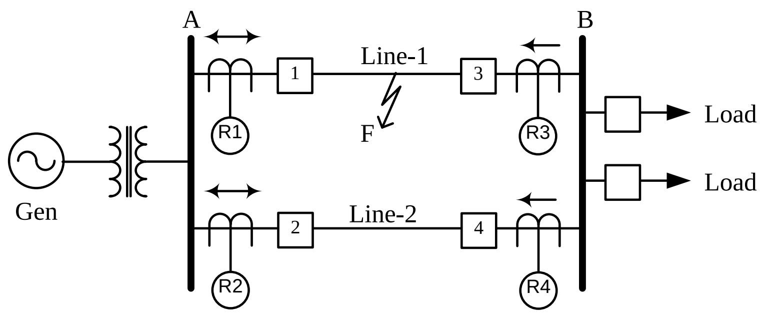


Fig. 3. Single-end feed parallel feeder.

CONNECTION DIAGRAM:

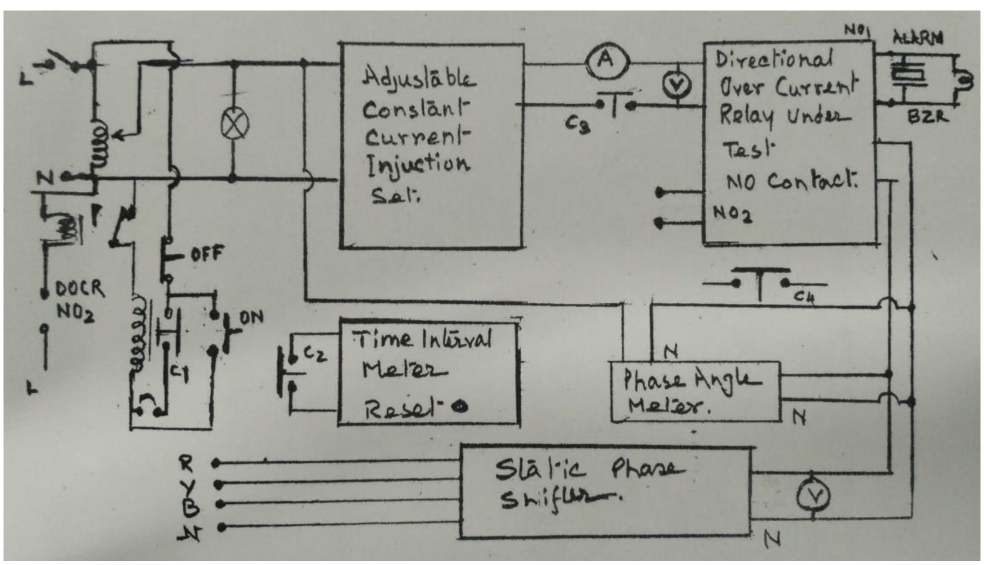


Fig. 4. Connection diagram of the experimental setup.

PROCEDURE:

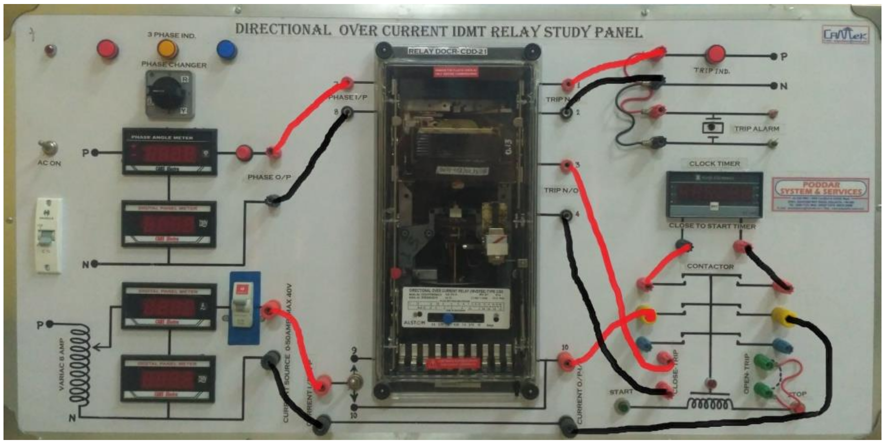


Fig. 5. Connected experimental kit.

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)

