Ahsanullah University of Science and Technology

Department of Electrical and Electronic Engineering

LABORATORY MANUAL
FOR
ELECTRICAL AND ELECTRONIC SESSIONAL COURSES

Student Name:
Student ID:

Course No: EEE 4252
Course Title: Power System Protection Lab

For the students of
Department of Electrical and Electronic Engineering
Year: 4 Semester: 2

AHSANULLAH UNIVERSITY OF SCIENCE AND TECHNOLGY
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
SWITCHGEAR AND PROTECTION LAB

Experiment: 1

Experiment name: Familiarization with different kinds of insulators fuses and miniature circuit breakers & Determination of Time Current Characteristics (TCC) curve of a rewire able fuse & MCB.

Objective:

1. To be familiar with electrical devices like insulators, fuses, lightning arrester & MCBs.
2. To take at least 5 set of reading of current and their corresponding fuse blow out time.
3. To take at least 5 set reading of currents and their corresponding tripping time of MCB.
4. To draw the TCC curve of fuse and MCB from the data.

Insulators:

Line conductors are bare. Insulators are used between line conductors and supports.

Function of Insulator:

- The main function of insulators is to provide perfect insulation between line conductors and supports and prevent any leakage current from the line conductors to earth through support.
- Mechanical strength should be adequate so that it can carry the conductor's weight.

Types of insulator:

Pin Insulators: Pin type insulator is secured to the cross-arm on the pole. There is a groove on the upper end of the insulator for housing the conductor. The conductor passes through this groove and is bound by the aluminum wire of the same material as the conductor.
Pin type insulators are used for transmission and distribution of electric power at voltages up to 33 kV. Beyond operating voltage of 33 kV, the pin type insulators become too bulky and hence uneconomical.

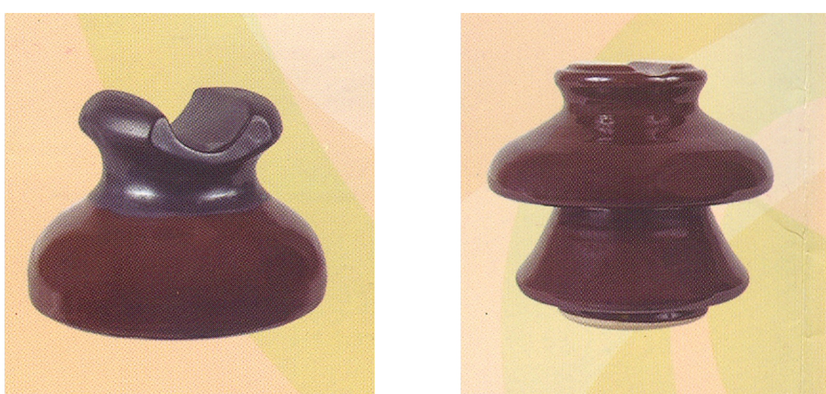


Fig1.1(a): Showing the 11 KV and 33 KV pin insulators.

Connection:

Fig1.1(b): Connection of pin type insulator.

Spool / **Shackle Insulators:** These insulators are used in the 0.4 KV overhead service lines.

Fig 1.2: showing the spool/shackle insulators and its connection.

Disc Insulators: These Insulators are used normally in HV overhead transmission lines. Each unit or disc is designed for low voltage; say 11.5 kV. Total Insulation of the string can be increased by increasing the number of disc unit in the string to use in EHV lines.

Fig 1.3 (a): Showing the Disc insulators

Fig 1.3 (b): Connection of Suspension type insulators

Typical number of disk insulator units for standard line voltages

Line voltage (kV)	Disks
34.5	3
46	4
69	5
92	7
115	8
138	9
161	11
196	13
230	15
287	19
345	22
360	23

Strain Insulators:

When there is a dead end of the line or there is corner or sharp curve, the line is subjected to greater tension. In order to relieve the line of excessive tension, strain insulators are used. For low voltage lines (< 11 kV), shackle insulators are used as strain insulators. However, for high voltage transmission lines, strain insulator consists of an assembly of suspension insulators as shown in Figure. The discs of strain insulators are used in the vertical plane. When the tension in lines is exceedingly high, at long river spans, two or more strings are used in parallel.

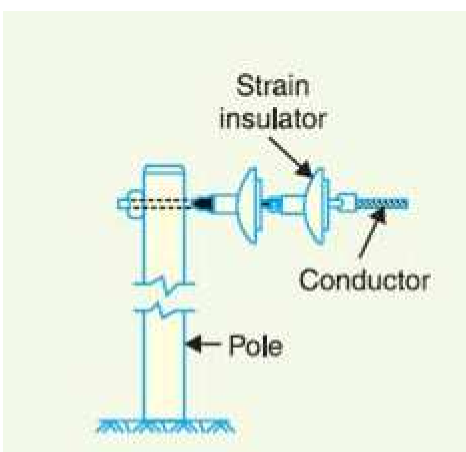


Fig 1.4: Showing the Strain insulators

Post Insulators:
Also called support insulator. It provides support to electrical equipments and separates them from ground.

Fig 1.5: Showing the Post insulators

Fuse:

Fuse is essentially a small piece of metal connected in between two terminals mounted on insulated base which forms a series part of the circuit. The duty of a rewire able fuse wire is to carry the normal working current safely without heating the wire but when the normal operating current is exceeded it should rapidly heat up to the melting point and eventually circuit is opened. It can provide two types of protection.

1. Short circuit protection
2. Over load protection

The melting point follows inverse characteristics between the melting time and the melting current. At normal rated current the fuse element will never be heated to its melting point. At overloaded current the melting will occur after certain time. As the amount of overloading is increased the melting time will be shorter.

Semi-enclosed or Re-wire able Fuse:
These types of fuses are used for the protection of appliances at 0.4 KV voltage level and usually called **cut-out.** The Fuse carrier can be pulled out and the blown out fuse element can be replaced.

Fig 1.6: Showing the Re-wire able fuse

Totally Enclosed or cartridge Fuse:

The Fuse Element (the conductor which melts) is enclosed in a totally enclosed container and is provided with metal contact on both side.

Fig 1.7: Showing the totally enclosed Fuse.

Drop out Fuse:

A fuse link in which the fuse carrier drop out after melting the fuse wire thereby providing isolation between the terminals. This type of fuse is normally used in 11 KV side of a 11/0.4 KV distribution transformer.

Fig 1.8: showing the drop out fuse

HRC (High Rupturing capacity) cartridge Fuse:

A cartridge fuse link having breaking capacity higher then certain specified value (e.g. above the 16 KA for medium voltage)

Fig 1.9: Showing the HRC fuse

Lightning Arrestor:

The main function of a Lightning arrestor is to divert any surge over voltage caused by lightning to the ground, so that equipment or devices behind the arrestor are saved from insulation failure and eventually short circuit fault.

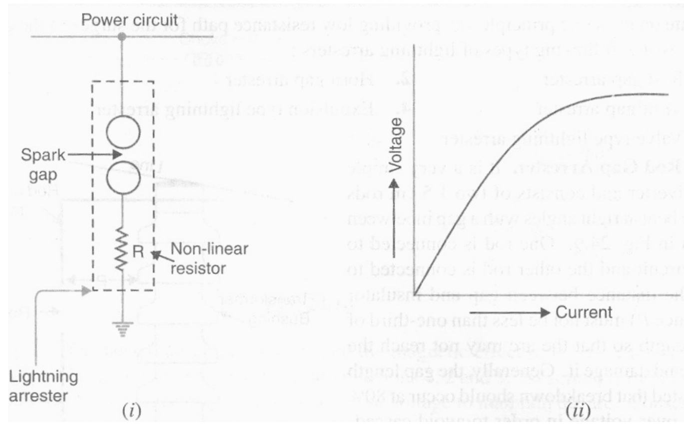


Fig 1.10: showing the Lightning arrestor

Low Voltage Circuit Breaker

Miniature Circuit Breaker (MCB):

MCBs are used extensively in LV domestic, commercial and industrial applications. They replace conventional fuses and combine the features of a good HRC fuse and a good switch. For normal operation it is used as switch. During overloads or faults, it automatically trips off. The tripping mechanism is actuated by magnetic and thermal sensing devices provided within the MCB. Over current is sensed by over current release which helps to open the contact of the MCB. On the other hand short circuit is sensed by magnetic release which provides the means of opening the contact of MCB.

Tripping mechanism and the terminal contacts are assembled in a moulded case, moulded out of thermo setting powders. They ensure high mechanical strength, high dielectric strength and virtually no ageing. The current carrying parts are made of electrolytic copper or silver alloy depending upon the rating of the breaker. All other metal parts are of non ferrous, non rusting type. Sufficient cross section for the current carrying parts is provided to ensure low temperature rise even under high ambient temperature environment. The arc chute has a special construction which increases the length of the arc by the magnetic field created by the arc itself and arc chute is so placed in the breaker that the hot gases may not come in contact with any of the important parts of the breaker.

Fig 1.11(a): Showing the MCBs

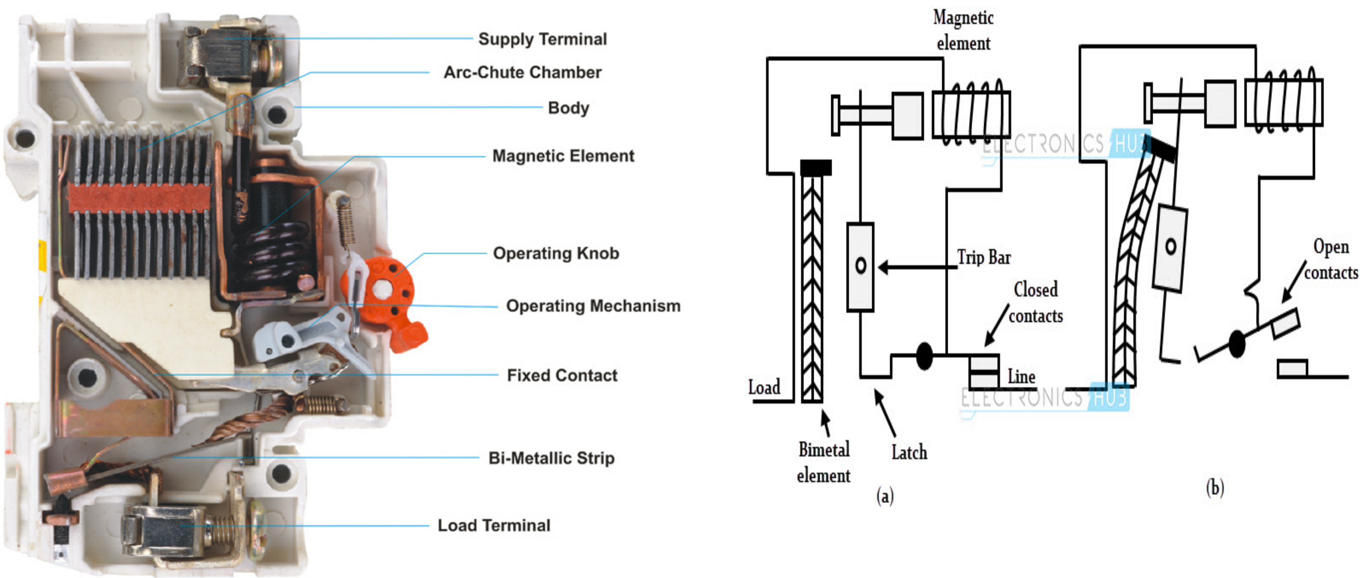


Fig 1.11(b): Construction and working principal of MCB

Types of MCB: MCBs are classified into three major types according to their instantaneous tripping currents. They are

i. Type B MCB
ii. Type C MCB
iii. Type D MCB

MCB Type	Minimum Trip Current	Maximum Trip Current
Type B	3 Ir	5 Ir
Type C	5 Ir	10 Ir
Type D	10 Ir	20 Ir

Ir= Rated current

Molded Case Circuit Breaker (MCCB):

The current rating of the MCCB is higher than 63 Amp.Its also provides short circuit and overload protection. Additional fact is, operating current setting can be controlled in a possible range.

Fig 1.12: Showing the MCCBs

Residual Current Circuit Breaker (RCB):

Residual Current Circuit Breaker basically is installed to prevent human from shocks or death caused by shocks. It prevents accidents by disconnecting the main circuit within fraction of seconds.

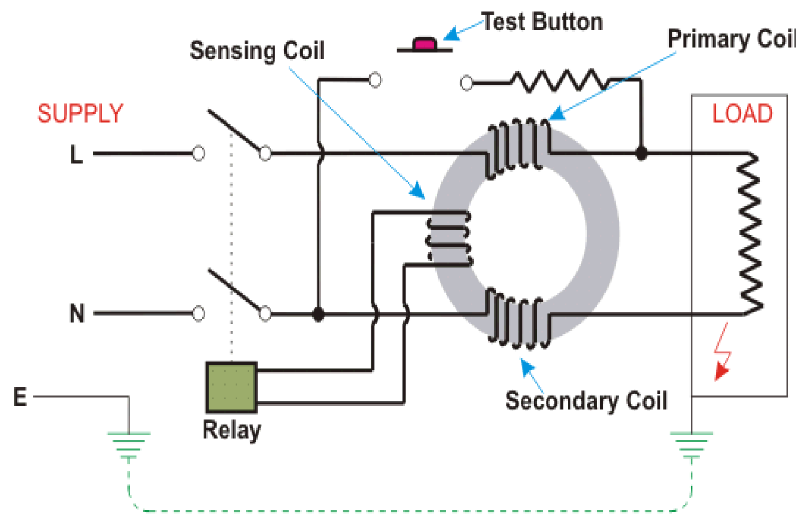


Fig 1.13: Showing the RCBs

The basic operating principle lies in the toroidal Transformer shown in the following diagram containing three coils. There are two coils say Primary (containing line current) and Secondary (containing neutral current) which produces equal and opposite fluxes if both currents are equal. Whenever in the case there is a fault and both the currents changes, it creates out of balance flux, which in-turn produces the differential current which flows through the third coil (sensing coil shown in the figure) which is connected to relay. The toroidal transformer, sensing coil and relay together is known as RCD - Residual Current Device.

Residual Current Circuit Breaker With Over Current Protection (RCBO):

A combination of RCB+MCB (miniature circuit breaker) is known as a RCBO.

Fig 1.14: Showing the RCBOs

Instrument and Components:

1. Current Injector.
2. Clamp on meter.
3. Rewire able Fuse Wire (5 A).
4. Wooden Board fitted with Fuse Holder.
5. MCB
6. Connecting Wire.

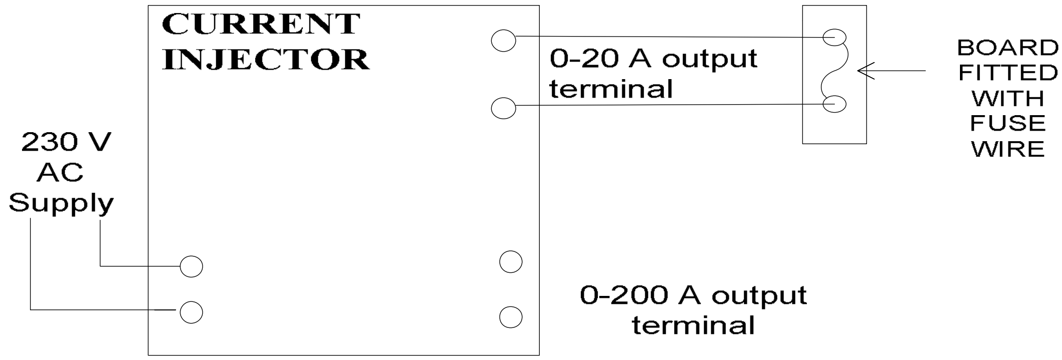
Procedure:

Connect the current injector set to a 230 V supply line. There are two output current terminals, one is of 0-20A and other is 0-200A. Use 0-20A output terminal. Set the output current at a desired value by changing the current varying knob. This can only be achieved by shorting the output terminals by a thick wire. Keeping the knob position at the desired current value, switch off the current injector and connect the fuse holder fitted with fuse wire across the output terminals. Then switch on the injector. The desired current flows through the fuse wire. Measure the blow out time of the fuse wire. As the increased current flows through the fuse wire, the fuse blow out time reduces. Measure and record the currents and the corresponding fuse and blow out time in the table 1.1 and for MCB, connect directly it to the 0-200A output terminals after disconnecting the shorting wire. Then switch on the current injector set. The desired current flows through the MCB. Measure and record the tripping time of the MCB. As the increased current flows through the MCB, the tripping time of the MCB is reduced. Measure and Record the currents and their corresponding tripping time of the MCB in Table 1.1

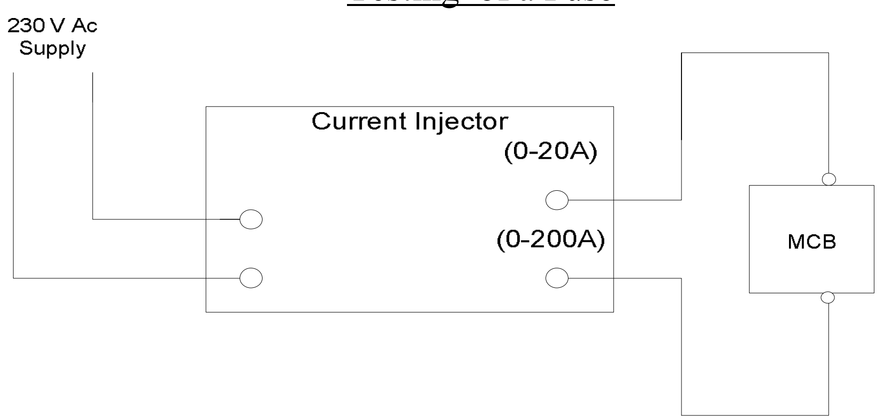
Table 1.1

Sl. No	Current (A)	Fuse blow out time (Sec).	Current (A)	Tripping time of the MCB (sec)
1				
2				
3				
4				
5				

Circuit Diagram:



Testing of a Fuse



Testing of a MCB

Warning:

There are two variable voltage output terminals, one is 110 V dc and other is 230 V ac. Do not touch the terminals of those voltage output.

Report:

1. Explain why pin insulators are not used above 33 KV voltages.
2. Explain how a fuse can provide time delayed protection for normal overload and high speed protection for short circuit.
3. What are the differences between a MCB and a MCCB?
4. Draw the TCC curve on a graph paper from the data of table 1.1. Use Current in the X-axis and time in Y-axis.
5. Discuss the special feature for selecting the fuse rating for the protection of motor.
6. Discussion the special feature for selecting rating of MCB for the protection of the motor.

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Experiment: 2

Experiment name: Study of the performance of an electro-mechanical over current relay and thermal overload relay.

Objectives:

1. To observe the performance of IDMT O/C relay and thermal overload relay.
2. To draw TCC curve from the data (over load currents and their corresponding relay tripping times) for different over load currents.

Theory:

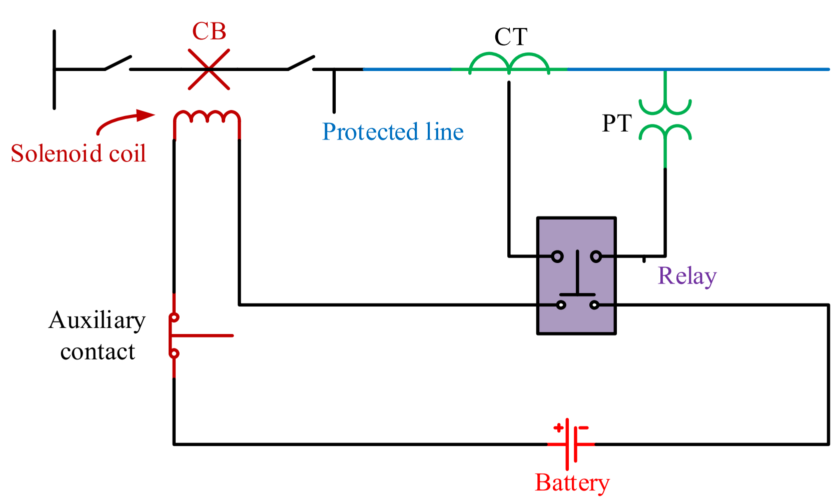
Protective relay senses the abnormal conditions in any part of a power system and gives an alarm or isolates the faulty part from the healthy system. The relays are compact, self contained devices which respond to abnormal conditions.

The relays distinguish between normal and abnormal condition. Whenever an abnormal condition develops, the relays close its contacts. Thereby the trip circuit of the CB is closed. Then the contacts of the CB are opened and the faulty part is disconnected from the supply.

The functions of a protective relaying include the following-

1. To sound an alarm or close the trip circuit of the CB so as to disconnect a component during an abnormal condition from the system. The abnormal condition include- overload, under voltage, temperature rise, balanced load, reverse power under frequency, short circuit etc.
2. To disconnect the abnormal operating part so as to prevent the subsequent fault.
3. To disconnect the faulty part quickly so as to minimize the damage to the faulty part.
4. To localize the effect of fault by disconnecting the faulty part from the healthy part, causing least disturbances to the healthy system.
5. To disconnect the faulty part quickly so as to improve the system stability, service continuity and system performance.

Trip Circuit:



Types of Relay:

Relays are basically of three types:

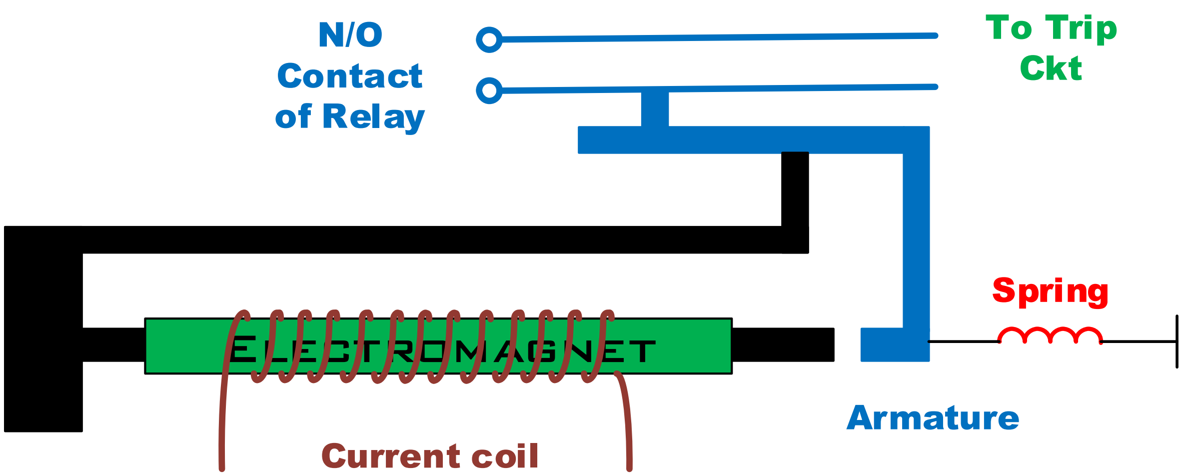
1) Electromechanical relay
2) Electronic/ Static relay
3) Microprocessor based relay

Electromechanical relays can be further classified into two types:

- Electromagnetic attraction
- Electromagnetic induction

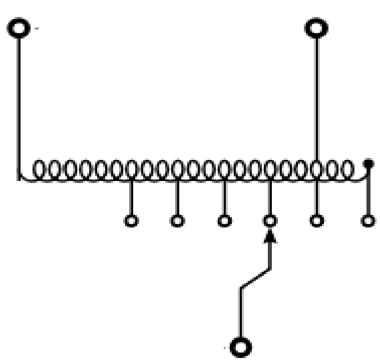
Electromagnetic attraction type:

This is the simplest type of relays. This relay has an electromagnet energized by coil. The coil is energized by the operating quantity which may be proportional to the circuit current or voltage. Working principle is "instantaneous" in nature.



Current settings of this kind of relay can be changed in two ways:

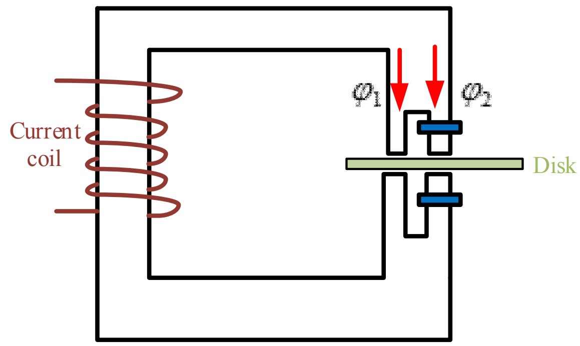
i. **Electrically**- by tapping

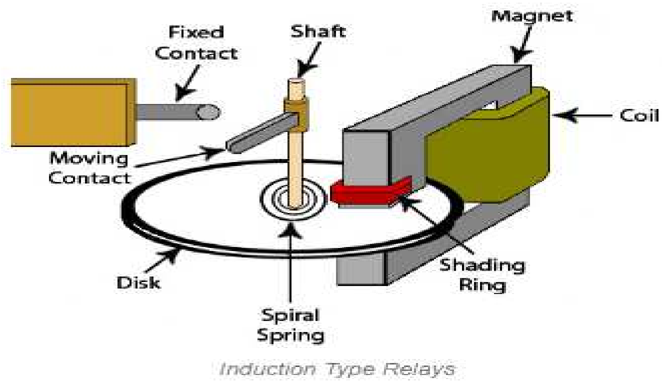


ii. **Mechanically-** by increasing the distance between electromagnet and armature. Also by increasing the strength of spring connected to armature.

