UNIT I - INTRODUCTION OF RELAYS

A relay comprises of an electromagnet and a contact unit. The definition is: Activating the contact unit using electromagnetic attraction, which is produced when electric current exceeding the specified value flows to the electromagnet; the voltage and current (input signal) applied to the coil opens or shuts the contact.

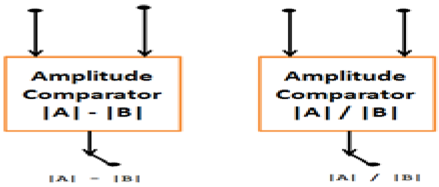
Relays used for i. as interfaces between control circuits and load circuits, ii. for signal multiplication, iii. for separation of direct current and alternating current circuits, iv.linking information.

Functions Number of pins Description 1 2 Normally closed contact 3 4 Normally open contact 5 6 Normally closed contact, time delay 7 8 Normally open contact, time delay 1 2 4 Changeover contact 5 6 8 Changeover contact, time delay A1 A2 The coil terminals (common) relay contacts are either normally open (NO) or normally closed (NC), The term “normally” refers to the state in which the coil is not energized. Relays can have many independent contacts, some NO and others NC, and each contact can be used in a different circuit for a different task. When the coil is energized, all NO contacts belonging to that relay close, whereas all NC contacts open.

PHASE AND AMPLITUDE COMPARATORS:

Amplitude Comparators:

An amplitude comparator compares the magnitude of two input quantities irrespective of the angle between them. One of the inputs is the operating quantity and the other a restraining quantity.
When the amplitude of the operating quantity exceeds that of restraining quantity, the relay sends a tripping signal to the circuit breaker.



- The Amplitude comparator compares two vector, |A| and |B|
- Gives an output: the algebraic difference between the magnitudes |A| and |B|
- Output is +ve, if |A| > |B|
- Output is –ve, if |A| < |B|
- Output is zero, if |A| = |B|

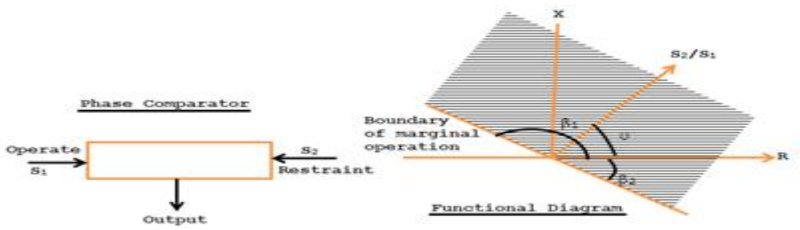
Comparison by ratio:
- Output is >1, if |A| > |B|
- Output <1, if |A| < |B|
- Output is Zero, if |A| is zero.

Phase Comparators:

Phase comparison technique is the most widely used one for all practical directional, distance, differential and carrier relays.

If the two input signals are S_1 and S_2 the output occurs when the inputs have phase relationship lying within the specified limits.

Both the input must exist for an output to occur. The operation is independent of their magnitudes and is dependent only on their **phase relationship**. The figures below show that the phase comparator is simple form. The function is defined by the boundary of marginal operation and represented by the straight lines from the origin of the S-plane.



The condition of operation is $\beta_1 \leq \theta \leq \beta_2$.

θ is the angle by which S_2 lands S_1. If $\beta_1 = \beta_2 = 90^o$, the comparator is called **cosine comparator** and if $\beta_1=0$ and $\beta_2=180^o$, it is a **sine comparator**.

In short, **a phase comparator compares two input quantities in phase angle** (vertically) irrespective of the magnitude and operates if the phase angle between them is $\leq 90^o$.

There are two **types of phase comparators**:

1. Vector product comparator
2. Coincidence type phase comparator.

Vector Product comparator:

This comparator recognizes the vector product or division between the two or more quantities. Thus, the output is A, B or A/B

Coincidence Comparator:

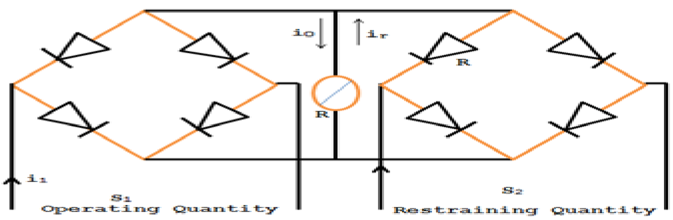
Consider two signals S_1 and S_2. The period of Coincidence of S_1 and S_2 will depend on the phase difference between S_1 and S_2. The fig below shows the coincidence of S_1 and $S_2$when S_2 lags S_1 by less than $\pi/2$ ie., θ.The period of coincidence of S_1 and S_2 with a phase difference of θ is $\Psi = 180^o - \theta$. Different techniques are used to measure the period of coincidence. Two of the important types are

1. Bloke Spike Method (Direct Phase Comparison) and
2. Coincidence type – Integrating phase comparator.

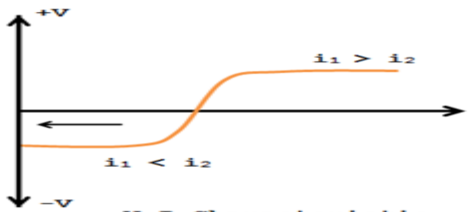
INTEGRATING COMPARATOR:

-Circulating Current Type
- Opposed Voltage Type

Circulating Current Type



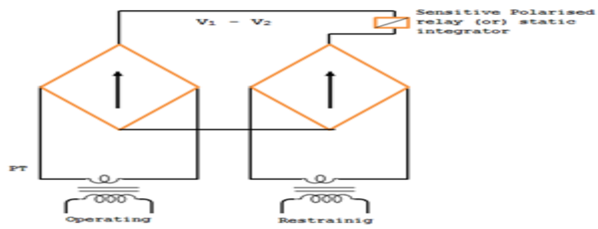
Circulating Current Type



V–I Characteristic

It can also be used as impedance relay. Two rectifier bridges can be arranged in such a manner as shown in the figure below, to function as amplitude comparator circulating type. The polarized relay operates when $S_1>S_2$ where $S_1=K_1i_1$ and $S_2 = K_2i_2$. This arrangement gives a sensitive relay whose voltage may be represented in the VI characteristic of the figure.

Opposed Voltage type

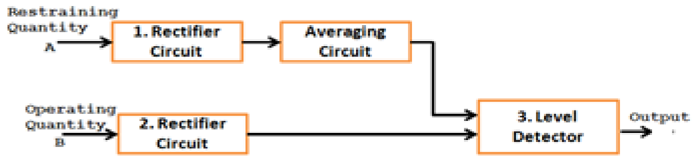


Opposed Voltage Type

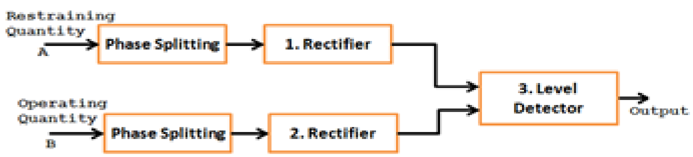
This type works with voltage input signals derived from PTs. The operation depends on the difference of the average **rectified voltage** (V1-V2).Here the rectifiers are not protected against higher currents. The relay operates when V1 >V2.

Instantaneous Comparator (Directing Amplitude Comparator) –

DIRECT COMPARATOR:



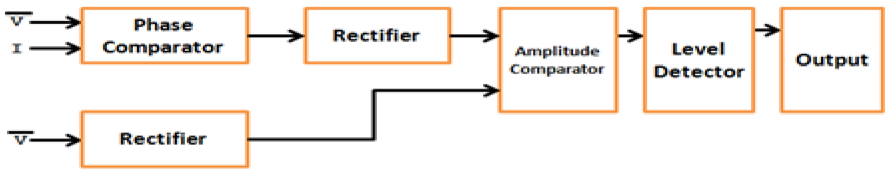
Here the restraining signal is rectified and smoothed completely in order to provide a level restraint.This is then compared with the peak value of operating signal, which may or may not be rectified but is smoothened. The tripping signal is provided if the operating signal exceeds the level of the restraint. The block diagram is shown in the fig above. Since this method involves smoothening, the operation is slow. A faster method is phase splitting the wave shapes of instantaneous amplitude comparator are shown in fig below before rectification and the averaging circuit can be eliminated.



Block Diagram of Phase Spliting for amplitude comparator

HYBRID COMPARATOR:

This kind of comparator compares both magnitude and phase of the input quantities. Hence this type is of mixed version. In the hybrid comparator, both amplitude and phase comparators are used. Inputs are given to a phase comparator. The output of the phase comparator is given to amplitude comparator.



Static impedance relays comparing V and I are generally of Hybrid Comparator.

HALL EFFECT TYPE AND MAGNETO RESISTIVITY TYPE:

HALL EFFECT:

The Hall effect is the production of a voltage difference (the Hall voltage) across an electrical conductor, transverse to an electric current in the conductor and to an applied magnetic field perpendicular to the current. It was discovered by Edwin Hall in 1879. For clarity, the original effect is sometimes called the ordinary Hall Effect to distinguish it from other "Hall Effects" which have different physical mechanisms.

The Hall coefficient is defined as the ratio of the induced electric field to the product of the current density and the applied magnetic field. It is a characteristic of the material from which the conductor is made, since its value depends on the type, number, and properties of the charge carriers that constitute the current.

Hall effect in semiconductors

When a current-carrying semiconductor is kept in a magnetic field, the charge carriers of the semiconductor experience a force in a direction perpendicular to both the magnetic field and the current. At equilibrium, a voltage appears at the semiconductor edges.

The simple formula for the Hall coefficient given above becomes more complex in semiconductors where the carriers are generally both electrons and holes which may be present in different concentrations and have different mobilities. For moderate magnetic fields the Hall coefficient is

$$R_H = \frac{p\mu_h^2 - n\mu_e^2}{e(p\mu_h + n\mu_e)^2}$$

or equivalently

$$R_H = \frac{(p - nb^2)}{e(p + nb)^2}$$

with

$$b = \frac{\mu_e}{\mu_h}.$$

Here is the electron concentration, the hole concentration, the electron mobility, the hole mobility and the elementary charge. For large applied fields the simpler expression analogous to that for a single carrier type holds.