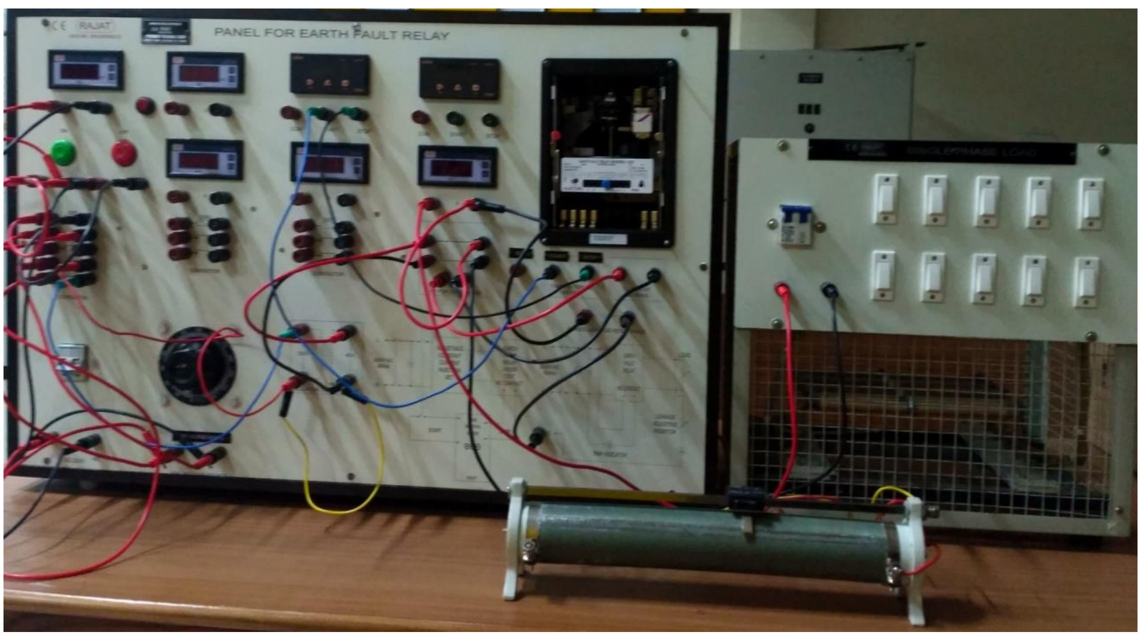
DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Advanced Power System Protection Lab

Course code: EEC514

Experiment No: 03

STUDY OF EARTH FAULT RELAY



TITLE: Study of Earth Fault Relay

OBJECTIVE: To study the characteristics of earth fault relay through experiment.

APPARATUS USED:

Serial 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 will increase 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 protection protects electrical power systems against excessive currents which are caused by short circuits, ground faults, etc. 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 fault operates first.

Ideal inversion of time characteristics cannot be achieved in an over current relay .As the current in the system increases, the secondary current of the current transformer is increased proportionally. The secondary current enters the relay current coil. But when the CT becomes saturated, there would not be a further proportional increase of CT secondary current with increased system current. From this phenomenon, it is clear that from trick value to certain range of faulty level, an inverse time relay shows specific inverse characteristic. But after this level of fault, the CT becomes saturated and relay current does not increase further with increasing faulty level of the system. As the relay current does not increase further, there would not be any further reduction in time of operation in the relay. It is defined the time as the minimum time of operation. Hence, the characteristic is inverse in the initial part, which tends to a definite minimum operating time as the current becomes very high. That is why the relay is referred as inverse definite minimum time over current relay or simply IDMT relay.

It is desirable to define and explain some important terms much used in connection with relays.

(v) **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.

(vi) **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

(vii) **Plug-setting multiplier (P.S.M.).** It is the ratio of fault current in relay coil to the pick-up current i.e.

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

(viii) Time-setting multiplier. 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:

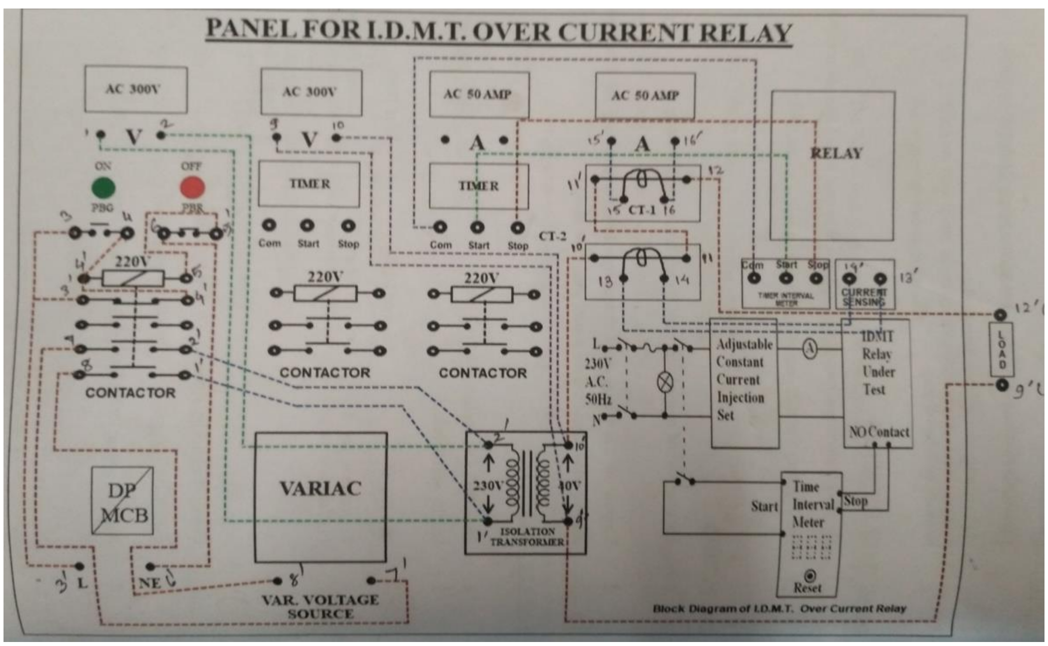


Fig. 1. Schematic diagram of the connected experimental kit.