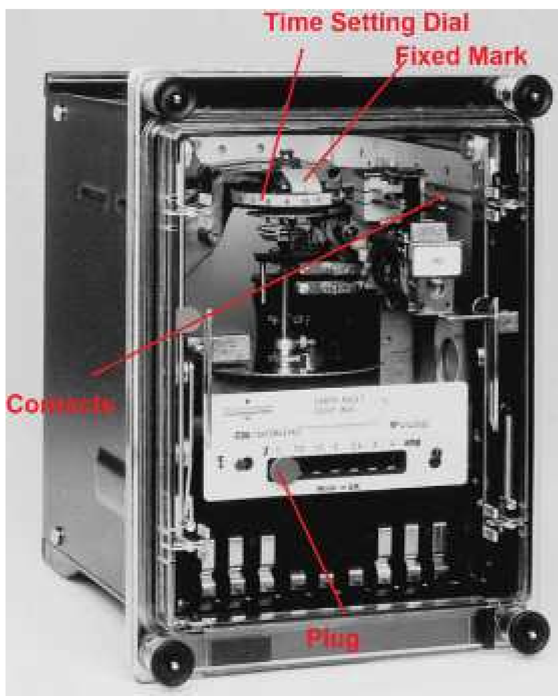
Electromagnetic induction type:

It is the most widely used for protective relaying purpose involving ac- quantity. They are not usable with dc quantity. Basically it is like a split phase induction motor. Actuating force is developed in a movable element (either disc or other form of rotor of non magnetic current conducting material) by the interaction of electromagnetic fluxes with eddy currents that are induced in the rotor by these fluxes.





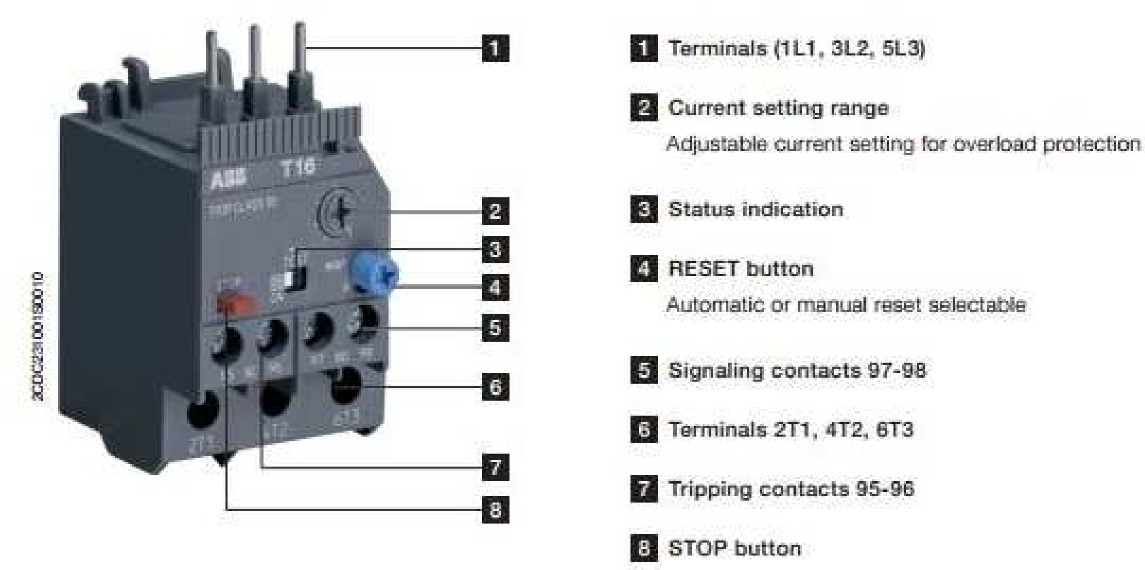
By varying Time Setting dial (disc position), time setting of this kind of relay can be controlled.



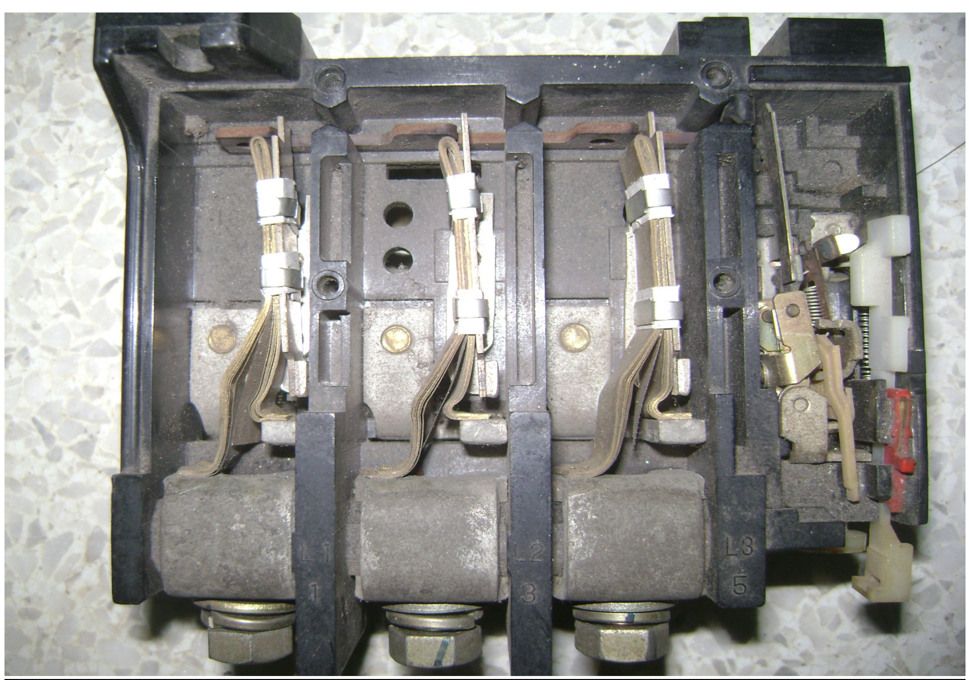
Thermal over load relay:

Thermal overload relays are 3 poles. The motor current flows through their bimetals (1 per phase) which are indirectly heated. Under the effect of the heating, the bimetals bend; cause the relay to trip and the position of the auxiliary contacts to change. The relay setting range is graduated in amps. In compliance with international and national standards, the setting current is the motor nominal current and not the tripping current (no tripping at 1.05 x setting current, tripping at 1.2 x setting current. The relays are built to be self protecting in the event of an overload until the short circuit protection device is activated. To make a fine adjustment, change the distance between the heater and the heat-sensitive element. An increase in this distance increases the tripping current. You can make another form of adjustment by changing the distance the bimetal strip has to move before the overload relay contact is opened.

BIMETAL. In the bimetal relay, the heat-sensitive element is a strip or coil of two different metals fused together along one side. When heated, the strip or coil deflects because one metal expands more than the other. The deflection causes the overload relay contact to open.

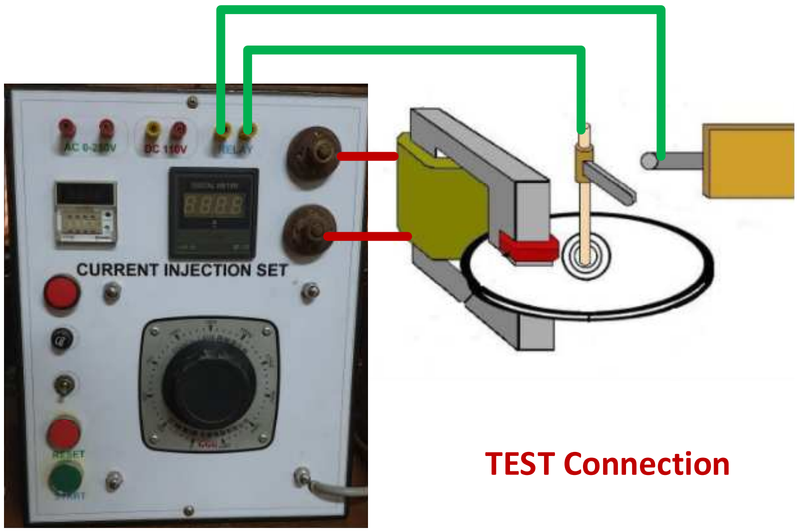


Thermal over load relay



Settings of IDMT O/C relay:

The standard IDMT relay has two controls- Plug setting (PS) and Time Setting Multiplier (TSM). The PS is a device used to provide a range of current settings at which the relay starts to operate. The setting ranges from 50% to 200% in the steps of 25% of the relay rated current. The TSM is a means adjusting the moveable backstop which controls the travel of the disc and thereby varies the time at which the relay closes its contact for a given value of fault current.



Procedure:

The PS of the relay is set at 5 amps, and the TSM at 0.9 sec (say). The current coil of the relay is connected to (0-20 A) output terminals of the current injector set. Adjust the current output at little over 5 A. Then observe the operation time of the relay. As the current in the operating coil is increased, the relay operation time is reduced. So the operating current and time are recorded in the following table.

Current in the relay coil (A)	Operating time of the Relay (Sec)
5.5	
6.0	
6..5	
7.0	
7.5	

Current in Thermal O/L Relay (A)	Operating time of the Relay (Sec)

Reports:

1. What is a relay?
2. Draw the TCC of the IDMT relay using the data of the table with current in X axis and time in Y axis.
3. Give Examples where times delayed O/C relay are applied?
4. What is the function of the O/C relay?

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Experiment: 3

Experiment name: Study of different components and their functions of an Air Circuit Breaker (ACB)

Objectives:

- To observe the contact closing operation manually
- To observe the contact closing operation automatically
- To observe the tripping mechanism
- To observe the under voltage shunt tripping mechanism

Theory:

In the ACB under discussion the over current relays and their corresponding CTs in three lines are built inside the ACB. The under voltage relay coils are also built inside the ACB.There is a spring charging motor in the ACB. When the motor is supplied from a single phase 230 V, the motor is started and the contact of the ACB are closed keeping the spring fully charged and latched. When there is any over current in all the phases or in any of the phases, the built in over current relay closes its trip circuit and the trip coil unlatch the fully charged spring, then the contacts are opened by the mechanical energy charged in the spring. The arc is extinguished in the medium of normal atmospheric air.

If the voltage in any of the three phases or in all three phases, supplied to the load through the ACB, are reduced below a preset level, the under voltage relay will be picked up and closes the trip circuit; consequently the trip coil will unlatch the fully charged spring and the contacts will be opened.

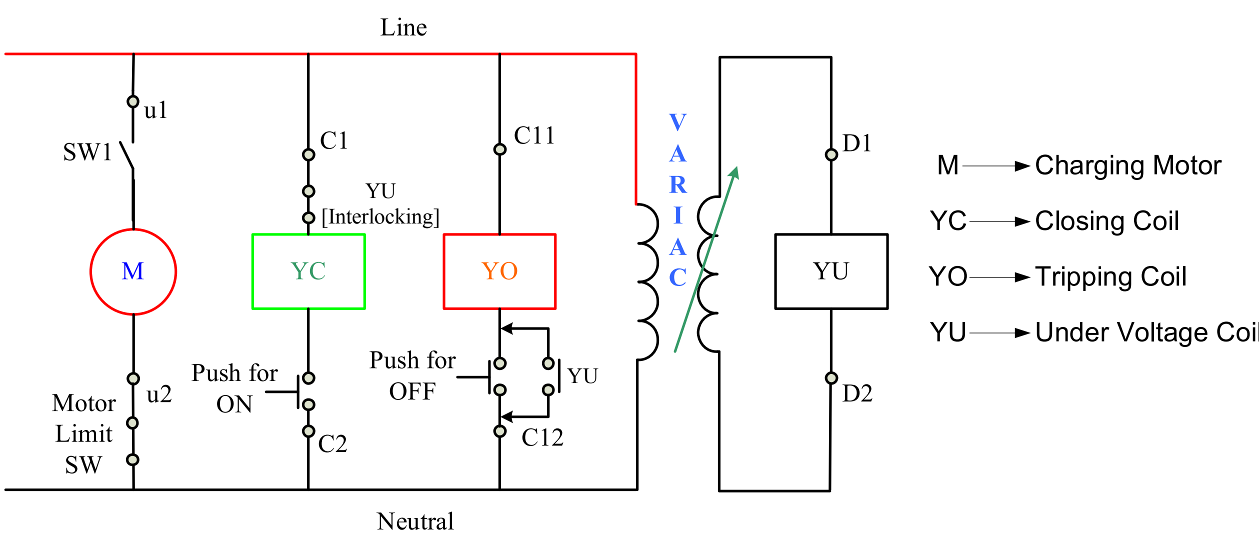
The closed contacts of the ACB can be manually opened by pushing the OFF button, which closes the trip circuit, then trip coil is energized and unlatch the spring to open the contacts.

Circuit diagram for motor operating mechanism, opening closing and under voltage release are shown in the figure.

Spring Operation:

Dual Spring for faster operation				
Switch	Closing spring	Trippng spring	CB status	OUTPUT
Motor switch/Hand liver	Energized	Discharge	OFF	
Push On Switch	Discharge	Energized	ON	
Tripping command/OFF command	Discharge	Discharge	OFF	
Push On Switch	Discharge	Discharge	OFF	
Motor switch/Hand liver	Energized	Discharge	OFF	
Push On Switch	Discharge	Energized	ON	
Motor switch/Hand liver	Energized	Energized	ON	
U/V Command	Energized	Discharge	OFF	
Push On Switch/U/V condition	Energized	Discharge	OFF/ Interlocking	
Push On Switch	Discharge	Energized	ON	
Motor switch/Hand liver	Energized	Energized	ON	
Tripping command	Energized	Discharge	OFF	

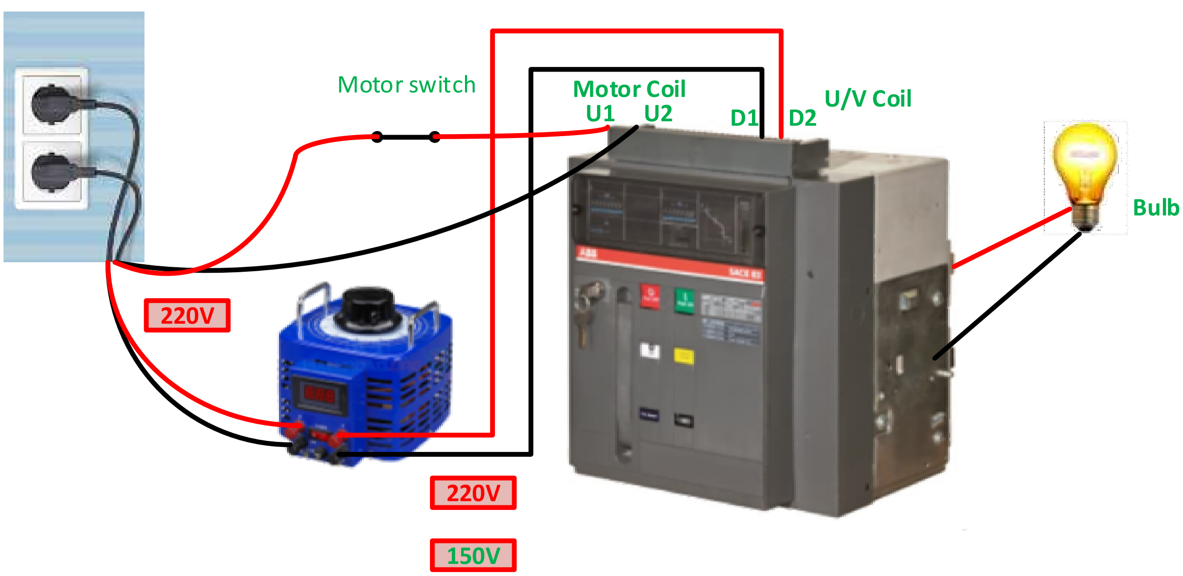
Circuit diagram:



Procedure:

For energizing the spring charging motor, close the SW1 switch. Now this charging motor will charge up the closing spring. One incandescent lamp is connected across one of the three phases of the contacts and the neutral. When the 'ON' switch is pushed the contacts will be closed and the lamp will glow and when the "OFF" switch is pushed the contacts will be opened and the lamp will stop glowing. It is important to keep in mind that the voltage across the under voltage coil (i.e D1 and D2) should be maintained at about 220 V (ac) otherwise contacts cannot be closed by pushing the 'ON' switch. If the voltage across the under voltage coil is reduced below 200 V (approax.) the breaker will automatically be tripped. Now to observe the interlocking mechanism, reduce the voltage to 160 V approximately. The circuit breaker is tripped in this condition. Now if you energize the closing coil by pressing ON switch, the circuit breaker will not close even though the closing spring is charged.

Experimental Setup



Report:

1. What are the difference between a MCB and the ACB used in this experiment?
2. What are the means of arc extinction in ACB?
3. Explain which condition is necessary to close the circuit breaker in HV system.
4. Explain why interlocking is necessary during the closing of CB.

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Experiment: 4

Experiment name: Performance study of different types of substation and trip circuit for a protected line.

Introduction:

A **substation** is a part of an electrical generation, transmission, and distribution system. Substations transform voltage from high to low, or the reverse, or perform any of several other important functions. Between the generating station and consumer, electric power may flow through several substations at different voltage levels. A substation may include transformers to change voltage levels between high transmission voltages and lower distribution voltages, or at the interconnection of two different transmission voltages.

Transmission substation

A *transmission substation* connects two or more transmission lines. The simplest case is where all transmission lines have the same voltage. In such cases, substation contains high-voltage switches that allow lines to be connected or isolated for fault clearance or maintenance. A transmission station may have transformers to convert between two transmission voltages, voltage control/power factor correction devices such as capacitors, reactors or static VAR compensators and equipment such as phase shifting transformers to control power flow between two adjacent power systems.

Distribution substation

A *distribution substation* transfers power from the transmission system to the distribution system of an area. It is uneconomical to directly connect electricity consumers to the main transmission network, unless they use large amounts of power, so the distribution station reduces voltage to a level suitable for local distribution. The input for a distribution substation is typically at least two transmission or sub-transmission lines. Input voltage may be, for example, 132 kV, or whatever is common in the area. The output is a number of feeders. Distribution voltages are typically medium voltage, between 2.4 kV and 33 kV, depending on the size of the area served and the practices of the local utility. In addition to transforming voltage, distribution substations also isolate faults in either the transmission or distribution systems. Distribution substations are typically the points of voltage regulation, although on long distribution circuits (of several miles/kilometers), voltage regulation equipment may also be installed along the line.

Switching station

A switching station is a substation without transformers and operating only at a single voltage level. Switching stations are sometimes used as collector and distribution stations. A switching station may also be known as a switchyard, and these are commonly located directly adjacent to or nearby a power station. An important function performed by a substation is switching, which is the connecting and disconnecting of transmission lines or other components to and from the system. Switching events may be planned or unplanned. A transmission line or other component may need to be de-energized for maintenance or for new construction, for example, adding or removing a transmission line or a transformer. To maintain reliability of supply, companies aim at keeping the system up and running while performing maintenance. All work to be performed, from routine testing to adding entirely new substations, should be done while keeping the whole system running.

Power System Protection – Main Functions

1. To safeguard the entire system to maintain continuity of supply.
2. To minimize damage and repair costs.
3. To ensure safety of personnel.

Power System Protection – Basic Requirements

1. *Selectivity*: To detect and isolate the faulty item only.
2. *Stability*: To leave all healthy circuits intact to ensure continuity of supply.
3. *Speed*: To operate as fast as possible when called upon, to minimize damage, production downtime and ensure safety to personnel.
4. *Sensitivity*: To detect even the smallest fault, current or system abnormalities and operate correctly at its setting.

Power System Protection – Basic Components

1. *Voltage transformers and current transformers*: To monitor and give accurate feedback about the healthiness of a system.

2. *Relays*: To convert the signals from the monitoring devices, and give instructions to open a circuit under faulty conditions or to give alarms when the equipment being protected, is approaching towards possible destruction.

3. *Fuses*: Self-destructing to save the downstream equipment being protected.

4. *Circuit breakers*: These are used to make circuits carrying enormous currents, and also to break the circuit carrying the fault currents for a few cycles based on feedback from the relays.

5. *DC batteries*: These give uninterrupted power source to the relays and breakers that is independent of the main power source being protected.

The sequence of operation during abnormal condition:

1. Fault occurs.
2. Relay sense the fault and close the trip circuit.
3. Energize the trip coil unlatch the spring.
4. Contacts start to apart and arc is drawn between the contacts of CB.
5. Arc is extinguished at the instant when fault ac current becomes zero.
6. Fault interruption is completed i.e. fault is cleared.

Objective:

Observe and draw the one line diagram of 132kV/33kV step down substation and switching substation model, connection diagram, and power flow and trip circuit operation during faulty condition.

Apparatus:

1. Circuit breaker----------33kV BUS Side
2. Protected line----------- 33kV BUS
3. Battery------------------- 110V DC
4. CT----------------------- 600/1
5. VAMP 50--------------- O/C IDMT Relay

Circuit Diagram:

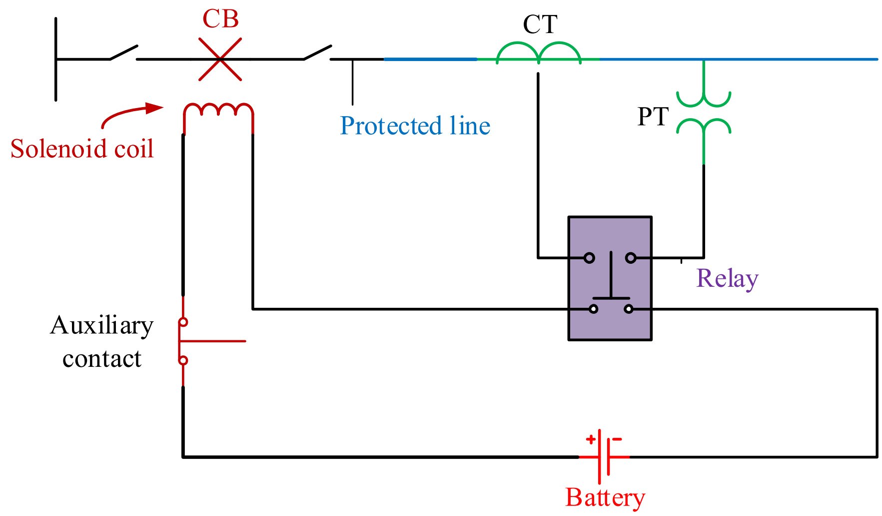

Figure 4.1: Trip Circuit

Observation: Observe different types of relays in substation I and substation II, their configuration & how they operate during fault condition.

Procedure:

1. Switch ON Substation I and II.
2. Switch ON every breaker of the substations by turning the breaker control switch.
3. Observe the current flow on the over current relay display by switching 100 Amp Load **only**.
4. Draw the one line diagram of the substations.
5. Observe the BUS trip circuit carefully and draw the diagram of this trip circuit.
6. Connect **VAMP50-I** relay with the communication cable to the computer.
7. Open the relay software, and assign output relay **T1** to trip the breaker for earth fault on the 33kV incoming bus, and assign fault LED to show E/F trip from matrix menu.
8. On the scaling menu give CT ratio **600:1**.
9. Activate Earth fault Protection. Assign definite time (DT) **3sec** and current setting **0.1In** of the relay.
10. Observe the connection diagram of the relay.
11. Now create fault on the **33kv incoming BUS** and observe tripping operation of the breaker.
12. Find magnitude of the fault current on the earth fault recording menu.

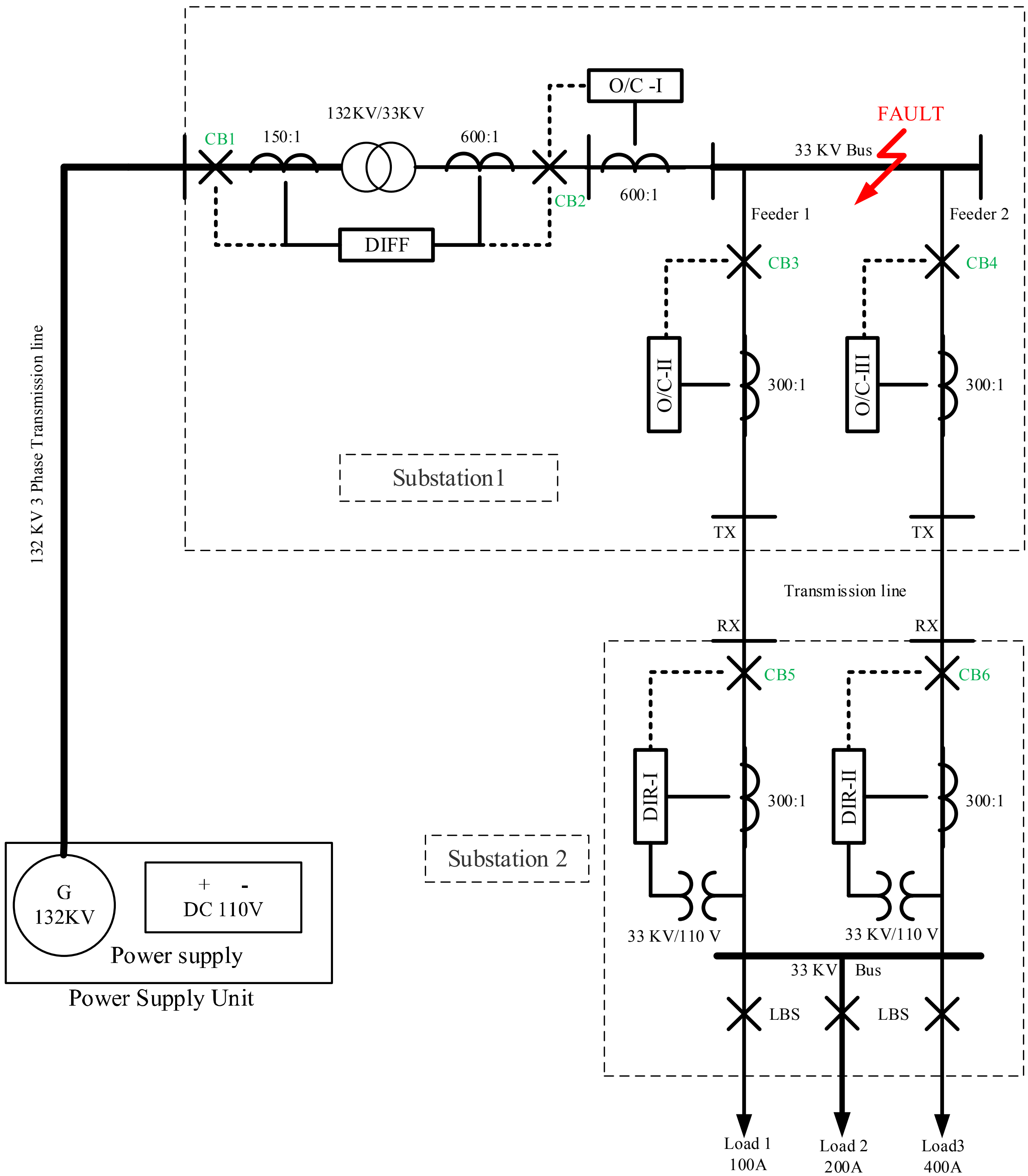

Figure 4.2: Substation one line diagram.