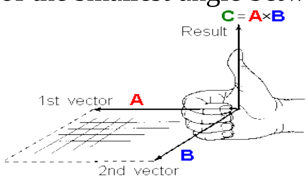
MAGNETO RESISTIVITY:

Magnetoresistance is the tendency of a material to change the value of its electrical resistance in an externally-applied magnetic field. There are a variety of effects that can be called magnetoresistance: some occur in bulk non-magnetic metals and semiconductors, such as geometrical magnetoresistance, Shubnikov de Haas oscillations, or the common positive magnetoresistance in metals.[1] Other effects occur in magnetic metals, such as negative magnetoresistance in ferromagnets[2] or anisotropic magnetoresistance (AMR). Finally, in multicomponent or multilayer systems (e.g. magnetic tunnel junctions), giant magnetoresistance (GMR), tunnel magnetoresistance (TMR), colossal magnetoresistance(CMR), and extraordinary magnetoresistance (EMR) can be observed.

The first magnetoresistive effect was discovered by William Thomson (better known as Lord Kelvin) in 1851, but he was unable to lower the electrical resistance of anything by more than 5%. Nowadays, systems are known (e.g. semimetals[3] or concentric ring EMR structures) where a magnetic field can change resistance by orders of magnitude. As the resistance may depend on magnetic field through various mechanisms, it is useful to separately consider situations where it depends on magnetic field directly (e.g. geometric magnetoresistance, multiband magnetoresistance) and those where it does so indirectly through magnetisation (e.g. AMR, TMR).

VECTOR PRODUCT:

Two types of vector multiplications have been defined, the scalar product and the vector product. $A\times B = A_xB_x + A_yB_y + A_zB_z$. The scalar product of twovectors A and B is a scalar quantity equal to theproduct of the magnitudes of the two vectors and the cosine of the smallest angle between them.



UNIT II - RELAY CIRCUIT

Static relay circuit (using analog and digital ic's) for over current:

The Solid State Relay (Static Relay):

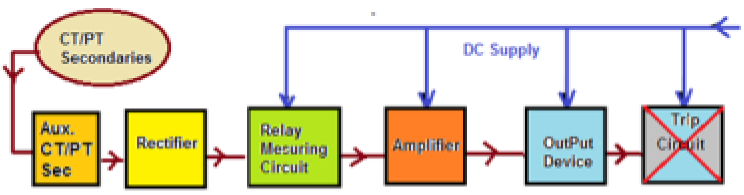
- **History of Relay:** The static relay are next generation relays .The Solid Static relays was first introduced in 1960's. The term 'static' implies that the relay has no moving mechanical parts in it. Compared to the Electromechanical Relay, the Solid Static relay has longer life-span, decreased noise when operates and faster respond speed. However, it is not as robust as the Electromechanical Relay.
- Static relays were manufactured as semi conductor devices which incorporate transistors, ICs, capacitors, small micro processors etc.
- The static relays have been designed to replace almost all the functions which were being achieved earlier by electromechanical relays.
- **Measuring principles:** The working principle of the Solid Static relays is similar to that of the Electromechanical Relay which means the Solid Static relays can perform tasks that the Electromechanical Relay can perform.
- The Solid Static relays use analogue electronic devices instead of magnetic coils and mechanical components to create the relay characteristics. the measurement is carried out by static circuits consisting of comparators, level detectors, filter etc while in a conventional electro-magnetic relay it is done by comparing operating torque (or force) with restraining torque (or force). The relaying quantity such as voltage/current is rectified and measured. When the quantity under measurement attains certain well-defined value, the output device is triggered and thereby the circuit breaker trip circuit is energized.

- In a solid state relay, the incoming voltage and current waveforms are monitored by analog circuits, not recorded or digitized. The analog values are compared to settings made by the user via potentiometers in the relay, and in some case, taps on transformers.
- In some solid state relays, a simple microprocessor does some of the relay logic, but the logic is fixed and simple. For instance, in some time over current solid state relays, the incoming AC current is first converted into a small signal AC value, and then the AC is fed into a rectifier and filter that converts the AC to a DC value proportionate to the AC waveform. An op-amp and comparator is used to create a DC that rises when a trip point is reached. Then a relatively simple microprocessor does a slow speed A/D conversion of the DC signal, integrates the results to create the time-over current curve response, and trips when the integration rises above a set point. Though this relay has a microprocessor, it lacks the attributes of a digital/numeric relay, and hence the term “microprocessor relay” is not a clear term.
- **Function of Relay:** Early versions used discrete devices such as transistors and diodes in conjunction with resistors, capacitors, inductors, etc., but advances in electronics enabled the use of linear and digital integrated circuits in later versions for signal processing and implementation of logic functions. While basic circuits may be common to a number of relays, the packaging was still essentially restricted to a single protection function percase, while complex functions required several cases of hardware suitably interconnected.

Static Relay

- User programming was restricted to the basic functions of adjustment of relay characteristic curves. Therefore it can be viewed in simple terms as an analogue electronic replacement for electromechanical relays, with some additional flexibility in settings and some saving in space requirements.
- In some cases, relay burden is reduced, making for reduced CT/VT output requirements. in a static relay there is no armature or other moving element and response is developed by electronic, magnetic or other components without mechanical motion.
- A relay using combination of both static and electro-magnetic units is also called a static relay provided that static units accomplish the response.
- Additional electro-mechanical relay units may be employed in output stage as auxiliary relays. A protective system is formed by static relays and electro-mechanical auxiliary relays.
- The performance of static relay is better than electromagnetic relays as they are fast acting and accuracy of measurement is better than electromagnetic relay.
- The constraint in static relay is limited function/features. In the last decade, some micro processors were introduced in this relay to achieve the functions like (i) Fuse failure features (ii) Self check feature (iii) Dead Pole detection and iv) Carrier aided protection features.
- **Operation of Relay:** The essential components of static relays are shown in fig. The output of CT and PT are not suitable for static components so they are brought down to suitable level by auxiliary CT and PT. Then auxiliary CT output is given to rectifier. Rectifier rectifies the relaying quantity i.e., the output from a CT or PT or a Transducer

Static Relay



- The rectified output is supplied to a measuring unit comprising of comparators, level detectors, filters, logic circuits. The output is actuated when the dynamic input (i.e., the relaying quantity) attains the threshold value. This output of the measuring unit is amplified by amplifier and fed to the output unit device, which is usually an electro-magnetic one. The output unit energizes the trip coil only when relay operates.

Advantages of Solid State Relay:

- Static Relay burden is less than Electromagnetic type of relays. Hence error is less.
- Low Weight
- Required Less Space which results in panel space saving.
- Arc less switching
- No acoustical noise.
- Multi-function integration.
- Fast response.
- Long life (High Reliability): more than 109 operations
- High Range of Setting compared to electromechanical Relay
- More Accurate compared to electromechanical Relay
- Low Electromagnetic Interference.
- Less power consumption.
- Shock and vibration resistant
- No contact bounce
- Microprocessor compatible.
- Isolation of Voltage
- No moving parts: There are no moving parts to wear out or arcing contacts to deteriorate that are often the primary cause of failure with an Electro Mechanical Relay.
- No mechanical contact bounce or arcing: A solid-state relay doesn't depend on mechanical forces or moving contacts for its operation but performs electronically. Thus, timing is very accurate even for currents as low as the pickup value. There is no mechanical contact bounce or arcing, and reset times are extremely short.
- Low input signal levels: Ideal for Telecommunication or microprocessor control industries. Solid state relays are fast becoming the better choice in many applications, especially throughout the telecommunication and microprocessor control industries.
- Cost Issues: In the past, there has been a rather large gap between the price of an electromechanical relay and the price of a solid state relay. With continual advancement in manufacturing technology, this gap has been reduced dramatically making the advantages of solid state technology accessible to a growing number of design engineers.

Limitations of static relays:

- Auxiliary voltage requirement for Relay Operation.
- Static relays are sensitive to voltage transients which are caused by operation of breaker and isolator in the primary circuit of CTs and PTs.
- Serious over voltage is also caused by breaking of control circuit, relay contacts etc. Such voltage spikes of small duration can damage the semiconductor components and also cause mal operation of relays.
- Temperature dependence of static relays: The characteristics of semiconductor devices are affected by ambient temperature.
- Highly sophisticated isolation and filter circuits are required to be built into the relay design to take care of electromagnetic interference and transient switching disturbances in the power system.
- Highly reliable power supply circuits are required.
- Effect of environmental conditions like humidity, high ambient temperature, dust accumulation on PCB leading to tracking.
- The component failure.
- Non availability of fault data.
- Characteristic variations with passage of time.

Digital Relay:

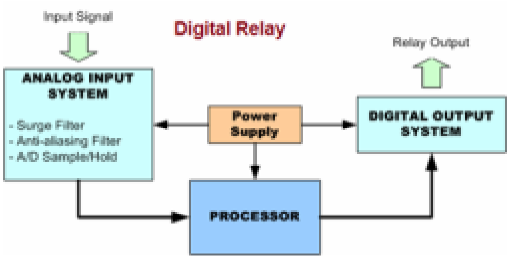
- **History of Relay:** Around 1980s the digital relay entered the market. Compared to the Solid State Relay, the digital relay takes the advantages of the development of microprocessors and microcontrollers. Instead of using analog signals, the digital relay converts all measured analog quantities into digital signals.
- Digital protection relays is a revolution step in changing Relay technology. In Digital Relay Microprocessors and micro controllers are used in replacement of analogue circuits used in static relays to implement relay functions. Digital protection relays introduced in 1980. However, such technology will be completely superseded within the next five years by numerical relays.
- By the mid-1990s the solid state and electromechanical relay had been mostly replaced by digital relay in new construction. In distribution applications, the replacement by the digital relay proceeded a bit more slowly. While the great majority of feeder relays in new applications today are digital, the solid state relay still sees some use

where simplicity of the application allows for simpler relays, and which allows one to avoid the complexity of digital relays.