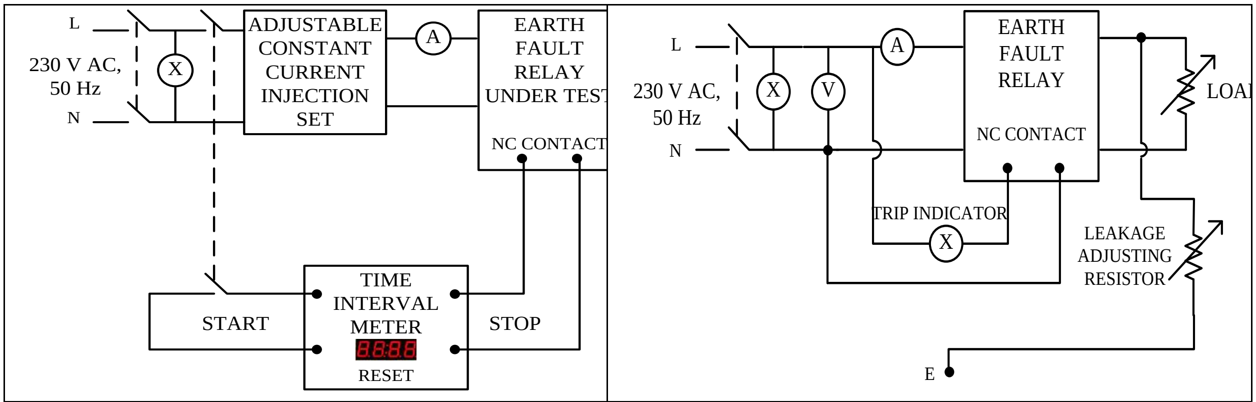


Fig. 1. Connection diagram of the experimental kit.

11. According to the above figure make all the connections of the relay study kit.
12. Set the variac to 230 V.
13. Set PSM=1.
14. Set a particular TSM (=0.5) in the IDMT over current relay.
15. Switch on the green push button.
16. Increase the load.
17. Once the relay start operating note down the fault currents and relay tripping times.
18. Set other TSM (=0.9) in the IDMT over current relay.
19. Repeat step 6-7.
20. 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:

11) Turn off the power switch to equipment before making connections.
12) Don’t use broken connecting wires.
13) Maintain a work space clear of extraneous material such as books, papers, and clothes.
14) Don’t wear loose clothes.
15) 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.	Time setting multiplier (TMS)	Fault current (A)	Trip time (s)
1	0.5		
2			
3			
4			
5			
6			

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

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(Signature of the teacher)

DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Advanced Power System Protection Lab

Course code: EEC514

Experiment No: 04

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 through experiment.

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 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).

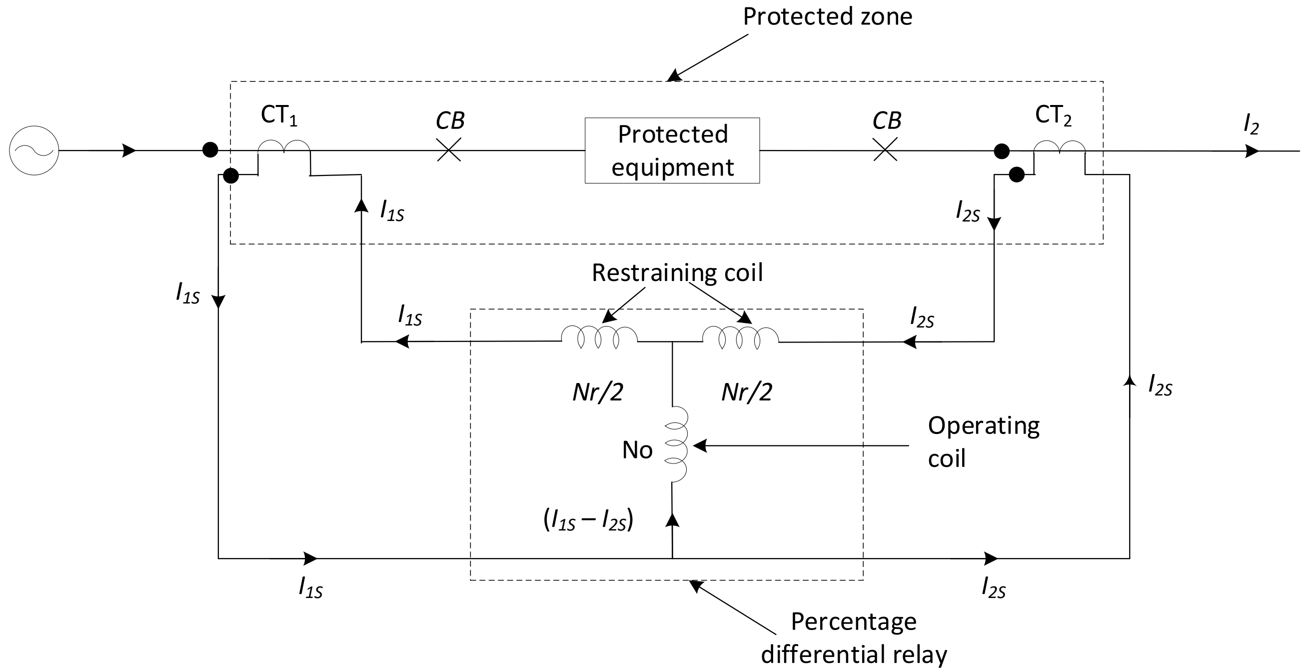

Figure 1. Percentage (biased) differential relay

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.