NOTE: TO RESET ALL LATCHE OF O/C RELAY PRESS HOME KEY AND THEN PRESS OK BUTTON.

Power Supply:

1. 3 phase 400 V/132 V Transformer.
2. 110 V DC for relay biasing.

Differential relay comprising of:

1. Primary CT 150:1 [132 KV side]
2. Secondary CT 600:1 [33 KV side]
3. BT : Bucholz Trip
4. PRD: Pressure release device
5. WT: Winding Temperature.
6. BA : Bucholz Alarm
7. TA : Temperature Alarm
8. TT : Temperature Trip
9. Neutral CT secondary 600:1 for restricted earth fault protection.
10. 132 KV/ 33 KV 3 Phase DY connected transformer which is to be protected.

IDMT O/C relay-I for over load protection of transformer & backup protection of Feeder comprising of:

1. CT 600:1 [33 KV side]

IDMT O/C relay-II for protection of feeder I comprising of

1. CT 300:1 [33 KV side]

IDMT O/C relay-III for protection of feeder II comprising of

1. CT 300:1 [33 KV side]

Directional O/C relay-I for protection of feeder I of substation -2comprising of

1. CT 300:1 [33 KV side]
2. PT 33 KV/110 V

Directional O/C relay-II for protection of feeder II of substation -2comprising of

1. CT 300:1 [33 KV side]
2. PT 33 KV/110 V

The figure below shows, as an example, the front panel of the device and the location of the user interface elements used for local control.

1. Navigation push-buttons
2. LED indicators
3. LCD
4. Local port

Navigation push-button function

CANCEL push-button for returning to the previous menu. To return to the first menu item in the main menu, press the button for at least three seconds.

INFO push-button for viewing additional information, for entering the password view and for adjusting the LCD contrast.

programmable function push-button. As default F1 toggles Virtual Input 1 (VI1) On/Off

programmable function push-button. As default F2 toggles Virtual Input 2 (VI2) On/Off

ENTER push-button for activating or confirming a function.

arrow UP navigation push-button for moving up in the menu or increasing a numerical value.

arrow DOWN navigation push-button for moving down in the menu or decreasing a numerical value.

arrow LEFT navigation push-button for moving backwards in a parallel menu or selecting a digit in a numerical value.

arrow RIGHT navigation push-button for moving forwards in a parallel menu or selecting a digit in a numerical value.

Figure 4.3: O/C relay.

LED indicator	Meaning	Measure/ Remarks
Power LED lit	The auxiliary power has been switched on	Normal operation state
Status LED lit	Internal fault, operates in parallel with the self supervision output relay	The relay attempts to reboot [REBOOT]. If the error LED remains lit, call for maintenance.
A- H LED lit	Application-related status indicators.	Configurable
F1 / F2 LED lit	Corresponding function key pressed / activated	Depending of function programmed to F1 / F2

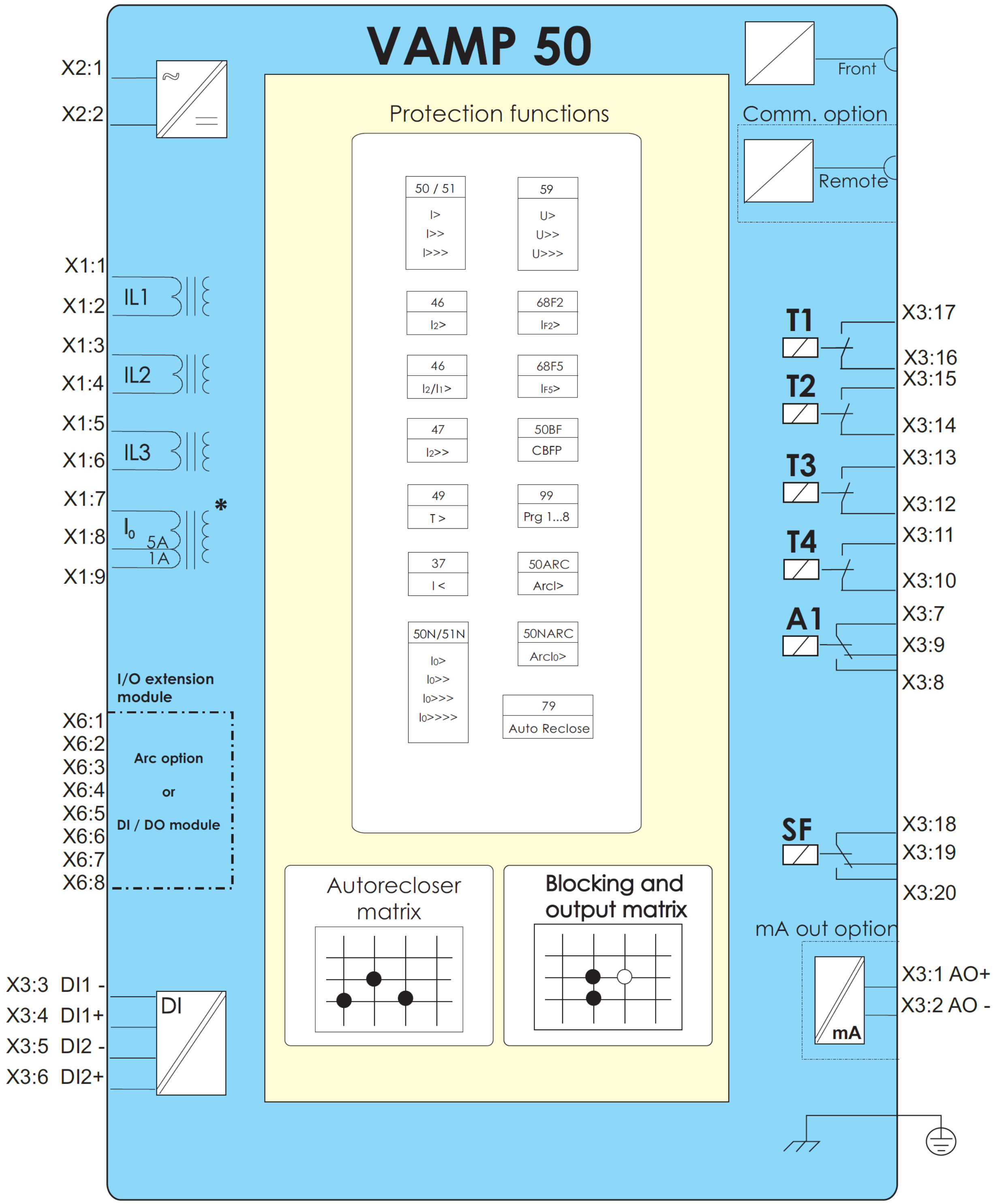

Figure 4.4: Block Diagram of O/C relay.

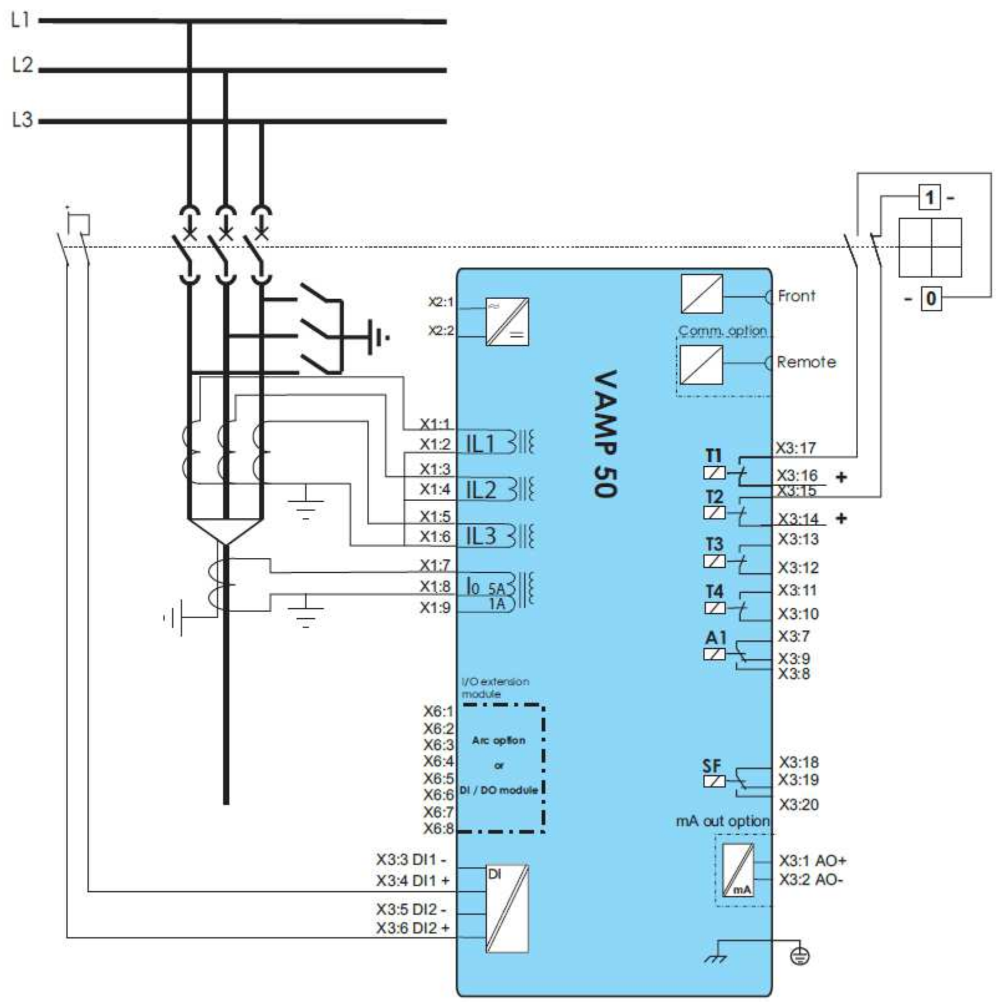

Figure 4.5: Connection example

Report:

1. Why do you need a trip circuit for the power system?
2. Explain the objective of different sub-station.
3. What is the function of auxiliary contact in the trip circuit?
4. Mention the name and usage of the equipment that is used in the substation.

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Experiment: 5
Experiment name: Performance study of directional relay.
Introduction:

Directional protection responds to the flow of power in a definite direction with reference to the location of CT's and PT's. Directional relay senses direction of power flow by means of phase angle between voltage (V) and current (I). When this angle exceeds certain predetermined value, the directional relay operates. A directional relay is a double actuating quantity relay with one input as current I from CT and the other input as voltage, V from PT. With the electromagnetic directional O/C relays, discrimination is affected when the voltage drops down to a low value due to faults close to the location of PT. With static or digital directional O/C relay can function well up to 1% of the system voltage.

Working principle:

Active power flowing through a part of an electric circuit is $P = VI \cos\theta$, where θ is the angle between voltage and current.

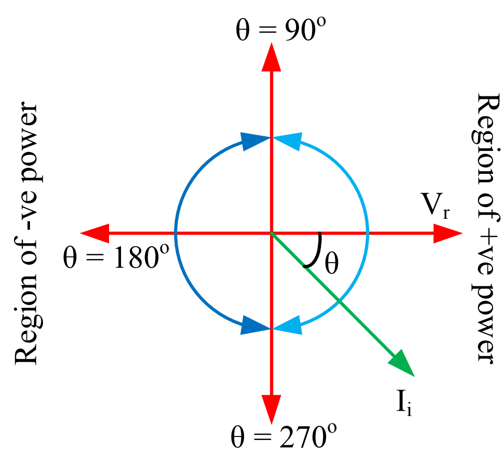


Fig 1: Vector diagram of power.

From the above vector diagram,

For $\theta < \pm 90^{\circ}$, $\cos\theta$ is positive, hence the real power is positive.

For $\theta > \pm 90^{\circ}$, $\cos\theta$ is negative, hence the real power is negative.

For $\theta = 90^{\circ}$ & $\theta = 270^{\circ}$, $\cos\theta$ is zero, hence the real power is zero.

The direction of power flow can be sensed by sensing the magnitude and sign of power. Here we used microprocessor based directional relay.

Directional phase fault Protection: (67)

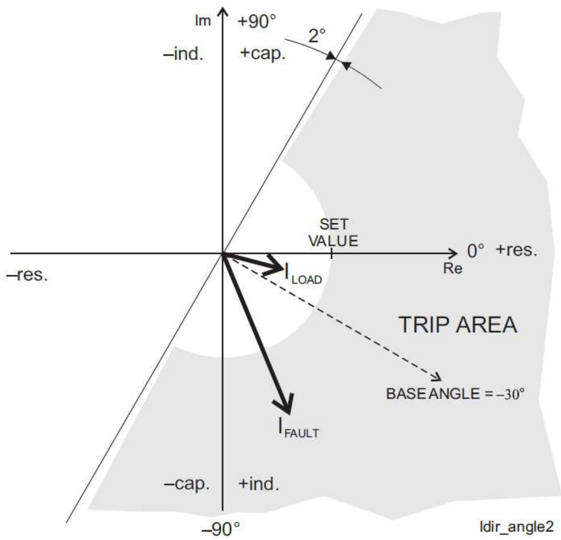


Figure 5.10: Example of protection area of the directional overcurrent function.

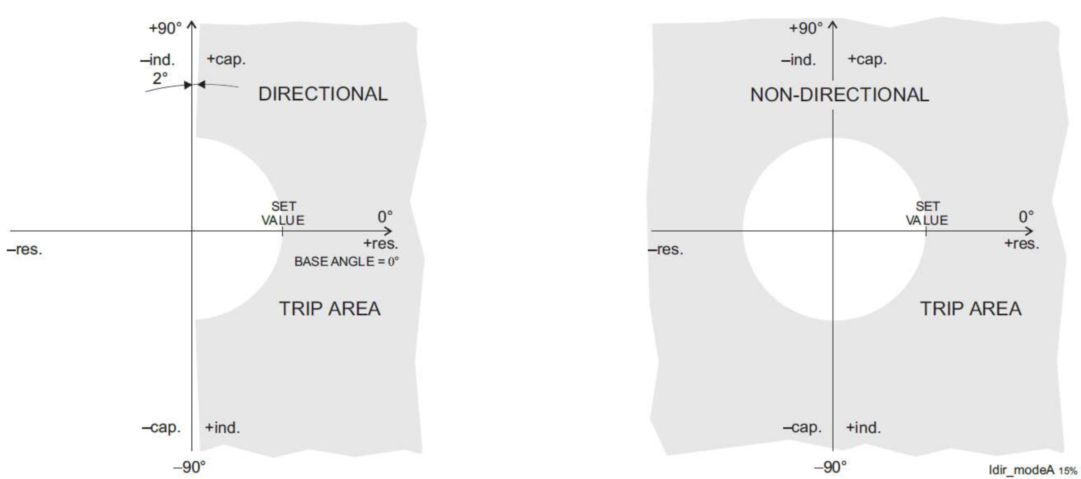


Figure 5.11: Difference between directional mode and non-directional mode. The grey area is the trip region.

Directional Earth fault Protection (67N)

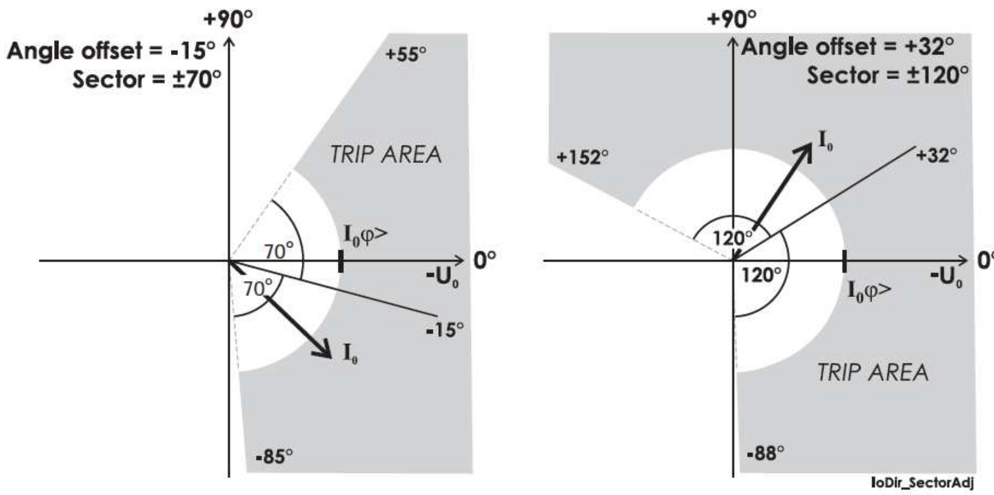
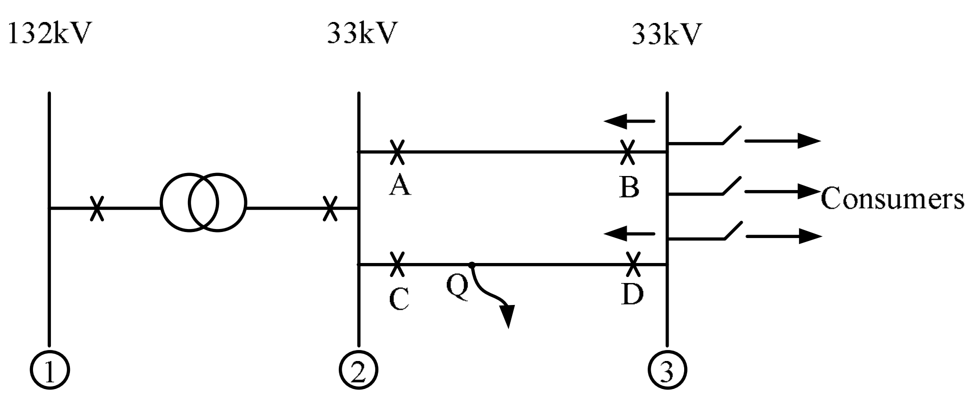


Figure 5.26: Two example of operation characteristics of the directional earth fault stages in sector mode. The drawn I_0 phasor in both figures is inside the trip area. The angle offset and half sector size are user's parameters.

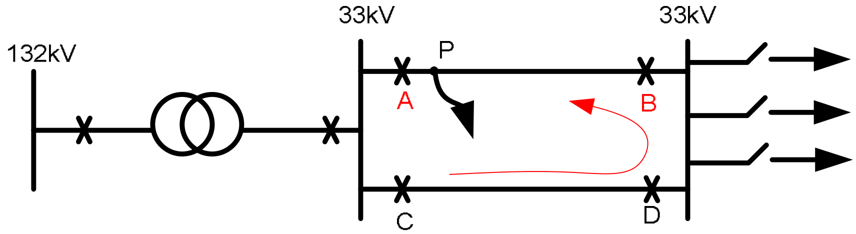
Description of the set up

The following figure shows the single line diagram of a power system which feeds 33 KV consumers of bus 3. The bus 3 is fed from bus 2 at 33 KV through two circuits in parallel. There are two breakers and associated relays at the two ends of each circuit. These relays are A & B and C & D as shown in the figure. Of these, A&C are non directional O/C relays whereas B and D are directional O/C relays.



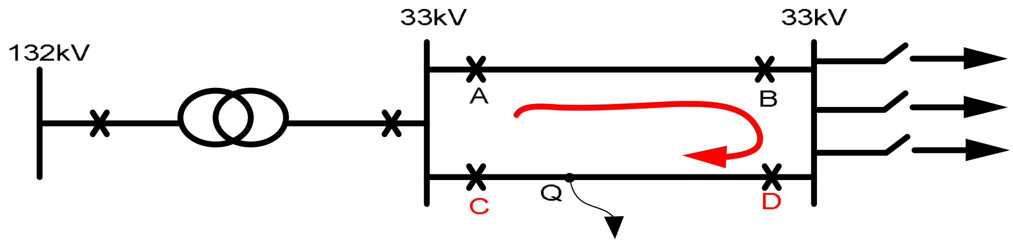
When the fault current flows through the relays B and D in the direction of arrow as shown in the figure, the relays operate and trip associated breakers.

Case I: For a fault at 'P' on one of the circuits, the direction current flow is as shown.



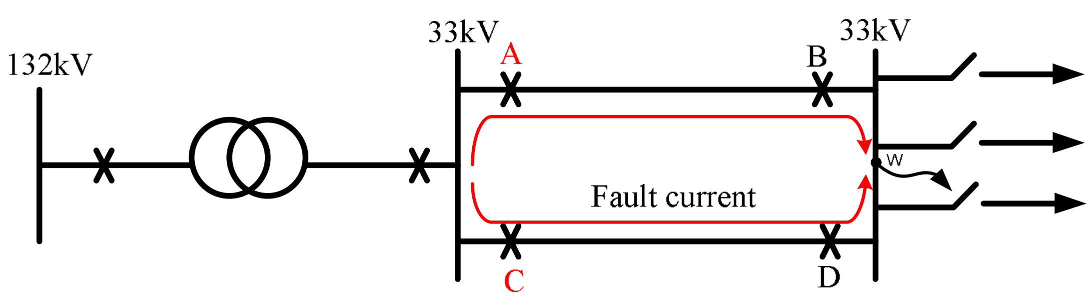
Under this fault condition, the non directional relay A and directional relay B operate and trip the associated breakers to isolate the fault.

Case II: For a fault at 'Q' in the other circuit, the direction of current flow is as shown.



Under the fault condition, the non directional relay C and the directional relay D operate and trip the associated breakers to isolate the faulty circuit.

Case III: For a fault at 'W' in the other circuit, the direction of current flow is as shown.

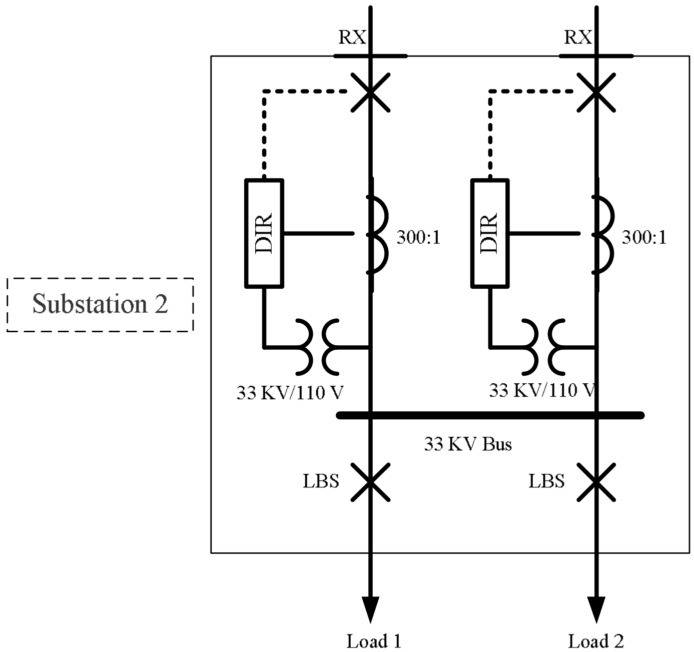


Under the fault condition, the non directional relay C and A operate and trip the associated breakers to isolate the faulty circuit. In this condition the directional relay should not work.

Apparatus:

1. Circuit breaker.
2. Protected line.
3. CT 300:1 – 6 no's
4. PT 33KV/110V – 6no's
5. Microprocessor based directional O/C Relay.

Circuit Diagram:



Procedure:

1. Switch ON Substation I & II.
2. Switch ON every breaker of the substations.
3. **Connect 100amp load of the substation -II.**
4. Draw the circuit diagram of this directional protection.
5. Observe the feeder trip circuit carefully.
6. Connect the **directional O/C relay I and II** with the communication cable to the computer.
7. Open the relay software. Activate directional protection Iφ>. Set pick up setting **0.1In** and angle offset **-100 degree for each relay to set correct coordination.**
8. Assign output relay (**T1 & A1**) and **fault LED** to trip the breaker for directional line and directional earth fault from Matrix menu.
9. On the scaling menu give CT ratio **300:1** and PT ratio **33kV/110V**.
10. Activate directional phase and earth fault Protection.
11. Assign time **0.2Sec DT** of the directional relay **Iφ>**.
12. Assign time **0.2Sec DT** of the directional earth fault relay **Ioφ>**

13. Now create fault on **feeder I, feeder II and BUS II** and observe tripping operation of the associated breaker.
14. Find magnitude of the fault current on the directional fault recording menu.

NOTE:

- **TO RESET ALL LATCHES OF VAMP 52 RELAY PRESS TWICE THE FUNCTION KEY F1.**

Reports:

1. In what conditions is it necessary to use directional protection? Explain how close up faults affects the relay operation.
2. How does directional protection determine the direction of current?
3. What is relay characteristic angle, and what are usual values for this angle?

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Experiment: 6

Experiment name: Performance study of an O/C relay, O/C relay co-ordination, advantage of parallel feeder.