- **Measuring principles:** Compared to static relays, digital relays introduce Analogue to Digital Convertor (A/D conversion) of all measured analogue quantities and use a microprocessor to implement the protection algorithm. The microprocessor may use some kind of counting technique, or use the Discrete Fourier Transform (DFT) to implement the algorithm.
- The Microprocessors used in Digital Relay have limited processing capacity and memory compared to that provided in numerical relays.
- **Function of Relay:** The functionality tends therefore to be limited and restricted largely to the protection function itself. Additional functionality compared to that provided by an electromechanical or static relay is usually available, typically taking the form of a wider range of settings, and greater accuracy.

Digital Relay

- The limited power of the microprocessors used in digital relays restricts the number of samples of the waveform that can be measured per cycle. This, in turn, limits the speed of operation of the relay in certain applications. Therefore, a digital relay for a particular protection function may have a longer operation time than the static relay equivalent. However, the extra time is not significant in terms of overall tripping time and possible effects of power system stability.
- **Operation of Relay:** Digital relay consists of: (1) Analogue input subsystem, (2) Digital input subsystem, (3) Digital output subsystem, (4) A processor along with RAM (data scratch pad), main memory (historical data file) and Power supply



- Digital relaying involves digital processing of one or more analog signals in three steps: Conversion of analogue signal to digital form Processing of digital form Boolean decision to trip or not to trip.

Advantages of Digital Relay:

- High level of functionality integration.
- Additional monitoring functions.
- Functional flexibility.
- Capable of working under a wide range of temperatures.
- They can implement more complex function and are generally more accurate
- Self-checking and self-adaptability.
- Able to communicate with other digital equipment (pear to pear).
- Less sensitive to temperature, aging
- Economical because can be produced in volumes
- More Accurate.
- plane for distance relaying is possible
- Signal storage is possible.

Limitations of Digital Relay:

- Short lifetime due to the continuous development of new technologies.
- The devices become obsolete rapidly.
- Susceptibility to power system transients.
- As digital systems become increasingly more complex they require specially trained staff for Operation.
- Proper maintenance of the settings and monitoring data.

Over Current Relay:

An "Over Current Relay" is a type of protective relay which operates when the load current exceeds a preset value. In a typical application the over current relay is used for over current protection, connected to a current transformer and calibrated to operate at or above a specific current level.

This project will attempt to design and fabricate over current protection relay using PIC micro controller. The PIC micro controller will cause the circuit breaker to trip when the current from load current reaches the setting value in the PIC micro controller.

In order to design it, first the load current need to measure in order to monitor it using current sensor including testing the fault (over current) and when such condition arise, it will isolate in the shortest time possible without harming the any other electrical devices. It will also including in developing the algorithm for instantaneous over current relay and IDMT (Inverse Definite Minimum Time) relay for the circuit breaker to trip. In this project, PIC microcontroller will be used to control and operate the tripping coil in circuit breaker

Objective

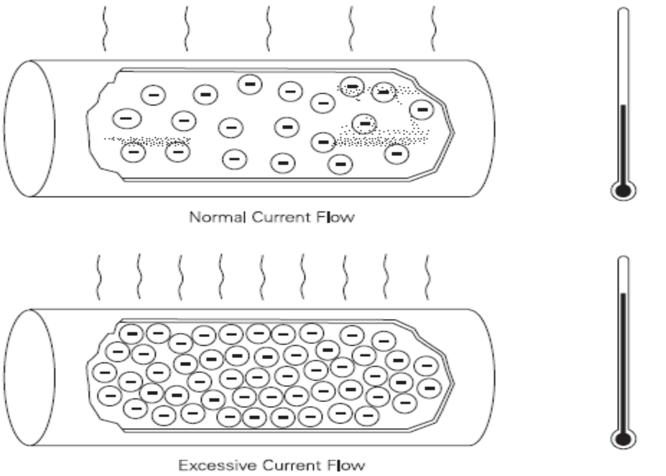
The objectives of this project are;

I. To design and fabricate over current protection relay using PIC micro controller which can operate on the permissible conditions by setting the over current value.

II. To test unwanted conditions (over current) and when such conditions arise to isolate the fault condition in the shortest time possible.

III. To investigate IDMT curve characteristic

What Is Over Current ?



The National Electrical Code defines over current as any current in excess of the rated current of equipment or the ampacity of a conductor. It may result from overload, short circuit, or ground fault. Current flow in a conductor always generates heat. The greater the current flow, the hotter the conductor. Excess heat is damaging to electrical components. For that reason, conductors have a rated continuous current carrying capacity or ampacity. Over current protection devices are used to protect conductors from excessive current flow. These protective devices are designed to keep the flow of current in a circuit at a safe level to prevent the circuit conductors from overheating.

Why Protection System Is Important?

Fault impose hazard to both user and the system itself and when it comes to user, life is the concern and when it concern the system it is merely to provide stable electrical power system on top of that prevent damage to the expensive equipment used. In summary, the needs of power protection are [1]:

User/Personnel Safety	Prevent injury and accident.
Equipment	Safe guard the equipment from over current, over voltage and frequency drift that can cause damage
General Safety	Prevent secondary accident that result from power system fault such as fire
Power Supply Stability	Ensure that continuous and stable electrical power supplied by the system/grid
Operation Cost	Ensure that the system is operating at optimal efficiency and reduce equipment maintenance and replacement cost

Shock Phenomenon is almost similar to electrocution. High voltage above 500V can cause human skin rupture. The effect of this is the decrease of human body resistance. In certain condition, the resistance may drop down to about 500Ω.
At 500V from Ohms law,
I=V/R therefore,
I=500/500 = 1A
Typically 16mA is considered hazardous to human. The following table shows the effect of current on human at 60Hz, AC. [2]

Table 2.2: Effect of Live Current on Human

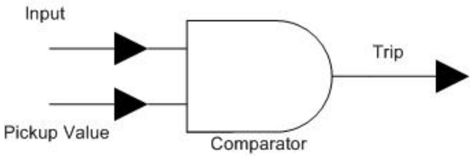
Current	Effect on Human
1 mA	Barely perceptible
16 mA	Maximum current an average man can grasp and "let go"
20 mA	Paralysis of respiratory muscles
100 mA	Ventricular fibrillation threshold
2 Amps	Cardiac standstill and internal organ damage
15/20 Amps	Common fuse or breaker opens circuit

Power System Protection Devices

The idea of power protection system is to isolate the fault in the shortest time possible. Once fault occurs, the isolation part takes place by opening or disconnecting the circuit at the fault section. Almost all protection devices will act automatically when fault occurs but that doesn't mean it will protect the electrical equipments. Relay is the most common device that can actually serve the problems. Relay is a device which disconnects the circuit when there is input (to relay). Relay can be dividing into three major types;

- **Instantaneous (Instant reaction)**

Instantaneous over current protection is considered the simplest protection scheme. It is widely used because of its quick reaction time.



The relay pick up value is commonly set to a value anywhere between 125-135% of the maximum load current and 90% of the minimum fault current. These values help to minimize unnecessary responses from the relay. The Following formula is used to calculate the pickup value: $1.2\times$ Max load current $\leq$ Pick up value $\leq 0.9\times$ Min fault current.

Time Delay (Tripping will only occurs after certain settable time)

There are two settings that must be applied to all time-delay over current relays: 1) the pickup value and 2) the time delay. Time relays over current are designed to produce high operation at high current slow operation at low current; hence, an inverse time characteristic. Relays from different manufactures may have different inverse time characteristics. In order to use these inverse time characteristics, you must first calculate the following:
“Multiples of pickup values” = fault current / pick up value.

Numerical Relay (Static relay uses microprocessor and operatebased on numerical method Calculation)

Numerical relay is a special type of digital relay that actually uses the capability of the modern microprocessor to actually calculate the fault value and perform analysis such as Fourier Analysis on the fault data before even making decision to trip the system or not. Numerical Relay also usually has the capability to record the faults value for analysis. Most often these relays are also equipped with communication port that allow maintainer to download information form the relay after the fault
has occurs or just for system health analysis purposes.

		
Microprocessor Base Relay	Time Delay Relay	Numerical Relay

Figure 2.3: Types of protection relay

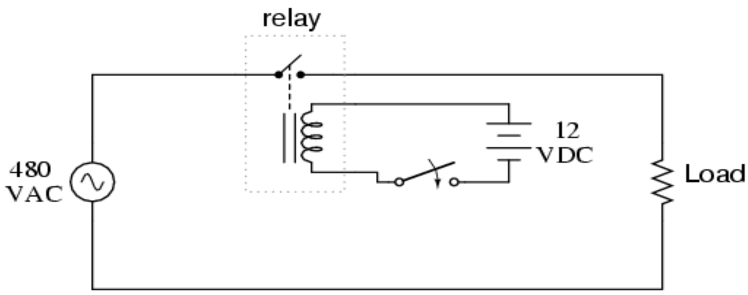


Figure 2.3 shows the basic principle of a relay and how it would be used in electrical circuit. The high voltage is connected to the load via the relay such that automatic disconnection of the load can happen in the case of fault occurrences.

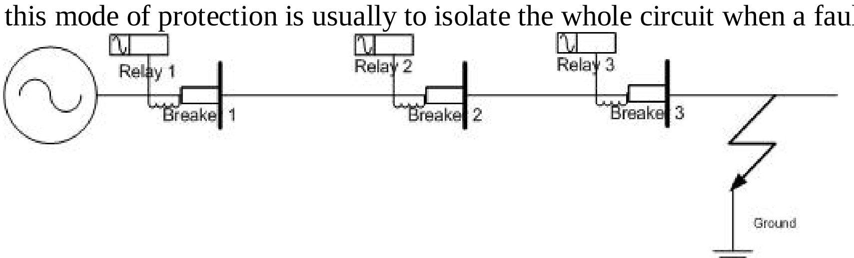
Relay is a passive device that can only be ON or OFF state by default. As such it does not actually know if when it should start to operate and when it should not. Active device that can actually “see” or sense the fault is required to instruct the relay on what to do. These devices are then connected to the relay input to make a mini protection scheme that can actually monitor faults and take necessary action. To be able to do a good job, the protection scheme should be able to eliminate the fault condition on the smallest portion of the circuit in the shortest time possible.

Types of Protection System

Power protection system can be implemented into two ways which are ‘no unit schemes’ and ‘unit schemes’.

Non-Unit Protection

The Non-Unit protection scheme work on the system and it might overlap with another protection device in the systems. The use of this mode of protection is usually to isolate the whole circuit when a fault occurs.