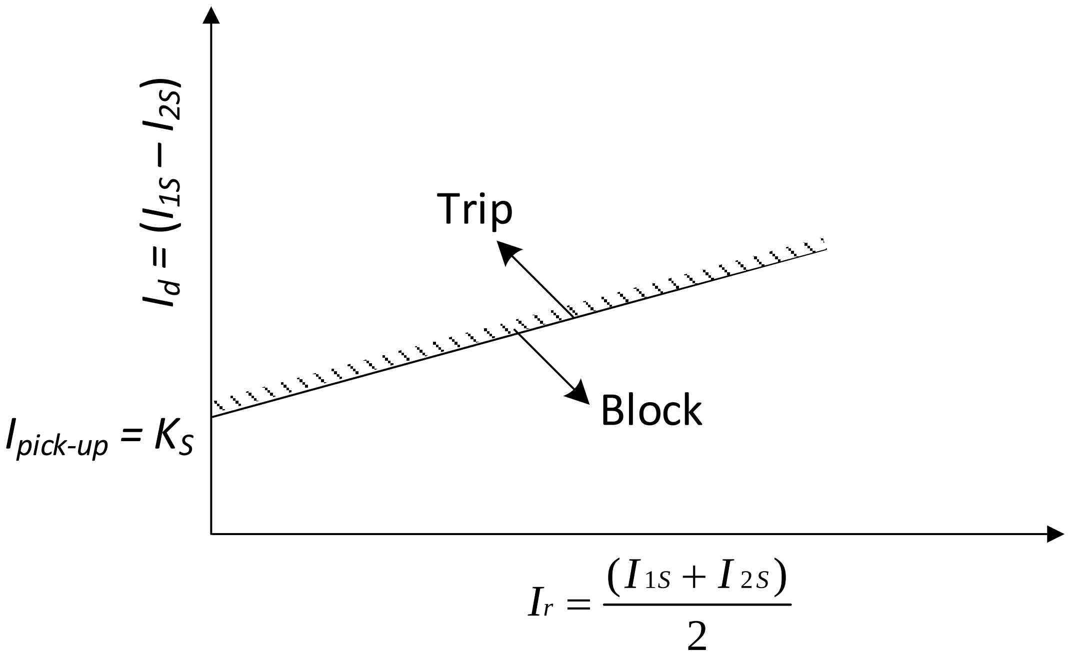

Figure 2. Operating characteristic of percentage differential relay

EXPERIMENTAL SETUP:

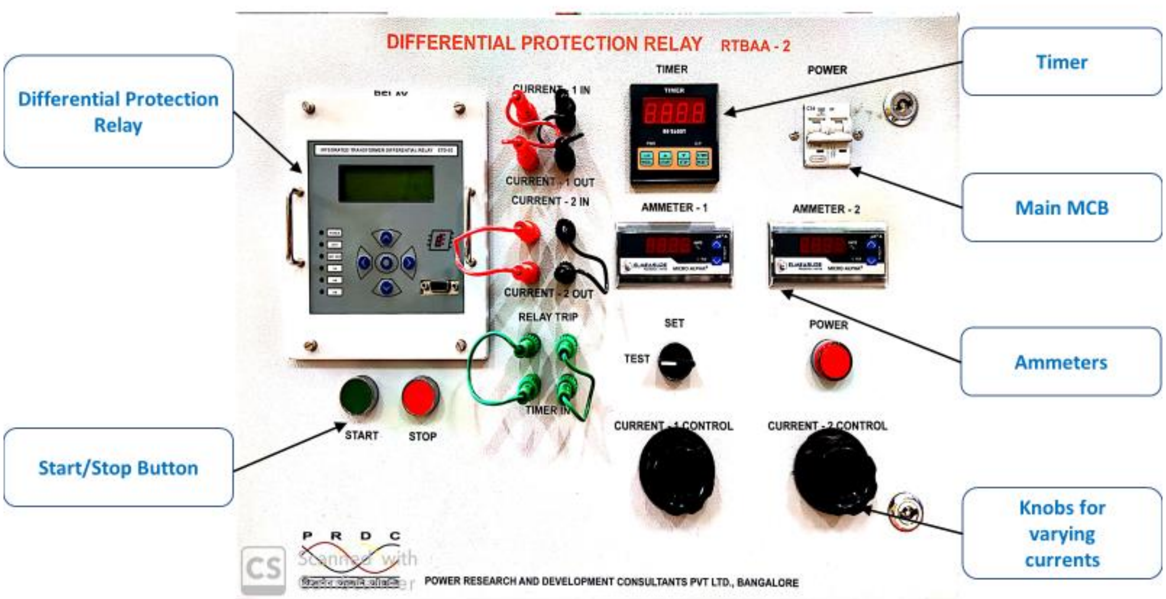

Figure 3. Experimental setup for percentage biased differential test kit.