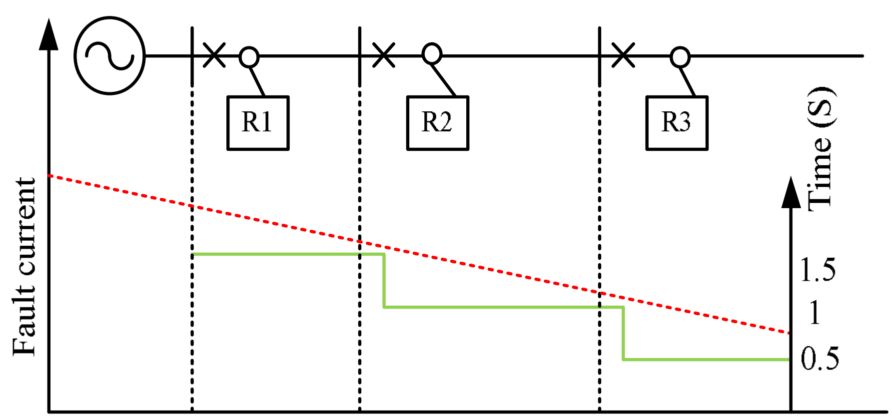
Introduction:

Though it may be possible to grade the relay settings based on the fault currents, it is noted that the fault currents in a series network differs marginally when the sections are connected by cables without any major equipment like transformers in between the two ends. In such types, if networks grading the settings based on current values do not serve the purpose. It is required to go for time grading between successive relays in most of the networks.

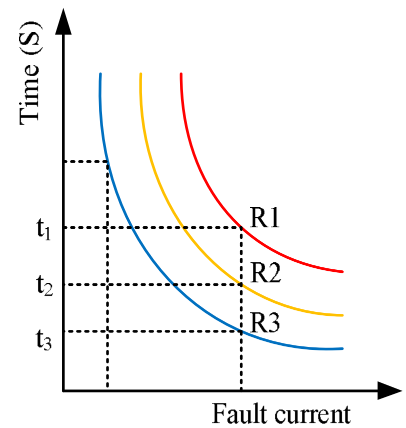
To achieve selectivity and coordination by time grading two philosophies are available, namely:

1. Definite time lag (DTL), or
2. Inverse definite minimum time (IDMT).

For the first option, the relays are graded using a definite time interval of approximately 0.5 sec. The relay *R*3 at the extremity of the network is set to operate in the fastest possible time, whilst its upstream relay *R*2 is set 0.5 s higher. Relay operating times increase sequentially at 0.5 sec intervals on each section moving back towards the source as shown in Figure 1.

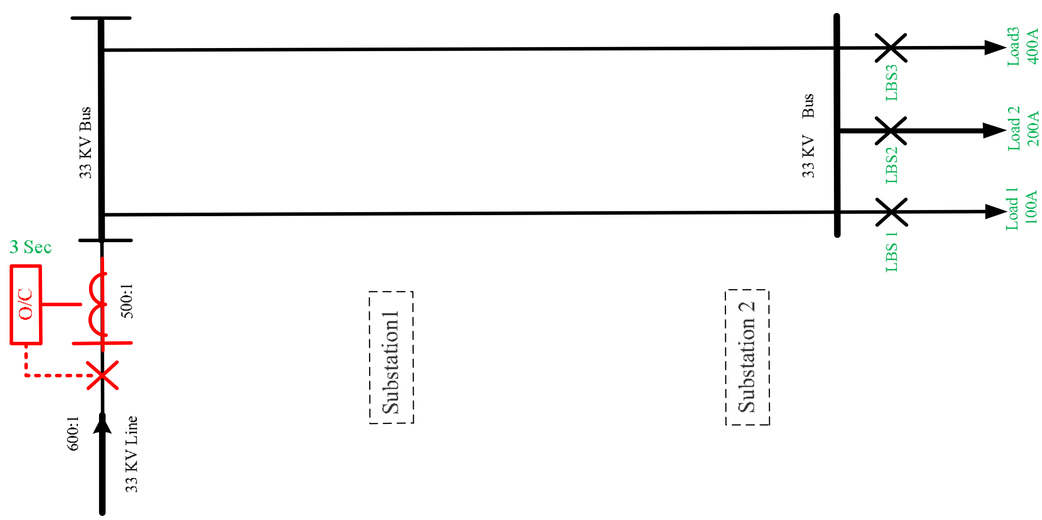


The problem with this philosophy is, the closer the fault to the source the higher the fault current, the slower the clearing time – exactly the opposite of what we should be trying to achieve. On the other hand, inverse curves as shown in Figure 2 operate faster at higher fault currents and slower at the lower fault currents, thereby offering us the features that we desire.

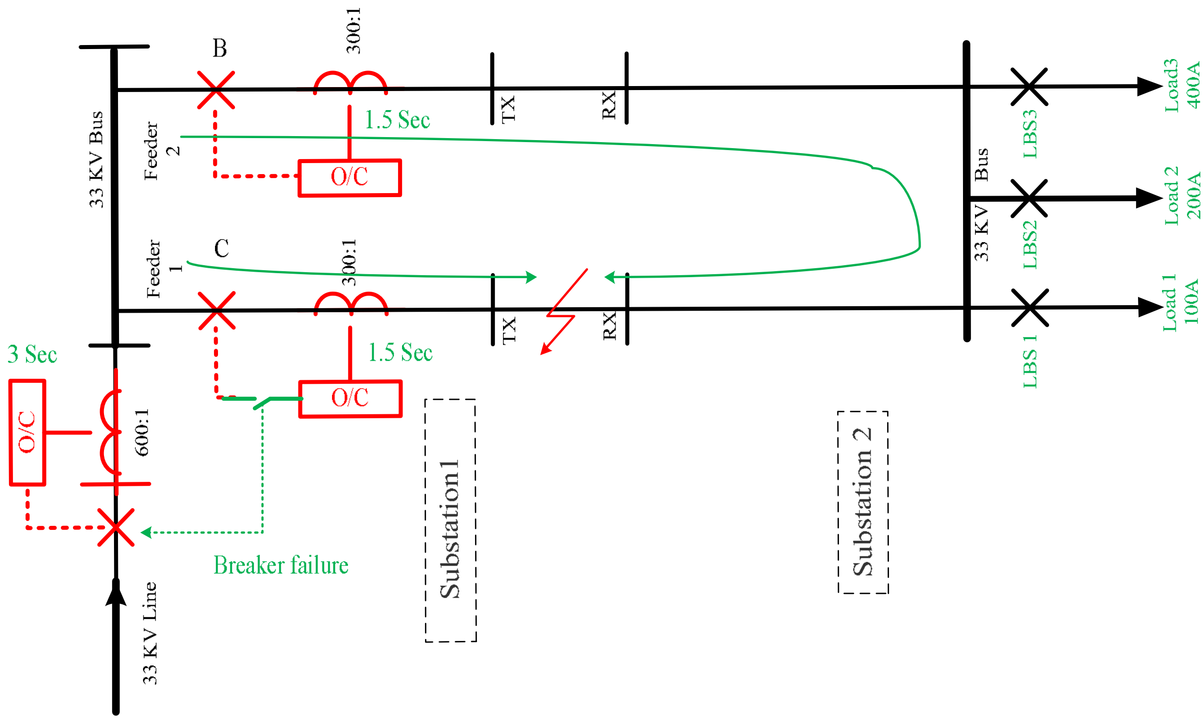


Protection of parallel distribution lines:

The usage of multiple lines improves the availability of power, i.e. using multiple lines in parallel allows more power to be conveyed to a given location. Two parallel connected lines are the simplest and most frequently encountered example of a closed ring. The protection system must be designed in such a way that when a fault is on one line, the other distribution line should continue with its normal operation. For better explanation why the directional protection is necessary in this case, the protection system will be firstly explained just with regular over current relays and it will be explained why it is not good solution and why directional protection must be used if we want to have good selectivity of relay protection. As it is already mentioned, the simple system with two parallel lines will be observed. Such a system is shown on this figure.

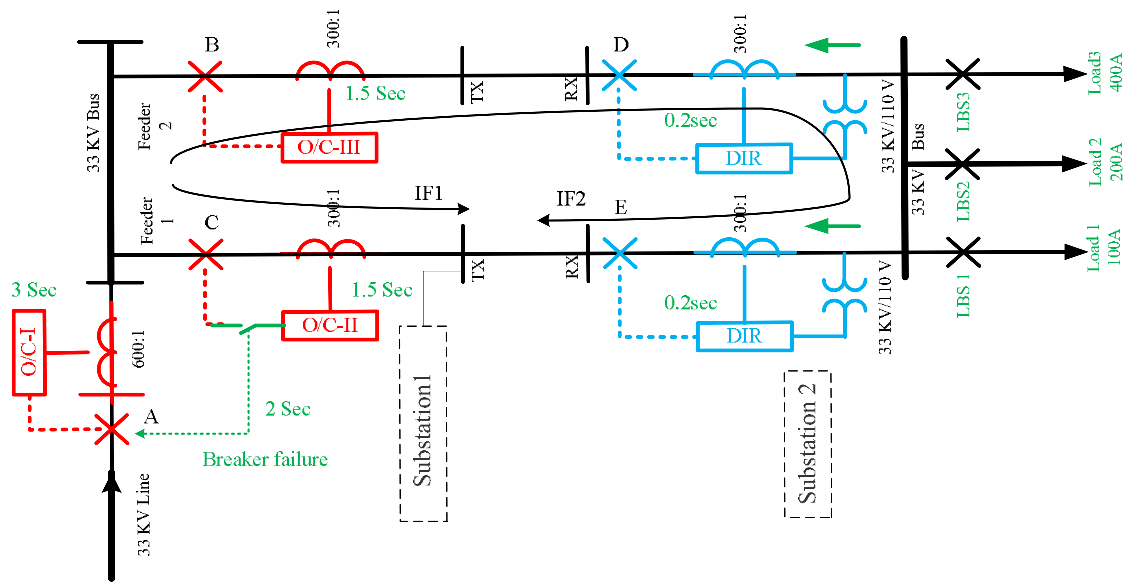


One of the possible protections of this simple system is to use 2 over current relays and a circuit breaker at the source end of each line as it is shown on the following figure. This solution protects the line properly, but the selectivity is not achieved at all. In other words, wherever the fault occurs, both lines would be out of function.



When a fault occurs on feeder 1, the fault is supplied with current form both lines, which means that both over current relays will react after 1.5 Sec (because of the time-delay), thereby opening circuit breakers B and C. This opens both power lines and the result is: power in no longer available at substation bus 2.

To solve this problem, i.e. to archive discriminative protection of the two power lines from above figure, a directional over current relays are required. The protection system with directional units is shown on the following figure:



The analysis will be done when the fault is on the feeder 1. In this case, fault current IF1flows through feeder 1 and fault current IF2 flows also through feeder 2, but in the opposite direction. The protection equipment time delays are shown in the figure. The current IF2 flows though relay B, D and E. Relay B detects the fault but because of time delay it won't react immediately, but after 1.5 Sec. The relay D doesn't detect the fault at all because the direction of current is opposite to the direction set in the relay. Finally, relay E would react because the direction of the current flow is the same as the direction set in the relay and there is time-delay of just 0.2s (1.5s lower than for relay B). With the reaction of the relay E, the over current relay B resets before its time delay has elapsed. The situation with current IF1 is much simpler for this fault because this current flows only through relay C. At the moment when the circuit breaker at location E opens, the circuit breaker at location C is still closed although this relay has reacted. The reason for this is that this relay has time -delay of 1.5s. After this time, the circuit breaker on location C opens and the fault is isolated while the healthy line is still in operation, providing electrical energy to the bus bar 2. A time setting of 1.5s is used on the over current relay at location B to allow the directional over current relay at location E to trip when a fault occurs on line. This ensures that feeder 2 is not disconnected when a fault occurs on feeder 1, thereby achieving proper fault discrimination. For the same reason the relay on location C has the same time delay, just this configuration has sense when the fault is on the feeder 2.

Circuit breaker failure protection:

The circuit breaker failure protection is based on supervision of phase and earth current after tripping events. The test criteria is whether all phase current have dropped to less than 5% of in within tCBFP. If one or more of the phase currents have not dropped to specific current within this time, CB failure is detected and the assigned output relay is activated to trip the upstream breaker.

Apparatus:

1. Circuit breaker.
2. Protected line.
3. Bus CT 600:1 – 3 no's
4. Feeder CT 300:1 – 3+3 no's
5. Feeder PT 33V/110V 3 no's
6. Microprocessor based IDMT O/C Relay: 3 no's
7. Microprocessor based directional O/C Relay: 2 no's

Procedure:

1. Switch ON the Substation.
2. Switch ON every breaker of the substations.
3. **Connect 100 Amp load of the substation -II.**
4. Connect the **O/C relay –II and III** with the communication cable to the computer.
5. **Activate over current Protection I> & Breaker failure protection for feeder-2 of O/C relay-III, Earth fault protection I_0> for feeder-1 of O/C relay-II.**
6. Open the relay software and assign output relay **T1 & A1** and assign **Fault LED** to trip the breaker for **over current on the bus, feeder I and feeder II from matrix menu.**
7. On the scaling menu give CT ratio **300:1** on each feeder.
8. Assign delay type **DT 1.5 Sec** for Feeder O/C RELAY II and III and set current setting **0.8In of I> for O/C relay-III and 0.08In of Io> for O/C relay-II.**
9. On over current relay-II of feeder -1 activate Earth fault protection and on over current relay-III of feeder -3 activate over current and breaker failure protection.
10. Activate breaker failure protection on Over current relay-II and assign output relay **T3 and assign fault LED** to trip the upstream breaker of over current relay –I.

11. Now create fault on **Bus-I, Feeder-1, Feeder-II and Bus-II** and each case observe which breaker are tripping for each faults.
12. Now open the trip coil of breaker CB4 by pressing breaker failure switch and create fault on feeder -2 and observe the tripping operation.

Report:

1. What are the advantages of Parallel feeder?
2. How correct co ordination is obtained by ring grid system?
3. Discuss the significance of the back up protection.
4. Under what condition back up protection is economically justified?

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Experiment: 7

Experiment name: Performance study of a differential relay for the protection of transformer.

Objectives:

The objectives of this experiment are to observe the performance of the following schemes of a power transformer.

1. Buchholz alarm
2. Buchholz trip
3. Temperature alarm
4. Temperature trip
5. Differential relay trip due to phase to phase and ground fault
6. Restricted E/F relay trip
7. PRD trip

Introduction:

The choice of the protection for any power transformer depends upon a number of factors such as its size, importance and cost. Power transformers are used in transmission network of higher voltages for step-up and step down application (400 kV, 200 kV, 110 kV, 66 kV, 33kV) and are generally rated above **200MVA**.

Differential Relay:

Differential relay provides unit protection. This relay is one that operates when there is a difference between two or more similar electrical quantities exceeds a predetermined value. In differential relay scheme circuit, there are two currents come from two parts of an electrical power circuit. These two currents meet at a junction point where a relay coil is connected. According to Kirchhoff Current Law, the resultant current flowing through the relay coil is nothing but summation of two currents, coming from two different parts of the electrical power circuit.

The polarity and amplitude of both the currents are so adjusted that the phasor sum of these two currents is zero at normal operating condition. Thereby there will be no current flowing through the relay coil at normal operating conditions. But due to any abnormality in the power circuit, if this balance is broken, that means the phasor sum of these two currents no longer remains zero and there will be non-zero current flowing through the relay coil thereby relay being operated. In current differential scheme, there are two sets of current transformer each connected to either side of the equipment protected by **differential relay**. The ratio of the current transformers are so chosen, the secondary currents of both current transformers matches each other in magnitude.

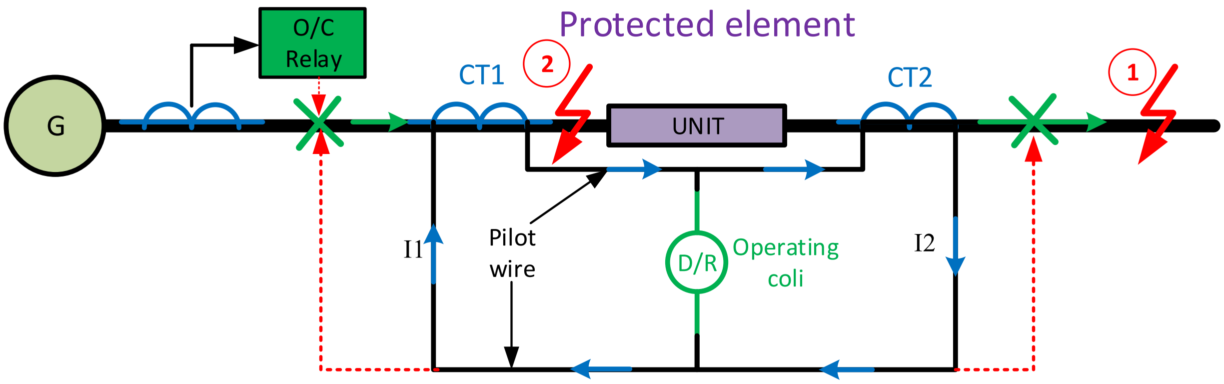


Figure: Differential protection for radial feeder

At healthy condition: $\mathbf{I_1 - I_2 = 0}$. For a unidirectional feeder, if fault occurs at location 1 (outside of unit), then current through the operating coil will be $\mathbf{I_1 - I_2 = 0}$. But for location 2, $\mathbf{I_1 - I_2 \neq 0}$.In case of bidirectional feeder, if fault occurs within unit, direction of I_2 current will be changed and current through the operating coil will be $\mathbf{I_1 + I_2}$ which is definitely not equals to zero.

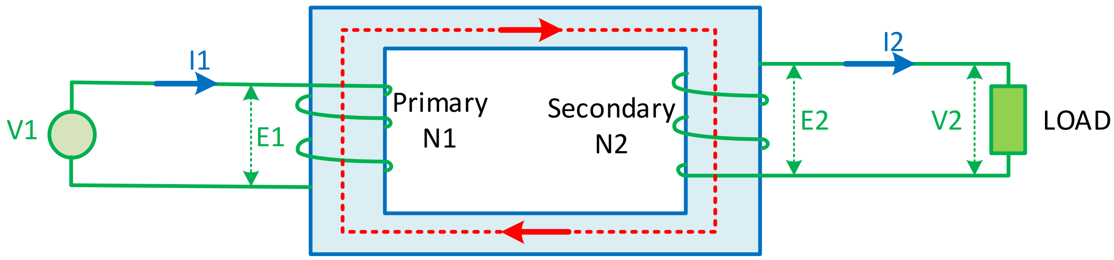
Fault outside the unit: Only over-current relay will operate
Fault inside the unit: Both over-current realy and differential will operate

Construction of Transformer:

A transformer is a static piece of equipment used either for raising or lowering the voltage of an a.c. supply with a corresponding decrease or increase in current. It essentially consists of two windings, the primary and secondary, wound on a common laminated magnetic core. The winding connected to the a.c. source is called primary winding (or primary) and the one connected to load is called secondary winding (or secondary).

1. Transformer Tank
2. High Voltage Bushing
3. Low Voltage Bushing
4. Cooling Fins/Radiator
5. Cooling Fans
6. Conservator Tank
7. System Ground Terminal
8. Drain Valve
9. Dehydrating Breather
10. Oil Temperature/Pressure gauges
11. Bushing Current Transformers
12. Control Panel

Working Principle:



When an alternating voltage V1 is applied to the primary, an alternating flux φ is set up in the core. This alternating flux links both the windings and induces e.m.f.s E1 and E2 in them according to Faraday's laws of electromagnetic induction. Magnitudes of E2 and E1 depend upon the number of turns on the secondary and primary respectively.

If N2 > N1, then E2 > E1 (or V2 > V1) and we get a **step-up transformer.**
If N2 < N1, then E2 < E1 (or V2 < V1) and we get a **step-down transformer.**

$$E1/E2 = N1/N2 = I2/I1$$

Types of faults:

1. Phase to phase fault &
   Phase to neutral fault
2. High voltage surge due to lightening
3. Fault inside the tank below oil level
4. Magnetic inrush current
5. Tank E/F protection

Protection Scheme:

1. **Phase to phase and phase to neutral fault protection: DR+ O/C relay**

In protection of a transformer, the CT connections and CT ratios are such that current fed into the pilot wires from both the ends are equal during normal and for through fault conditions. During any kind of internal fault, like phase to phase faults or phase to ground faults, the balance is disturbed. The out of balance current (I_1-I_2) flows through the relay operating coils. To avoid unwanted relay operation on through faults, restraining coils are provided in series with the pilot wires. The average current through the restraining coil is (I_1+I_2)/2. As a result the restraining current increases with the increase of (I_1-I_2) in the operating coil for a through fault condition. An additional over current relay is also used to provide over load protection.

2. **High voltage surge due to lightening:**

   - Lightening Arrester: For large transformers
   - Horn gap: in small distribution transformer

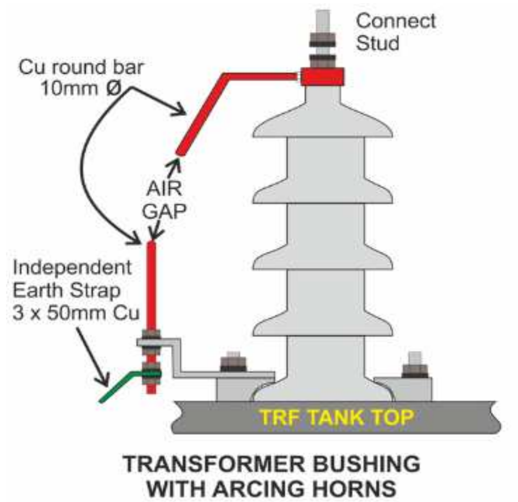


Fig.: Horn gap or Arcing horn

Arcing Horns bypasses the high voltage across the Insulator using air as a conductive medium between the Horns. The small gap between the horns ensures that the air between them breaks down resulting in a flashover and conducts the voltage surge rather than cause damage to the insulator.

Arcing Horns basically form a Spark Gap across the Insulator with a lower breakdown voltage than the air path along the insulator surface, so an overvoltage will cause the air to break down and the arc to form between the arcing horns, diverting it away from the surface of the insulator. An arc between the Horns is more tolerable for the equipment because it provides more time for the fault to be detected and the arc to be safely cleared by remote Circuit Breakers. Air gap length should be provided is such a way that at normal system voltage, there should not be any current flow through this horn gap path.

3. **Fault inside the tank below oil level:**

<u>Overheating Protection:</u>

The rating of the transformer is based on the temperature rise above an assumed maximum ambient temperature; under this condition no sustained overload is usually permissible. At lower ambient temperature some degree of overload can be safely applied. Short time overloading are also permissible to an extent dependent on the previous loading conditions. No precise ruling applicable to all conditions can be given concerning the magnitude and direction of safe overload.

Thermocouples or resistor temperature detectors are kept near each winding. These are connected to a bridge circuit. When temperature increases above safe value, an alarm is given. If measures are not taken, the circuit breaker is tripped after a certain temperature. Some typical settings for oil temperature are as follows-

At 60^0C, Switch on cooling fans

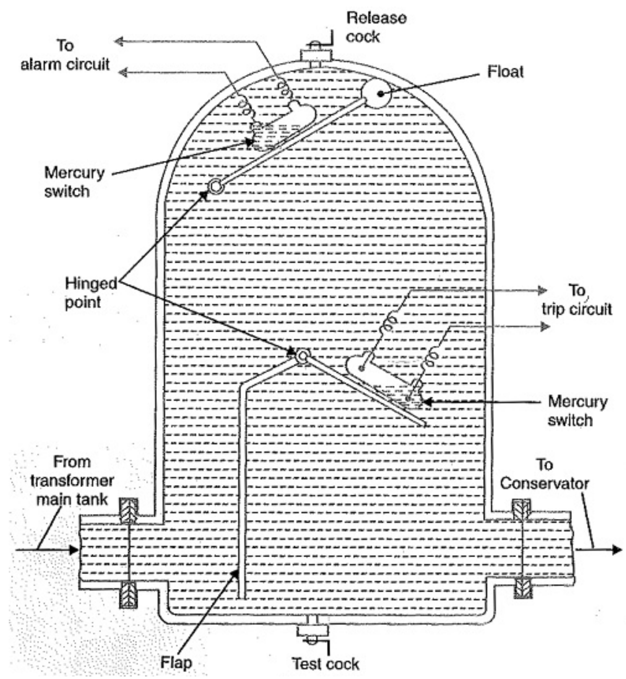
At 95^0C, give an alarm

At 120^0C, give a trip signal to trip the CB.

A temperature of about 95^0C is considered to be the normal maximum working value. Any further rise of 8^0-10^0C beyond this 95^0C will make the life of the transformer half if this rise is sustained.

Buchholz relay (Gas relay / Gas actuated relay):

All faults below oil in a transformer result in the localized heating and break down of the oil. Some degree of arcing will always take place in a winding fault and resulting decomposition of the oil will release gas such as hydrogen, carbon monoxide and light hydro carbons. When the fault is of a very minor type, such as a hot joint, gas is released slowly, but a major fault involving severe arcing cause's rapid release of large volumes of gas as well as oil vapor. The action is so violent that the gas and oil vapor do not have time to escape but instead build up pressure and bodily displace the oil. When such faults occur in transformers having oil conservators, the faults causes a blast of oil to pass up the relief pipe to the conservator.



(a)Buchholz Alarm:

The incipient faults (gradually developing faults in the winding below oil level) produce the gas and it gets collected in the upper portion of the relay, thereby the oil level in the relay drops down. The float, floating in the oil in the relay tilts down with lowering the oil level. While doing so the mercury switch attached to the float is closed on to the alarm circuit.

(b)Buchholz trip :

The short circuit fault causes a blast of oil rushes towards the conservator through Buchholz relay. The baffles (plate) in the Buchholz relay get pressed by the rushing oil. Thereby it closes another switch which in turn closes the trip circuit of the circuit breaker.

Pressure Relief Device:

The working principle of transformer pressure relief device is very simple. If pressure arises inside a transformer and exceeds a pre-set pressure limit, the pressure safety valve opens its valve clap, which is held by a spring and releases the internal pressure until it declines. After decrease of the pressure, the pressure valve clap moves back to its origin position and closes completely. Normally, the pressure relief device will be mounted on top of the transformer. Due to internal faults, it is suggested to have such pressure relief valves to protect the transformer and release arising pressure quite suddenly.