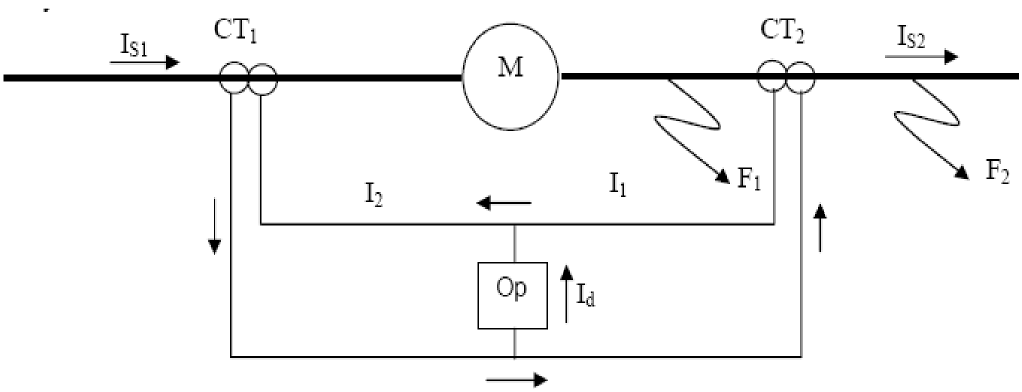


There are three protection relays installed in this system for the protection. If instantaneous relay is use, fault occurring at 3 will cause the whole system to trip because relay 1 and 2 also can see the fault. If IDMT (Inverse Definite Minimum Time) is use, the relay will isolate in the smallest section which in 3. Note that relay at 2 will trigger after several settable times and take over (isolate) the fault if relay at 3 fail to isolate the fault. The advantage of this system is it has the backup capability and it guarantee that the fault will be removed by at least one of the protection relay.

Unit Protection

The main purpose of the unit protection scheme is to protect a defined or discrete zone of location that is usually the zone bounded by the 2CT used for differential current measurement. Relay used in Unit Protection scheme are usually Differential Protection relay. The protection system should be designed to satisfy the following requirements:

1) Under normal conditions the breakers are not tripped
2) Under fault conditions only the breaker closest to the fault will trip
3) If the closest breaker fails to operate, then the next breaker closest to the fault will trip.



The figure above shows the operation of a unit protection. The two CT is used to measure the incoming and outgoing current into the protected load M. Under normal operating condition, IS1 will be equal to IS2, therefore, I1 = I2, thus result in Id=0. However, when I1 ≠ I2 (Fault at F1), then Id will have the value of I1-I2. The current is then detected by the relay that will then cause trip in the system. For this protection scheme, if the fault occurs at F2, the protection system will not be able to detect the fault because it is happening outside the protection zone of the system.

Inverse Time Over current Protection:

In a system for which the fault current is practically determined by the fault location, without being substantially affected by changes in the power source impedance, it is advantageous to use inverse definite minimum time (IDMT) over current protection. This protection provides reasonably fast tripping, even at a terminal close to the power source where the most severe faults can occur.

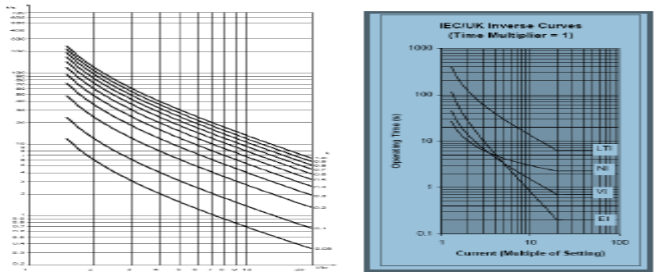
The inverse time over current protection elements have the IDMT characteristics defined by equation;

$$t = TMS \times \left\{ \left[\frac{k}{\left(I/I_s \right)^a - 1} \right] + c \right\}$$

Where:
t = operating time for constant current I (seconds),
I = energizing current (amps),
Is = over current setting (amps),
TMS = time multiplier setting,
k, a, c = constants defining curve.
Four curve types are available as defined in Table 2.3. They are illustrated in Figure below.

Table 2.3: Specification of IDMT Curves

Curve Description	k	a	c
IEC Normal Inverse (NI)	0.14	0.02	0
IEC Very Inverse (VI)	13.5	1	0
IEC Extremely Inverse (EI)	80	2	0
IEC/UK Long Time Inverse (LTI)	120	1	0



(a) (b)

Figure 2.8: Figure (a) shows that the 'Long Time Inverse' characteristic and (b) is types of IDMT Characteristic

'The Brain'

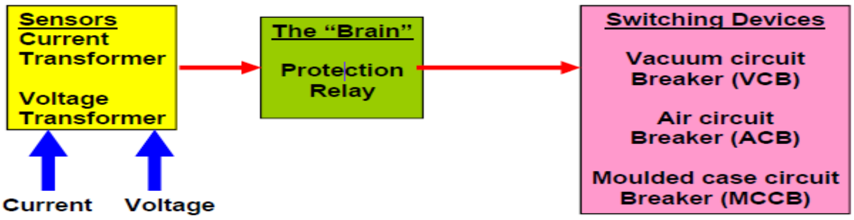


Figure 2.9: Building block of protection system

The block diagram above shows the protection system flow. Protection system is mainly controlled by the protection relay which is the brain of the protection system. Current transformer/voltage transformer will drop voltage/current in secondary windings. If there are over current/over load, the protection relay will
open the circuit (cut-off) and cause the switching devices to trip. Protection relay play an important role in this system to cause the circuit breaker to trip and it can be implemented at various stages and various types of protection devices. Most of all, the protection relay only act as the brain of the protection and actual switching work are done by the circuit breakers and isolators.

<u>Differential Relay</u>

The relays used in are of different types. Among them differential relay is very commonly used relay for and generators from localised faults.

Differential relays are very sensitive to the faults occurred within the zone of protection but they are least sensitive to the faults that occur outside the protected zone. Most of the relays operate when any quantity exceeds beyond a predetermined value for example operates when through it exceeds predetermined value. But the is somewhat different. It operates depending upon the difference between two or more similar electrical quantities.

<u>Definition of Differential Relay</u>

The differential 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 Electric Power circuit.

These two currents meet at a junction point where a relay coil is connected. According to 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. If the polarity and amplitude of both 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 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. The polarity of current transformers are such that the secondary currents of these opposes each other. From the circuit is clear that only if any nonzero difference is created between this to secondary currents, then only this differential current will flow through the operating coil of the relay. If this difference is more than the peak up value of the relay, it will operate to open the to isolate the protected equipment from the system. The relaying element used in differential relay is since differential scheme is only adapted for clearing the fault inside the protected equipment in other words differential relay should clear only internal fault of the equipment hence the protected equipment should be isolated as soon as any fault occurred inside the equipment itself. They need not be any time delay for coordination with other relays in the system.

Types of Differential Relay

There are mainly two **types of differential relay** depending upon the principle of operation.

1. Current Balance Differential Relay
2. Voltage Balance Differential Relay

1.Current Balance Differential Relay

In current differential relay two current transformers are fitted on the either side of the equipment to be protected. The secondary circuits of CTs are connected in series in such a way that the carry secondary CT current in same direction. The operating coil of the relaying element is connected across the CT's secondary circuit. Under normal operating conditions, the protected equipment (either power transformer or carries normal current. In this situation, say the secondary current of CT_1 is I_1 and secondary current of CT_2 is I_2. It is also clear from the circuit that the current passing through the relay coil is nothing but I_1-I_2. As we said earlier, the current transformer's ratio and polarity are so chosen, $I_1 = I_2$, hence there will be no current flowing through the relay coil. Now if any fault occurs external to the zone covered by the CTs, faulty current passes through primary of the both current transformers and thereby secondary currents of both current transformers remain same as in the case of normal operating conditions. Therefore at that situation the relay will not be operated. But if any ground fault occurred inside the protected equipment as shown, two secondary currents will be no longer equal. At that case the differential relay is being operated to isolate the faulty equipment (or alternator) from the system. Principally this systems suffers from some disadvantages

1. There may be a probability of mismatching in cable impedance from CT secondary to the remote relay panel.
2. These pilot cables' capacitance causes incorrect operation of the relay when large through fault occurs external to the equipment.
3. Accurate matching of characteristics of current transformer cannot be achieved hence there may be spill current flowing through the relay in normal operating conditions.

UNIT III - RELAY CIRCUIT

Distance Relays:

Distance functions have been in use for many years and have progressed from the original electromechanical types through analog types and now up to digital types of functions. The purpose of this paper is to discuss fundamental features of the three types of functions and possible problems that may be encountered in their design and application.

MEMORY ACTION:

A number of polarizing quantities have been used in developing phase and ground mho distance functions. Following are some of the more commonly used:

- Self-polarized (Va for Phase A function, Vab for the Phase AB function, etc.)
- Positive Sequence Voltage (Va1 for Phase A function, Vab1 for Phase AB function, etc.)
- Quadrature Voltage (Vbc shifted leading 90¡ for Phase A function)
- Median (midpoint of Vbc to Va for Phase A function)
- Leading phase (Vc shifted leading 240¡ for Phase A function)

An mho function that is other than self-polarized is often described as being cross-polarized. No attempt will be made here to describe the effect of all types of cross-polarization. Suffice it to say that cross-polarization will still result in a circular characteristic, but one that may also swivel and vary in size dependent on system conditions.

For example, consider the case of a distance function that uses positive sequence voltage as the polarizing signal. The characteristics for a phase distance function and a ground distance function that use positive sequence voltage polarization are shown in Figure 3 (1) and are drawn for a phaseto- phase and phase-to-ground fault respectively. As can be seen, these characteristics are not fixed in size, but will vary proportionately with the source impedance directly behind the function. Load flow(1) will cause the characteristic to swivel to the left (as shown) or to the right relative to the forward reach (point a), with the amount and direction of the swivel depending on the magnitude and the direction of load flow. The effect of the swivel and variability is to accommodate more resistance in the fault (to be discussed later) than would be obtained with a self-polarized mho function. Note that the plots of Figure 3 are for faults in the forward (tripping) direction. The function will not operate for an inductive fault behind them.