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.

DATA SHEET

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)				

____

(Signature of the teacher)

DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Advanced Power System Protection Lab

Course code: EEC514

<u>Experiment No.: 05</u>

<u>STUDY THE APPLICATION OF NUMERICAL TYPE OVER CURRENT RELAY FOR DISTRIBUTION FEEDER PROTECTION AND SYNCHROPHASOR ASSISTED CURRENT DIFFERENTIAL RELAY FOR TRANSMISSION/DISTRIBUTION LINE PROTECTION</u>

TITLE:

(i) Study the application of numerical type over current relay for radial feeder protection.

(ii) Study of synchronized phasor measurement assisted current differential relay for Transmission / Distribution line protection.

OBJECTIVE: To study the application of numerical type over current relay for distribution line protection through experiment.

APPARATUS USED:

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

(I) OVERCURRENT RELAY SETTING DETAILS:

- Keep the SET button pressed for 4 seconds.
- Password is "1111" use the increment/decrement button to change number and press ser to go to the next.
- CT=5A- use the increment/decrement button to change number and press ser to go to the next.
- CT Ratio-Keep 5/5; use the increment/decrement button to change number and press ser to go to the next.
- Trip Setting: Keep at 50% (of 5A); use the increment/decrement button to change number and press ser to go to the next.
- Time Setting: keep at 1 second; Max 3 seconds; use the increment/decrement button to change number and press ser to go to the next.
- Press SET to update the setting.

CIRCUIT DIAGRAM:

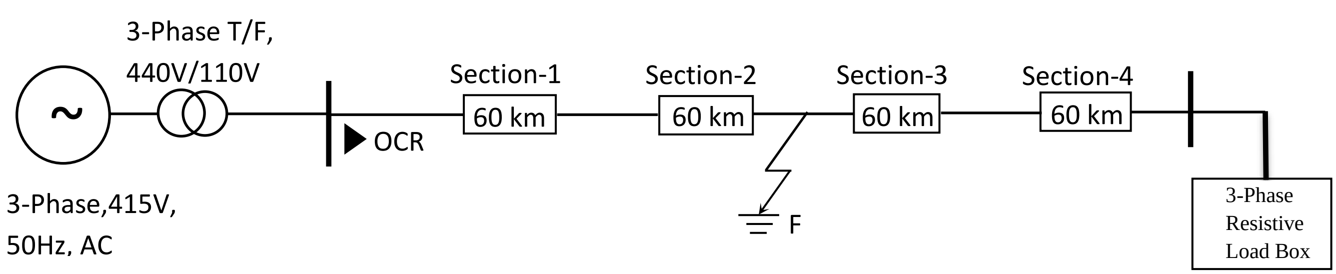

Fig. 1. Radial Feeder.

Three Phase Resistive Load:

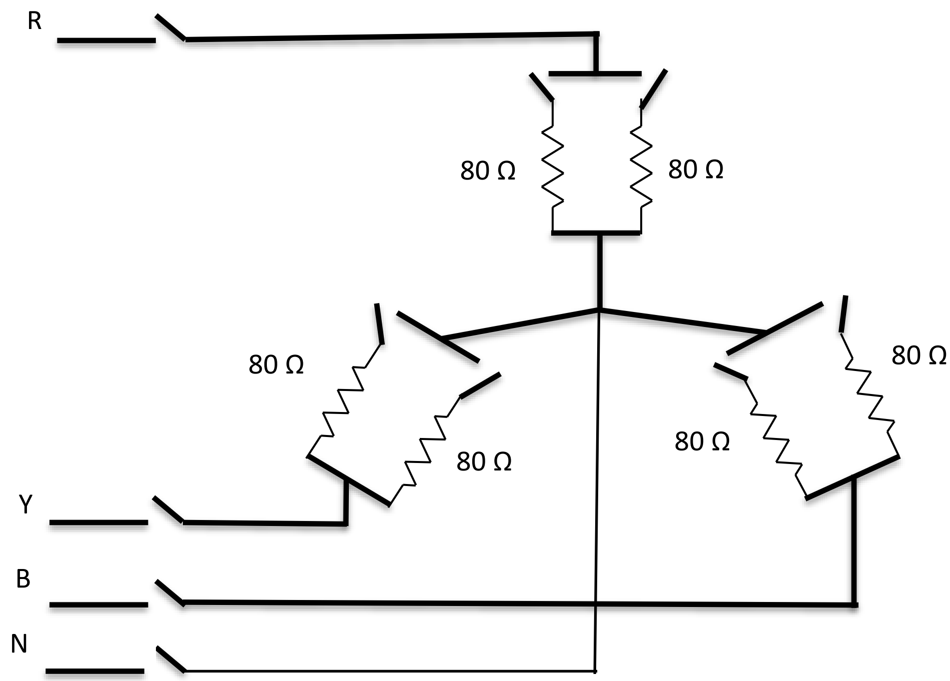

Fig. 2. 3-phase resistive load.