4. **Magnetic Inrush Current Protection:**

The transformer inrush current is the maximum instantaneous current drawn by the primary of the transformer when their secondary is open circuit. The inrush current does not create any permanent fault, but it causes an unwanted switching in the circuit breaker of the transformer. During the inrush current, the maximum value attained by the flux is over twice the normal flux.

In the FFT analysis of inrush and fault current, it's been observed that the second harmonic content of the inrush current is lying in the high range almost above 60%. The second harmonic content for fault in all the cases is lying below 25%. So, on the basis of FFT analysis the inrush and fault transients can easily be differentiated.

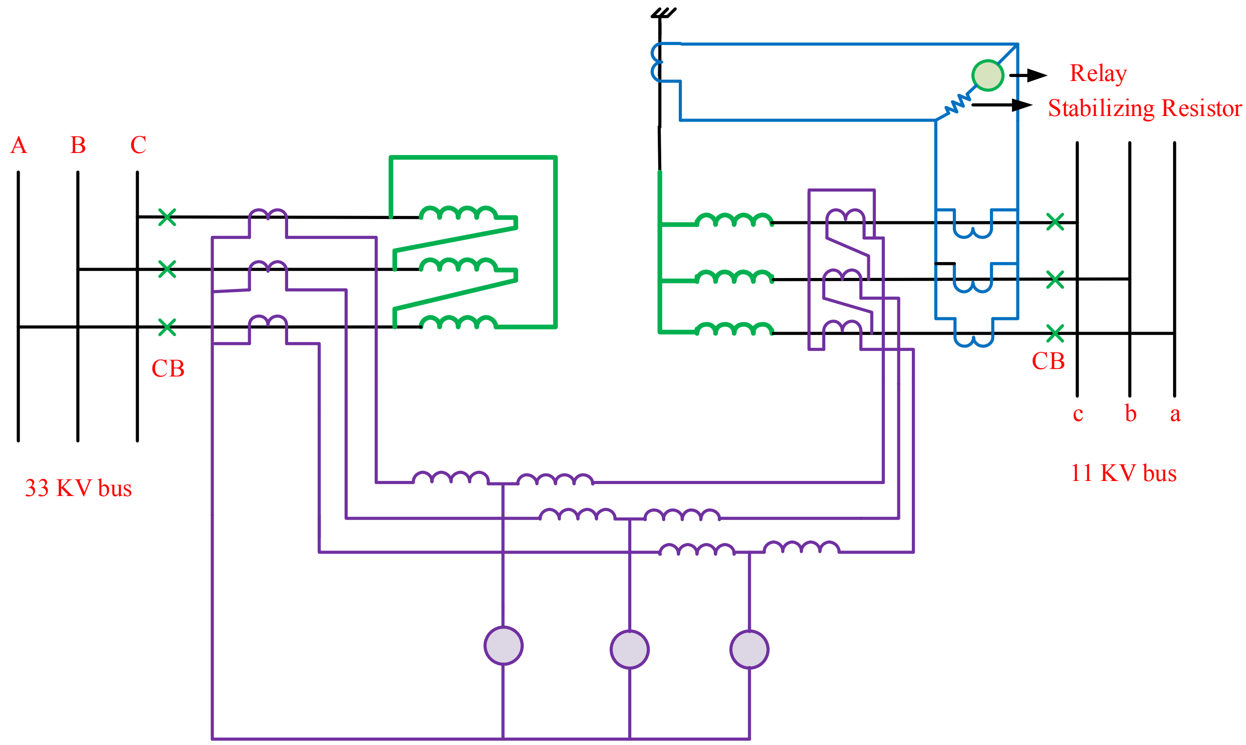
Unnecessary tripping can be occurred due to inrush current. In order to avoid this phenomenon, a second harmonic filter is used whose NC contact is connected in series with the operating coil of differential relay.

5. **Restricted Earth Fault Protection of Y-winding**

When E/F occurs very near to the neutral point of Y-winding of the transformer, the voltage available for driving earth fault current is small. Hence the fault current is low. If the normal biased different relay is to sense such faults, it has to be too sensitive and would therefore operate for spurious signal like, external faults and switching surges; under this condition restricted earth fault protection scheme has evolved. Here the practice is to set the relay such that it operates for earth fault current of the order of 15% of rated winding current, such setting protects restricted portion of the winding.

Procedure:

A 3φ, 38 MVA, 33/11KV, Δ-Y connected power transformer feeds power to an 11 KV bus from a 33 KV bus as shown in the figure below-



Procedure:

Temperature Alarm:

For pushing the temperature alarm switch, which represents the closing of a contact due to rise in winding temperature, an alarm signal will be displayed on the relay display board.

Temperature trip:

If the winding temperature goes to a very high level, the transformer should be isolated from the system. By pushing the temperature trip switch, the temperature relay essentially closes the trip circuit and fault is cleared by two breakers on the two sides of the transformer.

Buchholz Alarm:

Pushing this button means closing the contact of Buchholz relay as an indication of incipient fault in the winding inside the oil, so an alarm indication is displaced on the relay.

Buchholz trip:

Pushing this button means closing the contact of Buchholz rely as an indication of internal short circuit fault. So the breakers on both sides of the transformer are tripped.

Internal Fault:

A short circuit fault in the winding is created by shorting the two phase of any side. This fault is detected by the differential relay and the breakers on both sides of the transformer are tripped to isolate the fault.

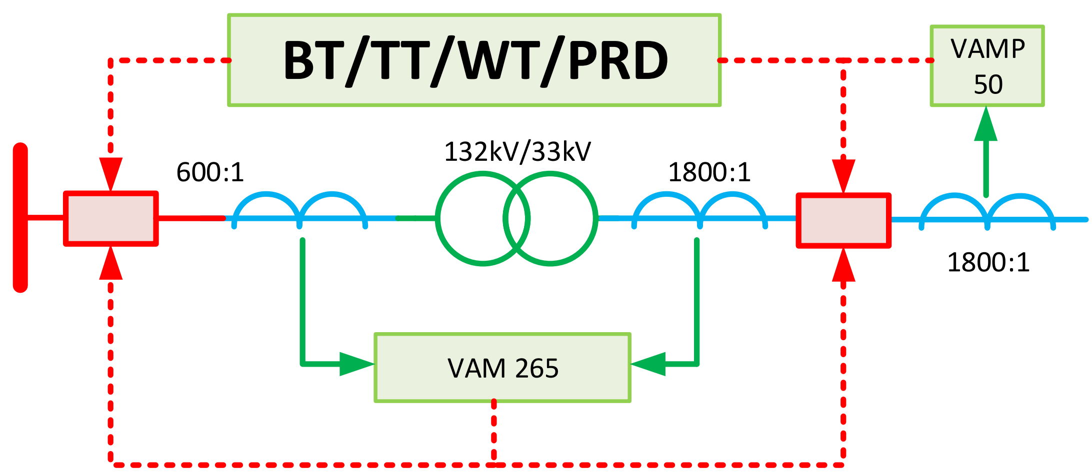
Restricted E/F Protection:

An earth fault close to the neutral end of the Y- winding of the transformer is created by shorting the phase terminal and neutral terminal. This fault is detected by the concerned relay and the breakers on both sides of transformer are tripped to isolate the fault.

Apparatus:

1. Circuit breaker: 2 no's
2. 3 Phase 38.1 MVA Δ-Y 33KV/11KV transformer.
3. CT 600:1 – 3 no's
4. CT 1800:1 – 3 no's
5. Microprocessor based differential Relay: P632
6. Microprocessor based O/C Relay: P122

Circuit Diagram:



Observation:

- How VAMP 265 relay operate during fault condition.
- VAMP 265 relay configurations.
- Transformer voltage.
- Power
- REF

- CT/PT ratio
- Differential protection
- Vector group.
- BT, TT, WT, PRD trip
- LED configures.

Report:

1. What do you mean by incipient faults in the transformer winding? What are the possible causes if this fault?

2. Is the earth fault close to neutral end of a wye connected winding very common? Why?

3. Explain why percentage differential relay is not suitable for detecting the E/F near neutral end of an wye connected winding whose neutral is grounded through high resistance.

AHSANULLAH UNIVERSITY OF SCIENCE AND TECHNOLGY

DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING

SWITCHGEAR AND PROTECTION LAB

Experiment: 8

Experiment name: **Study of different types of motor protection system**

Objectives:

- To observe the connection diagram of DOL protection system and its operation.
- To observe the connection diagram of MMS protection system and its operation.
- To observe the connection diagram of Inverter protection system and its operation & control.

Theory:

The following two basic protections are provided for every motor:

1. Thermal over load protection
2. Short circuit protection.

The switchgear used for the motor protection can also be classified into the following two groups depending on the size of the motor:

1. For small motor (up to 150 hp), fuse and thermal over current protection are used
2. For large motors, circuit breakers and associated relays are used.

For small motors:

Short circuit protection:

Fuse will provide the short circuit protection of stator winding. The operating time current characteristics of the fuse should be such that the fuse should not blow during the motor starting which could be 5 to 7 times the motor full load current. The fuse should blow at current more than those which can be interrupted by the contactors. Here we used magnetic contactor for short circuit protection.

Over load protection:

Thermal relay should provide the overload protection. Thermal relay should not operate during starting period of the motor. Starting period is generally considered to be 5 to 10 seconds.

For large motor:

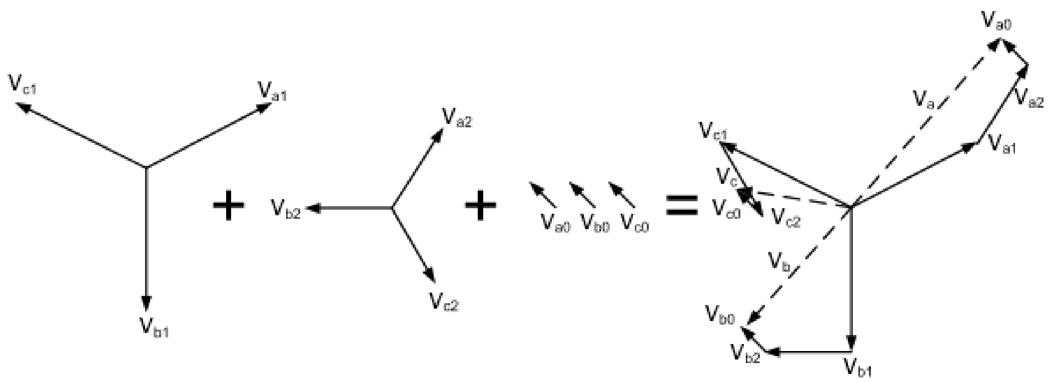
Overload and short circuit protection:

Over current relay and earth fault relay (either instantaneous or inverse time or both depending on the importance of the motor) are used to protect against phase fault and earth fault on stator winding. If the motor is very large and expensive, it is essential to provide differential protection for the winding. The short circuit protection characteristic is set just above the maximum starting current of the motor.

Types of motor	Short Circuit protection	O/L protection	Phase unbalance protection
Small motor (up to 150 hp)	Fuse/ CB	Thermal O/L relay	---
Large motor	Differential relay + CB	O/C relay + CB	NPS relay + CB

NPS Relay:

A relay which protects the electrical system from negative sequence component is called a negative sequence relay or unbalance phase relay.



When a three phase rotating electric machine, including an alternator is connected to the perfectly balanced three phase power system, no negative sequence current is developed in the rotor winding. If, however, the power system is unbalanced, as usually in the case, a negative sequence current double the system frequency is induced in the rotor winding. This naturally causes motor rotor overheating that in the absence of this current. Flow of large amount of negative phase sequence current in the rotor winding for long period can cause damage to the rotor winding. Under this situation, a necessary measure must be taken to save the machine. So, the negative phase sequence current can be used as a parameter in the design of negative sequence protection scheme of large and expensive rotating electric machines including generator.

Protection Types:

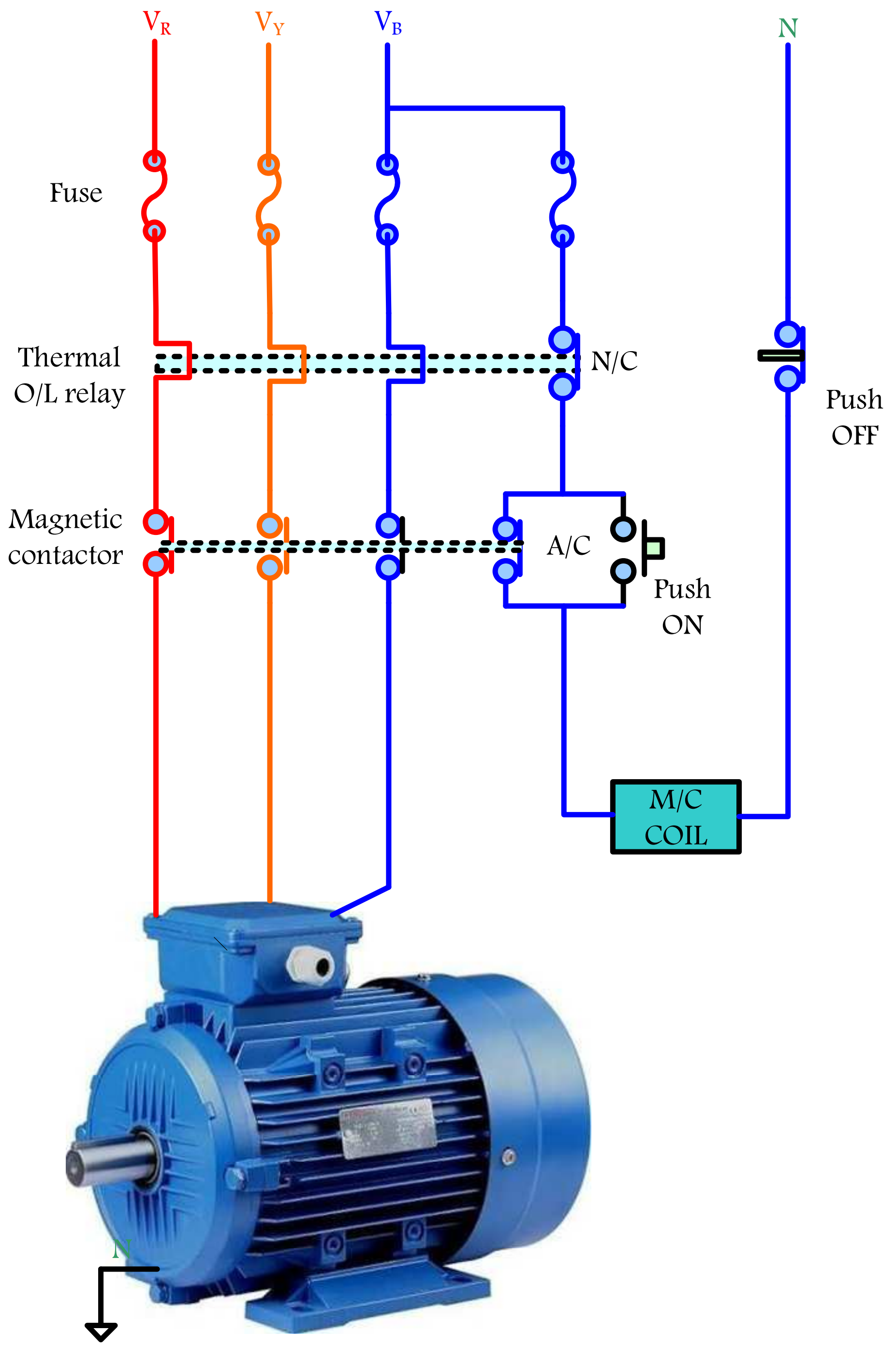
- DOL (Direct on line)
- MMS (Manual motor starter)
- Y-Δ starter
- Resistance starter
- Auto transformer method
- Inverter method
- Soft starter method

DOL protection system:

In electrical engineering, a **direct on line** (DOL) or **across the line** starter starts electric motors by applying the full line voltage to the motor terminals. This is the simplest type of motor starter. A DOL motor starter also contain protection devices, and in some cases, condition monitoring. Smaller sizes of direct on-line starters are manually operated; larger sizes use an electromechanical contactor (relay) to switch the motor circuit. Solid-state direct on line starters also exist.

A direct on line starter can be used if the high inrush current of the motor does not cause excessive voltage drop in the supply circuit. The maximum size of a motor allowed on a direct on line starter may be limited by the supply utility for this reason. For example, a utility may require rural customers to use reduced-voltage starters for motors larger than 10 kW.

DOL starting is sometimes used to start small water pumps, compressors, fans and conveyor belts. In the case of an asynchronous motor, such as the 3-phase squirrel-cage motor, the motor will draw a high starting current until it has run up to full speed. This starting current is commonly around six times the full load current, but may be as high as 6 to 7 times the full load current. To reduce the inrush current, larger motors will have reduced-voltage starters or variable speed drives in order to minimize voltage dips to the power supply.



DOL protection system.

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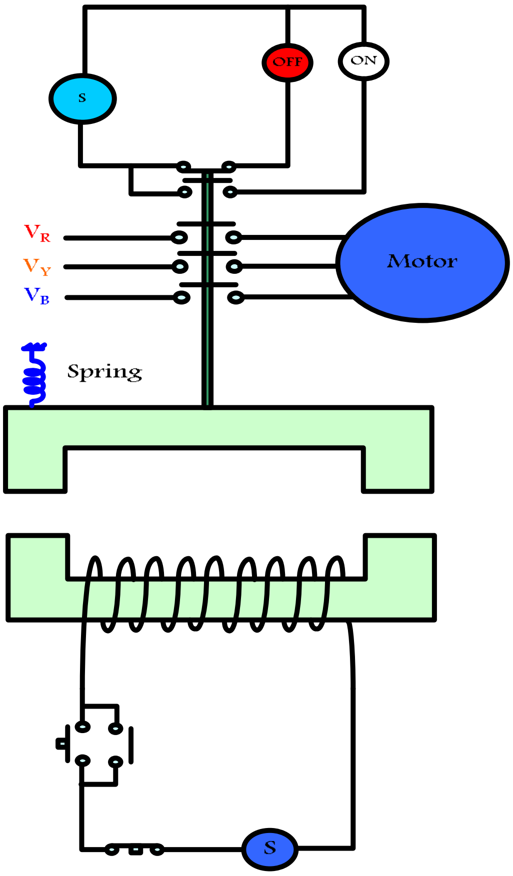
Magnetic Contactor:



MMS protection system:

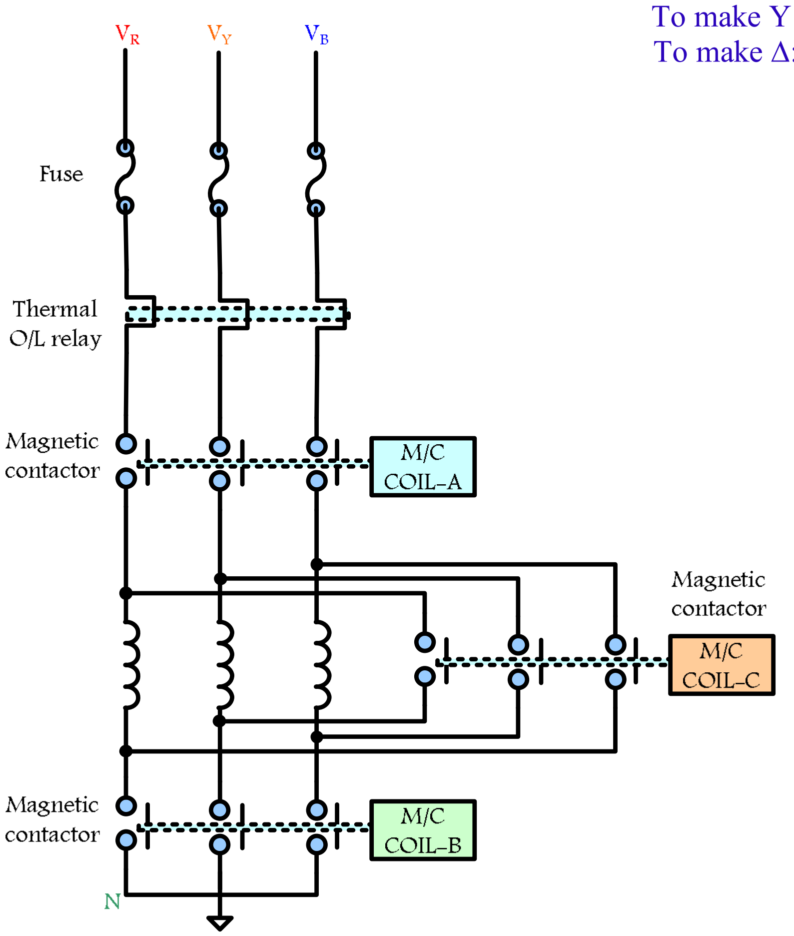
MMS is the integrated form of magnetic contactor, overload relay and a switch. You can use an extra magnetic contactor for remote control. The characteristics of manual motor starter are:

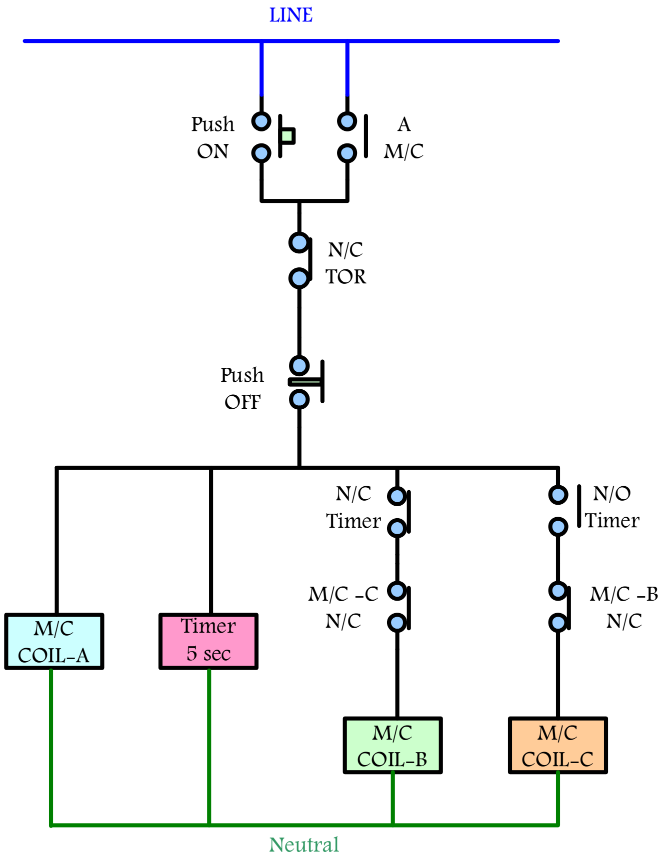
- Overload protection
- Phase failure sensitiveness
- Disconnect function for safety isolation of the installation and the supply
- Temperature compensation from -25 … +60 °C
- Adjustable current setting for overload protection
- Suitable for three- and single-phase application

Y-Δ starter Protection Scheme:

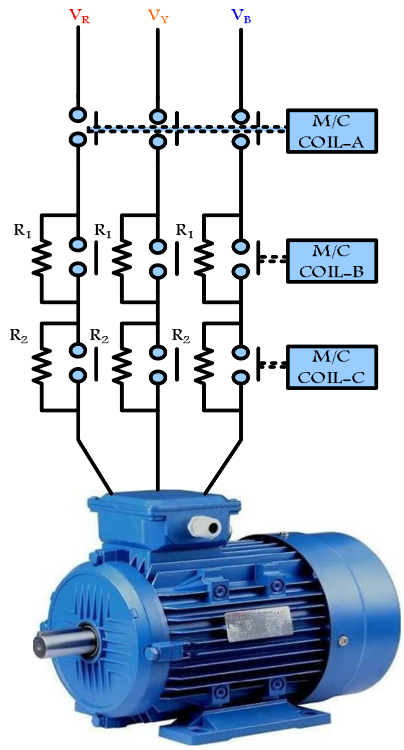
A, B, C: Magnetic Contactor

To make Y: A+B
To make Δ: A+C





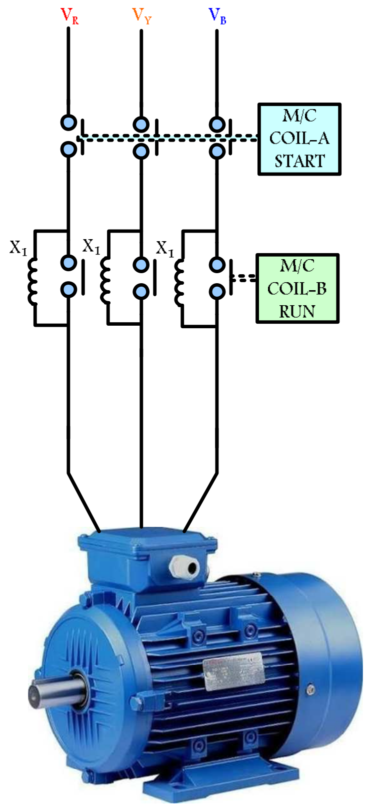
Resistance starter:



In this method, external resistances are connected in series with each phase of stator winding during starting. This causes voltage drop across the resistances so that voltage available across motor terminals is reduced and hence the starting current. The starting resistances are gradually cut out in steps (two or more steps) from the stator circuit as the motor picks up speed. When the motor attains rated speed, the resistances are completely cut out and full line voltage is applied to the rotor.

This method suffers from two drawbacks. First, the reduced voltage applied to the motor during the starting period lowers the starting torque and hence increases the accelerating time. Secondly, a lot of power is wasted in the starting resistances.

Auto transformer starter:



This method also aims at connecting the induction motor to a reduced supply at starting and then connecting it to the full voltage as the motor picks up sufficient speed. The tapping on the autotransformer is so set that when it is in the circuit, 65% to 80% of line voltage is applied to the motor.
At the instant of starting, the change-over switch is thrown to "start" position. This puts the autotransformer in the circuit and thus reduced voltage is applied to the circuit. Consequently, starting current is limited to safe value. When the motor attains about 80% of normal speed, the changeover switch is thrown to "run" position. This takes out the autotransformer from the circuit and puts the motor to full line voltage. Autotransformer starting has several advantages viz low power loss, low starting current and less radiated heat. For large machines (over 25 H.P.), this method of starting is often used. This method can be used for both star and delta connected motors.