In electro-mechanical and analog type mho functions, memory is accomplished through the use of tuned filter circuits. The circuits are tuned to the power system frequency and in effect remember the voltage seen by the function prior to the fault. The filters are designed with a factor sufficient to allow mho function operation until the memory dies away; i.e., during the filter ring-down period. Typical filter outputs lasts in the order of three to five cycles of power system frequency, which is sufficiently long to allow the function to produce an output and so initiate zone 1 direct tripping or high speed pilot tripping. Time-delayed backup tripping could not be counted on for close-in faults however, because the filter ring-down time is generally not long enough to allow the backup timers to time out.

Memory in digitally implemented mho functions is accomplished using digital techniques, consequently there is no ring-down as with analog filters, and the remembered voltage can be held for any desired period of time. If the remembered time is set long enough, then time-delayed backup tripping can also be initiated for close-in faults. In general, It is best to allow the voltage applied to a mho function to adapt to the system voltage as soon as possible following a system disturbance so that the function is in step with the system when the disturbance is cleared. For example, consider a fault of sufficient duration so that the voltage at the relay may have shifted considerably as the result of a system swing caused by the fault. If the memory is set long enough such that the function is still sensing the voltage prior to the disturbance when the disturbance is cleared, then problems may be introduced. To avoid any possible problems, memory time should be kept to a minimum, or an adaptive memory can be used. An adaptive memory can be implemented by sensing the voltage at the time of the fault. If the voltage is less than a set value (10 percent for example) then the voltage prior to the fault will be remembered and used by the function until the fault is cleared as indicated by reset of the function. On the other hand, if the voltage is greater than the set value, then the voltage prior to the fault will be remembered for a short period of time (5 cycles for example) after which the voltage applied to the function will adapt to the actual voltage. In this way, time-delayed backup protection can be implemented for close-in faults while allowing the function to change to the system voltage with minimum time delay for all other faults. The result of memory action is to produce a dynamic (time varying) response from the function that is different from the steady-state response. This results in the dynamic and steady-state characteristics shown in Figure 4 (remember that this diagram is the same as an R-X diagram except for the inclusion of the current 1). This difference in response comes about because the function is using a different polarizing voltage during the memory period as opposed to that used steady-state. The dynamic characteristic lasts as long as the memory time. If the memory changes with time, as would happen with an analog filter, then the dynamic characteristic changes in time as the remembered voltage changes to the steady-state value. In terms of Figure 4, the function produces the dynamic characteristic using the remembered voltage, E, and then changes to the actual voltage, V to produce the steady-state characteristic. The function in Figure 4 would theoretically operate dynamically because the fault impedance (Zf) just falls on the characteristic, but it would not operate steady-state because Zf falls outside of the steady-state characteristic.

<u>Distance and Impedance relay Brief History:</u>

•1921 Voltage restrained time over current
•1929 balance beam impedance
•1950 Induction cup phase comparator
•1965 Solid state implementations
•1984 Microprocessor based implementation

<u>Distance Relay</u>
<u>Need</u>

•Faults level are higher in high voltage transmission line
•Faults need to be cleared rapidly to avoid instability and extensive damage

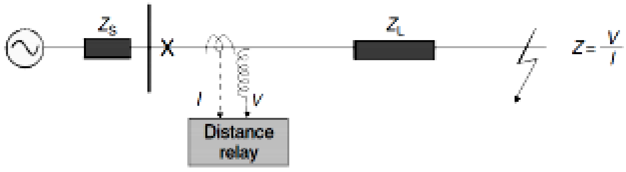
<u>Advantages</u>

•The impedance zone has a fix impedance rich
•Great instantaneous trip coverage with security
•Easier setting calculations and coordination
•Fixed zone of protection that are relatively impedance of the system change

•Higher independence of load

Basic Principle:

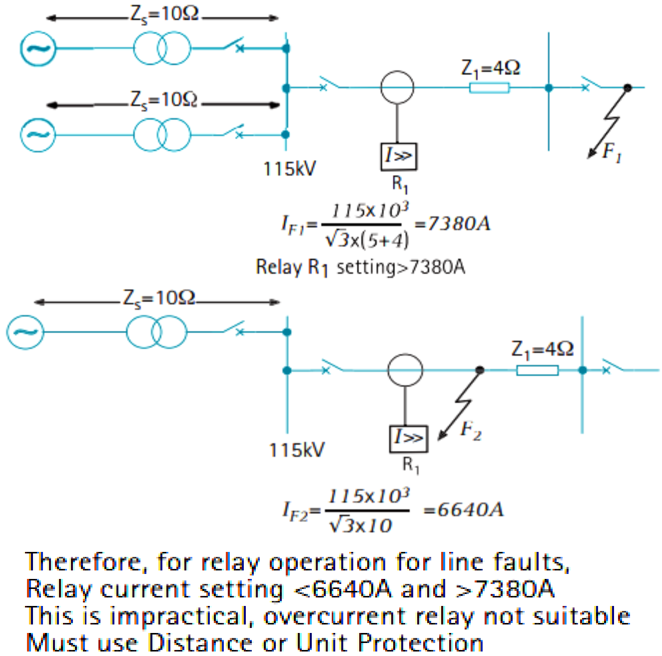
• A distance relay has the ability to detect a fault within a pre-set distance along a transmission line or power cable from its location. Every power line has a resistance and reactance per kilometer related to its design and construction so its total impedance will be a function of its length. A distance relay therefore looks at current and voltage and compares these two quantities on the basis of Ohm's law.



Since the impedance of a transmission line is proportional to its length, for distance measurement it is appropriate to use a relay capable of measuring the impedance of a line up to a predetermined point (the reach point). Distance relay is designed to operate only for faults occurring between the relay location and the predetermined (reach) point, thus giving discrimination for faults that may occur in different line sections. The basic principle of distance protection involves the division of voltage at the relaying point by the measured current. The calculated apparent impedance is compared with the reach point impedance. If the measured impedance is less than the reach point impedance, it is assumed that a fault exists on the line between the relay and the reach point.

Advantage of Distance Relay:

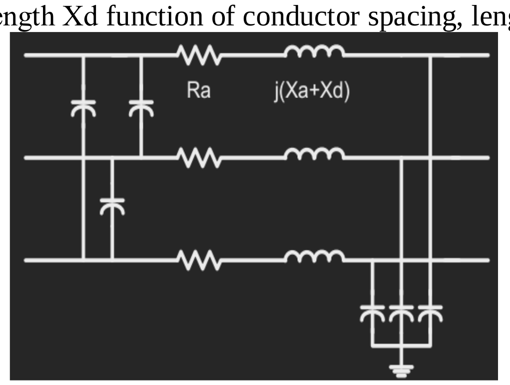
•The key advantage of distance protection is that its fault coverage of the protected circuit is virtually independent of source impedance variations.



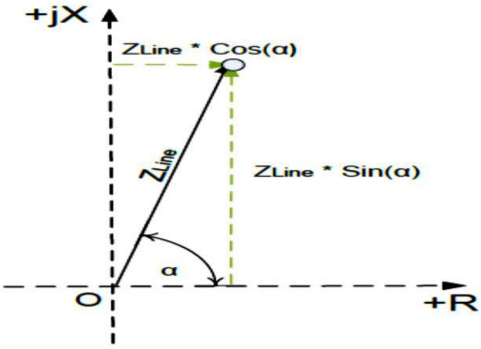
Transmission Line Impedance:

•Z ohms/mile = Ra+ j (Xa+ Xd)

•Ra, Xa function of conductor type, length Xd function of conductor spacing, length Xa+ Xd >> Ra at higher voltages

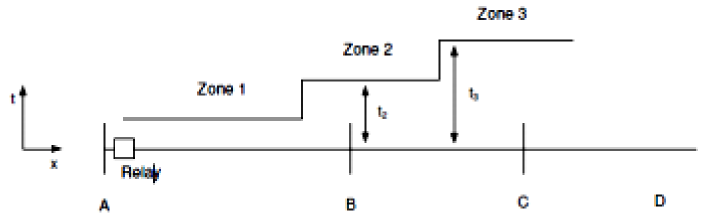


Line Impedance:

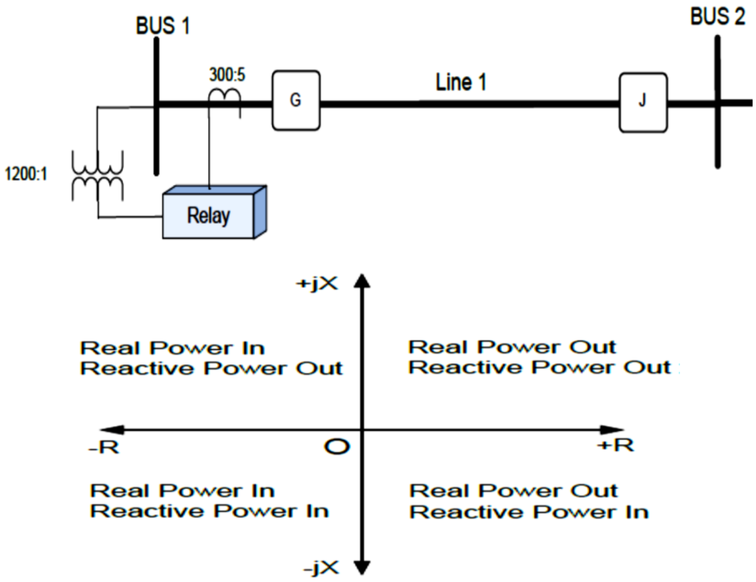


Zones of Protection:

•**Zone 1:** this is set to protect between 80% of the line length AB and operates without any time delay. This "under-reach" setting has been purposely chosen to avoid "over-reaching" into the next line section to ensure selectivity since errors and transients can be present in the voltage and current transformers. Also manufacturing tolerances limit the measurement accuracy of the relays.
•**Zone 2:** this is set to protect 100% of the line length AB, plus at least 20% of the shortest adjacent line BC and operates with time delay t2. (≈0.5s) It not only covers the remaining %20 of the line, but also provides backup for the next line section.
•**Zone 3:** this is set to protect 100% of the two lines AB, BC, plus about 25% of the third line CD and operates with time delay t3. (≈1.5s)