Fig. 3. Experimental setup of over-current relay-based distribution feeder protection.

PROCEDURE:

21. According to the above figure make all the connections of the relay study kit.
22. Now switch on the MCBs, AC switch and Loads.
23. Switch on green push button for contactor.
24. Now create different types of faults (LG/LL/LLG/LLL) in the line.
25. Save the data for each fault case in the excel sheet.
26. Draw the graph for each fault case as mentioned in the Table.

PRECAUTIONS:

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

Table I: Experimental results of the numerical type overcurrent relay for radial feeder protection.

Sl. No.	Fault Type	Fault Location	**Instruction**
1	AG	120 km	For each fault case, store data (Vabc & Iabc) at relay point in excel sheet and plot the record Time (sec) v/s Vabc (V) & Time (sec) v/s Iabc (A)
2	AB	180 km	
3	ABC	180 km	

(I) **Experimental study of the Synchro-phasor assisted current differential relay for Transmission / Distribution line protection.**

When differential current principle is applied to transmission line protection, problem of sampling misalignment and communication arise due to disturbance between the line ends, which make accurate current comparison difficult to achieve. These problems are due to phase synchronization, time delay of the communication channel, the line capacitive charging current and error in current transformer (CT) and protection system etc.

To overcome the problem of the sampling misalignment issue, recently the current differential protection based on synchronized current measurements using Global Positioning system Satellite (GPS) has been developed for transmission line protection.

Synchro-phasor / Phasor Measurement Unit:

Satellite Arrangement: 24 satellites on six orbits, at a height of 10898 miles. Each satellite covers 42% of the globe

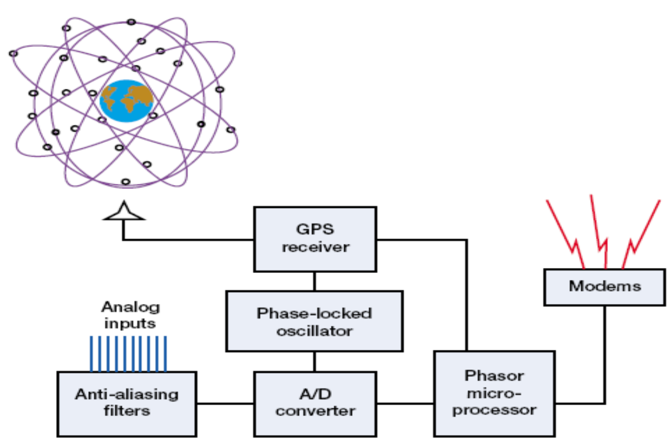

Fig. 4. Phasor Measurement Unit (PMU).

Typical PMU Configuration

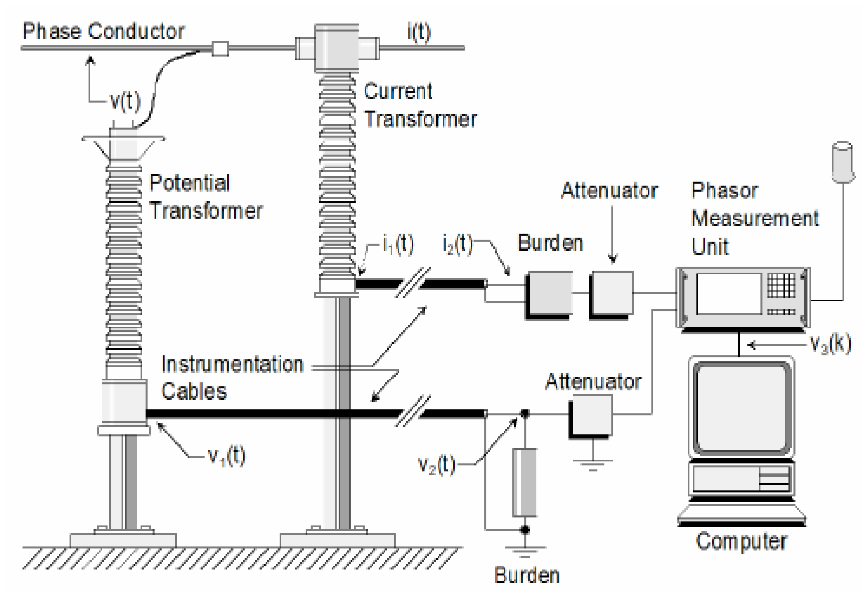

Figure 10: Typical PMU Installation at a Substation

Case-II: Application of synchro phasor assisted current differential protection for radial Transmission line or Distribution line.