Inverter protection system:

You can control and protect the motor using inverter. A frequency inverter controls AC motor speed picture. The frequency inverter converts the fixed supply frequency (50 Hz) to a variable-frequency, variable-voltage output to enable precise motor speed control.

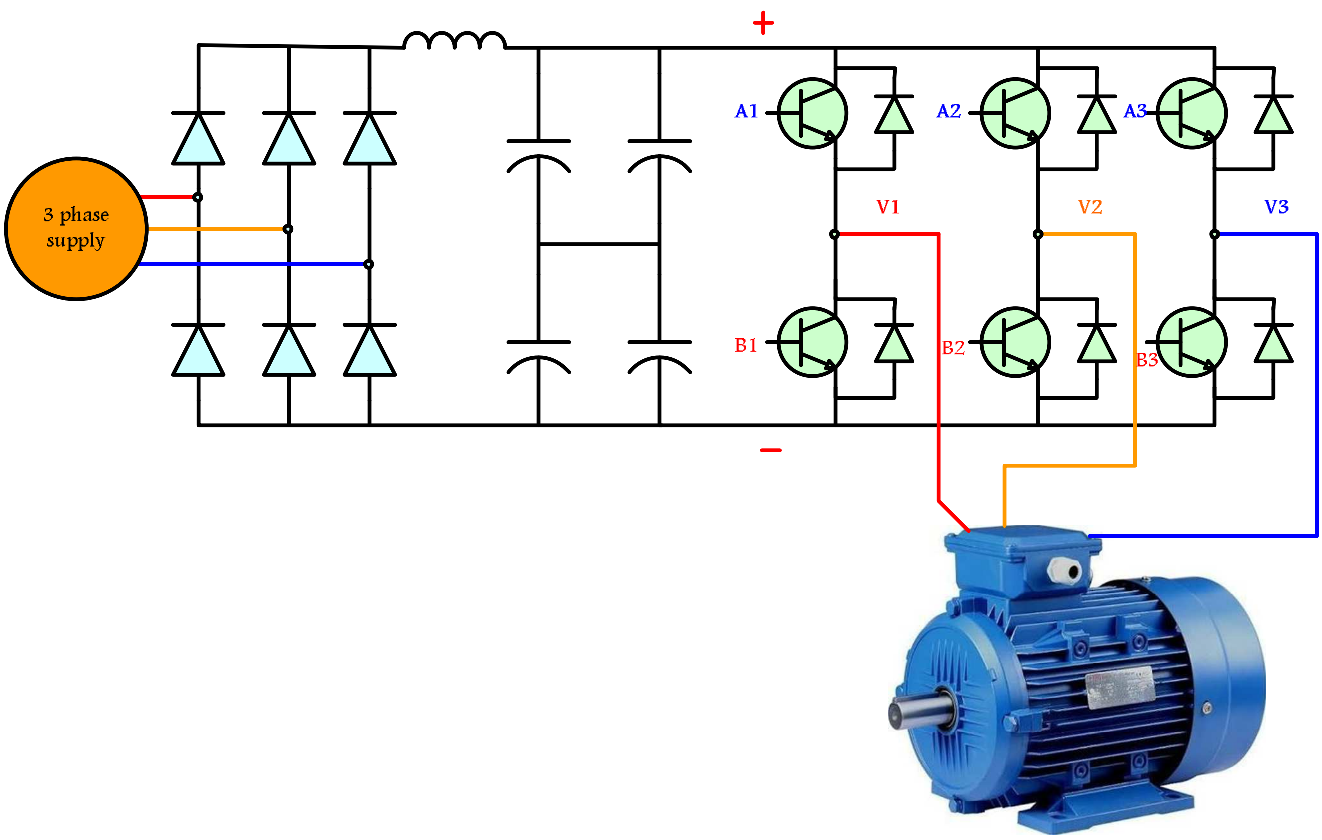
A variable frequency drive (VFD) is a motor control device that protects and controls the speed of an AC induction motor. A VFD can control the speed of the motor during the start and stop cycle, as well as throughout the run cycle. VFDs are also referred to as adjustable frequency drives (AFDs). VFDs are used in applications where complete speed control is required, energy savings is a goal and custom control is needed.

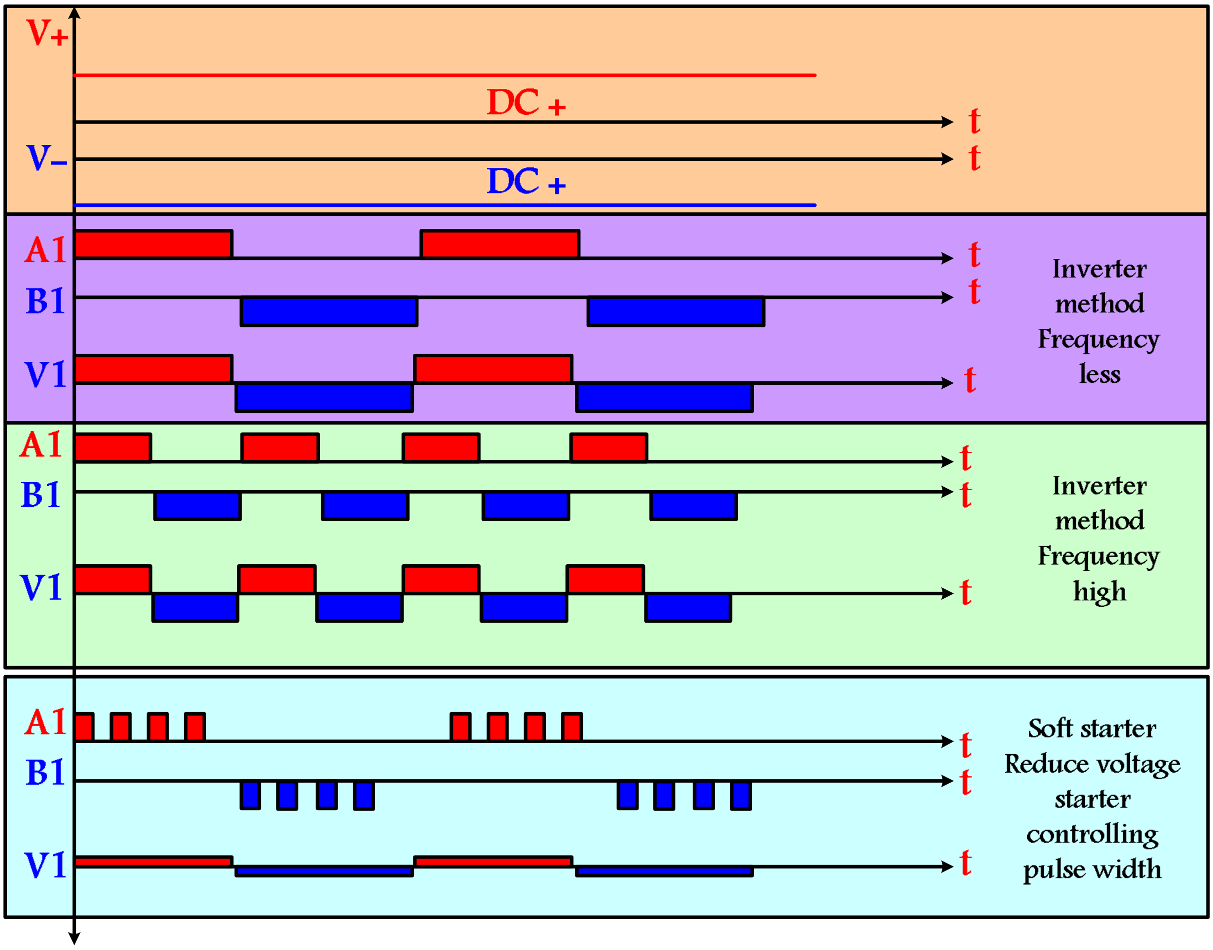
VFDs convert input power to adjustable frequency and voltage source for controlling speed of AC induction motors. The frequency of the power applied to an AC motor determines the motor speed.
The VFD's input power comes from the facility power network (typically 400V, 50 Hz AC). It has a rectifier that converts network AC power to DC power. A filter and DC bus work together to smooth the rectified DC power and to provide clean, low ripple DC power to the inverter, which uses DC power from the DC bus and filter to invert an output that resembles sine wave AC power using a pulse width modulation (PWM) technique.

Soft Starter method:

A soft starter continuously controls the three-phase motor’s voltage supply during the start-up phase. This way, the motor is adjusted to the machine’s load behavior. Mechanical operating equipment is accelerated smoothly.

Soft starters are used in applications where speed and torque control are required only during startup (and stop if equipped with soft stop) or where there is a need to reduce large startup inrush currents associated with a large motor is required. Electrical soft starters temporarily reduce voltage or current input by reducing torque. Some soft starters may use solid-state devices to help control the flow of the current. They can control one to three phases, with three-phase control usually producing better results. Most soft starters use a series of thyristors or silicon controlled rectifiers (SCRs) to reduce the voltage. In the normal OFF state, the SCRs restrict current, but in the normal ON state, the SCRs allow current. The SCRs are engaged during ramp up, and bypass contactors are pulled in after maximum speed is achieved. This helps to significantly reduce motor heating.

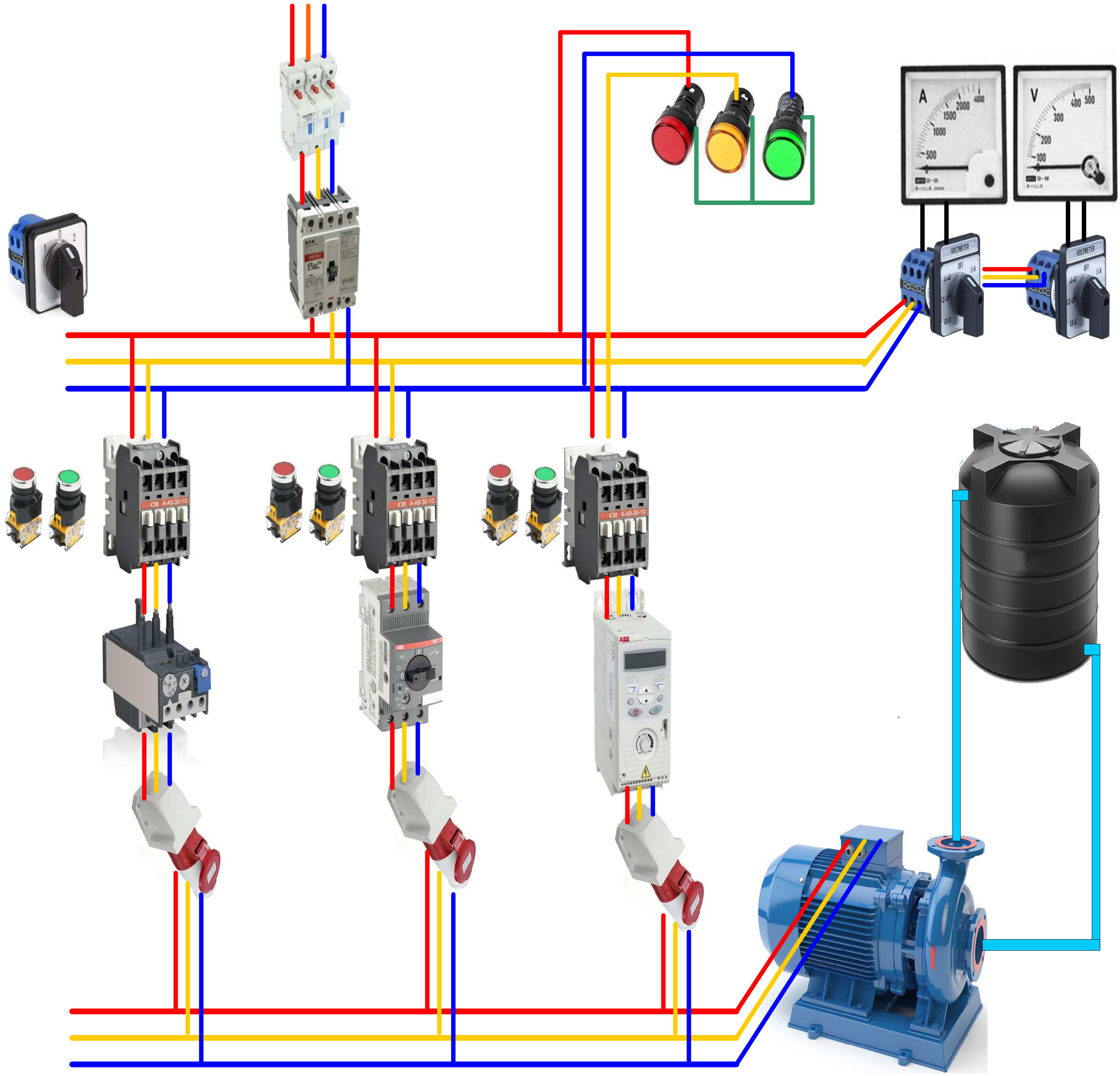




Report:

1. What kind of protections is given in small and large motor?
2. How can you control the speed of a motor?
3. Draw the control circuit of resistance and auto transformer starter.
4. Why thermal over load relay is used in motor protection system?

Experimental Setup



10

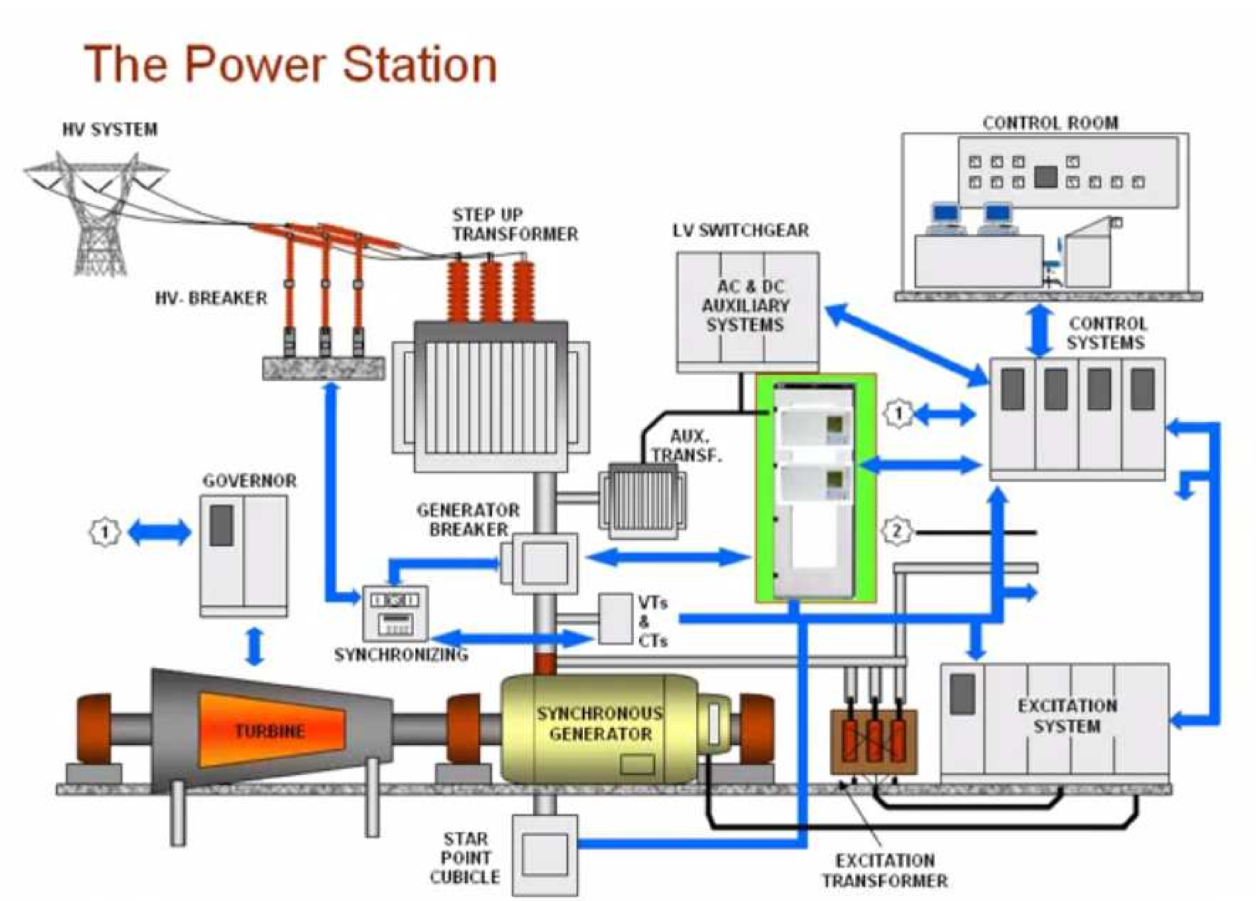
AHSANULLAH UNIVERSITY OF SCIENCE AND TECHNOLGY
DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
SWITCHGEAR AND PROTECTION LAB

Experiment 9: Generator protection by using microprocessor based VAMP relay. (PART-1)

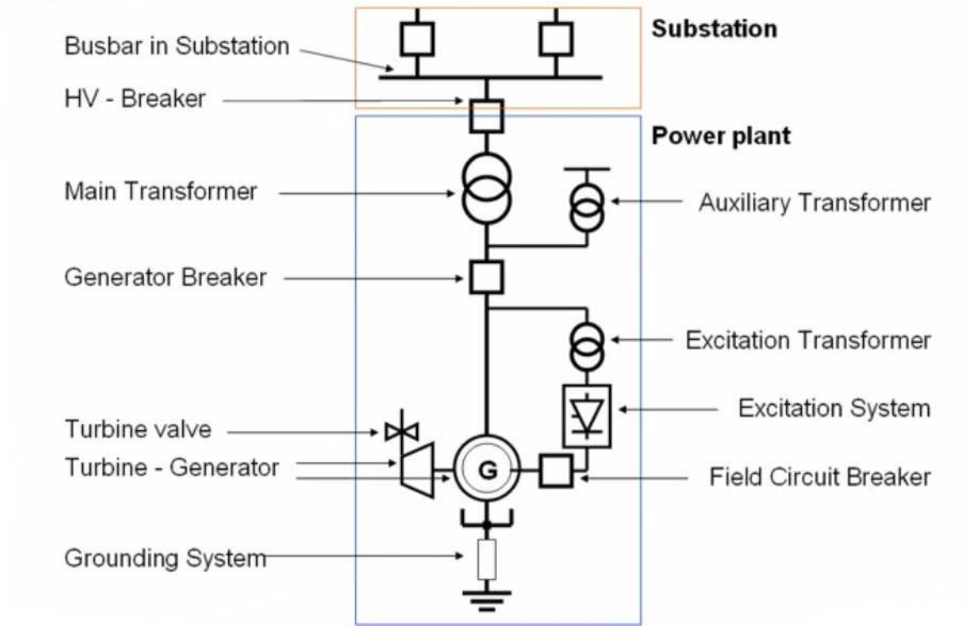
Generator Fault:

- Generator O/C Protection
- Reverse Power protection
- Generator earth fault protection by calculating zero sequence
- Generator earth fault protection by calculating zero sequence voltage.

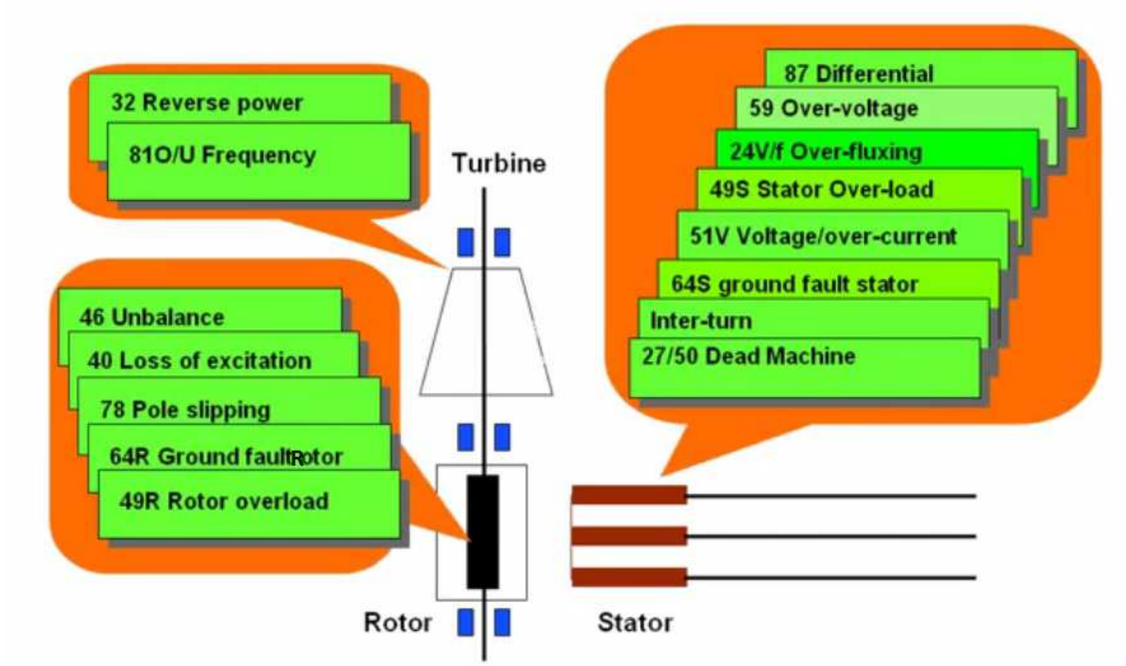
Theory: A modern generating unit is a complex system comprising the generator stator winding and associated transformer and unit transformer, the rotor with its field winding and exciters, and the turbine and its associated condenser and boiler complete with auxiliary fans and pumps. Faults of many kinds can occur within this system for which diverse protective means are needed. The amount of protection applied will be governed by economic considerations, taking into account the value of the machine and its importance to the power system as a whole. In this experiment we will show how different faults occur in a generator and how the protections are given by using microprocessor based VAMP RELAY.



Typical configuration of a power plant



Allocation of protection functions



Over current protection I> (50/51)

Over current protection is used against short circuit faults and heavy overloads. The over current function measures the fundamental frequency component of the phase currents. The protection is sensitive for the highest of the three phase currents. Whenever this value exceeds the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation delay setting, a trip signal is issued.

Reverse power and under-power protection P< (32)

Reverse power function can be used for generators against motoring to protect the prime mover against over-speeding or to disconnect a motor in case the supply voltage is lost and thus prevent any power generation by the motor. Under-power function can be used to detect loss of the mechanical load of a motor. Reverse and under power function is sensitive to active power. Whenever the active power goes under the pick-up value, the stage picks up and issues a start signal. If the fault situation stays on longer than the delay setting, a trip signal is issued. The pick-up setting is proportional to the nominal power of the prime mover parameter P_m, which is part of the basic configuration.

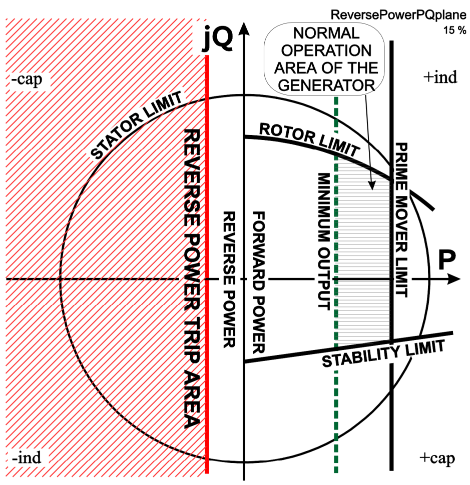


Figure 2.23-1. Characteristics of reverse power function.

Reverse power

For reverse power protection a negative pick-up value is used (Figure 2.23-1).

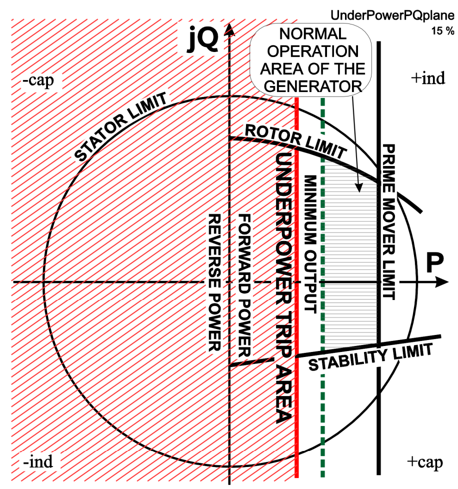


Figure 2.23-2. Characteristics of under power function.

Under power

When the pick-up value is positive, the function is called under-power (Figure 2.23-2).

If two or more generators are run in parallel then if one of them drags behind due to any reason, instead of delivering electric power to the bus, it takes power from the bus acting like a motor and trying to drive the turbine. Then generator can enter a state called "motoring", where the prime mover is no longer providing the power for the generator to the electric grid. Under this condition the generator is using power instead of providing power. Hence power flows in reverse direction. This condition is known as reverse power.

Reasons of Reverse power

There are mainly two reasons for which reverse power can occur.

I. **Motoring**

The failure can be caused to a starvation of fuel in the prime mover, a problem with the speed controller or other breakdown. When the prime mover of a generator running in a synchronized condition fails. There is a condition known as motoring, where the generator draws power from the bus bar, runs as a motor and drives the prime mover. This happens as in a synchronized condition all the generators will have the same frequency. Any drop in frequency in one generator will cause the other power sources to pump power into the generator. The flow of power in the reverse direction is known as the reverse power relay.

II. **Synchronization**

Another cause of reverse power can occur during synchronization. If the frequency of the machine to be synchronized is slightly lesser than the bus bar frequency and the breaker is closed, power will flow from the bus bar to the machine. Hence, during synchronization (forward), frequency of the incoming machine is kept slight higher than that of the bus bar i.e. the synchro-scope is made to rotate in the "Too fast" direction. This ensures that the machine takes on load as soon as the breaker is closed.