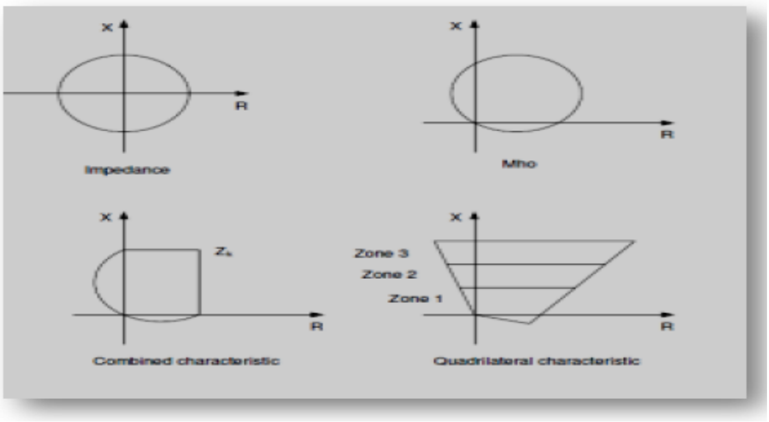
P-Q and R-X relationships:



If the direction of real and reactive power is from bus 1 to bus 2, the R-X coordinates are located in quadrant I. If the direction of real power is from bus 1 to bus 2 and the reactive power is from bus 2 to bus 1, then the R-X coordinates are located in quadrant IV

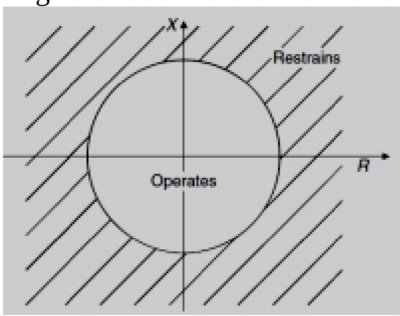
Tripping Characteristics:

The shape of the operation zones has developed throughout the years. An overview of relay characteristics can be seen below:



Impedance Characteristic:

If the relay's operating boundary is plotted on an R-X diagram, its impedance characteristic is a circle with its center at the origin of the coordinates and its radius will be the setting (the reach point) in ohms. The relay will operate for all values less than its setting i.e. for all points within the circle. This type of relay, however, is non-directional. It can operate for faults behind the relaying point. It takes no account of the phase angle between voltage and current. It is also sensitive to power swings and load encroachment due to the large impedance circle.



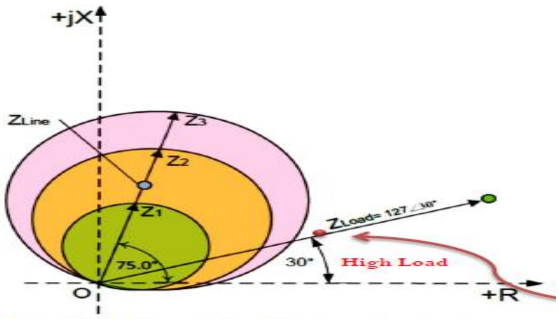
Relay Impedances – Zr:

The relay impedances are the values that a distance relay uses for zones of protection

•Diameter of each mho circle is based on the value of each zone of protection

•During steady-state or normal system conditions, the load impedance remains constant and is high enough to keep it away from the relay zones of protection

Hint: As load increases, the load apparent impedance decreases, moving it closer to the origin



Line 1 Relay mho Characteristics

Reverse Power Relay:

• Protection of generator prime movers against reverse power
• Visual indication of power, pick-up and relay tripping
• High precision digital countdown timer for delayed output
• Direct Line-Line supply where neutral is not available
• Accepts high supply voltage variations:
50 - 110%

• Cost effective and highly reliable compact design
• 50 hours burn-in before final test
• Operating temperature range:
-20°C to +70°C
• Certified by major marine classification societies
• Flame retardant enclosure
• DIN rail or screw mounting

Application:

The T2000 Reverse Power Relay willunder parallel operation prevent thegenerator from running as a motor, thusprotecting the prime mover (e.g. adiesel engine) by tripping the generatorbreaker, and at the same time avoidingoverload on the remaining generatorswith a possible blackout of the system.Together with the T2100 Excitation LossRelay, the T2500 Overcurrent and ShortCircuit Relay and the T2700 PowerRelay, the T2000 provides the optimalsolution for complete generator protection,both in marine and land-based

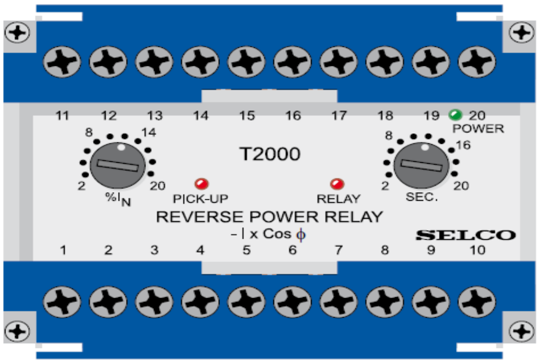
.

Function:

The T2000 measures the voltage acrossphases L1 and L2 (or between L1 andneutral for L-N operation) and thecurrentthrough a current transducerattached on phase L1.The T2000 calculates I x cos F, representingthe active power. If the activepower becomes negative and exceedsthe preset level (2 - 20%), the pick-up LED will indicate and the delay timerwill be started.After the preset time (2 - 20 sec.) hasexpired, the output relay and LED willbe activated, provided that the reversepower level was exceeded for the entire delay time.The output relay is a latching relay. Thelatching can be reset or disabled bybridging terminals 13 and 14.

Installation:

Typical setting of reverse power: Fordiesel engines 8%, delay 10 sec. and forturbines 4%, delay 10 sec. Example of setting:Required trip level: 8%Generator rating: 714A at PF = 0.8I p max: 714 x 0.8 = 571ACurrent transformer: 800/5ASetting: 8 x 571/800 = 5.7%It is important that the phase where thecurrent is measured always is connectedto terminals 1 or 2. See connection diagram.For L- L operation terminal 3 isconnected to the next phase in the phasesequence. For L- N operation terminal 3is connected to neutral.It is important that the phase sequenceis correct and the current transformerside nearest the generator side is connectedto terminal 5.The LED based pick-up indication is ideal for testing. The T2000 can betested by reducing the speed on thegenerator, until the pick-up LED indicates exceeding the preset reversepower level.



UNIT IV - TRANSIENT BEHAVIOR OF RELAYS

Capacitive Voltage Transformers (CVTs) are the predominant source of voltage signals for monitoring, protection relays and control application at transmission and sub-transmission voltage level. Poor CVT transient responses causes serious concern for high-speed line protection. For faults that cause very depressed phase voltages, the CVT output voltage may not closely follow its input voltage due to the internal CVT energy storage elements. Because these element stake time to change their stored energy, they introduce a transient to the CVT output following a significant input voltage change.

Theoretically, the output waveform of a CVT should be an exact replica of the input waveform under all operating system conditions. This requirement can easily be satisfied under steady-state condition. However, electric power systems are subjected to many types of disturbances that results in electric transients due to lightning, system fault, line energization and de energization, switching of inductive or capacitive load. Under such transient conditions, the CVT output waveform may not follow closely to its input waveform due to internal storage elements such as capacitive, inductive and non-linear components (saturable magnetic core) of the CVT. The phenomenon of

Ferroresonance is of particular concern during CVT transients because it may cause thermal overstress and consequently deterioration of CVT components due to transient over voltages produced inside the CVT [1].

This type of related work are carried in the [2] In order to have a better access to the above issues, a thorough investigation of the CVT transient performance is needed. A typical 132kV CVT model to be used in connection with the ATP-EMTP is presented. Digital time domain simulations corresponding to system fault and Ferroresonance.

GENERAL CVT STRUCTURE:

Fig. 1.gives the general structure of the CVT. It consists of the following components: Coupling capacitor (C1 and C2),
Compensating reactor (L), Step-down transformer, Ferro resonance-suppression circuit.
Fig.1.

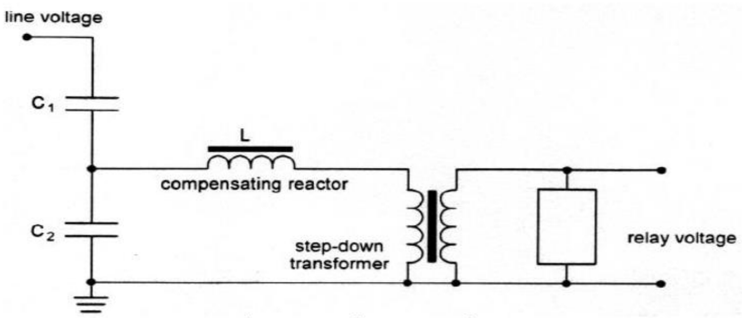


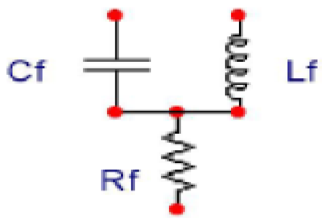
Fig.1. General Structure of CVT

The Capacitors of the CVT function as a voltage divider to step down the line voltage to an intermediate-level voltage, typically 5 to 15 kV. The compensating reactor cancels the capacitor reactance at the system frequency. This reactance cancellation prevents any phase shift between the primary and secondary voltages at the system frequency. The step-down transformer further reduces the intermediate-level voltage to the nominal relaying voltage, typically 115/√3 volts. The compensating reactor and step-down transformer have iron cores. Besides introducing copper and core losses, the compensating reactor and step-down transformer also produce Ferro resonance due to the nonlinearity of the iron cores.

For compensate the Ferro resonance phenomenon Ferro-resonance Suppression circuit normally used on the secondary of the step-down transformer. This circuit is required to avoid dangerous and destructive over voltages caused by Ferro resonance and at the same time it can aggravate the CVT transient. Whether or not this suppression circuit aggravates the CVT transient depends upon the suppression circuit design.

A) Effect of Ferro resonance suppression circuit design on CVT transient response:

A specific design of FSC is often treated as proprietary information and is seldom available. However, two generic models of FSC that are commonly used in CVT will be considered here. They are the active Ferro resonance suppression circuit (AFSC) and passive Ferro resonance suppression circuit (PFSC) as shown in Fig. 3 (a) and Fig. 3 (b) respectively.



Active Ferro resonance Suppression Circuit contains the parallel connection of Inductor and Capacitor are in series with the Resistor.
Passive Ferro resonance Suppression Circuit contains the Inductor or resistor which is permanently connected to load side of electromagnetic transformer.
FSC is designed to avoid dangerous and destructive overvoltage caused by Ferroresonance. It loads a CVT and creates an extra path apart from the burden for dissipating energy. The AFSC acts like a band-pass filter and introduces extra time delay in the CVT secondary output. The energy storage elements in the AFSC contribute to the severity of the CVT transient. In contrast, the PFSC has little effect on the CVT transient.

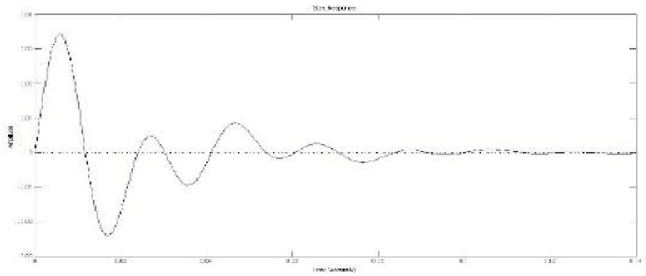
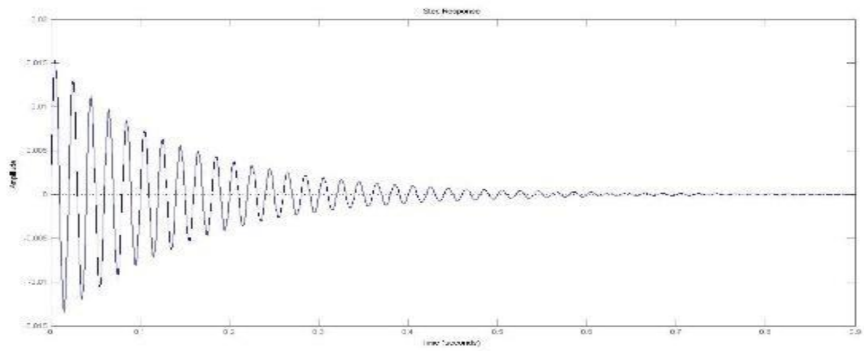


Fig. 4(a) CVT Transient with AFSC

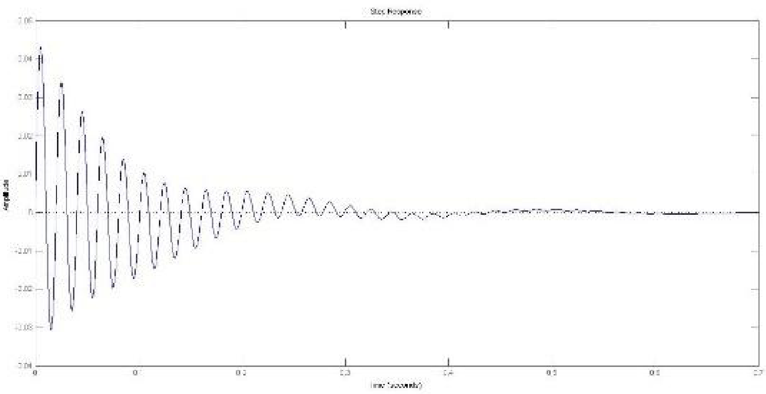
The transient response of CVT with AFSC are shown above with percentage overshoot and settling time which is more than transient response of CVT with PFSC.

B) Effect of types of burden on CVT Transient response:

Burden with high power factor or nearly resistive gives better transient response. However, the CVT transient response better with low resistive burden and the response worsens with high burden. The response shown in Fig. 5(a)

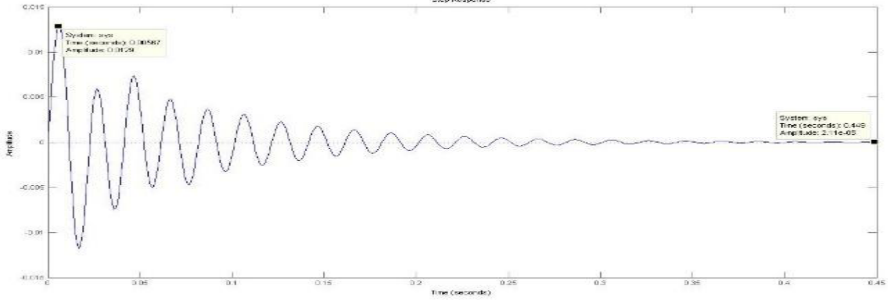


and 5(b).



C) Effect of Capacitor value on CVT transient response:

Fig. 6(a) shows the transient response for the 100 nF capacitor.



For 100nF value of capacitor, Overshoot is 88% and settling time is 0.449 sec and this transient overshoot are enough to trip the power system relay because the relay are very sensitive to transient.

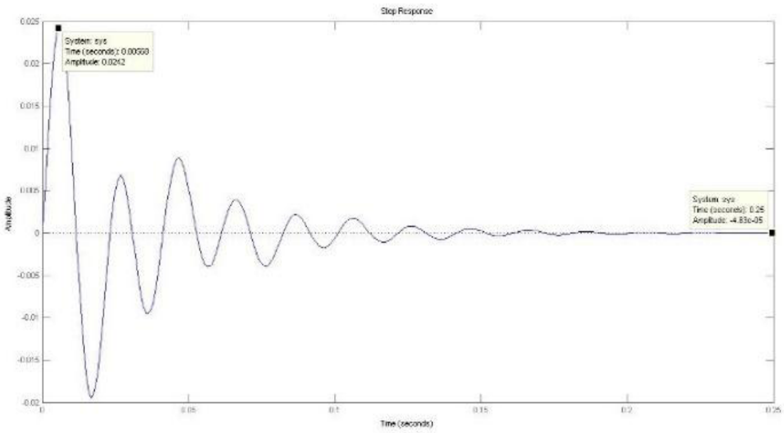


Fig. 6(b) shows the transient response for the 200nF capacitor. For this value of capacitor the overshoot is 77.4% and settling time is 0.25 sec.

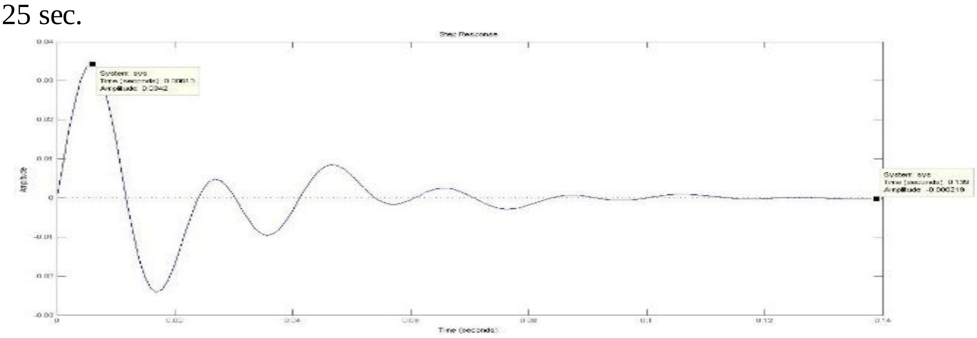


Fig. 6(c) shows the transient response for the 300nF capacitor. For this value of capacitor the Overshoot is 68.1% and settling time is 0.139 sec.

UNIT V - MICROPROCESSOR BASED RELAYS

INTRODUCTION:

With the developments in large scale integrated technology,sophisticated and fast microprocessors are coming up. Their applications to the problems of protective relaying schemes are of current interest to power system engineers. With the growing complexity of modern power networks, fast, accurate and reliable protective schemes are becoming necessary. Microprocessor based protective schemes can easily fulfil these requirements at competitive price. These schemes offer attractive compactness and flexibility. They reduce the number and types of relaying units. Electromechanical relays were used in the beginning for protection in power systems. These had several drawbacks such as high burden on instrument transformers, high operating time, contact problems, frequent maintenance etc. Solid state relays which avoid most of these disadvantages are gradually replacing electromagnetic relays. Static relays have also been increasingly used in recent years because of their inherent advantages of compactness, lower burden, less maintenance, sensitivity and high speed. Though successfully used, these suffer from a number of disadvantages such as inflexibility, duplication of specification efforts, inadaptibi1ity to changing system conditions, complexity and cost. Software schemes avoid most of these disadvantages. Programmable equipment can respond fast and can be used to implement complex threshold characteristics at low cost. They can also be self-checking in nature thereby requiring less maintenance and providing greater reliability.

MICROPROCESSOR BASED OVERCURRENT RELAYS:

Over current relays are used for the protection of distribution circuits owned and operated by utilities and customers. Many sub transmission lines are also protected by relays of this type. Distribution circuits are sometimes interconnected to form loops . In these situations, the over current relays alone can not protect the circuits effectively. Ability to detect the direction of "power flow" along with the ability to detect current exceeding a threshold is generally used for protection of loop circuits. Many shapes of time over current characteristics are available in directional over current relays. The proposed scheme deals with the development of microprocessor based protection scheme for sub transmission and distribution lines, large industrial motors and equipments. The microprocessor simulates the relaying signals for test purpose and monitors the relay performance. Based on the proposed hardware, a test procedure for over current and reverse power relays arc presented in detail. Typical test results of various routine tests conducted on a single-phase over current and reverse power relays are presented.

PRINCIPLE, TECHNIQUE AND PROCEDURE INVOLVED IN THE RELAYS:

The schematic block diagram of the interface used is shown in the fig. 4.1. This scheme is designed for the operation of four types of relays. The hardware and the software part of these relays are explained in the subsequent sections. The different four types of relays are

1. Inverse Definite Minimum Time (IDMT) overcurrent relay.
2. Definite Minimum Time (DMT) overcurrent relay.
3. Phase Comparator (Directional Relay).
4. Reverse Power Relay.

1. INVERSE DEFINITE MINIMUM TIME (I.D.M.T.) OVERCURRENT RELAY

The time-current characteristic of an overcurrent relay is given by t = KM/(I -1) where K is the design constant, M is the time multiplier setting and I is the multiple of tap current. The operating time for different values of current are calculated and tabulated. These values are stored in the memory as predetermined informations. The microprocessor obtains the required signals to obtain a particular relaying characteristic by sending proper commands to the multiplexer. The microprocessor receives signals only in voltage form. So a current to voltage converter has been developed to give an output voltage proportional to the load current. This voltage is converted into a d.c. voltage using precision rectifier as shown in fig. 4.2. The output of the rectifier is fed to the multiplexer. The microprocessor sends a command to switch on the channel S to obtain the rectified current. This rectified current is fed to the A/D converter which uses the successive approximation method to convert analog signal to digital. The microprocessor sends a signal to the A/Dconverter for start of conversion and examines whether the start of conversion is over or not. The microprocessor, after receiving the end of conversion from the A/D converter, reads the current signal in digital form and examines whether it is more than pickup value. If current exceeds the pick-up value, the microprocessor sends the tripping signal. In this type of an over current relay, the microprocessor can sense the fault currents of a number of lines using multiplexers and send the tripping signal to the circuit breaker of the faulty line.

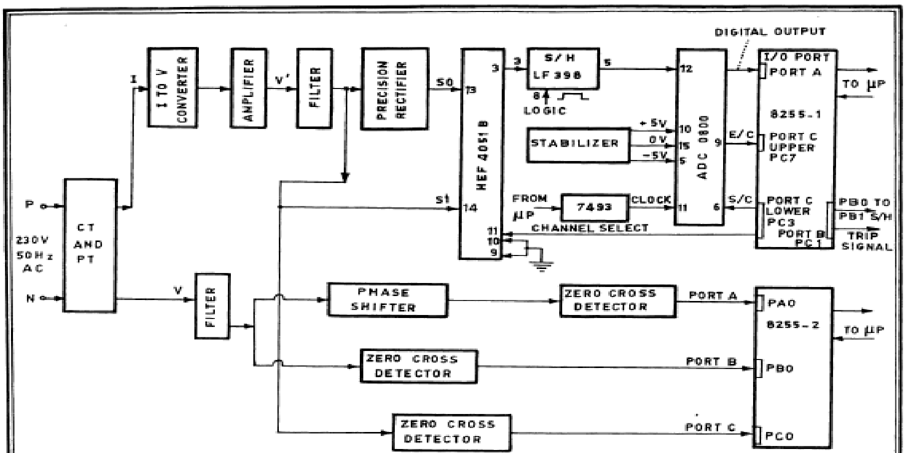


FIGURE 4.1 SCHEMATIC DIAGRAM FOR INTERFACE OF OVERCURRENT AND REVERSE POWER RELAY

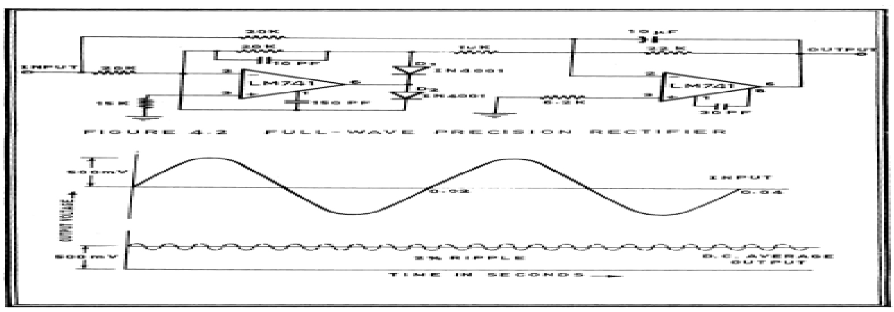


FIGURE 4.2 FULL-WAVE PRECISION RECTIFIER

DEFINITE MINIMUM TIME (DMT) OVER CURRENT RELAY:

In the case of definite minimum time over current relay, the operating time is constant irrespective of the magnitude of the current above the pickup value. The microprocessor first compares the measured current with the pick-up value of the current which remains in the memory as the stored information. If the measured current is more than the pick-up value, the microprocessor sends tripping signal after a predetermined delay. The program of a DMT overcurrent relay is simpler than that of a IDMT over current relay.

PHASE COMPARATOR (DIRECTIONAL RELAY)

A directional relay, in the simplest form, measures the phase angle between V and I. The voltage and current signals are pulsed at positive going zero points. The microprocessor measures the time between the positive going zero point of the voltage signal and that of the current signal. The phase angle between voltage and current is proportional to the measured time. Thus,the phase angle between voltage and current is measured by the microprocessor. The measured phase angle is compared with the predetermined phase angle, and the microprocessor distinguishes between healthy and faulty conditions depending upon the magnitude of the phase angle. A subroutine of multisystem precision subtraction is used for comparison. The range of phase angles for faulty conditions remain in the memory as stored information. It can also judge the direction of power flow where it is required. It sends a tripping signal within one cycle, if the measurement is made only in the positive half cycle, or within half cycle if the measurement is made for every half cycle. As it does not require A/D converter, its interface is simpler and cheaper compared to the reverse power relay.

REVERSE POWER RELAY:

A program is developed to find the fault point whether it is in the forward or reverse direction with respect to relay location. The polarity of the instantaneous value of the current at the moment of voltage peak is found to determine the direction of power flow. The instantaneous value of the current at the moment of voltage peak is I cos 6. If a fault point lies in the forward direction I cos 0 is positive for 9 lying within + or « 90. For a fault point lying in the reverse direction, I cos 0 becomes negative. These can be observed from the given waveforms shown in fig.4.3.a. and 4.3.b. A phase shifter and a zero-cross detector (fig. 4.4) is used to obtain a pulse at the moment of voltage peak. The voltage is fed to the phase shifter to get a o phase shift of 90 . Then the output of phase shifter is fed to a zero-cross detector to obtain the required pulse. The microprocessor reads the output of the zero-cross-detector to examine whether the voltage has crossed its peak. After receiving the pulse, the microprocessor sends a command to the multiplexer to switch on the channel S to obtain the instantaneous value of 1 the current at the moment of voltage peak. This instantaneous value of the current, which is equal to I cos 9 , is fed to an A/D converter. The microprocessor reads the output of the A/D converter and examines whether it is positive. This type of relay can be used to sense the reversal of power flow when it is

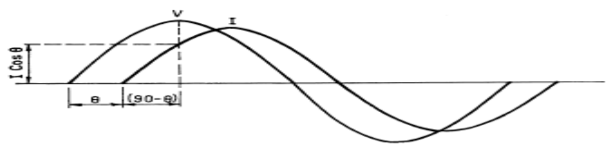


FIGURE 4.3a INSTANTANEOUS VALUE OF I AT VOLTAGE PEAK

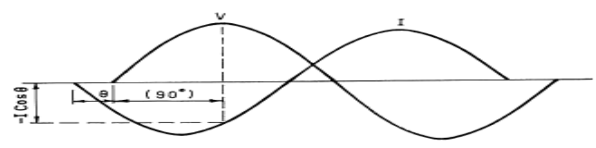


FIGURE 4.3b I COS θ FOR FAULTS IN REVERSE DIRECTION

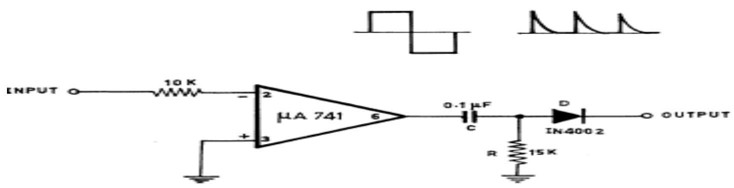
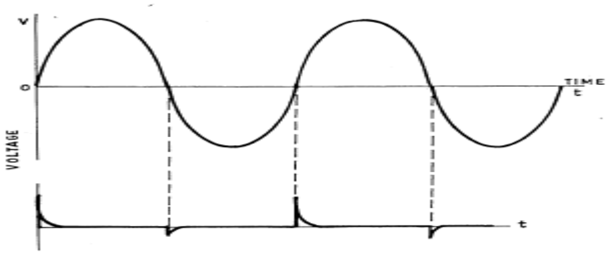


FIGURE 4.4 ZERO CROSS DETECTOR



required. When the power flow is reversed I cos 6 becomes negative and the microprocessor sends the tripping signal to the circuit breaker.

TESTING OF THE RELAYS:

The microprocessor based over current relays and reverse power relay were successfully tested in the laboratory using SDA 85 kit. Two photos, giving details of printed circuit board and test set up.In case of IDMT over current relay, the operating time for different values of current are calculated and tabulated. These values are stored in the memory as predetermined information. After switching on the supply, I and V , the program is executed. The microprocessor has not shown trip signal till the threshold value is reached, ie. in this case the threshold value is 2.0 volts. As soon as the threshold value exceeded, themicroprocessor has sent the trip signal which is observed through LED. The tripping time goes on decreasing as the load current is

FIGURE 4-10 PRINTED CIRCUIT BOARD FOR OVER CURRENT AND REVERSE POWER RELAYS

FIGURE 4-11 TESTING CIRCUIT CONNECTIONS FOR OVER CURRENT AND REVERSE POWER RELAYS

increased. A sample result is shown in table 4.1 and is plotted in fig. 4.12. Different IDMT characteristics can be incorporated. In case of DMT overcurrent relay the time remains constant irrespective of the load current. The microprocessor sends the tripping signal when the load current exceeds the threshold value. Here the tripping time remains constant throughout, even for different values of load current, which is also shown in fig.

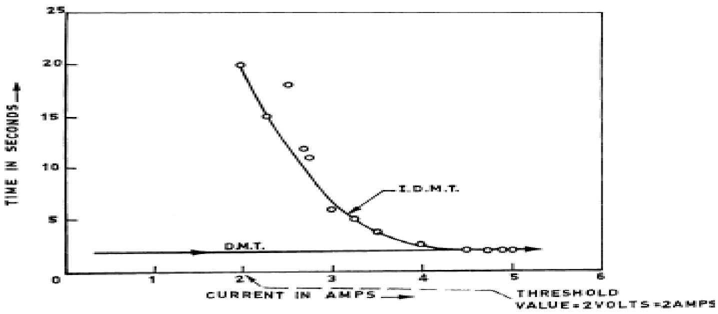


FIGURE 4-12 TIME-CURRENT CURVE OF IDMT AND DMT OVER-CURRENT RELAY