Sl No.	Fault Type	Fault Location	**Instruction**
1	AG	120 km	For each fault case, store data (Vabc & Iabc) at both end in excel sheet and plot differential current of both ends for each phase Time (sec) v/s [Iabc (**SE**)-Iabc (**RE**)]
2	AB	180 km	
3	ABC	180 km	

SE = Sending End; **RE** = Receiving End

DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Advanced Power System Protection Lab

Course code: EEC514

Experiment No.: 06

Study of transmission line fault detection, classification and location estimation using distance relays by simulating different faults on the WSCC 9-bus test power system through PSCAD/EMTDC software or MATLAB/Simulink

Instruction: Refer Chapter-5 (Section 5.4) of Power System Relaying Book (4^{th} Edition) by S. H. Horowitz and A. G. Phadke to study the theoretical and mathematical details of transmission line protection using distance relaying schemes.

Objective:

The main objective of the project is to simulate the different type of faults on transmission lines of WSCC 3-Machine 9-Bus Power System through PSCAD/EMTDC and further to detect, classify and locate fault using digital distance relay.

Procedure:

Simulate the WSCC 3-Machine 9-Bus Power System as shown in Fig. 1 through PSCAD/EMTDC or MATLAB/Simulink for fault study.

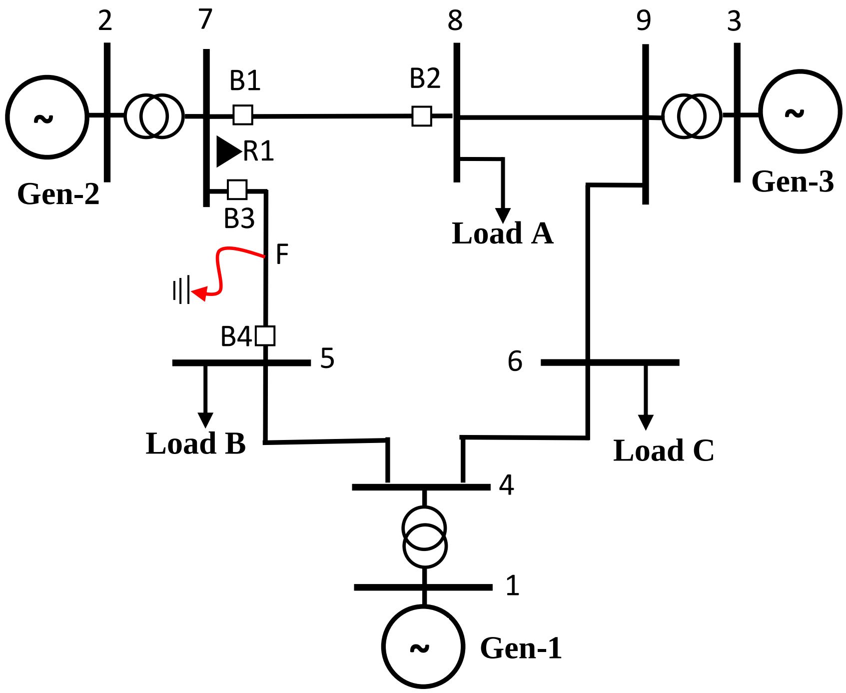

Fig.1 Single line diagram of the WSCC 3-Machine 9-Bus Power System.

Deliverables:

- Familiar with PSACD/EMTDC and MATLAB/Simulink software
- Theoretical knowledge gain on the analysis and study different type of faults occurs in power transmission networks.
- Knowledge gain how to simulate different power system scenarios in a standard test system using PSCAD/EMTDC software.
- Generation of different type of faults and extraction of data to MATLAB platform for further study.
- Knowledge gain how to write program in MATLAB and how to use PSCAD/EMTDC simulated data in MATLAB.
- Project Development Skills:
    - Problem analyzing skills
    - Problem solving skills
    - Creativity and imaginary skills
    - Programming skills
    - Deployment

System Data for WSCC 3-Machine 9-Bus Power System

Generators:

Gen-1: 600MVA, 22 kV, 50 Hz.

Gen-2: 465MVA, 22 kV, 50 Hz.

Gen-3: 310 MVA, 22 kV, 50 Hz.

X_d = 1.81 p.u., X_d' = 0.3 p.u., X_d'' = 0.23 p.u., T_{do}' = 8 s, T_{do}'' = 0.03 s, X_q = 1.76 p.u., X_q'' = 0.25 p.u., T_{qo}'' = 0.03 s., R_a = 0.003 p.u., X_p (Potier reactance) = 0.15 p.u.

Transformers:

T1: 600MVA, 22/400 kV, 50 Hz, Δ/Y.

T2: 465MVA, 22/400 kV, 50 Hz, Δ/Y.

T3: 310MVA, 22/400 kV, 50 Hz, Δ/Y.

X = 0.163 p.u., X_{core} = 0.33 p.u., R_{core} = 0.0 p.u., P_{copper} = 0.00177 p.u.

Transmission lines:

Length of line 7-8 = 320 km., line 8-9 = 400 km., line 7-5 = 310 km., line 5-4 = 350 km., line 6-4 = 350 km., line 6-9 = 300 km.

Positive-sequence impedance = 0.03293 + j 0.327 Ω/km.

Zero-sequence impedance = 0.309 + j 1.297 Ω/km.

Positive-sequence capacitive reactance = $280.1 X 10^3$ Ω.km.

Zero-sequence capacitive reactance = $461.2546 X 10^3$ Ω.km.