III. Load variation problem

Effects:

I. **Steam unit:** Overheating of turbine and turbines blades.

II. **Hydro unit:** Cavitation of the blades.

Over current:

Over current protection is used against short circuit faults and heavy overloads.

Reverse Power:

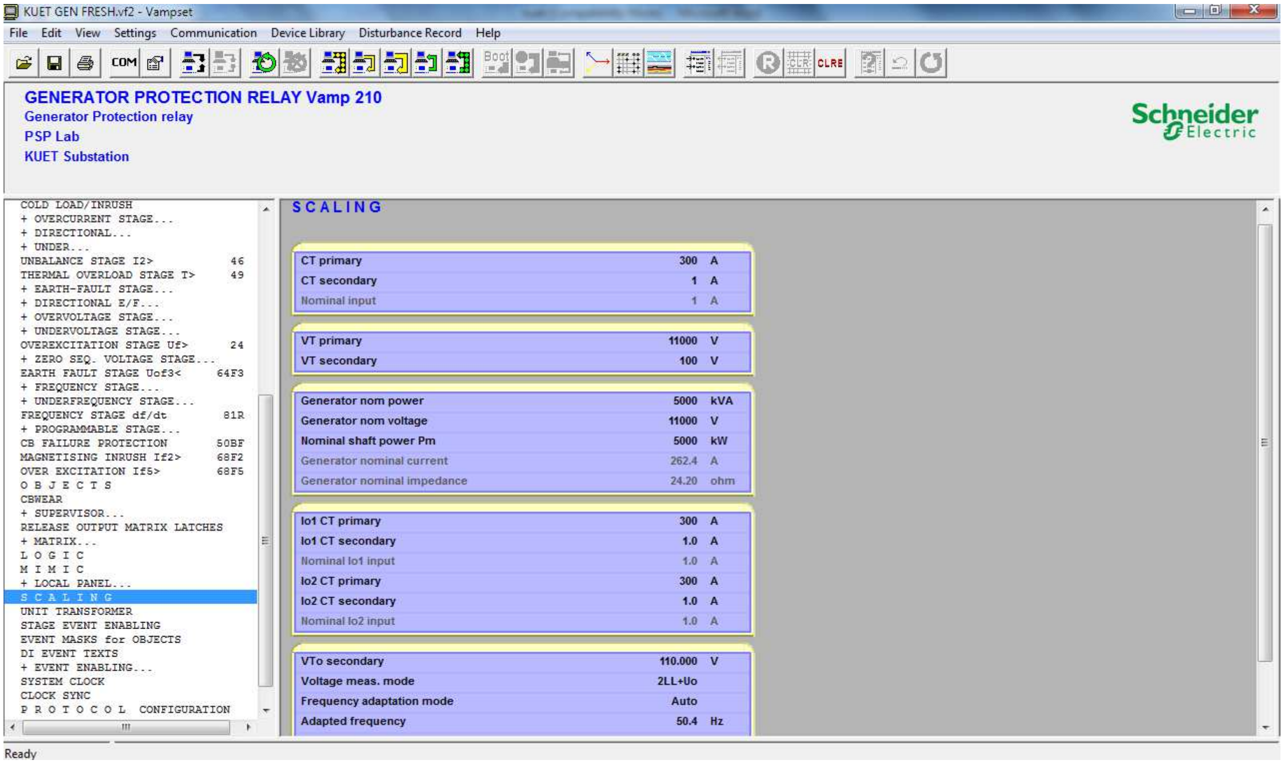
Reverse power relays are used on generators to trip them if this condition occurs. A reverse power relay is a directional power relay that is used to monitor the power from a generator running in parallel with another generator or the utility. The function of the reverse power relay is to prevent a reverse power condition in which power flows from the bus bar into the generator.

The reverse power relay operates by measuring the active component of the load current, I cos ϕ. When the generator is supplying power, the I x cos ϕ is positive, in a reverse power situation it turns negative. If the negative value exceeds the set point of the relay, the relay trips the generator breaker after the preset time delay.

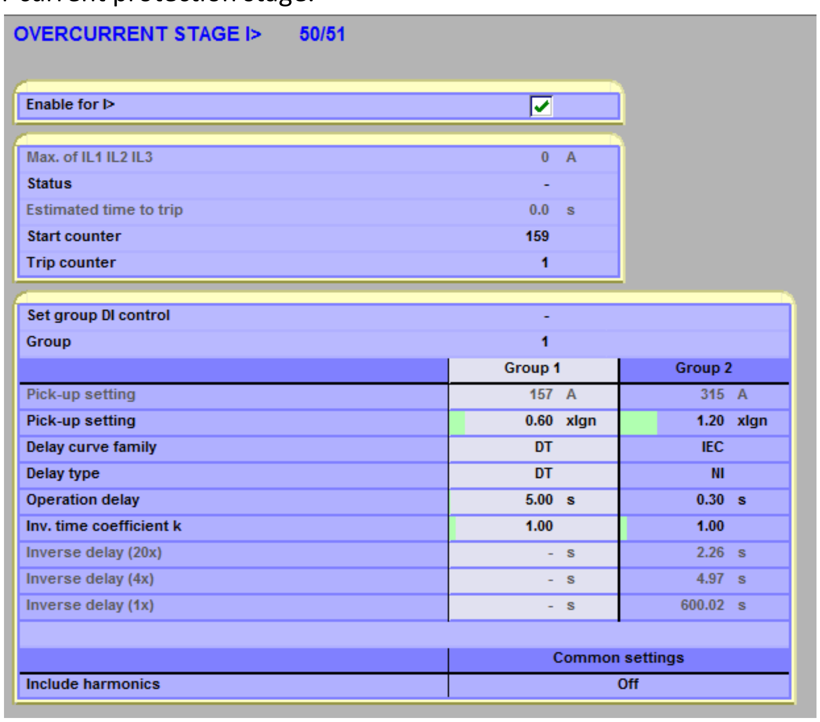
Procedure:

- Connect the Generator with the CT's and PT's like above figure.[Already given]
- CT's and PT's output should be connected with the relay like above figure. [Already given]
- Output relay should be connected with the breaker like the diagram [Already given]
- Now configure the relay by using VAMP setting software.
- Connect the relay with the VAMP setting software by the given USB cable.
- After open the software set the required port.

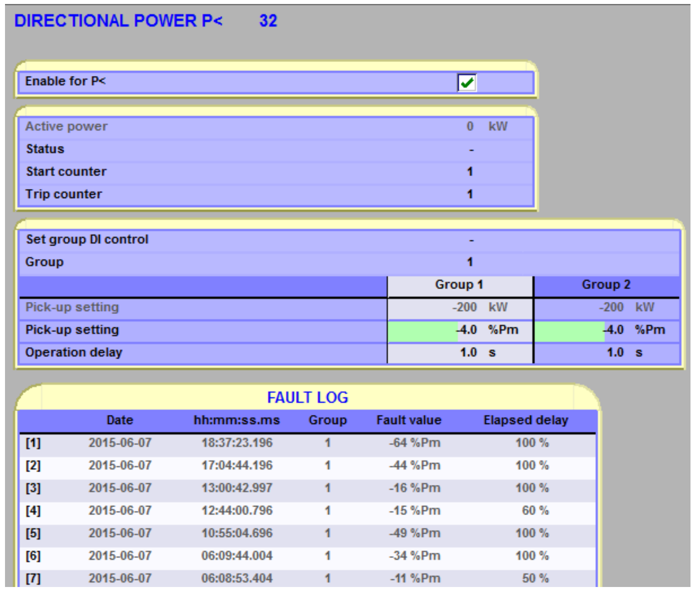
- And then click connect.
- Default password is 2.
- Now configure CT setting, generator rating from the scaling menu.



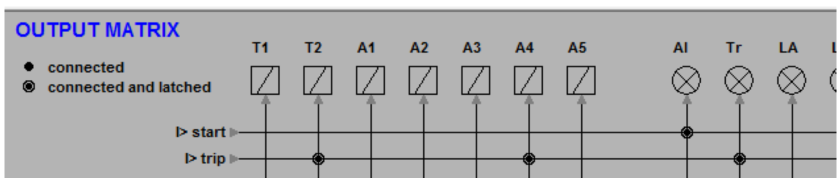
- Configure over current protection stage.

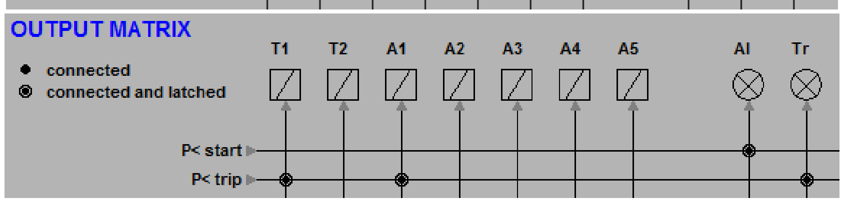


- Configure reverse power protection stage.



- Configure output relays and output LED on the output matrix menu.





- Now synchronize the generator with the line. [Note: To synchronize the generator with the line you should match the voltage frequency, phase sequence and phase angle. Everything should be approximately same.]
- Match the phase sequence of the line and generator. If the phase sequence of the generator is different from the source, then the phase sequence meter given an un-even movement. To match the sequence you should interchange any two phases. This is done by phase sequence switch. Then you can show the even movement of the phases from the sequence meter.
- Now vary the excitation by tuning excitation knob to match the generated voltage with the system voltage.
- Now vary the frequency by tuning frequency knob to match the generated frequency with the system frequency. Here we change the frequency by varying the coupling voltage of the VS drive motor.
- You can see the system and generated voltage and frequency in the two digital multifunction meters.
- Synchroscope is used to detect the phase displacement between system and generator.

- When the synchronizing conditions are satisfied then green LED of the synchroscope will be glowing, then ON the generator breaker.
- Now after synchronizing condition if you increase the frequency by tuning frequency knob you can see the over current scenario happens and if it is cross the threshold value of the relay setting it will instantly pick up and trip the breaker and alarming a signal.
- Synchronize the generator again.
- Now after synchronizing condition if you decrease the frequency by tuning frequency knob you can see the reverse power scenario happens and if it is cross the threshold value of the relay setting the relay will instantly pick up and trip the breaker and alarming a signal.
- You can see the actual current, harmonics, phasor diagram from the respective menu.

Communication:

- Communicate with the relay to the given software and USB cable.
- Port selection must be OK to communicate with the relay.

Observation:

- Device info
- Measurement
- Phasor diagram
- Event buffer
- Scaling
- Output matrix
- Over current stage
- Reverse power stage
- Harmonics
- Scaling
- Clock sync.
- You can create stator fault line to line and line to ground by pushing of push button on the top of the Generator diagram.

Generator earth fault protection by calculating zero sequence current and zero sequence voltage by using microprocessor based VAMP relay.

Theory:

Causes of stator ground fault:

- Transient over voltage due to lightning.
- Temporary over voltage.
- Degraded insulation due to high temperature or ageing.
- Mechanical impact.

Impact:

- Damages on the stator iron.
- Increase voltage on healthy phases.
- Small fault currents.

In case of short-circuits between phases in the stator winding or between the generator terminals, the machine must quickly be disconnected from the network and brought to a complete shutdown in order to limit the damage. Phase short-circuits on the generator bus, in the unit transformer or in the high voltage winding of the unit transformer, must also be quickly disconnected from the network. The generator must be brought to a complete shutdown in case of a transformer fault if there is no circuit-breaker between the machine and the transformer.

Earth fault protection I_0 > (50N/51N)

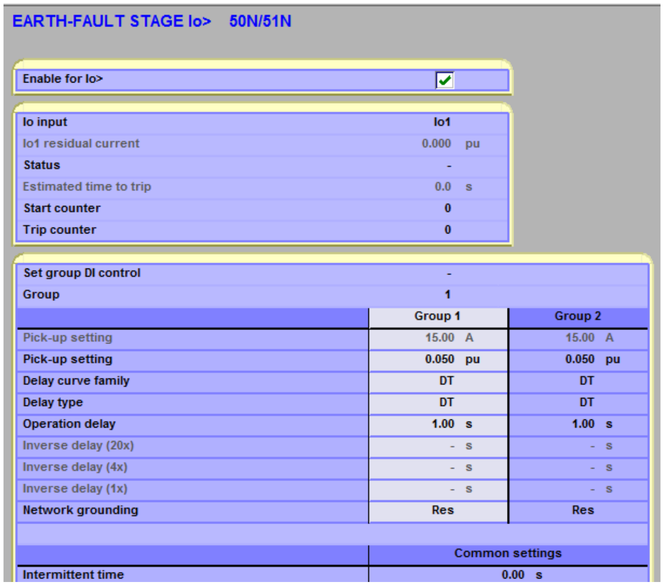
Un-directional earth fault protection is used for generator's stator earth faults in low impedance earthed networks. In high impedance earthed networks, compensated networks and isolated networks un-directional earth fault can be used as back-up protection. The un-directional earth fault function is sensitive to the fundamental frequency component of the residual current $3I_0$. The attenuation of the third harmonic is more than 60 dB. Whenever this fundamental value exceeds the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation time delay setting, a trip signal is issued.

Zero sequence voltage protection U_0 > (59N)

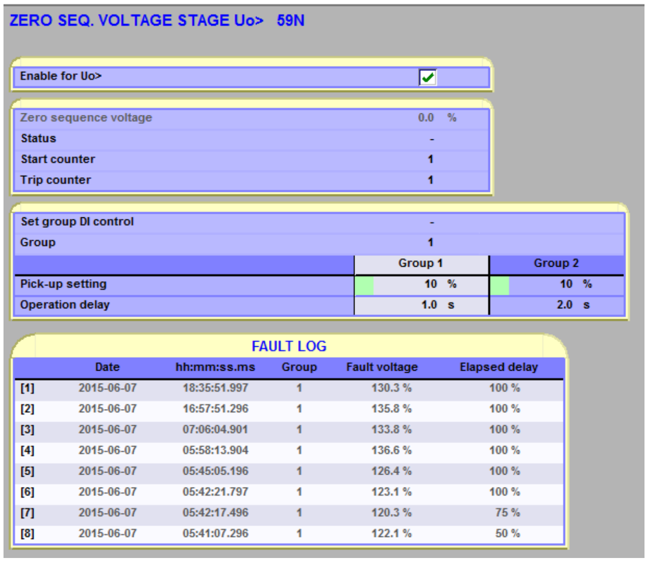
The zero sequence voltage protection is used as unselective backup for earth faults and also for selective earth fault protections for generators having a unit transformer between the generator and the bus bar. This function is sensitive to the fundamental frequency component of the zero sequence voltage. The attenuation of the third harmonic is more than 60 dB. This is essential, because 3n harmonics exist between the neutral point and earth also when there is no earth fault. Whenever the measured value exceeds the user's pick-up setting of a particular stage, this stage picks up and a start signal is issued. If the fault situation remains on longer than the user's operation time delay setting, a trip signal is issued.

Procedure:

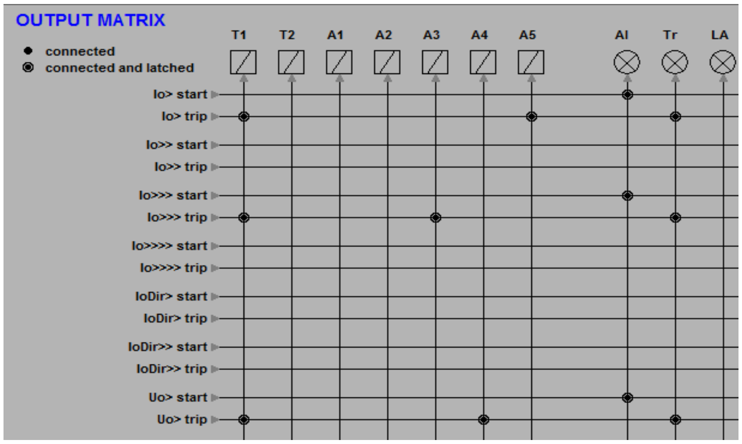
- Connect the Generator with the CT's and PT's like above figure.[Already given]
- CT's and PT's output should be connected with the relay like above figure. [Already given]
- Output relay should be connected with the breaker like the diagram [Already given]
- Now configure the relay by using VAMP setting software.
- Connect the relay with the VAMP setting software by the given USB cable.
- After open the software set the required port.
- And then click connect.
- Default password is 2.
- Now you should configure CT setting, transformer setting on the scaling menu.
- Configure Earth fault protection stage for I_0.



- Configure Earth fault protection stage for U_0.



- Configure output relays and output LED on the output matrix menu.

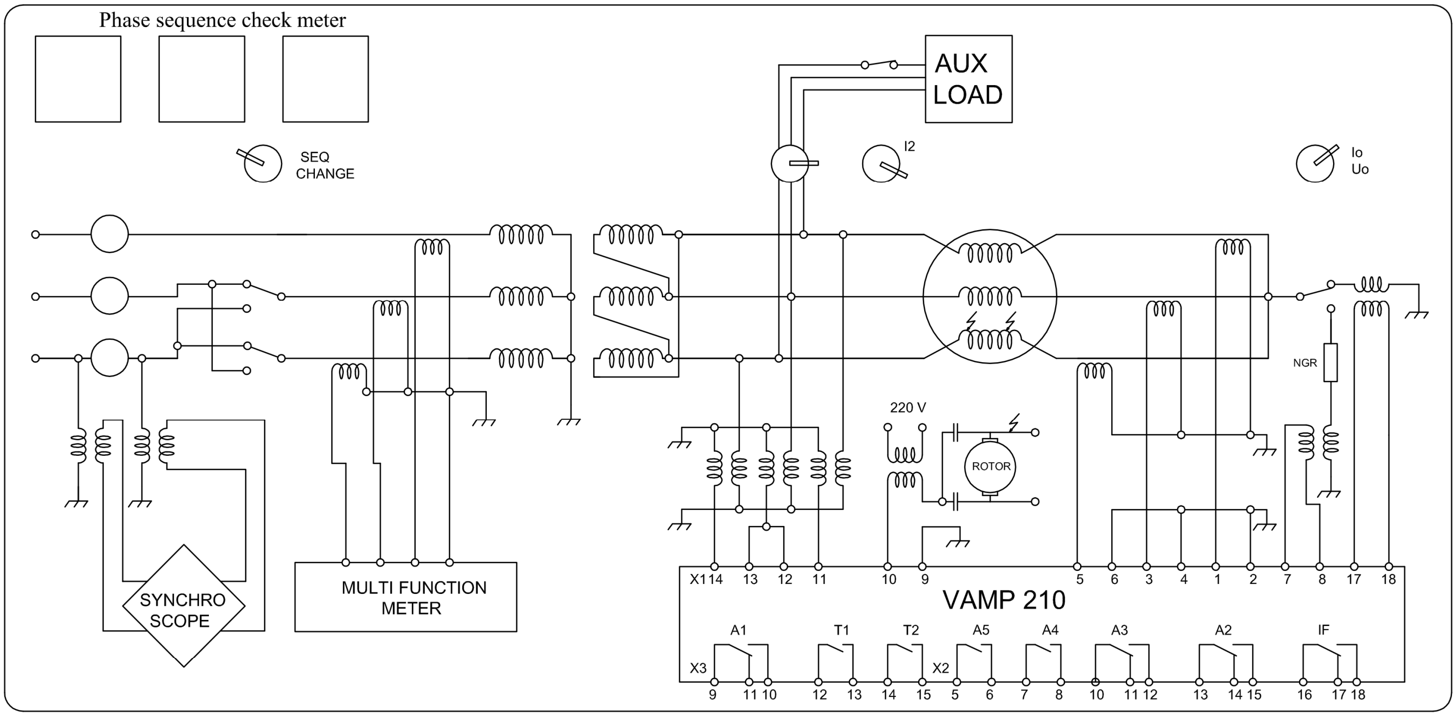


- Now start the generator.
- Now observe the third harmonics components of current and voltage.
- Now push the stator earth fault switch by selecting knob at I_o.
- Observe the third harmonics of the current wave shapes.
- Observe how this protection system works.
- Now start the generator.
- Now observe the third harmonics components of current and voltage.
- Now push the stator earth fault switch by changing knob position to U_o.
- Observe the third harmonics of the voltage wave shapes.
- Observe how this protection system works.
- You can see the actual current, harmonics, phasor diagram from the respective menu.

Equipments:

Generator 2KW:	1
VS Drive motor 2KW:	1
Unit transformer 0.6KVA	3
R.P.M adjustment mechanism Load control device.	1
Voltage adjustment mechanism/Excitation control device.	1
Synchronizing mechanism: Analog synchroscope.	1
Multifunction digital meter	2
Miniature CB 20A	1
Magnetic contactor 20A	4
CT 10/5 A 5VA	6
PT 400/110 5VA	2
PT 220/110 V 5VA	2
Fault simulators	10
Control switches 6A	10
Neutral grounding resistance 200 ohm	1
Generator protection relay: Vamp210	1

Circuit diagram:



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DEPARTMENT OF ELECTRICAL AND ELECTRONIC ENGINEERING
SWITCHGEAR AND PROTECTION LAB

Experiment 10: Generator protection by using microprocessor based VAMP relay. (PART-2)

Generator Fault

- Generator rotor fault
- U/F detection and protection by
- Generator unbalance loading
- Under excitation
- Generator over voltage
- Over frequency protection by using microprocessor based VAMP relay.

Theory:

Rotor earth fault: I_{02}

While the winding in the rotor is insulated from the ground during normal operation, the Rotor is subjected to stresses due to vibration, heat, etc. These stresses can cause the winding to give way in a particular place and the winding can get earthed.

Reasons of Rotor Earth Fault:

Failures in the rotor, caused by low exciting voltage do not occur that often and single earth faults are not that dangerous. But it was obvious, that in case of a second breakdown of isolation, the turn-to-turn-fault exerts a force on the axle. The detection of turn-to-turn faults is difficult. With a low exciting voltage they occur in case of operation of the machine only. Centrifugal forces and heating utilize the winding mechanically and thermally.

This explains why a turn-to-turn fault occurs during special load conditions and not if the generator was out of service. Measurements are difficult due to a low resistance of the rotor winding. Only a careful assembly of the winding was a sufficient protection because the isolation was aged by the de-excitation.

Effects of Rotor Earth Fault:

The currents produced during a rotor earth fault can cause excessive vibration and disturb the magnetic balance inside the alternator. These forces can cause the rotor shaft to become eccentric and in extreme cases cause bearing failure.

Protection Method:

There are several methods of power system grounding. These include low-resistance grounded (LRG), effectively grounded, reactance grounded, high-resistance grounded (HRG), and ungrounded. Source grounding may be accomplished by the grounding of the generator(s). The rotor earth fault protection can be realized with the non-directional earth fault stage using the energizing current input I_{02} in combination with a simple current injecting device. Here we used resistive grounding system.

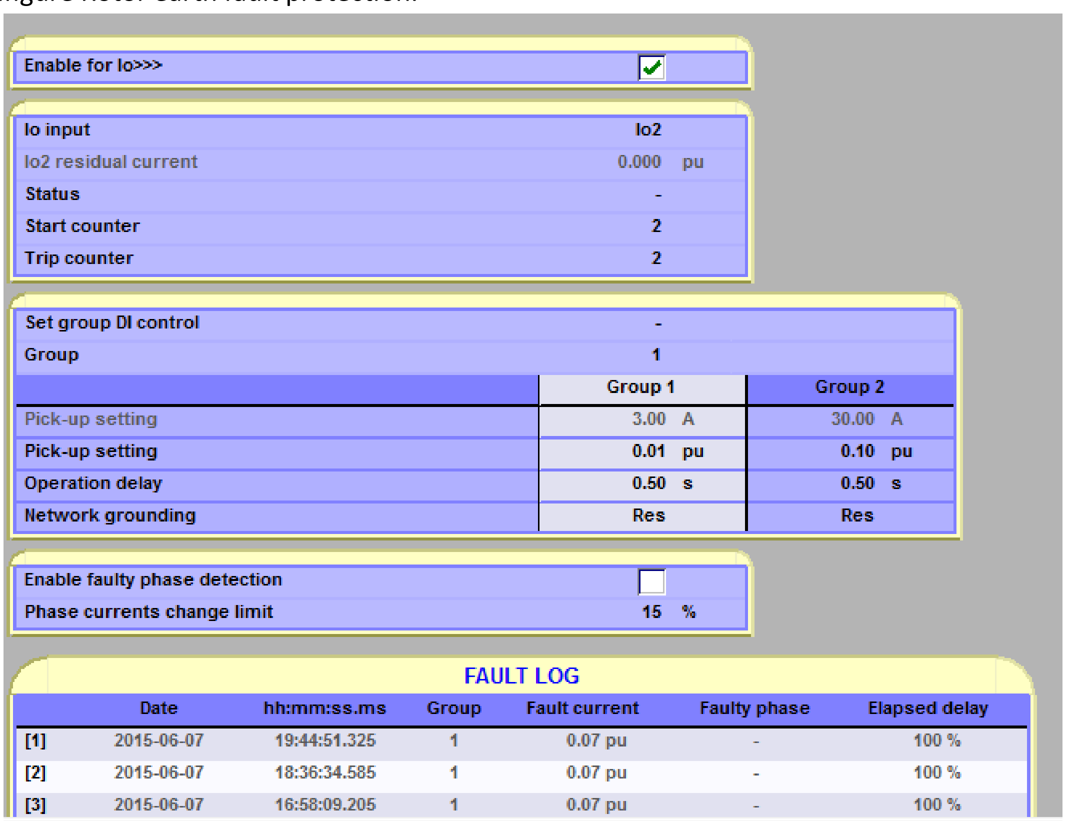
Over Excitation (V/F)

A synchronous generator is driven by a prime mover to run at a constant speed. Based on the dc excitation current flowing through the rotating poles, the stator armature coils generate more and more current--- all at a constant voltage. Voltage is dependent on the speed, which is constant, because it is being run at synchronous speed. But the process has a limit. After a certain stage, sending higher and higher dc current through the poles (Over-excitation) will make the generator unstable! It will start hunting, and there is even risk of the generator falling out of synchronism.