Loads:

Load A = 300 + j 100 MVA, Load B = 200 + j 75 MVA, Load C = 150 + j 75 MVA.

DEPARTMENT OF ELECTRICAL ENGINEERING

Course name: Advanced Power System Protection Lab

Course code: EEC514

Experiment No.: 07

Study the impacts of power swing on distance relaying-based transmission line protection and remedial measures through PSCAD/EMTDC and MATLAB/Simulink software

Instruction: Study the following standard to understand power swing and its impact on the distance relay.

- IEEE Power System Relaying Committee of the IEEE Power Eng. Soc., Power Swing and Out-of-Step Considerations on Transmission Line. Rep. PSRC WG D6, Jul. 2005. [Online]. Available: http://www. pes-psrc.org

Objective:

The main objective of the project is to investigate the impacts of power swing on distance relay protecting high voltage transmission lines simulated through PSCAD/EMTDC and verified through MATLAB.

Procedure:

Simulate a simple two-bus double circuit test system as shown in Fig. 1 through PSCAD/EMTDC or MATLAB/Simulink.

System Description:

The sending end (SE) is modelled as an equivalent machine and the receiving end (RE) is modelled as an infinite bus. In normal conditions, power is transferred from SE to RE through two parallel lines. Line-1 has two sections, each of 140 km length, and Line-2 is 280 km long. Lines are modelled with distributed parameters in the simulation. Generator is modelled with one damper winding in Q-axis and an IEEE SCRX solid-state exciter. All transformer parameters are considered except core losses. Power angle is the difference between the voltage angles at SE and RE.

The distance relay at breaker B1 is considered for power swing study. Zone-1 of this relay covers 112 km (80% of the line) which corresponds to an apparent impedance of 99.47 Ω.

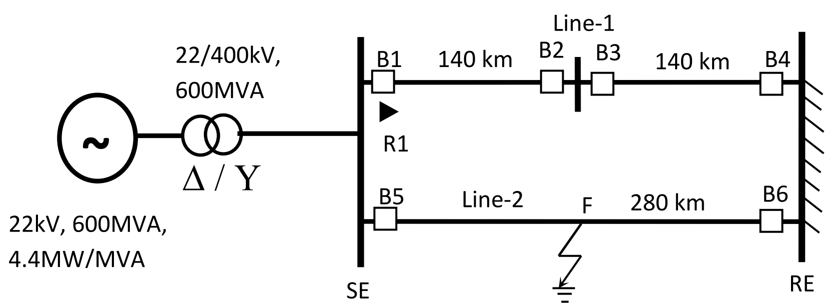

Fig. 1. Single line diagram of the study system.

Procedure to carry out the simulation:

- Create a permanent three-phase short circuit fault on Line-2 at a certain instant of time and since, the fault is permanent, remove Line-2 after the operation times of relay and circuit breaker, e.g., 0.1 s after the initiation of the fault by opening both end breakers B5 and B6.
- Sudden shifting of power of Line-2 to Line-1 will introduce power swing condition to relay R1 of Breaker B1.
- Plot the voltage, current, load angle and impedance waveforms at relay R1 during power swing.
- Through MATLAB programming, set the three zones of relay R1 and plot the apparent impedance seen by relay R1 in R-X plane.
- By varying the load angle between the SE and RE, create stable and unstable power swing and for both stable and unstable power swings, plot the impedance trajectory in R-X plane of relay R1.
- Study the effect of pre-fault loading on power swing.

Deliverables:

- Familiar with PSACD/EMTDC and MATLAB/Simulink software
- Theoretical knowledge gain on the cause of power swing in power systems.
- Knowledge gain how to simulate different power system scenarios in a standard test system using PSCAD/EMTDC software.
- Generation of power swing condition and extraction of swing data to MATLAB platform for further study.
- Knowledge gain how to write program in MATLAB and how to use PSCAD/EMTDC simulated data in MATLAB.
- Project Development Skills:
    - Problem analysing skills
    - Problem solving skills
    - Creativity and imaginary skills
    - Programming skills
    - Deployment

System data:

Generator:

600MVA, 22 kV, 50 Hz, inertia constant = 4.4 MW/MVA.
X_d = 1.81 p.u., X_d' = 0.3 p.u., X_d'' = 0.23 p.u., T_{do}' = 8 s, T_{do}'' = 0.03 s, X_q = 1.76 p.u., X_q'' = 0.25 p.u., T_{qo}'' = 0.03 s., R_a = 0.003 p.u., X_p (Potier reactance) = 0.15 p.u.

Transformer:

600MVA, 22/400 kV, 50 Hz, Δ/Y, X = 0.163 p.u., X_{core} = 0.33 p.u., R_{core} = 0.0 p.u., P_{copper} = 0.00177 p.u.

Transmission lines:

Length of Line-1 and Line-2 = 280 km each.
Positive-sequence impedance = 0.03293 + j 0.327 Ω/km.
Zero-sequence impedance = 0.309 + j 1.297 Ω/km.
Positive-sequence capacitive reactance = $280.1X10^3$ Ω.km.
Zero-sequence capacitive reactance = $461.2546X10^3$ Ω.km.