Reasons of Over Excitation Fault: Excessive dc excitation causes over excitation**.**

Procedure:

- Connect the Generator with the CT's and PT's like above figure.[Already given]
- CT's and PT's output should be connected with the relay like above figure. [Already given]
- Output relay should be connected with the breaker like the diagram [Already given]
- Now configure the relay by using VAMP setting software.
- Connect the relay with the VAMP setting software by the given USB cable.
- After open the software set the required port.
- And then click connect.
- Default password is 2.
- Now you should configure CT setting, transformer setting on the scaling menu.
- Configure Rotor earth fault protection.



Enable for Io>>>	✔

Io input	Io2
Io2 residual current	0.000 pu
Status	-
Start counter	2
Trip counter	2

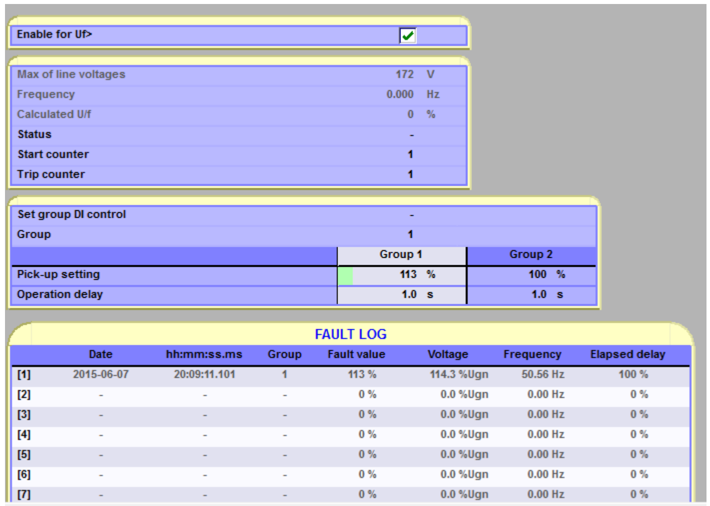
Set group DI control	-	
Group	1	
	Group 1	Group 2
Pick-up setting	3.00 A	30.00 A
Pick-up setting	0.01 pu	0.10 pu
Operation delay	0.50 s	0.50 s
Network grounding	Res	Res

Enable faulty phase detection	☐
Phase currents change limit	15 %

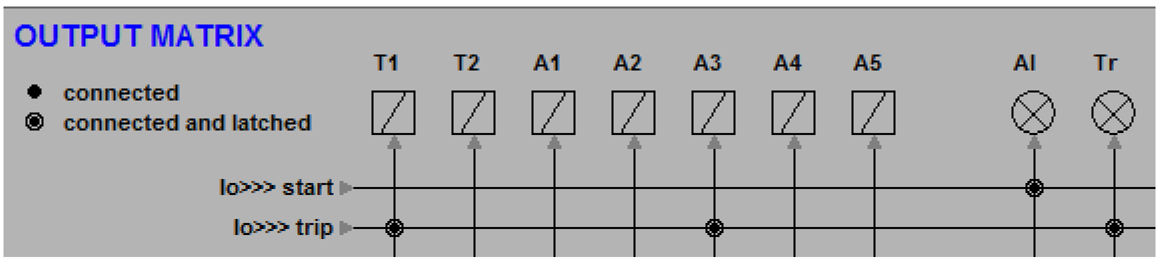
FAULT LOG

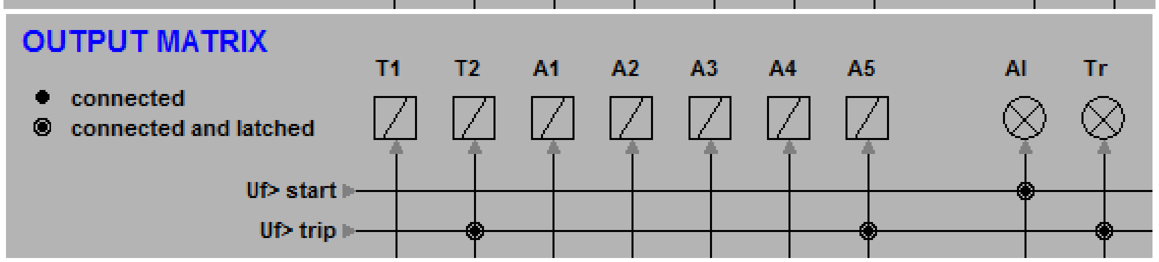
	Date	hh:mm:ss.ms	Group	Fault current	Faulty phase	Elapsed delay
[1]	2015-06-07	19:44:51.325	1	0.07 pu	-	100 %
[2]	2015-06-07	18:36:34.585	1	0.07 pu	-	100 %
[3]	2015-06-07	16:58:09.205	1	0.07 pu	-	100 %

- Configure Earth fault protection stage for U_0.



- Configure output relays and output LED on the output matrix menu.





- Now start the generator.
- Now push the rotor earth fault switch.
- Observe how this protection system works.
- Now start the generator.
- Now fix the voltage at approximately 234 Volt and frequency approximately at 48 Hz. Now observe how this protection works.
- You can see the actual current, harmonics, phasor diagram from the respective menu.

Observation:

- Device info
- Measurement
- Phasor diagram
- Event buffer

- Scaling
- Output matrix
- Rotor fault
- U/F

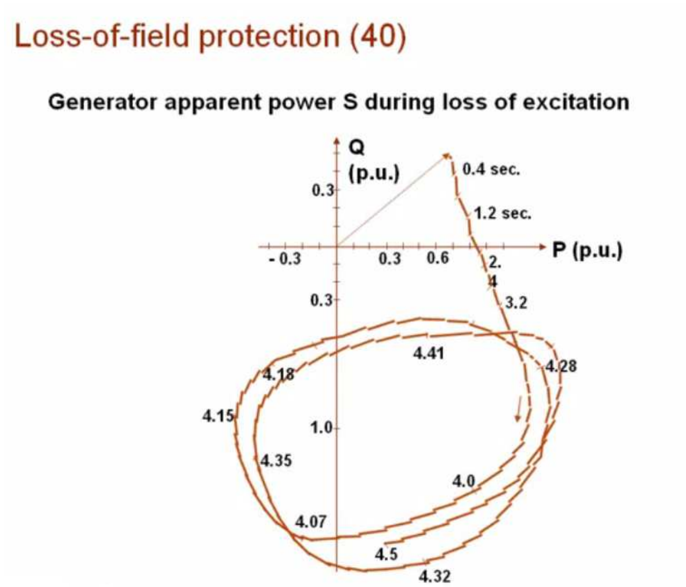
Generator unbalance loading and under excitation protection by using microprocessor based VAMP relay.

Causes of under excitation:

- Open field circuit
- Field short circuit
- Accidental tripping of field CB
- AVR
- Loss of field at the main exciter

Consequence:

- Machine speed higher than synchronous speed
- Asynchronous running of synchronous machine without excitation
- Stator end core heating
- Induced rotor current



Reasons of Negative-sequence

When the generator is connected to a balanced load, the phase currents are equal in magnitude and displaced electrically by 120°. The ampere-turns wave produced by the stator currents rotate synchronously with the rotor and no eddy currents are induced in the rotor parts.

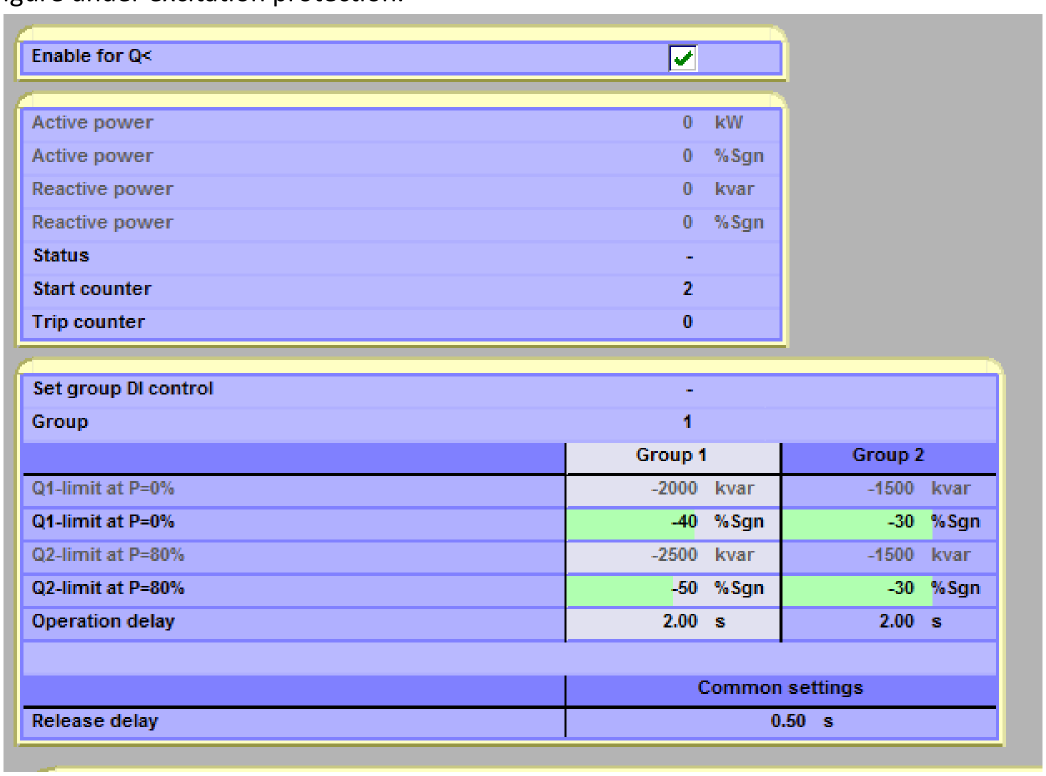
Unbalanced loading gives rise to a negative sequence component in the stator current. The negative-sequence current produces an additional ampere-turn wave which rotates backwards, hence it moves relatively to the rotor at twice the synchronous speed. The double frequency eddy currents induced in the rotor may cause excessive heating, primarily in the surface of cylindrical rotors and in the damper winding of rotors with salient poles.

Effects of Negative-sequence fault

The approximate heating effect on the rotor of a synchronous machine for various unbalanced fault or severe load unbalance conditions is determined by the product I_2^2 t = K, where I_2 is the negative sequence current expressed in per unit (p.u.) stator current, to the duration in seconds and K a constant depending on the heating characteristic of the machine, i.e., the type of machine and the method of cooling adopted. The capability of the machine to withstand continuously unbalanced currents is expressed as negative sequence current in percent of rated stator current.

Procedure:

- Connect the Generator with the CT's and PT's like above figure.[Already given]
- CT's and PT's output should be connected with the relay like above figure. [Already given]
- Output relay should be connected with the breaker like the diagram [Already given]
- Now configure the relay by using VAMP setting software.
- Connect the relay with the VAMP setting software by the given USB cable.
- After open the software set the required port.
- And then click connect.
- Default password is 2.
- Configure under excitation protection.

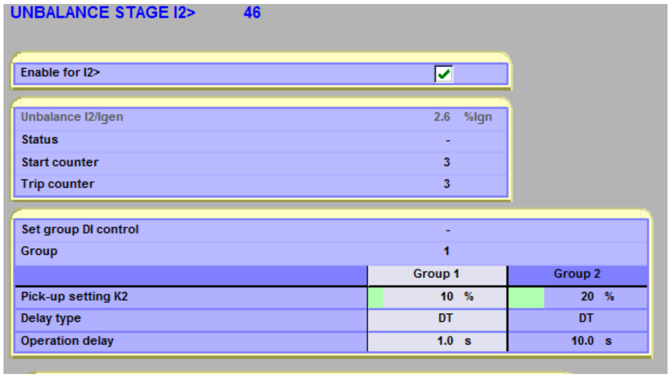


Enable for Q<	✓	

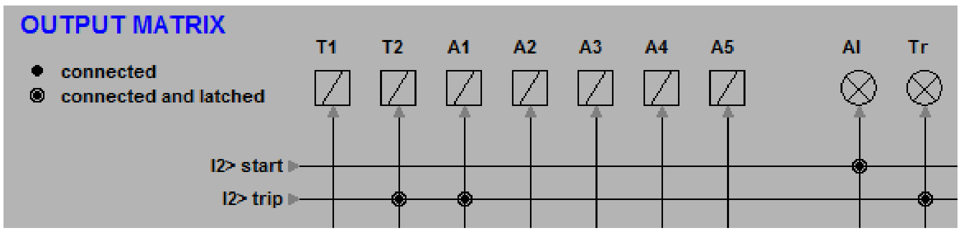
Active power	0	kW
Active power	0	%Sgn
Reactive power	0	kvar
Reactive power	0	%Sgn
Status	-	
Start counter	2	
Trip counter	0	

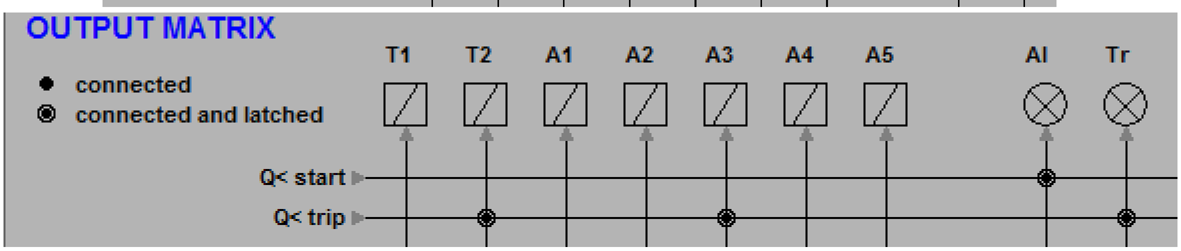
Set group DI control	-	
Group	1	
	Group 1	Group 2
Q1-limit at P=0%	-2000 kvar	-1500 kvar
Q1-limit at P=0%	-40 %Sgn	-30 %Sgn
Q2-limit at P=80%	-2500 kvar	-1500 kvar
Q2-limit at P=80%	-50 %Sgn	-30 %Sgn
Operation delay	2.00 s	2.00 s
	Common settings	
Release delay	0.50 s	

- Configure phase unbalance protection stage.



- Configure output relays and output LED on the output matrix menu.





- Now synchronize the generator with the line. [Note: To synchronize the generator with the line you should match the voltage frequency, phase sequence and phase angle. Everything should be approximately same.]
- Match the phase sequence of the line and generator. If the phase sequence of the generator is different from the source, then the phase sequence meter given an un-even movement. To match the sequence you should interchange any two phases. This is done by phase sequence switch. Then you can show the even movement of the phases from the sequence meter.
- Now vary the excitation by tuning excitation knob to match the generated voltage with the system voltage.
- Now vary the frequency by tuning frequency knob to match the generated frequency with the system frequency. Here we change the frequency by varying the coupling voltage of the VS drive motor.
- You can see the system and generated voltage and frequency in the two digital multifunction meters.
- Synchroscope is used to detect the phase displacement between system and generator.
- When the synchronizing conditions are satisfied then green LED of the synchroscope will be glowing, then ON the generator breaker.

- Now after synchronizing condition if you reduce the excitation by tuning excitation knob you can see the under excitation scenario happens and if it is cross the threshold value of the relay setting it will instantly pick up and trip the breaker and alarming a signal.
- For creating unbalance condition you have to open one phase or just rotate the unbalance switch position and observe how this protection system works.

Observation:

- Device info
- Measurement
- Phasor diagram
- Phase unbalance protection
- Under excitation protection
- Output matrix
- Over current stage
- Reverse power stage
- Harmonics
- Scaling
- Clock sync.
- You can create stator fault line to line and line to ground by pushing of push button on the top of the Generator diagram.

Generator over voltage and over frequency protection by using microprocessor based VAMP relay.

Over frequency:

Over frequency results from the excess generation and it can easily be corrected by reduction in the power outputs with the help of the governor or manual control.

Under frequency operation:

Under frequency occurs due to overload, generation capability of the generator increases and reduction in frequency occurs.

Protection:

The power system survives only if we drop the load so that the generator output becomes equal or greater than the connected load. If the load increases the generation, then frequency will drop and load need to shut down to create the balance between the generator and the connected load. The rate at which frequency drops depend on the time, amount of overload and also on the load and generator variations as the frequency changes. Frequency decay occurs within the seconds so we cannot correct it manually.

Therefore automatic load shedding facility needs to be applied.

These schemes drops load in steps as the frequency decays. Generally load shedding drops 20 to 50% of load in four to six frequency steps. Load shedding scheme works by tripping the substation feeders to decrease the system load. Generally automatic load shedding schemes are designed to maintain the balance between the load connected and the generator. The present practice is to use the under frequency relays at various load points so as to drop the load in steps until the declined frequency return to normal. Non-essential load is removed first when decline in frequency occurs. The setting of the under frequency relays based on the most probable condition occurs and also depend upon the worst-case possibilities. During the overload conditions, load shedding must occur before the operation of the under frequency relays. In other words load must be shed before the generators are tripped.

The under-frequency relay is basically a protection for various apparatuses in a network, which in case of a disturbance, may be separated from the rest of the system and supplied from one generator. Operation at low frequency must be limited, also, in order to avoid dam- age on generators and turbines.

In practice, prolonged generator operation at low frequency can only occur when a machine with its local load is separated from the rest of the network.

The necessity of under-frequency protection has to be evaluated from knowledge of the network and the characteristics of the turbine regulator.

Over voltage protection:

Over voltage

During the starting up of a generator, prior to synchronization, the correct terminal voltage is obtained by the proper operation of the automatic voltage regulator (AVR). After synchronization, the terminal voltage of the machine will be dictated by its own AVR and also by the voltage level of the system and the AVRs of nearby machines.

Effects of over voltage fault

Generally, the rating of one machine is small in comparison with an interconnected system. It is, therefore, not possible for one machine to cause any appreciable rise in the terminal voltage as long as it is connected to the system. Increasing the field excitation, for example owing to a fault in the AVR, merely increases the reactive Mvar output, which may, ultimately, lead to tripping of the machine by the impedance relay or the V/Hz relay. In some cases, e.g. with peak-load generators and synchronous condensers, which are often called upon to work at their maximum capability, a maximum excitation limiter is often installed. This prevents the rotor field current and the reactive output power from exceeding the design limits.

Protection

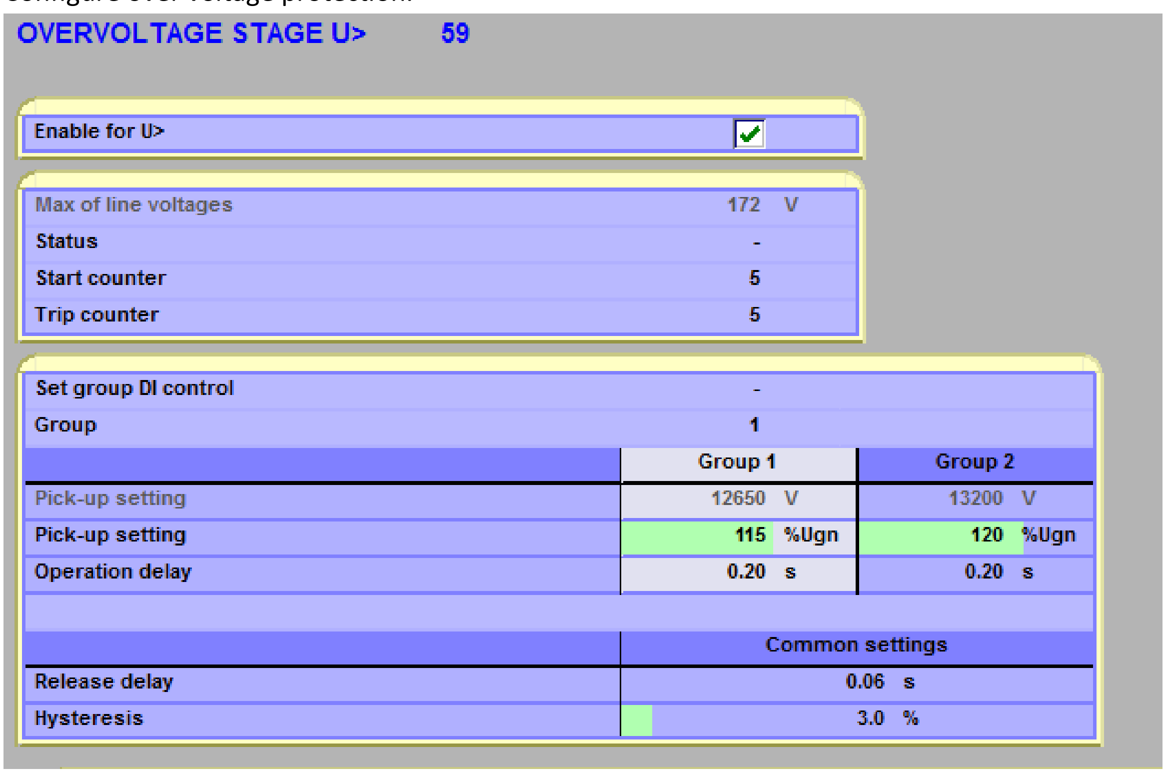
If the generator circuit breaker is tripped while the machine is running at full load and rated power factor, the subsequent increase in terminal volt- age will normally be limited by a quick acting AVR. However, if the AVR is faulty, or, at this particular time, switched for manual control of a volt- age level, severe over voltages will occur. This voltage rise will be further increased if simultaneous over speeding should occur, owing to a slow acting turbine governor. In case of a hydroelectric generator, a voltage rise of 50 - 100 % is possible during the most unfavorable conditions.

Modern unit transformers with high magnetic qualities have a relatively sharp and well-defined saturation level, with a knee-point voltage between 1.2 and 1.25 times the rated voltage U_n. A suitable setting of the overvoltage relay is, therefore, between 1.15 and 1, 2 times U_n and with a definite delay of 1-3 s. An instantaneous high set voltage relay can be included to trip the genera- tor quickly in case of excessive over-voltages following a sudden loss of load and generator over-speeding.

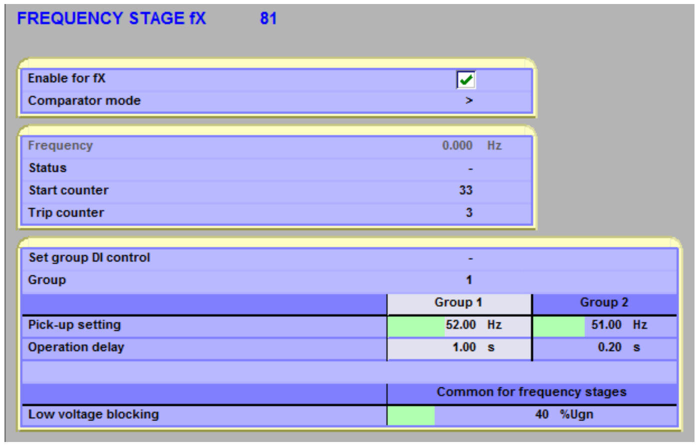
For high impedance earthed generators, the over-voltage relay is connected to the voltage between phases to prevent faulty operation in case of earth-faults in the stator circuits.

Procedure:

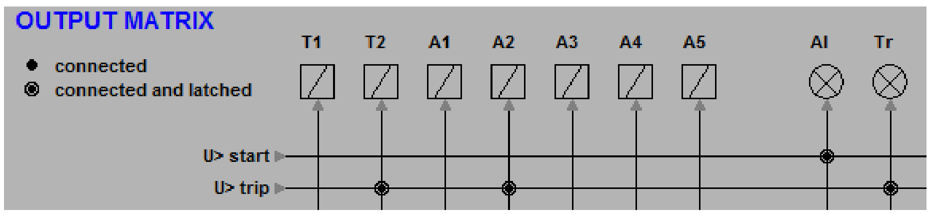
- Connect the Generator with the CT's and PT's like above figure.[Already given]
- CT's and PT's output should be connected with the relay like above figure. [Already given]
- Output relay should be connected with the breaker like the diagram [Already given]
- Now configure the relay by using VAMP setting software.
- Connect the relay with the VAMP setting software by the given USB cable.
- After open the software set the required port.
- And then click connect.
- Default password is 2.
- Now you should configure CT setting, transformer setting on the scaling menu.
- Configure over voltage protection.

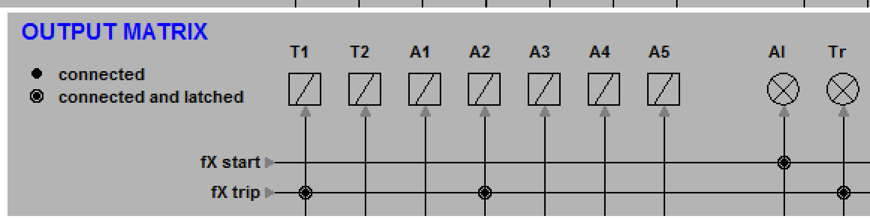


- Configure over frequency protection stage.



- Configure output relays and output LED on the output matrix menu.





- Now start the generator.
- Increase the voltage by increasing excitation.
- Observe the protection system.
- Observe how this protection system works.
- Now start the generator.
- Now increase the frequency by varying frequency knob.
- Observe over frequency protection stage.

Observation:

- Device info
- Measurement
- Phasor diagram
- Event buffer
- Scaling
- Output matrix
- Over voltage stage .
- Over frequency stage.

Equipments:

Generator 2KW:	1
VS Drive motor 2KW:	1
Unit transformer 0.6KVA	3
R.P.M adjustment mechanism Load control device.	1
Voltage adjustment mechanism/Excitation control device.	1
Synchronizing mechanism: Analog synchroscope.	1
Multifunction digital meter	2
Miniature CB 20A	1
Magnetic contactor 20A	4
CT 10/5 A 5VA	6
PT 400/110 5VA	2
PT 220/110 V 5VA	2
Fault simulators	10
Control switches 6A	10
Neutral grounding resistance 200 ohm	1
Generator protection relay: Vamp210	1

Circuit diagram: