

CHAPTER ONE

INTRODUCTION

1.1 Background:

In this modern world, the dependence on electricity is so much that it has become a part and parcel of our life. The ever increasing use of electric power for domestic, commercial and industrial purposes necessitates providing bulk electric power economically. This is achieved with the help of suitable power producing units, known as Power plants or Electric power generating stations.

The modern electric power system consists of several elements such as generator, transformer, station bus-bar, transmission lines and other associated equipment, it imperative to protect these elements from different types of faults, which likely to occur sooner or later, protection of generators is the most complex and elaborate because of following reason:

1. Generator is a costly equipment and one of the major links in a power system.
2. Generator is not a single equipment but is associated with the unit-transformer, auxiliary transformer, station bus-bar, excitation system, prime-mover, voltage regulation equipment, cooling system etc. the protection of generator, is therefore, to be coordinate with the associated equipment.
3. The generator capacity has sharply risen in recent years from 30 MW to 500 MW with the result that loss of even a single machine may cause overloading of the associated machines in the system and eventual system instability.

The main features of each protection system are: speed, sensitivity, reliability, economic, selectivity and stability. The first and second generation of protection systems based on electromagnetic and static relays are suffer from many disadvantages such as needs regular maintenance, the needs to calibrate from one

period to another to ensure the accuracy of the measurement, It's also relatively slow and need time to start the movement and the instrumentation used affected by climate temperature so it is unstable. All these defects reduce the efficiency and reliability of traditional protection and therefore justify the introduction of reliable new technology known as numeric protection based on microprocessor and digital technology.

Numerical protection used possibilities of modern technology where it employee programmable microprocessor relays. In this case the relay can be used from multiple functions such as over current protection or differential protection just by changing microprocessor program and relay setting.

1.2 problem statement:

Power station represents the source of power in power system network. Any fault occure in the station will eliminate the services from consumer for this reason effective protection action is required to reduce power station outages. Traditional protection as mention above suffers from some disadvantages such as maintenance, relatively low speed. To improve the power station protection microprocessor based protection is used which offer many advantages as speed, multi-function, less maintenance and improve protection system stability.

1.3 Objective:

The main objectives of this research are:

- 1- To develop and investigate protection system used for synchronous generator used insteam power plant .
- 2- Design of Numeric Relay using Micro-controller

1.4 Methodology:

The methodology used to achieve the research objectives are subdivided as follow:

Task1: At first gather general information about steam power plant and the concept of operation and knowledge of equipment used in the station.

Task2: Study the protection for synchronous generator and type of faults may occur and the protection used.

Task3: Visiting steam power plant and gathering operation parameters.

Task4: Investigate the operation of numeric protection including components and algorithms.

Task5: Implementation of numeric protection.

1.5 Thesis Lay-out:

The project contains five chapters:

Chapter II: It's about the types of power station and the equipment of steam power plant and the points should be considered while selecting site for a steam power station.

Chapter III: It's contains the general concept of protection and the types of faults happens for synchronous generator and the relative protection.

Chapter IV: It's contains the concept of numerical protection and components and how to use them and also was the presentation of the program and the result obtained.

Chapter V: It's contains conclusion some recommendations that are supposed to do in the future.

CHAPTER TWO

STEAM POWER PLANT EQUIPMENT

2.1 introduction:

A generating station essentially employs a prime mover coupled to an alternator for the production of electric power. The prime mover (e.g., steam turbine, water turbine etc.) converts energy from some other form into mechanical energy. The alternator converts mechanical energy of the prime mover into electrical energy. The electrical energy produced by the generating station is transmitted and distributed with the help of conductors to various consumers. It may be emphasised here that apart from prime mover-alternator combination,

2.2 classification of power plant

Depending upon the form of energy converted into electrical energy, the generating stations are classified as under :

- Steam power stations.
- Hydroelectric power stations.
- Diesel power stations.
- Nuclear power stations.

A generating station which converts heat energy of coal combustion into electrical energy is known as a steam power station.

A steam power station basically works on the Rankine cycle. Steam is produced in the boiler by utilizing the heat of coal combustion. The steam is then expanded in the prime mover (i.e., steam turbine) and is condensed in a condenser to be fed into the boiler again. The steam turbine drives the alternator

which converts mechanical energy of the turbine into electrical energy. This type of power station is suitable where coal and water are available in abundance and a large amount of electric power is to be generated.

A generating station which utilizes the potential energy of water at a high level for the generation of electrical energy is known as a hydro-electric power station.

Hydro-electric power stations are generally located in hilly areas where dams can be built conveniently and large water reservoirs can be obtained. In a hydro-electric power station, water head is created by constructing a dam across a river or lake. From the dam, water is led to a water turbine. The water turbine captures the energy in the falling water and changes the hydraulic energy (i.e., product of head and flow of water) into mechanical energy at the turbine shaft. The turbine drives the alternator which converts mechanical energy into electrical energy. Hydro-electric power stations are becoming very popular because the reserves of fuels (i.e., coal and oil) are depleting day by day. They have the added importance for flood control, storage of water for irrigation and water for drinking purposes.

A generating station in which diesel engine is used as the prime mover for the generation of electrical energy is known as diesel power station.

In a diesel power station, diesel engine is used as the prime mover. The diesel burns inside the engine and the products of this combustion act as the “working fluid” to produce mechanical energy.

The diesel engine drives the alternator which converts mechanical energy into electrical energy. As the generation cost is considerable due to high price of diesel, therefore, such power stations are only used to produce small power. Although steam power stations and hydro-electric plants are invariably used to generate bulk power at cheaper cost, yet diesel power stations are finding favour

at places where demand of power is less, sufficient quantity of coal and water is not available and the transportation facilities are inadequate.

These plants are also used as standby sets for continuity of supply to important points such as Hospitals, radio stations, cinema houses and telephone exchanges.

A generating station in which nuclear energy is converted into electrical energy is known as a nuclear power station.

In nuclear power station, heavy elements such as Uranium (U235) or Thorium (Th232) are subjected to nuclear fission* in a special apparatus known as a reactor. The heat energy thus released is utilized in raising steam at high temperature and pressure. The steam runs the steam turbine which converts steam energy into mechanical energy. The turbine drives the alternator which converts mechanical energy into electrical energy. The most important feature of a nuclear power station is that huge amount of electrical energy can be produced from a relatively small amount of nuclear fuel as compared to other conventional types of power stations. It has been found that complete fission of 1 kg of Uranium (U235) can produce as much energy as can be produced by the burning of 4,500 tons of high grade coal. Although the recovery of principal nuclear fuels (i.e., Uranium and Thorium) is difficult and expensive, yet the total energy content of the estimated world reserves of these fuels are considerably higher than those of conventional fuels, viz., coal, oil and gas. At present, energy crisis is gripping us and, therefore, nuclear energy can be successfully employed for producing low cost electrical energy on a large scale to meet the growing commercial and industrial demands.

2.3 Equipment:

Steam power plant consists of equipment that can be classified into these some sections.

2.3.1 Steam generating equipment:

This is an important part of steam power station. It is concerned with the generation of superheated steam and includes such items as boiler, boiler furnace, superheater, economiser, air pre-heater and other heat reclaiming devices.

2.3.1.1 Boiler:

A boiler is closed vessel in which water is converted into steam by utilising the heat of coal combustion. The heat of combustion of coal in the boiler is utilised to convert water into steam at high temperature and pressure. The flue gases from the boiler make their journey through superheater, economiser, air pre-heater and are finally exhausted to atmosphere through the chimney. Steam boilers are broadly classified into the following two types:

(a) Water tube boilers

(b) Fire tube boilers

In a water tube boiler, water flows through the tubes and the hot gases of combustion flow over these tubes. On the other hand, in a fire tube boiler, the hot products of combustion pass through the tubes surrounded by water. Water tube boilers have a number of advantages over fire tube boilers viz., require less space, smaller size of tubes and drum, high working pressure due to small drum, less liable to explosion etc. Therefore, the use of water tube boilers has become universal in large capacity steam power stations.

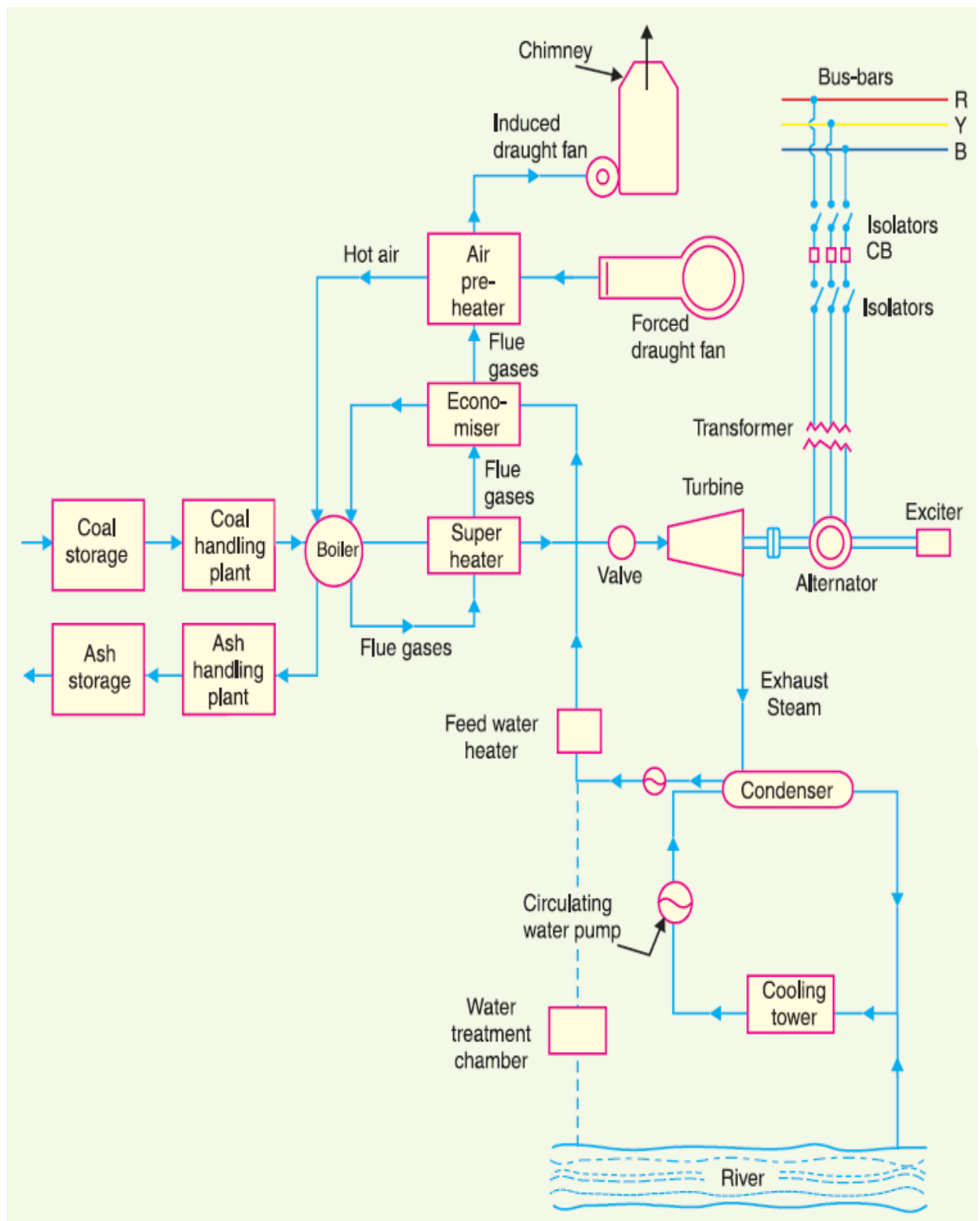


Figure 2.1: schematic arrangement of Steam Power Station

2.3.1.2 Boiler furnace:

A boiler furnace is a chamber in which fuel is burnt to liberate the heat energy. In addition, it provides support and enclosure for the combustion equipment i.e., burners. The boiler furnace walls are made of refractory materials such as fire clay, silica, kaolin etc. These materials have the property to resist change of shape, weight or physical properties at high temperatures.

There are following three types of construction of furnace walls :

- Plain refractory walls
- Hollow refractory walls with an arrangement for air cooling
- Water walls.

The plain refractory walls are suitable for small plants where the furnace temperature may not be high. However, in large plants, the furnace temperature is quite high and consequently, the refractory material may get damaged. In such cases, refractory walls are made hollow and air is circulated through hollow space to keep the temperature of the furnace walls low. The recent development is to use water walls. These consist of plain tubes arranged side by side and on the inner face of the refractory walls. The tubes are connected to the upper and lower headers of the boiler. The boiler water is made to circulate through these tubes. The water walls absorb the radiant heat in the furnace which would otherwise heat up the furnace walls.

2.3.1.3 Superheater:

A superheater is a device which superheats the steam i.e., it raises the temperature of steam above boiling point of water. This increases the overall efficiency of the plant. A superheater consists of a group of tubes made of These tubes are heated by the heat of flue gases during their journey from the furnace to the chimney.

The steam produced in the boiler is led through the superheater where it is superheated by the heat of flue gases. The steam produced in the boiler is wet

and is passed through a superheater where it is dried and superheated (i.e., steam temperature increased above that of boiling point of water) by the flue gases on their way to chimney. Superheating provides two principal benefits.

Firstly, the overall efficiency is increased. Secondly, too much condensation in the last stages of turbine (which would cause blade corrosion) is avoided. The superheated steam from the superheater is fed to steam turbine through the main valve. Superheaters are mainly classified into two types according to the system of heat transfer from flue gases to steam viz.

- Radiant superheater
- Convection superheater

The radiant superheater is placed in the furnace between the water walls and receives heat from the burning fuel through radiation process. It has two main disadvantages. Firstly, due to high furnace temperature, it may get overheated and, therefore, requires a careful design. Secondly, the temperature of superheater falls with increase in steam output. Due to these limitations, radiant superheater is not finding favour these days. On the other hand, a convection superheater is placed in the boiler tube bank and receives heat from flue gases entirely through the convection process. It has the advantage that temperature of superheater increases with the increase in steam output. For this reason, this type of superheater is commonly used these days.

2.3.1.4 Economiser:

It is a device which heats the feed water on its way to boiler by deriving heat from the flue gases. This results in raising boiler efficiency, saving in fuel and reduced stresses in the boiler due to higher temperature of feed water. An economiser consists of a large number of closely spaced parallel steel tubes connected by headers or drums. An economiser is essentially a feed water heater and derives heat from the flue gases for this purpose. The feed water is fed to the economiser before supplying to the boiler. The economiser extracts a part of heat

of flue gases to increase the feed water temperature. The feed water flows through these tubes and the flue gases flow outside. A part of the heat of flue gases is transferred to feed water, thus raising the temperature of the latter.

2.3.1.5 Air Pre-heater:

Superheaters and economisers generally cannot fully extract the heat from flue gases. Therefore, pre-heaters are employed which recover some of the heat in the escaping gases. An air preheater increases the temperature of the air supplied for coal burning by deriving heat from flue gases. Air is drawn from the atmosphere by a forced draught fan and is passed through air preheater before supplying to the boiler furnace. The air preheater extracts heat from flue gases and increases the temperature of air used for coal combustion. The principal benefits of preheating the air are : increased thermal efficiency and increased steam capacity per square metre of boiler surface. The function of an air pre-heater is to extract heat from the flue gases and give it to the air being supplied to furnace for coal combustion. This raises the furnace temperature and increases the thermal efficiency of the plant. Depending upon the method of transfer of heat from flue gases to air, air pre-heaters are divided into the following two classes :

- ❖ Recuperative type
- ❖ Regenerative type

The recuperative type air-heater consists of a group of steel tubes. The flue gases are passed through the tubes while the air flows externally to the tubes. Thus heat of flue gases is transferred to air. The regenerative type air pre-heater consists of slowly moving drum made of corrugated metal plates. The flue gases flow continuously on one side of the drum and air on the other side. This action permits the transference of heat of flue gases to the air being supplied to the furnace for coal combustion.

2.3.2 Condensers:

A condenser is a device which condenses the steam at the exhaust of turbine. It serves two important functions. Firstly, it creates a very low *pressure at the exhaust of turbine, thus permitting expansion of the steam in the prime mover to a very low pressure. This helps in converting heat energy of steam into mechanical energy in the prime mover. Secondly, the condensed steam can be used as feed water to the boiler. There are two types of condensers, namely :

- Jet condenser
- Surface condenser

In a jet condenser, cooling water and exhausted steam are mixed together. Therefore, the temperature of cooling water and condensate is the same when leaving the condenser. Advantages of this type of condenser are : low initial cost, less floor area required, less cooling water required and low maintenance charges. However, its disadvantages are : condensate is wasted and high power is required for pumping water.

In a surface condenser, there is no direct contact between cooling water and exhausted steam. It consists of a bank of horizontal tubes enclosed in a cast iron shell. The cooling water flows through the tubes and exhausted steam over the surface of the tubes. The steam gives up its heat to water and is itself condensed. Advantages of this type of condenser are : condensate can be used as feed water, less pumping power required and creation of better vacuum at the turbine exhaust. However, disadvantages of this type of condenser are : high initial cost, requires large floor area and high maintenance charges.

2.3.3 Steam turbine:

The dry and superheated steam from the superheater is fed to the steam turbine through main valve. The heat energy of steam when passing over the blades of turbine is converted into mechanical energy. After giving heat energy

to the turbine, the steam is exhausted to the condenser which condenses the exhausted steam by means of cold water circulation.

2.3.4 Prime movers:

The prime mover converts steam energy into mechanical energy. There are two types of steam prime movers viz., steam engines and steam turbines. A steam turbine has several advantages over a steam engine as a prime mover viz., high efficiency, simple construction, higher speed, less floor area requirement and low maintenance cost. Therefore, all modern steam power stations employ steam turbines as prime movers. Steam turbines are generally classified into two types according to the action of steam on moving blades viz.

- Impulse turbines
- Reaction turbines

In an impulse turbine, the steam expands completely in the stationary nozzles (or fixed blades), the pressure over the moving blades remaining constant. In doing so, the steam attains a high velocity and impinges against the moving blades. This results in the impulsive force on the moving blades which sets the rotor rotating. In a reaction turbine, the steam is partially expanded in the stationary nozzles, the remaining expansion takes place during its flow over the moving blades. The result is that the momentum of the steam causes a reaction force on the moving blades which sets the rotor in motion.

2.3.5 Water treatment plant:

Boilers require clean and soft water for longer life and better efficiency. However, the source of boiler feed water is generally a river or lake which may contain suspended and dissolved impurities, dissolved gases etc. Therefore, it is very important that water is first purified and softened by chemical treatment and then delivered to the boiler. The water from the source of supply is stored in storage tanks. The suspended impurities are removed through sedimentation,

coagulation and filtration. Dissolved gases are removed by aeration and degasification. The water is then 'softened' by removing temporary and permanent hardness through different chemical processes. The pure and soft water thus available is fed to the boiler for steam generation.

2.3.6 Electrical equipment:

A modern power station contains numerous electrical equipment. However, the most important items are :

2.3.6.1 Alternators:

Each alternator is coupled to a steam turbine and converts mechanical energy of the turbine into electrical energy. The electrical output from the alternator is delivered to the bus bars through transformer, circuit breakers and isolators. The alternator may be hydrogen or air cooled. The necessary excitation is provided by means of main and pilot exciters directly coupled to the alternator shaft.

2.3.6.2 Transformer:

- . A generating station has different types of transformers, viz.,
 - main step-up transformers which step-up the generation voltage for transmission of power.
 - station transformers which are used for general service (e.g., lighting) in the power station.
 - auxiliary transformers which supply to individual unit-auxiliaries.

2.3.6.3 Switchgear:

It houses such equipment which locates the fault on the system and isolate the faulty part from the healthy section. It contains circuit breakers, relays, switches and other control devices.

2.3.7 Feed water:

The condensate from the condenser is used as feed water to the boiler. Some water may be lost in the cycle which is suitably made up from external source. The feed water on its way to the boiler is heated by water heaters and economiser. This helps in raising the overall efficiency of the plant.

2.3.8 Cooling arrangement:

In order to improve the efficiency of the plant, the steam exhausted from the turbine is condensed by means of a condenser. Water is drawn from a natural source of supply such as a river, canal or lake and is circulated through the condenser. The circulating water takes up the heat of the exhausted steam and itself becomes hot. This hot water coming out from the condenser is discharged at a suitable location down the river. In case the availability of water from the source of supply is not assured throughout the year, cooling towers are used. During the scarcity of water in the river, hot water from the condenser is passed on to the cooling towers where it is cooled. The cold water from the cooling tower is reused in the condenser.

2.4 Choice of Site for Steam Power Stations:

In order to achieve overall economy, the following points should be considered while selecting a site for a steam power station :

- Supply of fuel. The steam power station should be located near the coal mines so that transportation cost of fuel is minimum. However, if such a plant is to be installed at a place where coal is not available, then care should be taken that adequate facilities exist for the transportation of coal.
- Availability of water. As huge amount of water is required for the condenser, therefore, such a plant should be located at the bank of a river or near a canal to ensure the continuous supply of water.

- Transportation facilities. A modern steam power station often requires the transportation of material and machinery. Therefore, adequate transportation facilities must exist i.e., the plant should be well connected to other parts of the country by rail, road. etc.
- Cost and type of land. The steam power station should be located at a place where land is cheap and further extension, if necessary, is possible. Moreover, the bearing capacity of the ground should be adequate so that heavy equipment could be installed.
- Nearness to load centres. In order to reduce the transmission cost, the plant should be located near the centre of the load. This is particularly important if d.c. supply system is adopted. However, if a.c. supply system is adopted, this factor becomes relatively less important. It is because a.c. power can be transmitted at high voltages with consequent reduced transmission cost. Therefore, it is possible to install the plant away from the load centres, provided other conditions are favourable.
- Distance from populated area. As huge amount of coal is burnt in a steam power station, therefore, smoke and fumes pollute the surrounding area. This necessitates that the plant should be located at a considerable distance from the populated areas.

It is clear that all the above factors cannot be favourable at one place. However, keeping in view the fact that now-a-days the supply system is a.c. and more importance is being given to generation than transmission, a site away from the towns may be selected. In particular, a site by river side where sufficient water is available, no pollution of atmosphere occurs and fuel can be transported economically, may perhaps be an ideal choice. ^[1]

CHAPTER THREE

PROTECTION OF SYNCHRONOUS GENERATOR

3.1 Introduction

Power system protection is a branch of electrical power engineering that deals with the protection of electrical power systems from faults through the isolation of faulted parts from the rest of the electrical network. The objective of a protection scheme is to keep the power system stable by isolating only the components that are under fault, whilst leaving as much of the network as possible still in operation. Thus, protection schemes must apply a very pragmatic and pessimistic approach to clearing system faults and is necessary for:

- Safety of electrical equipment.
- Safety of human personnel.

Electrical power systems must be designed to serve a variety of loads safely and reliably. Effective control of short-circuit current, or fault current as it is commonly called, is a major consideration when designing coordinated power system protection. In order to fully understand the nature of fault current as it is applied to electrical power system design, it is necessary to make distinctions among the various types of current available, normal as well as abnormal. It is also important to differentiate between the paths which the various types of current will take both current type and current path, as well as current magnitude, will affect the selection and application of over current protective devices.

3.2 Machine Current classification

-The Normal current may be defined as the current specifically designed to be drawn by a load under normal, operating conditions. Depending upon the nature of the load, the value of normal current may vary from a low level to a full-load

level. Motors offer a good example. Normal motor current varies from low values (under light loading) to medium values (under medium loading) to maximum values (under maximum loading). Maximum load current is called full load current and is included on the motor nameplate as FLA (Full Load Amperes). Normal current, therefore, may vary from low values to FLA values. Additionally, normal current flows only in the normal circuit path. The normal circuit path includes the phase and neutral conductors. It does not include equipment grounding conductors.

-The Overload current is greater in magnitude than full load current and flows only in the normal circuit path. It is commonly caused by overloaded equipment, single phasing, or low line voltage, and thus is considered to be an abnormal current. Some overload currents, such as motor starting currents, are only temporary, however, and are treated as normal currents. Motor starting current is a function of the motor design and may be as much as twenty times full-load current in extreme cases. Motor starting current is called locked-rotor current and is included on the motor nameplate as LRA (Locked Rotor Amperes). Overload current, then, is greater in magnitude than full-load amperes but less than locked-rotor amperes and flows only in the normal circuit path.

-The Short-circuit current is greater than locked-rotor current and may range upwards of thousands of amperes. The maximum value is limited by the maximum short-circuit current available on the system at the fault point. Short-circuit current may be further classified as bolted or arcing

- Bolted short-circuit current.
- Arcing short-circuit current.
- Failure classifications.

-The Ground-fault current Consists of any current which flows outside the normal circuit path. A ground fault condition then, results in current flow in the

Equipment grounding conductor for low-voltage systems. In medium- and high-voltage systems, ground-fault current may return to the source through the earth. Ground-fault protection of

Medium voltage and high-voltage a system has been applied successfully for years using ground current relays. Ground-fault protection of low-voltage systems is a considerable problem because of the presence and nature of low-level arcing ground faults. Ground-fault current on low-voltage systems may be classified as leakage, bolted, or arcing.

- *Leakage ground-fault current.*
- *Bolted ground-fault current.*
- *Arcing ground-fault current.*

-The Sources of short-circuit current All sources and the impedances of these sources must be considered when designing coordinated power system protection.^[2]

3.3 Power System Protective Equipment

There are many devices that are used to protect electrical power systems from damage due to abnormal conditions. For instance, switches, fuses, circuit breakers, lightning arresters, and protective relays are all used for this purpose. Some of these devices automatically disconnect the equipment from power lines before any damage can occur. Other devices sense variations from the normal operation of the system and make the changes necessary to compensate for abnormal circuit conditions. The most common electrical problem that requires protection is short circuits. Other problems include overvoltage, under voltage, and changes in frequency. Generally, more than one method of protection is used to protect electrical circuits from faulty conditions. The purpose of any type of protective device is to cause a current-carrying conductor to become inoperative when an excessive amount of current flows through it.

-Fuses The simplest type of protective device is a *fuse*. Fuses are low-cost items and have a fast operating speed. However, in three-phase systems, since each hot line must be fused, two lines are still operative if only one fuse burns out. Three-phase motors will continue to run with one phase removed.

-Circuit Breaker Are somewhat more sophisticated overload devices than are fuses. Although their function is the same as that of fuses, circuit breakers are much more versatile. In three-phase systems, circuit breakers can open all three hot lines when an *overload* occurs.

Is basically a switch to interrupt the flow of current

- It opens on relay command.
- It has to handle large voltages and currents.
- The inductive nature of power system results in arcing between the terminals of a CB.
- CBs are categorized based on the interrupting medium used.

- relay Is a logical element which processes the inputs (mostly voltages and currents) from the system and issues a trip decision if a fault within its jurisdiction is detected Inputs to a relay are

- Current from a current transformer.
- Voltage from a voltage transformer.

Some common types of faults that relays protect against are *line-to-ground short circuits, line-to-line short circuits, double line-to-ground short circuits, and three-phase line short circuits*. Each of these conditions is caused by faulty circuit conditions that draw abnormally high current from the power lines.

Fig 3.1 and 3.2 represents the relay device and its application

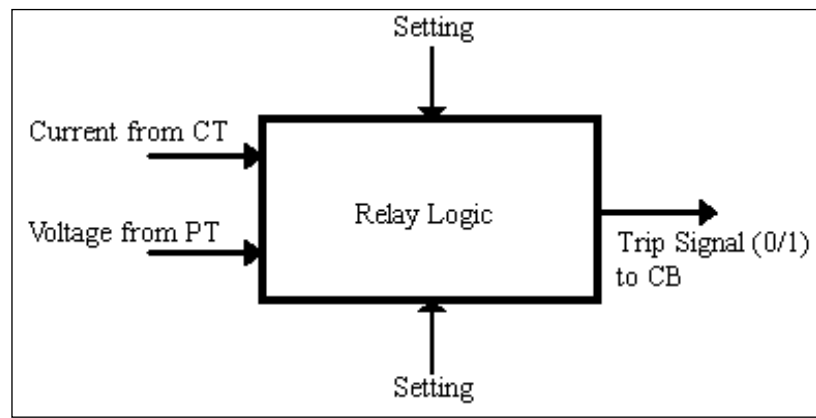


Figure 3.1. show relay device

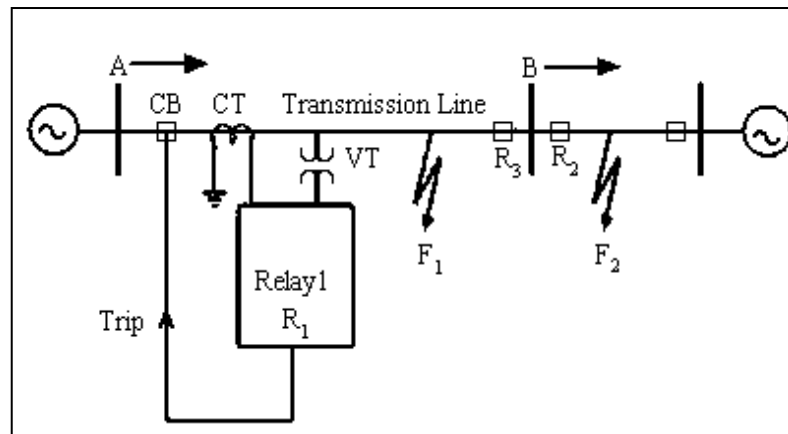


Figure 3.2. shows relay application

-Evolution of Relays

There are three different types of relays:-

- Electromechanical Relays
 - First generation of relays.
 - Uses the principle of electromechanical energy conversion.
 - Immune to electromagnetic interference and rugged.
- Solid State Relays

These relays were developed with the advent of transistors, operational amplifiers etc. Their functionality is through various operations like comparators etc. Their advantages are

- More flexible.
- Self-checking facility.
- Less power consumption and low burden.
- Improved dynamic performance characteristics.
- High seismic withstand capacity.
- Reduced panel space.

➤ Numerical Relays

Numerical relays are microprocessor based relays and having the features of recording of parameter used as disturbance recorder flexibility of setting & alarms & can be used one relay for all type of protections of one equipments hence less area is required. Numeric relays take the input analogue quantities and convert them to numeric values. All of the relaying functions are performed on these numeric values

The setting of numeric relay is entered using input unit (keypad) and by a helping of LCD screen to show the entering of data or completely entering data by using personal computer and also will talk about the manual setting of the relay and testing which make by simulation device (testing device) before connected the relay to the field to ensure effective of the device and ability to do the task which is made to it.

- Engineers change digital relay settings using a personnel computer. In some companies, management of the setting files is performed by the maintenance teams, who store the files in a server designed to access the involved areas. This is necessary to ensure only one activity area is responsible for the management of the settings files. This ensures the setting files in the server are identical to those stored in the relay. If it is necessary to change the settings, the file in the server is only substituted by a new file after the

implementation of the new settings in the field, and assuming identification of the changes in the setting order has been agreed.

- In some companies, remote access to relays is only used to download oscillographic records and event files. In other companies, remote management of settings is performed by an independent team who checks the settings installed by the maintenance team.
- Some companies have recently invested in high performance communication networks and used them to manage relay settings. Concern about this approach is related to the associated risks and the number of installed relays on the system.
- The advent of digital technology has not only produced a range of advanced protection relays but has also allowed the utilisation of more realistic relay testing facilities. It is especially pertinent that numeric relays, which generally give superior performance under distorted waveform conditions than more conventional relays, are tested under realistic conditions. The advantages of computer-based relay test sets include greater bandwidth of faulted relaying signals, versatility of power system structure and automated testing.
- **User interface:**
 - ❖ **Front panel user interface:**
 - The features of the relay can be accessed through a user-friendly menu system. The menu is arranged so that related items (menu cells) are grouped into individual sections, each of which is identified by a title.
 - The user navigates around the menu by using the arrow keys, first to select a particular section title and then to select an item within it.
 - The front panel liquid crystal display is limited to displaying one menu cell at a time.

❖ **Remote access user interface:**

- The menu can be accessed via the remote communications facility. This allows all of the menu cells in a section to be displayed on the screen of a PC. Changes to the menu cell can be made from the PC keyboard.

❖ **Connection of the relay:**

• **Serial communication:**

- The relays are interconnected via a shielded, twisted wire pair known as K-Bus. Up to 32 relays may be connected in parallel across the bus.
- The K-Bus is connected through a protocol converter known as KITZ, either directly or via a modem, to the RS232 port of the PC. The KITZ provides signals over the bus which are RS485 based and are transmitted at 64kbits/s. The K-Bus connection is shown in Figure 3.3. This system allows up to 32 relays to be accessed through one RS232 communications port. A pictorial representation of this is shown in Figure 3.3.

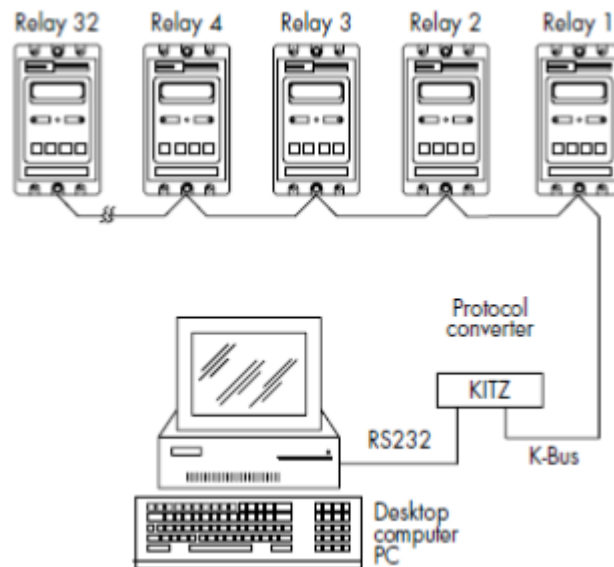


Figure 3.3 serial communication

- Software is available with each KITZ to provide access to the relay to read and change settings.

- Additional software entitled ‘Protection Access Software & Toolkit’ is available. This provides access to the event recorder and other additional functions.
- Each relay is directly addressable over the bus to allow communication with any selected relay. Global commands may also be given to all relays on the network. It should be noted that protection tripping and blocking signals are not routed via the K-Bus. Separate conventional cabling is used for this purpose; where appropriate the isolated 48V dc supply available on each relay is used to energize the optically-isolated inputs.

- **Communications protocol:**

- The communications protocol used with K Range relays is designated Courier. The Courier language has been developed specifically for the purpose of developing generic PC programs that will, without modification, communicate with any device using the Courier language. In the Courier system, all information resides within the relay. Each time communication is established with the relay, the requested information is loaded to the PC. The protocol includes extensive error checking routines to ensure the system remains reliable and secure.

- **Password protection:**

- Password protection is provided on settings which alter the configuration of the relay, any accidental change to which could seriously affect the ability of the relay to perform its intended function, ie. enable/disable settings, protection function characteristic selection, scheme logic settings and system VT and CT ratios.^[4]

1 LGPG 111 for generator protection:



Figure 3.4 LGPG 111 for generator protection

- The LGPG111 is a multi-function relay which integrates a number of common generator protection functions and associated scheme logic into a single relay case.

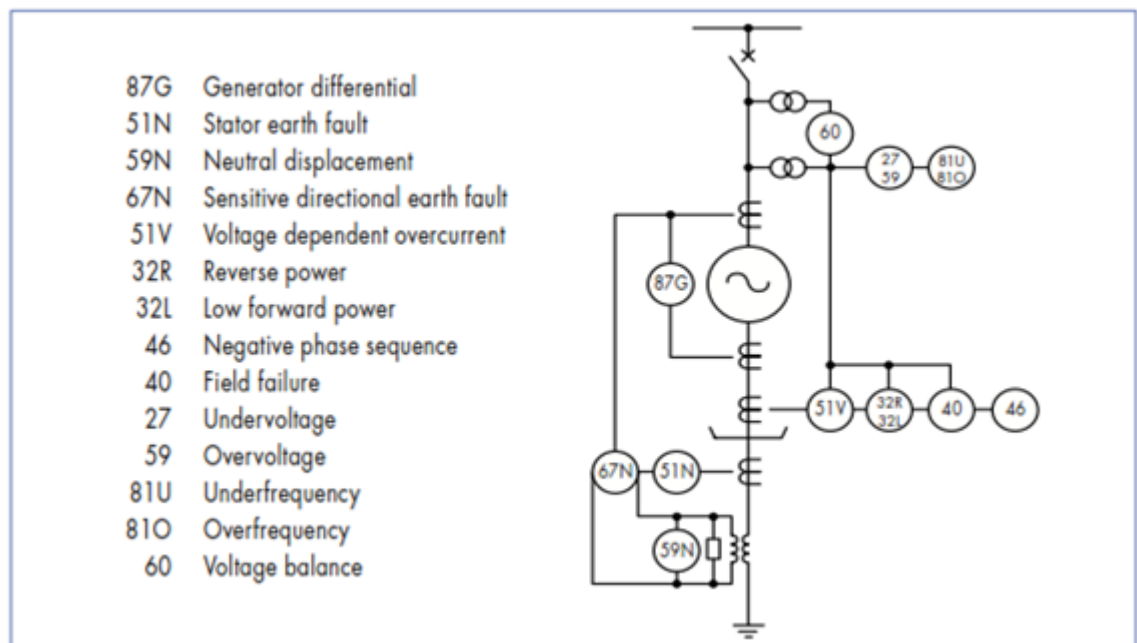


Figure 3.5 : generator protection type

- Contacts from external protection and plant monitoring equipment can be connected to any of the eight optically-isolated inputs. This allows external information to be incorporated into the relay's userconfigurable scheme logic. The optically-isolated inputs and relay outputs may be labeled in the software for local or remote monitoring.

3.4 Synchronous Generator faults:

The basic function of protection applied to generator is, therefore, to reduce the outage period to a minimum by rapid discriminative clearance of faults.

3.4.1 External faults

During external faults with large short-circuit currents, severe mechanical stress will be imposed on the stator windings, if any mechanical defects already exist in the winding, these may be further aggravated. The temperature rise is however, relatively slow and dangerous temperature level may be obtained after about 10 seconds. With asymmetrical faults, severe vibrations and overheating of the rotor may occur.

The external faults such as faults on bus-bars are not covered by generators protection zone. Hence differential protection of generator does not respond to external fault.

The overcurrent and earth faults protection of generator provided back-up protection to external faults, while the primary protection as provided by the protective system of respective equipment (e. g. bus-bars, transmission lines).

3.4.2 Thermal overloading

Continued overloading may increase the winding temperature to such an extent that the insulation will be damaged and its useful life reduced.

Temperature rise can also be caused by failure of cooling system. In large machine thermal elements (thermo-couples or resistance thermometers) are embedded in the stator slots and cooling system.

The electrical over current protection is generally set at higher value for responding the excessive overloads. Hence it cannot sense the continuous overloads of less value. Neither can it sense the failure of cooling system.

3.4.3 Unbalanced loading

Continued unbalanced loads, equal to or more than 10 per cent of the rated current cause dangerous heating of the cylindrical rotor in turbo-generators. Salient pole rotors in hydro-generators often include damper windings and are, therefore, much less affected by unbalance loading (negative phase-sequence currents).

Unbalanced loading on generator can be due to

- Unsymmetrical faults in the system near the generating station.
- Mal-operation of a circuit-breaker near generating station, the three phases not being cleared.

Negative sequence protection senses unbalanced loading of generators.

3.4.4 Stator winding faults

Stator winding faults involve armature winding and must therefore be cleared quickly by complete shutdown of the generator. Only opening the circuit does not help since the e.m.f. is induced in the stator winding itself. The field is opened and de-energized by “field suppression”.

❖ **The stator faults include.**

Phase to Earth faults. These faults normally occur in the armature slots. The damage at the point of fault is directly related to the selected neutral earthing resistor. With fault currents less than 20 A, negligible burning of the iron core will result if the machine is tripped within some seconds. The repair work then amounts to changing the damaged coil without restacking of core laminations.

If, however, the earthing resistor is selected to pass a much larger earth-fault current (> 200 A) severe burning of the stator core will take place, necessitating restacking of lamination. Even when a high speed earth-fault differential protection is used, severe damage may be caused owing to the large time constant of the field-circuit and the relatively long time required to completely suppress the field flux. In the case of high earth-fault currents it is

therefore normal practice to install a circuit breaker in the neutral of the generator in order to reduce the total fault-clearance time.

Circulating current biased differential protection provides the earth fault protection. However the sensitivity of such a protection for earth fault depends upon the resistance in neutral to earth connection and the position of earth fault in the winding.

A separate and sensitive earth fault protection is generally necessary for generators with resistance earthing.

Phase to phase faults Short circuits between the stator windings very rarely occur because the insulation a slot between coils of different phases is at least twice as large as the insulation between one coil and the iron core. However a phase to earth fault may cause a phase-to-phase fault within the slots. If a phase-to-phase fault should occur, this is most likely to be located at the end-connections of the armature windings, i.e. in the overhanging parts outside the slots, a fault of this nature causes severe arcing with high temperatures, melting of copper and risk of fire if the insulation is not made of fire-resistant, non-flammable material. Since the short-circuit current in this case do not pass via the stator core, the limitations will not be particularly damaged. The repair work may therefore be limited to replacing the affected coil and mechanical parts of the end structure.

Circulating current biased differential protection gives adequate and fast protection against phase-to-phase in the generator zone.

Stator inter-turn faults Short circuits between the turns of one coil may occur if the stator winding is made up of multiturn coils. Such faults may develop owing to incoming current surges with a steep wave-front which may cause a high voltage ($L \, di/dt$) across the turn at the entrance of the stator winding.

If, however, the stator winding is made up of single-turn coils, with only one coil per slot, it is, of course, impossible to have an inter-turn fault, if there

are two coils per slot the insulation between the coils is of such dimension that an inter-turn fault is not likely to occur.

For large machines (> 50 MVA), it is the normal practice in some countries to use single-turn coils whereas in the U.S.A and Canada multi-turn coils are used. In the latter countries, therefore, the inter-turn, or split-phase, protection has become very popular.

Differential protection and overcurrent protection does not sense inter-turn faults, stator interturn fault protection detects the inter-turn faults.

3.4.5 Field winding fault

Rotor faults include rotor inter-turn fault and conductor-to-earth faults. These are caused by mechanical and temperature stresses.

The field system is normally not connected to the earth so that a single earth fault does not give rise to any fault current. A second earth fault will short circuit part of the winding and may thereby produce an unsymmetrical field system, giving unbalanced force in the rotor, such a force will cause, excess pressure on bearing and shaft distortion, if not cleared quickly.

The unbalanced loading on generator gives rise to negative sequence currents which cause negative sequence component of magnetic field. The negative sequence field rotates in opposite direction of the main field and induces e.m.f.'s. in rotor winding. Thus the unbalanced loading causes rotor heating.

Reduced excitation may occur due to short circuit or an open circuit in the field or exciter circuits or fault in automatic voltage regulator. If the field circuit breaker opens by mistake, the fully loaded generator falls out of step within 1 second, and continues to run as an induction generator of field circuit breaker causes the tripping of generator unit breaker.

‘Rotor earth fault protection is provided for large generators.

Rotor temperature indicators are used with large sets for detecting rotor overheating due to unbalanced loading of generator.

3.4.6 Overvoltages

Atmospheric surge-voltages are caused by direct lightning strokes to the aerial line in the H.V. system. Induced and capacitively transferred voltage surges can, however, reach the generator via the unit transformer. The amplitude and the duration of the surge on the generator side depend on the type of lightning arresters used on the H.V. side and also on the actual configuration of the H.V. busbar.

To protect generators from severe voltage surges, surge arresters surge capacitors and often used. In the case of smaller machine directly connected to a distribution network comprising overhead lines, such protective devices are of prime importance.

Switching surges. Switching operations may cause relatively high transient voltages if restriking occurs across the contacts of the circuit-breakers. These transient are similar to those obtained during intermittent earth faults (arcing grounds) and may be using modern circuit-breakers.

Arcing grounds. The amplitude of the transient voltages during arcing grounds may theoretically, under the most unfavorable conditions of arc-restriking reach a value of 5 times normal line to neutral peak voltage. By means of the resistance earthing of the generator neutral these over-voltages will be reduced to a maximum value of about 2.5 times the rated peak voltage. In the case of generator-transformer units, stray voltage may appear at the generator neutral during an earth fault in the HV network. This is due to the capacitive coupling between the HV and LV windings of the step up transformer. The magnitude of these stray voltage depends on: (a) the method of neutral earthing of the HV network, i.e., effectively earthed or reactance earthed (peterson-coil)

and (b) the step up transformer inter-winding capacitance, and (c) the ohmic value of the generator neutral earth resistor.

When the HV system is directly earthed, the voltage across the generator earthing resistor, during an HV earth fault will be small and can normally be disregarded. However, if the HV network is Peterson coil earthed, the neutral displacement voltage of the generator can reach the normal setting of the earth fault protection; this problem must therefore be investigated for each particular installation, and can be solved by either increasing the earth-fault relay setting or reducing the ohmic value of the generator earthing resistor.

Surge arresters and R-C surge suppressors installed between the generator circuit-breaker and the generator may also assist in reducing some of the highest switching surges.

Specially developed indoor type surge arresters are connected near generator terminals. These comprise three star connected unit plus another unit between star point and earth and thus provide overvoltage protection for all phase and between phases. Capacitors rated about 0.1 mF to earth are fitted to absorb surge voltages.

3.4.7 Other abnormal conditions

Loss of excitation results in loss of synchronism and slightly increased speed. The machine continues to run as an induction generator, drawing excitation current from bus bars, the damper winding acts like a squirrel cage. The currents are taken at a high lagging power factor and magnitude is of the order of full load current. This causes overheating of stator winding and rotor winding. This condition should not be allowed to persist for a long time. The field should be either restored or the machine should be shut off. Before system stability is lost.

Field-failure protection or loss of field protection is provided for generators

In addition to the above mentioned electrical faults, the running of a machine can be endangered by relatively minor mechanical defects in any of the auxiliary apparatus associated with the prime mover.

Loss of synchronism

If the machine losses synchronism with respect to the network after a short circuit has been interrupted, a certain amount of slip is generally permissible, providing that the stator current does not exceed 85% of the maximum asymmetric short current with a solid short-circuit at the terminals.

Wrong synchronization

Present day requirement stipulate that a generator must be short-circuit proof. However, with low reactance of the network and at the unit-connected transformer, in the event of wrong synchronization the current can be higher than under short-circuit conditions. This is not permissible. In the other word wrong synchronization must not occur. Preventive measures must therefore be taken. In particular, uncontrolled reclosure after complete isolation of the generator from the network must be avoided because this quickly results in an excessive phase angle. In this connection it must also be noted that recovery voltage in the network following inter-ruption of a short circuit can lead to considerable stresses.

Asynchronous running without excitation

If asynchronous running is permitted by the manufacturer and requested by the operator for emergency conditions, it must be monitored. It must be decided whether asynchronous running is to be carried out with open or short-circuited rotor. Slip and stator current must not be allowed to exceed the specified limits.

Local overheating

Local overheating can occur in generators for various reasons and it is often a difficult matter to locate these with the usual protection equipment. Normally, emission products, in the form of gas, mist or smoke escape and these can be used for tripping a signal. An analysis of these products provides a basis for decision.

Leakage in hydrogen circuit

Hydrogen losses are predetermined on the basis of gas consumption. However, continuous direct display is not recommended because temperature fluctuation in the generator cause variations in pressure and therefore gas make up is not directly related to losses. Consequently, long term monitoring is more suitable. It is only hydrogen leakage into the pure water system which is detected separately by the gas blow-off device in the pure water tank. Other points of leakage are not directly detected. It is essential for adequate ventilation to be provided in the vicinity of the generator and terminal box. Special attention must be paid to the cooling water circuit because any hydrogen carried along by the water is a danger factor and therefore be prevented.

Moisture in the generator winding

Moisture in the generator is to be avoided. Moisture detectors and drains must be provided at all points where liquids can collect. The situation can arise where the make up hydrogen is moist and can thus introduce moisture into the generator even if the cooling water circuits are absolutely leakproof. This can be overcome by a gas drying plant which must be kept operation by the staff.

Oxygen in pure water circuit

Dissolved oxygen in the pure water circuit leads to wear at the copper of the hollow conductors of winding with direct cooling. At hydrogen cushion of adequate pressure in the pure water compensating tank reduces the oxygen content to a minimum continuous supervision of oxygen content thus because superfluous.

Overspeeding

May occur as a result of a fault in the turbine governor or its associated equipment. If the main generator circuit-breaker is tripped while full electrical power is being delivered to the network, dangerous overspeeding is prevented by the normal action of the governor. It is essential, therefore that the normal working of the governor be supervised by some additional protective devices. Over-frequency and under-frequency protection

Motoring of generator

Will occur if the driving torque of the prime mover is reduced below the total losses of the turbo-generator unit. Active power will then be drawn from the network in order to maintain synchronous running, and the generator will work as a synchronous motor. If this allowed to persist (>20 seconds), serious overheating of the steam turbine blades may occurs. Depending on the type turbine and the design limits imposed by the manufacturer.

Reverse-power protection achieved by directional power relays are incorporated in the generator protection scheme.

Vibrations

May occur owing to unbalanced loads or certain types of mechanical faults. Vibration detectors are usually mounted on the generator bearing pedestal.

Excessive bearing temperature

May arise due to mechanical faults, impurities in the lubricating oil or defects in the oil circulation system. These fault may be detected by means of a temperature monitoring device embedded in the bearing.

Some abnormal conditions and protection system

S.NO	Abnormal condition	Effect	Protection
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1.	Thermal overloading Continuous overloading Failure of cooling system	Overheating of stator winding and insulation failure.	Thermocouples of resistance thermometer imbedded in stator slots and cooling system. With overcurrent relays
2.	External fault fed by generator	Unbalanced loading stresses on winding and shaft, excessive heating for short-circuit.	Negative phase sequence protection for large machines.
3.	Stator fault Phase to phase Phase to earth Inter-turn	Winding burn-out, welding of core laminations, shut down.	Biased differential protection, sensitive earth-fault protection, interturn fault protection
4.	Rotor earth faults	Single fault does not harm second fault causes unbalanced magnetic forces causing damage to shaft, bearing.	Rotor earth-fault protection.
5.	Loss of field Tripping of field circuit-breaker.	Generator runs as induction generator deriving excitation currents from bus-bar. Speed increases slightly.	'loss of field' or 'field failure' protection.
6.	Motoring of generator..	Effect depends upon type of prime mover and the power draws from the bus during motoring.	Reverse power protection by directional power relays direct the reversal of power.
7.	Over-voltages.	Insulation failure	Lightning arresters connected near generator terminals.
8.	Over-fluxing of generator transformer and auxiliary transformer	Heating of core	V/f relay. Connected in voltage regulator circuit generator.
9.	Under-frequency	Failure of blades of steam turbines	Frequency relays

Table 3.1

Bearing current

An induced e.m.f. of some volt may be developed in shaft of a generator owing to certain magnetic dissimilarities in the armature field. If the bearing pedestals at each side of the generator are earthed, the induced e.m.f. will be impressed across the thin oil films of the bearings. A breakdown of the oil-film insulation in the two bearing can give rise to heavy bearing current owing to the very small resistance of the shaft and the external circuit thus developed.

Consequently, the bearing pedestal farthest from the prime mover is usually insulated from earth and the insulation supervised by a suitable relay. Further, to prevent the rotor and the shaft from being electrostatically charged, the is usually earthed via slipring and a 200 ohm resistor. This resistor also contributes by taking the injected a.c. leakage current of the field circuit earth-fault protective scheme.

3.5 generator protection:

The basic function of protection applied to generators is, therefore, to reduce the outage period to a minimum by rapid discriminative clearance of faults.

3.5.1 Percentage differential protection of alternator stator

windings (also called biased differential protection or Merz-Price Protection)

(a) principle

The differential protection is that which responds to the vector difference between two or more similar electrical quantities. In generator protection, The current transformer are provided at each end of the generator armature windings. When there is no fault in the windings and through faults. The current in the pilot wires fed from CT connections are equal. The differential current $I_1 - I_2$ is zero. When fault occurs inside the protected winding, the balance is disturbed and the differential current $I_1 - I_2$ flows through the operating coil of the relays causing

relay operation. Thereby the generator circuit-breaker is tripped. The field is disconnected and discharged through a suitable impedance

(b) connections of CT's for differential protection of generator

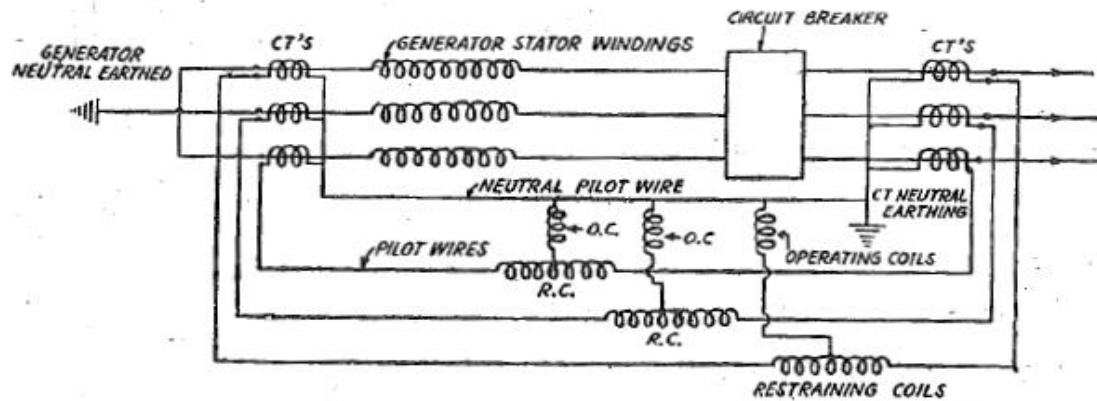


Figure 3.6: Percentage differential relaying of a star connected generator,
For phase-phase faults.

The percentage differential relay has an operating coil and restraining coil, one for each phase. The restraining coil is connected centrally in pilot wires. The operating coil is connected between mid-point of restrains coil neutral pilot wire.

The CT connections are as shown in Fig. 3.7.

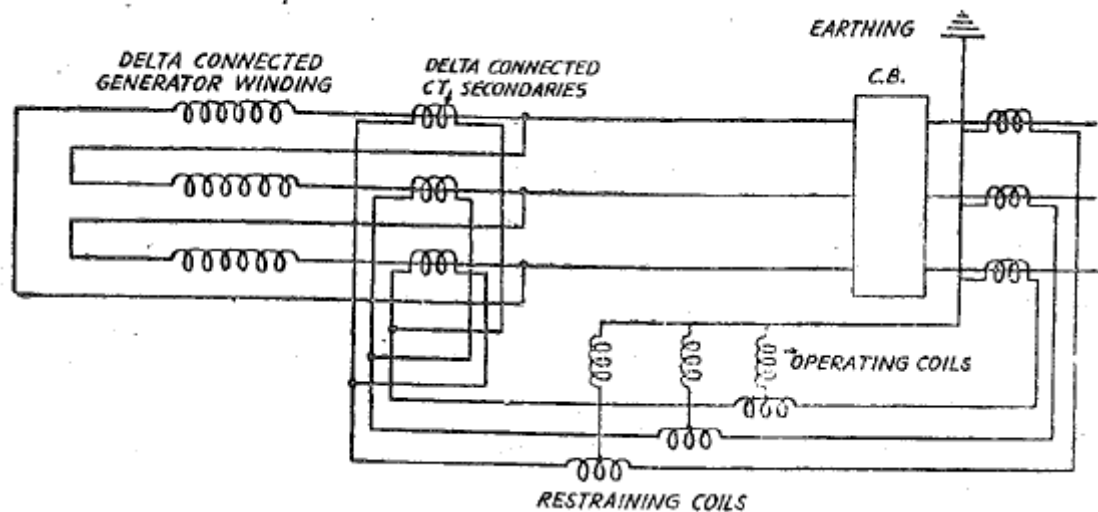


Figure 3.7: Percentage differential relay of a delta connected generator,
for phase-phase fault.

Typical protective arrangement of a generator connected to bus bars is shown in Fig.3.8.

Differential relay provides fast protection to the stator winding against phase to phase faults and phase to ground faults. If neutral is not grounded or is grounded through impedance, additional sensitive ground fault relaying should be provided. Differential protection is recommended for generators above 2 MVA rating. Separate sets of CT's are used for each protection. Desirable features of generator differential protection are:

- High speed operation, about 15 ms. With static protection
- Low setting
- Full stability on external faults.

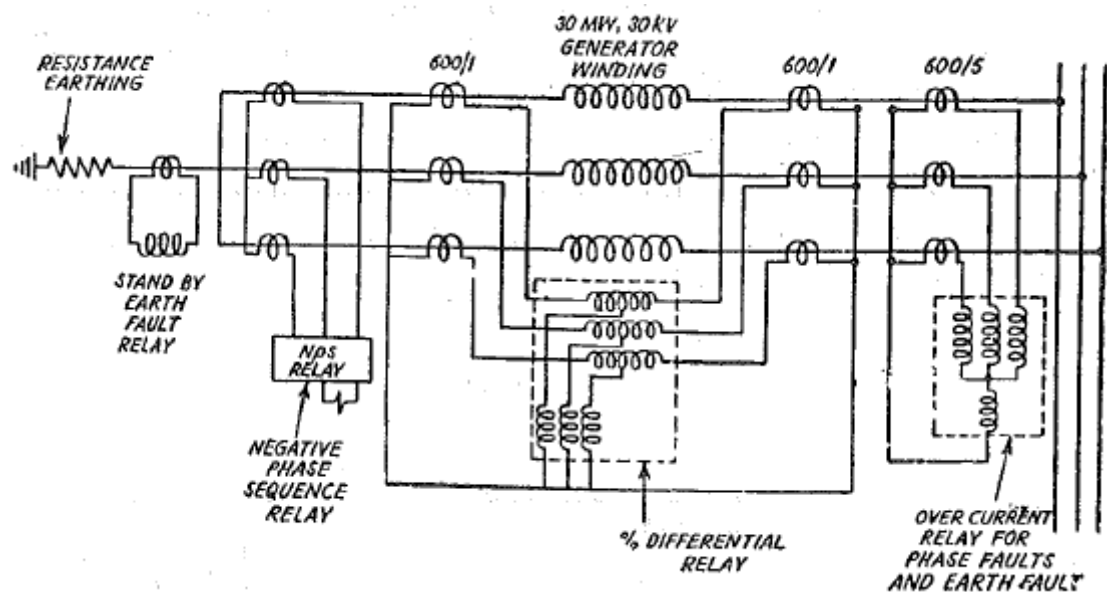


Figure 3.8: Protection of a direct connected generator

Differential protection which protects only generator is arranged to trip main circuit breaker and to suppress the field.

Differential protection does not respond to through faults and overloads.

Differential protection gives complete protection to generator windings against phase to phase faults.

The biasing of the differential relay eliminates the problem associated with CT's. The protection against earth faults by differential is influenced by the magnitude of earth-fault current. The magnitude of earth-fault current depends upon value of the reactance/reactance connected between neutral and earth; and the position of earth fault in generator winding. When the generator winding is earthed through impedance, a separate additional earth fault protection is necessary in addition to differential protection. The differential protection provides earth-fault protection to about 85% of generator winding.

3.5.2 Restricted earth-fault protection by differential system

When neutral is solidly grounded, it is possible to protect complete alternator of transformer winding against phase to ground fault.

However, neutral is earth through resistance to limit earth-fault currents.

With resistance earthing, it is not possible to protect complete winding from earth-fault and the % of winding protected depends on the value of neutral earthing resistor and the relay setting.

While selecting the value of the resistor and earth-fault relay setting, the following aspects should be kept in mind:

- The current rating of the resistor, resistance value, relay setting etc. should be selected carefully.
- Setting should be such that the protection does not operate for earth-fault on EHV side. Earth faults are not likely to occur near the neutral point due to less voltage w.r.t. earth it is usual practice to protect about 80 to 85% of generator winding against earth-faults. The remaining 20 to 15% winding from neutral side left unprotected by the differential protection. In addition to differential

protection, a separate earth-fault protection is provided to take care of the complete winding against earth faults.

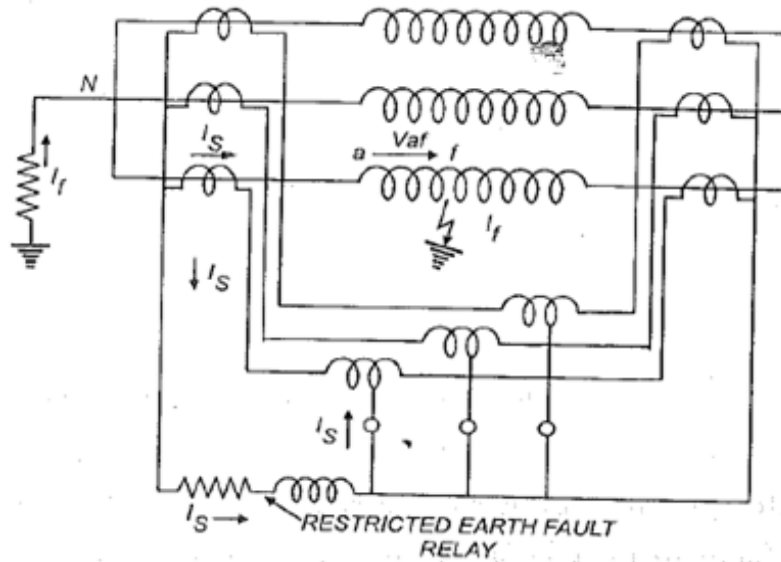


Figure 3.9: Percentage differential with protection

Restricted earth fault relay

The restricted earth-fault relays in the differential protection is explained here. During earth fault I_f in the alternator winding, the current, I_f flows through a part of the generator winding and neutral to ground circuit. The corresponding secondary current I_s flows through the operating coil and restricted earth-fault coil of the differential protection. The setting of the restricted earth fault relay can be selected independent of the setting of the overcurrent relay.

If the earth-fault I_f occurs at point f of alternator winding V_{af} is available to drive earth-fault current I_f through the neutral to ground connection. If point is nearer to terminal a (nearer to the neutral point) the forcing voltage V_{af} will be relatively less. Hence earth fault current I_f will reduce. It is not practicable to keep the relay setting too sensitive to sense the earth-fault currents of small magnitudes. Because, if too sensitive, the relay may respond during through fault of other faults due to inaccuracies of CT's, saturation of CT's etc. hence a practice is to protect about 85% of the generator winding against phase to earth fault and to

leave the 15% portion unprotected by the differential protection against earth-faults. A separate earth-fault protection covers the entire winding against earth-faults.

The resistance R limits the earth-fault current. If R is too small (solid earthing) earth fault to machines upto 3.3KV.

For low resistance earth the resistance R is such that full load current passes through neutral, for a full line to neutral voltage.

Medium resistance earthing is commonly used on generator transformer units. The earth-fault current is restricted to about 200 A for full line to neutral voltage, for a 60 MW unit.

In high resistance earthing maximum earth-fault current is of the order of 10 A. such earthing is used for distribution transformers and generator transformer units.

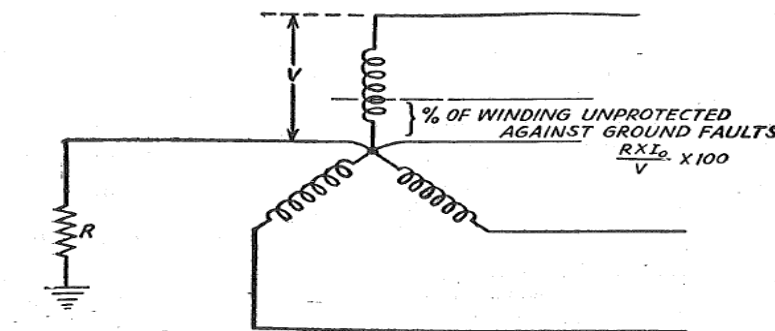


Figure 3.10: Percentage of unprotected winding against phase to ground fault

With higher neutral resistance, the earth fault current is reduced, hence lesser percentage of winding is protected by the restricted earth fault protection.

Assuming R is the resistance in neutral connection to the earth and the fault current for line to ground fault is equal to full load current of the generator or transformer, the value of impedance to be inserted in neutral to earth connections is given by,

$$R = V/I$$

Where

R = impedance in ohms between neutral and ground

V = line to neutral voltage

I = full load current of largest machine or transformer

If a relay setting of 15% is chosen this affords protection of 85% of the winding of largest machine while a greater percentage of windings of smaller machines running in parallel with the large machine.

$$\% \text{ of winding unprotected} = (R \times I_0 \times 100) / V$$

R = ohmic value of impedance

I_0 = minimum operation current in primary of CT

V = line to neutral voltage

If 15% of relay setting is used, I_0 is 15% of full load current of the machine.

3.5.3 Overcurrent And Earth-Fault Protection For Generator Back-Up

For generators above 1 MW, where primary protection to stator winding is provided by Differential Protection, the overcurrent and earth-fault protection gives back-up protection for external phase to phase faults and earth-faults (Ref. Fig. 3.11).

Induction type inverse definite minimum time relays may be used for generator back-up protection for external faults.

Since the faults in stator winding are fed by the stator winding itself, their influence on current

in the outgoing terminals of generator depends upon fault level of the main bus (Ref. Fig. 3.12).

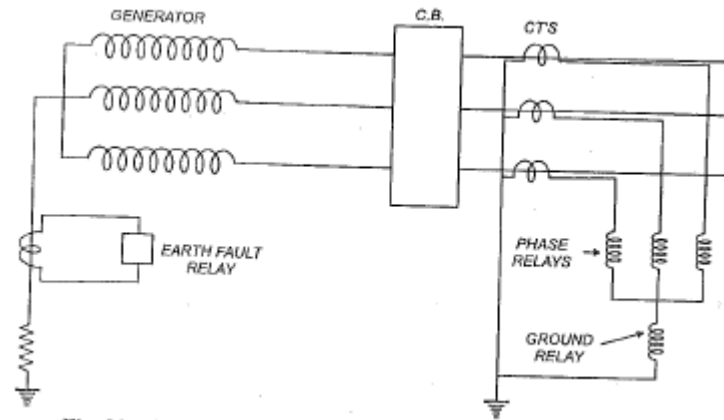
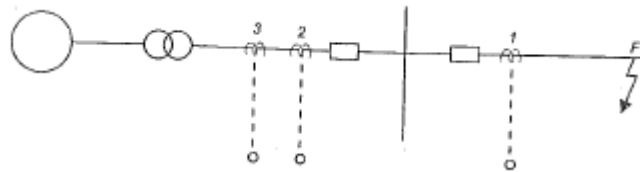


Figure 3.11: Back-up protection by overcurrent protection



Sequence of operation=1,2,3

- 1- Line protection. 2-Bus bar protection.
- 3- The generator back-up protection, earth fault protection.

Figure 3.12: The generator back-up protection should be the last to operate for external faults.

Hence overcurrent and earth-fault relays do not provide satisfactory protection against internal faults.

However the overcurrent and earth-fault relays provide back-up protection to generator against external faults (e.g. faults in bus zone, transmission zone).

The setting is selected that the generator overcurrent and earth-fault protection does not normally operate for external faults such as F.

However, if fault F continues for a long time due to failure of line protection (1), the fault will be fed by the generator. Hence the over-current and earth-fault protection of generator (3) may be set to operate with due time lag for higher values of external fault currents, Hence high set, definite minimum time,

induction type, inverse over-current earth fault relays are recommended for generator back-up.

(A) Sensitive Stator Earth fault Protection

When generator neutral is earthed through a high impedance, differential protection does not protect the complete alternator stator winding against earth faults, hence a separate sensitive earth-faults protection is necessary. The method for sensitive earth-fault protection depends upon the generator connection.

Two alternative methods are employed for neutral connection.

- The neutral connected through resistor which limits the maximum earth-fault current to much lower value than full load current, Fig.3.13 (a). This method is preferred for large units,
- The neutral connected through a voltage transformer. The earth- fault current is limited to the magnetising current of the voltage transformer plus the zero-sequence current of generator, Fig. 3.13 (b).

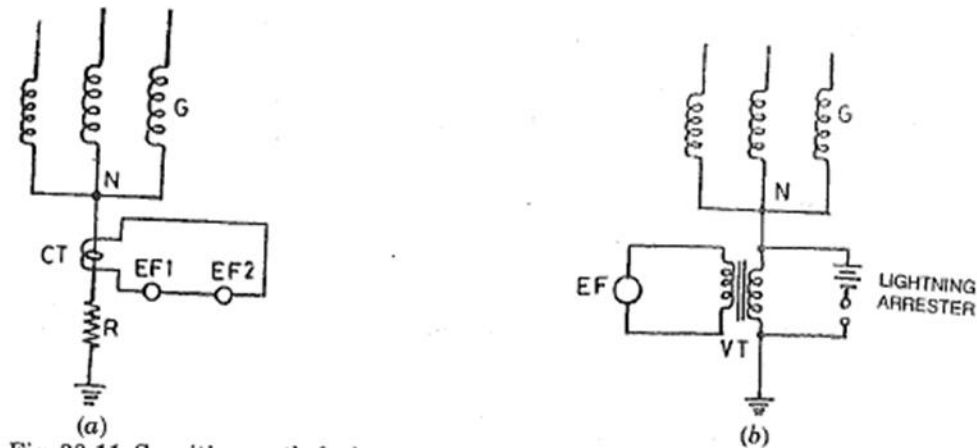


Figure 3.13: sensitive earth-fault protection of generator-transformer unit.

With resistance earthing (Fig .3.13) two earth-fault relays may be provided on the secondary side of neutral CT. The First EF relay is set at 10 per cent and is instantaneous type. The second EF relay is inverse definite minimum time

(IDMT) and is set at 5 per cent. (The relay pick-up when earth fault current is 5 per cent of full load current of generator).

Depending upon sensitivity, the first relay would protect about 90 per cent of stator winding and the second winding about 95 per cent, For such sensitive settings, it is necessary to provide a time delay, otherwise the relays may respond to transient neutral currents during external faults.

When neutral is connected through VT (Fig.3.13), the rated primary voltage of VT is generally equal to phase to neutral voltage of generator. The EF relay is connected to the secondary of VT with a setting of 10% of rated secondary voltage of VT. When the voltage between neutral and earth reaches 10% of phase to neutral voltage of generator, the earth-fault relay operates.

The VT for neutral connection is specially designed. It should not saturate for twice the maximum neutral to earth voltage. The VT is protected from high voltage surges by Lightning Arrester connected in parallel with the primary. (Fig. 3.13(b)).

(b) 100% STATOR EARTH-FAULT PROTECTION .

The earth-fault protection by differential relays or by residually connected relay can give effective protection to about 80 to 85% of generator winding. 100% stator earth- fault protection is provided in recent installations.

A coupling transformer is connected in neutral to ground circuit. A coded signal current is continuously injected into stator winding through the coupling transformer. The frequency of coded signal is 12.5 Hz. During normal condition the signal fed into stator winding flows only into stray capacitance of generator and directly connected system. In case of earth-fault, the capacitance is by-passed and the monitoring current increases. The increase in monitoring current (of 12.5 Hz) is sensed by the measuring system.

This protection covers 5 to 20% of stator winding from the neutral end. The remaining 80% winding is protected by differential protection or earth fault protection discussed in Sec. 33.6 (a).

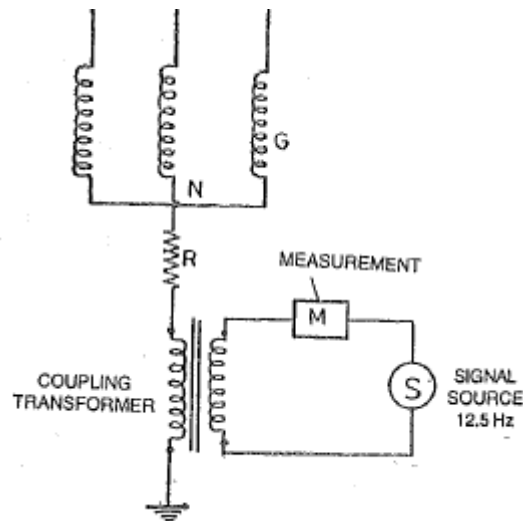


Figure 3.14: 100% Stator earth fault protection by signals through neutral.

3.5.4 Protection Against Turn-To-Turn Fault On Stator Winding

The incidence of turn to turn fault in alternator is rare, One method of detecting inter-turn faults is by employing five limb voltage transformer with tertiary connected to watt hour meter type induction relay. The inter-turn faults are detected by measuring the residual voltage of generator terminals. This voltage appears across the tertiary winding which is connected to operating winding of a three element directional relay. The quadratic winding is operated from secondary side of the voltage transformer (Fig. 3.15). During normal condition, the residual voltage is zero, i.e.,

$$V_{RES}=V_{RN}+V_{YN}+V_{BN}=0$$

This balance is disturbed during inter-turn fault on any of the single windings. And the residual voltage is fed to the relay coil.

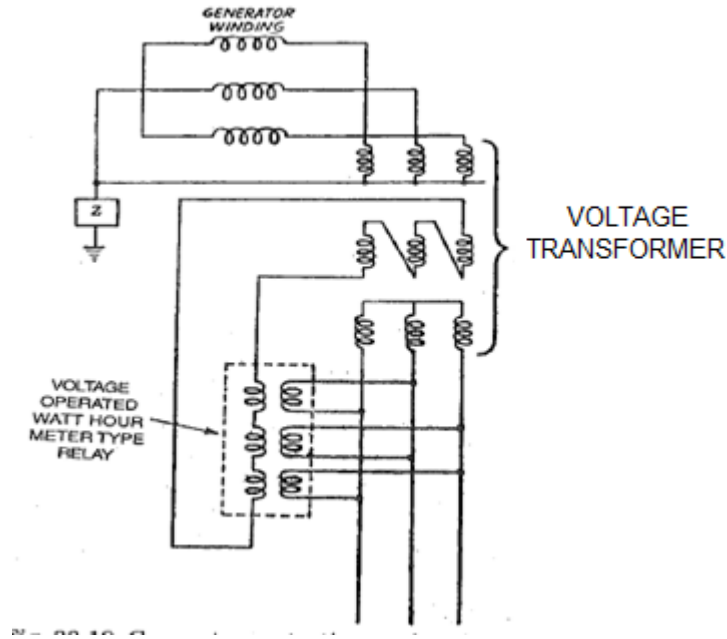


Figure 3.15: Generator protection against inter-turn faults
by residual voltage direction.

When the generator is with single winding per phase, the Residual Voltage Detection method is employed for inter-turn fault protection.

Another method is to connect main voltage transformers in star-delta and connect an auxiliary VT in the delta circuit. A voltage V_{res} proportional to the residual voltage

$$V_{RES} = V_{RN} + V_{YN} + V_{BN}$$

flow through the secondary delta connected winding of the VT. The relay is connected in this circuit via an auxiliary VT. The short circuit between turns gives residual voltage of fundamental frequency which should operate the relay, The relay should not operate for earth fault. Earth fault also causes residual voltage. Hence the zero-sequence voltages of third harmonic are fed to the restraining coil of the relay. The LC circuit tuned to fundamental frequency offers low resistance path to power frequency voltages appearing due to inter-turn faults. Hence for inter-turn faults the restraining current does not flow and relay operates only for inter-turn fault.

3.5.5 Rotor Earth Fault Protection:

A single ground fault does not cause flow of current since the rotor circuit is ungrounded. When the second ground fault occurs part of the rotor winding is by-passed and the currents in the remaining portion may increase. This causes unbalance in rotor and may cause mechanical as well as thermal stresses resulting in damage to the rotor. In some cases the vibrations have caused damage to bearings and bending of rotor shaft. Such failures have caused extensive damage.

One method of detecting earth fault on rotor circuit is described below. A high resistance is connected across the rotor circuit. The centre point of this is connected to earth through a sensitive relay. The relay detects the earth faults for most of the rotor circuit (Fig.3.16) except the centre point of rotor.

Other methods of rotor earth fault protection include d.c. injection method and a.c. injection method, (Fig. 3.17). A single earth fault in the rotor circuit completes the circuit comprising voltage Source S, sensitive relay earth fault. Thereby the earth fault is sensed by the voltage relay. D.C. injection method is simple and has no problems of leakage currents.

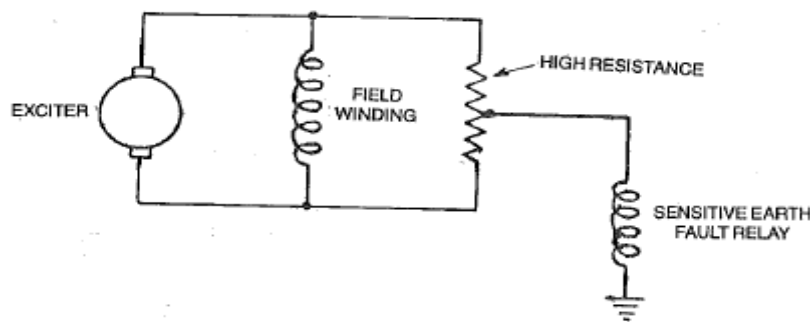


Figure 3.16: Schematic diagram of rotor e.f. protection

3.5.6 Rotor Temperature Alarm

This protection is employed only to large sets and indicates the level of temperature and not the actual hot spot temperature. It is not practicable to embed thermocouples in rotor winding since the slip ring connections would be

complicated. Resistance measurement is adopted. The rotor voltage and current are compared by a moving coil relay. The voltage coil of the relay is connected across the slip ring brushes. The current coil is connected across the shunt in the field circuit.

Double actuating quantity moving coil relay is used, the restraining coil being circuit coil and the operating coil is the voltage coil (Fig. 3.18). Resistance increases with temperature.

The relay measures the ratio

$$V/I = R \text{ (which gives a measure of rotor temperature).}$$

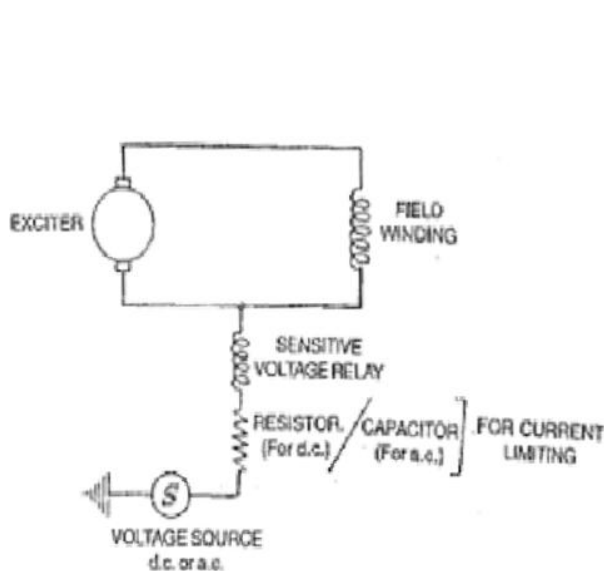


Figure 3.17: principle of d.c/a.c injection

Earth fault protection

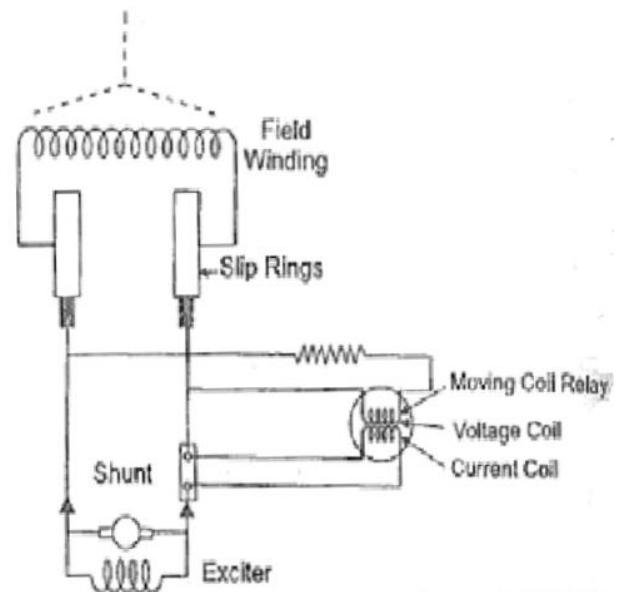


Figure 3.18. Rotor temperature

protection by measuring V/I .

3.5.7 Negative Sequence Protection Of Generators Against Unbalanced Loads

The unbalanced 3-phase stator currents cause double frequency currents to be induced in rotor. They cause heating of rotor and damage the rotor. Unbalanced stator currents also cause severe vibrations and heating of stator. From the theory of symmetrical components, we know that unbalance three-phase currents have a negative sequence component. This component rotates at

synchronous speed in a direction opposite to the direction of rotation of rotor. Therefore double frequency currents are induced in the rotor.

Negative sequence current filter with overcurrent relay provides protection against unbalanced loads (Fig. 3.19).

The relative asymmetry of a three-phase generator is defined as the ratio of negative sequence current (I_2) to rated current (I_n) i.e.,

$$\%S = \frac{I_2}{I_n} \times 100$$

In case of loss of one phase the relative asymmetry %S is equal to 58%.

The time for which the machine can be allowed to operate for various amounts of relative asymmetries depends on type of machine. The additional heat caused by negative sequence currents in rotor is proportional to $I_2^2 t$. The product $I_2^2 t$ is a machine characteristic.

$I_2^2 t = 30$ is a generally accepted figure as per ASA, I_2 in per unit, t in sec for wound rotor machines and 40 for salient pole machine.

It is generally necessary to install negative sequence relays that match with the $I_2^2 t$ characteristic of the machine, (Ref. Fig. 3.19 (b)).

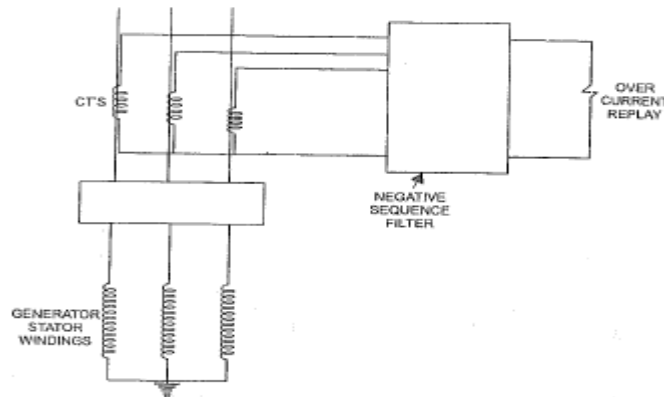


Figure 3.19(a): Protection against unbalanced load using negative sequence filter.

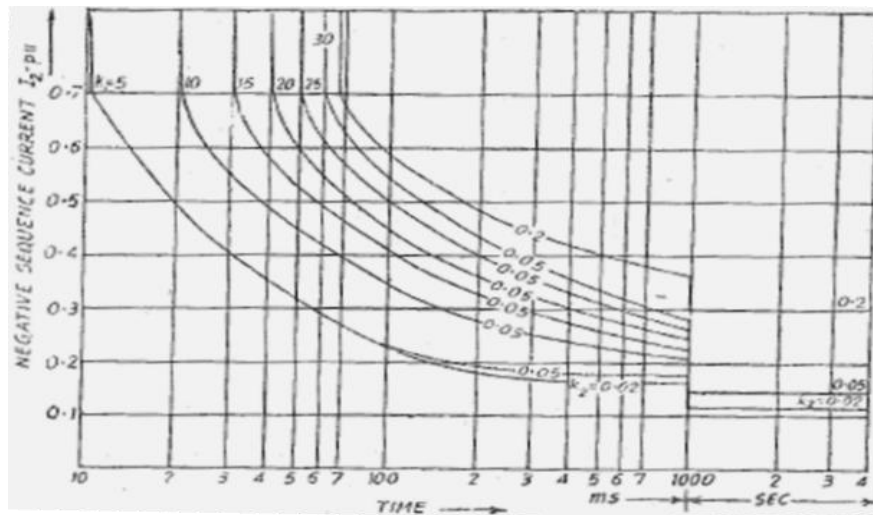


Figure 3.19: (b) Current time characteristics of a static negative phase sequence relay.

Negative sequence filter circuit comprises resistors and inductors connected in the secondary circuit in such a way that negative sequence component flows through the relay coil, Z_L (Ref: Fig.3.20).

The overcurrent relay (Z_L) of negative phase sequence protection is with inverse characteristics matching with the I_{2t}^2 rating curve of the machine and is arranged to trip the unit.

❖ Negative Phase Sequence Circuit:

Fig. 3.20 illustrates the principle of the negative phase sequence circuit. The twin windings of the two auxiliary current-transformers are so connected to the line current-transformers that under normal balanced-load condition, currents I_a , I_b and I_c flow in the direction shown. Impedance

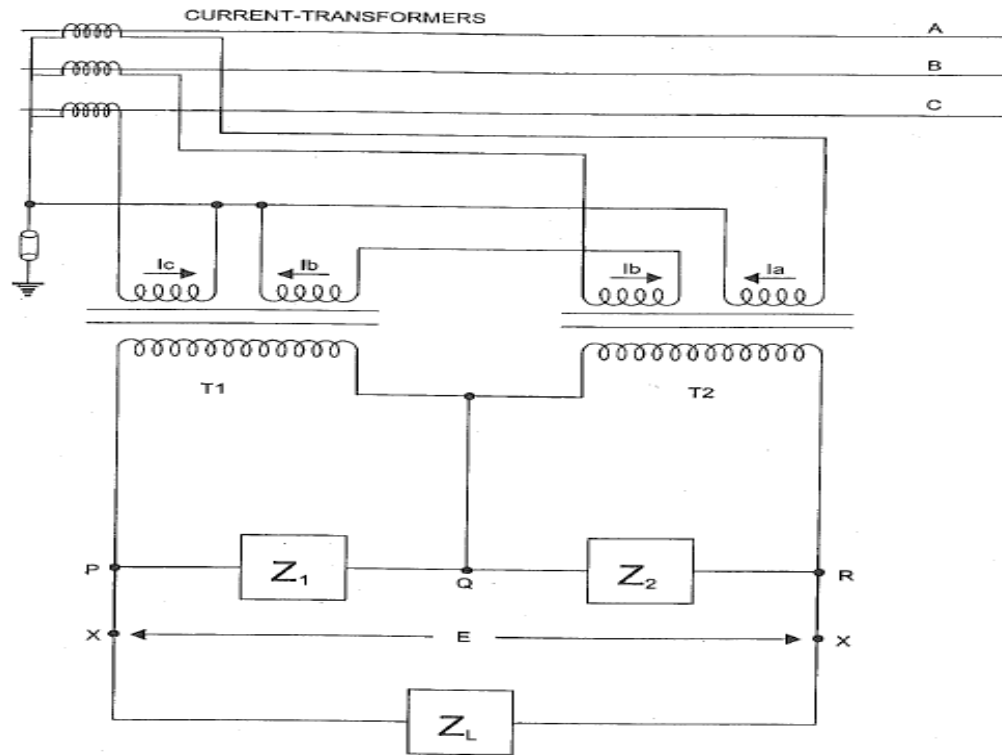


Figure 3.20: Circuit showing principle of negative phase-sequence circuit.

Z_1 and Z_2 are connected across auxiliary current-transformers T_1 and T_2 , and a load impedance

Z_L is connected across the terminals XX

When primary load current flows, the current through T_1 will be $(I_b - I_c)$ and that through

T_2 will be $(I_a - I_b)$. For a given value of load impedance Z_L , (over-current relay) the impedance Z_1 and Z_2 are chosen such that points P and R remain at the same potential, i.e., the voltages across QR and QP are equal and opposite. Under unbalanced conditions these voltages differ, and an output is produced proportional to the negative-phase sequence across XX (voltage E) so as to operate the relay. The protection remains stable on symmetrical overloads up to about three times rated full load.

As the output is instantaneous in operation, it is necessary to operate the equipment in conjunction with a time-lag relay.

Negative phase sequence relays are used for protection against unbalanced loads.

3.5.8 Stator Heating Protection

Generator overheating can be caused by failure cooling system or by sustained overloads.

Embedded resistance detectors or thermocouples are provided in the slots among with the stator coils for large generators. These give an alarm if temperature rises above safe value. The protection is provided for generators above 1 MW.

It is not practicable to provide overload protection by back-up stator-fault over-current protection. Because back-up over-current protection is generally set for sensing fault currents and should not trip for overloads. Electrical over-current relays cannot sense the winding temperature accurately because temperature rise depends on I^2R_t and also on cooling. Electrical protection cannot detect a cooling system failure.

3.5.9 Loss of Field Protection:

A 'loss of field' or 'field failure' can be caused by opening of field switch or field circuit-breaker.

The behavior of the generator depends upon whether the generator connected singly to a load or whether the generator is connected in parallel with other units or the system.

If it is a single unit supplying a local load, the loss of field causes loss of terminal voltage and subsequently loss of synchronism depending upon the load conditions, If the generator is connected in parallel with other units it can draw the magnetizing currents from the bus-bars and continue to runs as induction generator. The magnetising currents are large and are to be supplied by other units. Hence the stability of the other units is affected.

The power-output of the generator is reduced while running as induction generator. The slip frequency e.m.f. is induced in the rotor.

In wound rotor generators, the e.m.f, induced in the rotor gives rise to circulating currents in the rotor body and slot wedges resulting in overheating. In salient pole machines there are no rotor slots and the rotor body is formed of laminations. Hence salient pole machines can endure the condition for a longer duration.

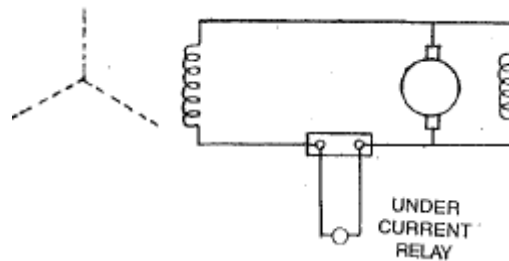


Figure 3.21: Loss of field protection.

The stator currents may increase above normal current rating of generator during the run as induction generator. High currents may cause voltage drop and overheating of generator bus-bars, stator winding, etc,

Fig. 3.21 illustrating the loss of field protection by means of an under-current relay connected across a shunt in series with the field winding.

3.5.10 Reverse Power Protection:

When the input to the turbine is stopped the generator continues to rotate as a synchronous motor, taking power from the bus bars. It then rotates as synchronous motor and the turbine acts as a load. Such incidents have occurred in old stations.

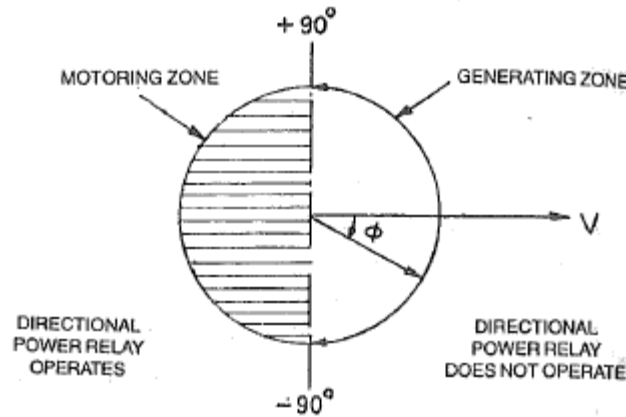


Figure 3.22: Operating characteristic of reverse power protection

Motoring protection is mainly for the benefit of the prime-mover, and load coming on generator bus while motoring. Reverse power protection measures the power flow from bus-bars to the generator running as a motor. Normally the power taken in most cases is low of the order of 2 to 10% of the rated power, Power factor and current depends on excitation level.

During the motoring action of the generator, the power flows from the bus-bars to the machine and the conditions in the three phases are balanced. Hence a single-element directional power relay (reverse power relay, Sec, 26.6 sensing the direction of power flow in any one phase is sufficient.

The CT's for reverse-power protection may be either at the neutral end or the bus-bar and of the generator winding. The setting depends on the type of prime-mover. Intentional time lag is provided in the reverse power protection so that the protection does not operate during system disturbances and power swings.

1. Steam Turbine. Time delay sensitive directional relays, set to operate on somewhat less than 3% of rated power. Back-pressure steam turbine sets should be protected with sensitive reverse power protection.

The blades of such steam turbine get overheated quickly as the stem gets trapped if rotated in opposite direction due to windage.

In steam turbines the steam acts like a coolant of the turbine blades and maintain them at constant temperature. If the steam flow stops, the blades get overheated due to windage (friction with air).

In condensing type steam turbine, the heating of blades is slower hence reverse power protection may not be necessary.

For large turbogenerators with back-pressure type, non-condensing steam turbines, sensitive reverse power protection with sensitivity of the order of 0.5% of rated power is preferred. The relay should have directional stability for the entire relay operating zone (Fig. 3.22).

2. Reciprocating Engine. Motoring is harmful to the engine. Hence the reverse power protection should be sensitive and the engine must be disconnected from generator shaft during motoring.

3. Hydraulic Turbines. The water-turbine is generally fitted with mechanical devices which detect the low water flow because such a flow causes cavitation. However reverse power protection may be provided to operate for motoring power less than 3 per cent of rated power. .

4. Gas Turbine. The gas turbine driven generator should not be permitted to operate as a motor because the gas turbine offers a load of 10 to 50% of full load during motoring.

The factors to be considered are :

- Capability of prime-mover to run as a load.
- Load current drawn while motoring.

The reverse power protection is generally set for 10% rated power in reverse direction.

3.5.11 Over-Speed Protection

It is essential to incorporate safety device in turbine governing system to prevent overspeeding.

Overspeeding can occur due to sudden loss of electrical load on generator due to tripping of

- generator circuit-breaker, before disconnection of prime-mover.
- The speed of the generator should be maintained by the governor.
- The overspeeding results in over voltages and increase in frequency.

Hydro-generators. Overspeeds are prevented by centrifugal governors. Sensitive frequency relays operated from an auxiliary permanent magnet alternator fitted on the shaft sense the over- speed.

Steam turbines. The generator responds to the over-speed caused by load rejection. However, the steam beyond governor keeps on expending causing further increase in speed. The steam beyond governor should be bypassed by some other path quickly so that input to steam turbine is bypassed quickly and increase in speed is checked. This is achieved by sensing overspeeding by electrical measurements on generator side and by steam measurement on turbine side.

The emergency valve is closed momentarily so as to stop the steam supply more rapidly. The valve opens again automatically, meanwhile the governor responds to changed Conditions and regulates the speed.

With gradual reduction in load the emergency valve does not operate.

3.5.12 Field Suppression

When a fault develops in an alternator winding even though the generator circuit-breaker is tripped, the fault continues to be fed because e.m.f. is induced in the generator itself. Hence the field circuit-breaker is opened and the stored energy in the field winding is discharged through another resistor. This method is known as field suppression.

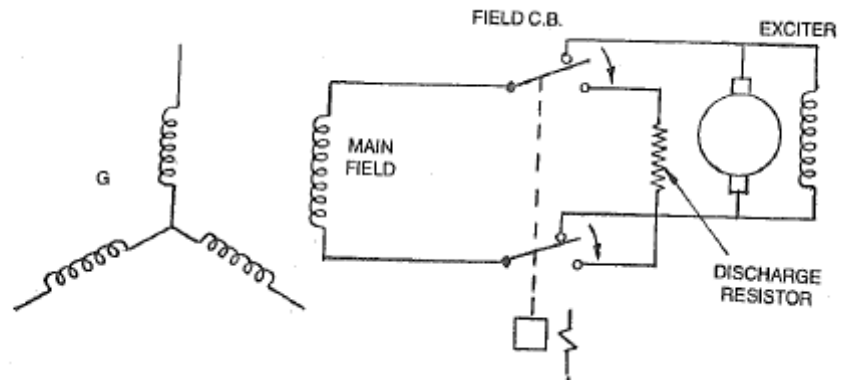


Figure 3.23: Principle of field suppression (The energy in main field is discharged Through resistor by C.B. on to the discharge resistor).

CHAPTER FOUR

PROTECTION APPLICATION ON SYNCHRONOUS GENERATOR

4.1 Introduction:

Some protection techniques could be applied for synchronous generator and to show how this protection functions in practical faults.

4.2 Hardware:

Circuit for this application consists of some parts as following:

4.2.1 Micro controller(atmega 16 L 8pu):

The ATmega16 is a low-power CMOS 8-bit microcontroller based on the AVR enhanced RISC architecture. By executing powerful instructions in a single clock cycle, the ATmega16 achieves throughputs approaching 1 MIPS per MHz allowing the system designer to optimize power consumption versus processing speed.

The ATmega16 provides the following features: 16 Kbytes of In-System Programmable Flash Program memory with Read-While-Write capabilities, 512 bytes EEPROM, 1 Kbyte SRAM, 32 general purpose I/O lines, 32 general purpose working registers, a JTAG interface for Boundaryscan, On-chip Debugging support and programming, three flexible Timer/Counters with compare modes, Internal and External Interrupts, a serial programmable USART, a byte oriented

Two-wire Serial Interface, an 8-channel, 10-bit ADC with optional differential input stage with programmable gain (TQFP package only), a programmable Watchdog Timer with Internal Oscillator, an SPI serial port, and six software selectable power saving modes. The Idle mode stops the CPU while allowing the

USART, Two-wire interface, A/D Converter, SRAM, Timer/Counters, SPI port, and interrupt system to continue functioning.

❖ Pin Descriptions

VCC	Digital supply voltage.
GND	Ground.
Port A	Port A serves as the analog inputs to the A/D Converter.
(PA7..PA0)	Port A also serves as an 8-bit bi-directional I/O port, if the A/D Converter is not used. Port pins can provide internal pull-up resistors (selected for each bit). The Port A output buffers have symmetrical drive characteristics with both high sink and source capability. When pins PA0 to PA7 are used as inputs and are externally pulled low, they will source current if the internal pull-up resistors are activated. The Port A pins are tri-stated when a reset condition becomes active, even if the clock is not running.
Port B	Port B is an 8-bit bi-directional I/O port with internal pull-up
(PB7..PB0)	resistors (selected for each bit). The Port B output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port B pins that are externally pulled low will source current if the pull-up resistors are activated. The Port B pins are tri-stated when a reset condition becomes active, even if the clock is not running.

Port C (PC7..PC0)	Port C is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port C output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port C pins that are externally pulled low will source current if the pull-up resistors are activated. The Port C pins are tri-stated when a reset condition becomes active, even if the clock is not running. If the JTAG interface is enabled, the pull-up resistors on pins PC5(TDI), PC3(TMS) and PC2(TCK) will be activated even if a reset occurs.
Port D (PD7..PD0)	Port D is an 8-bit bi-directional I/O port with internal pull-up resistors (selected for each bit). The Port D output buffers have symmetrical drive characteristics with both high sink and source capability. As inputs, Port D pins that are externally pulled low will source current if the pull-up resistors are activated. The Port D pins are tri-stated when a reset condition becomes active, even if the clock is not running.
RESET	Reset Input. A low level on this pin for longer than the minimum pulse length will generate a reset, even if the clock is not running.
XTAL1	Input to the inverting Oscillator amplifier and input to the internal clock operating circuit.
XTAL2	Output from the inverting Oscillator amplifier.

AVCC AVCC is the supply voltage pin for Port A and the A/D Converter. It should be externally connected to VCC, even if the ADC is not used. If the ADC is used, it should be connected to VCC through a low-pass filter.

AREF AREF is the analog reference pin for the A/D Converter.^[6]

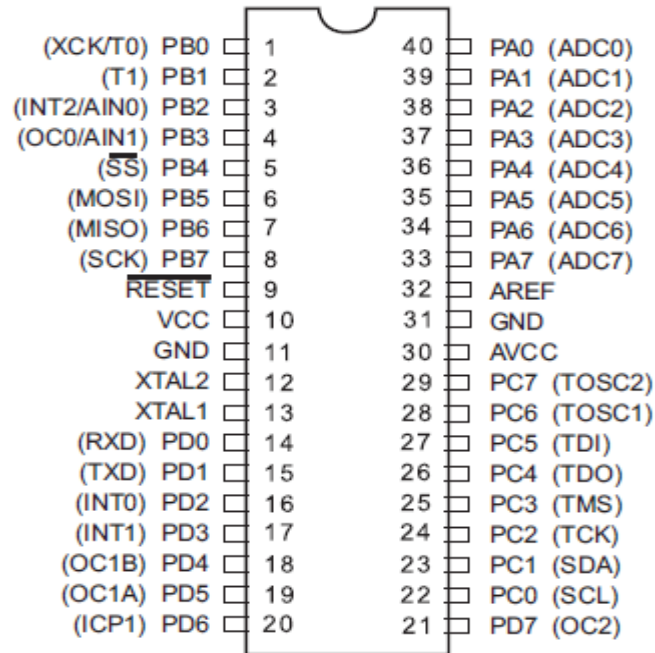


Figure 4.1:Atmega 16

4.2.3 Potentiometer:

A potentiometer is a simple knob that provides a variable resistance, which can read into the microcontroller board as an analog value. In this example, that value controls the rate at which an LED blinks.

Connect three wires to the microcontroller board. The first goes to ground from one of the outer pins of the potentiometer. The second goes from 5 volts to the other outer pin of the potentiometer. The third goes from analog input to the middle pin of the potentiometer.

4.2.4 LCD:

A liquid-crystal display (LCD) is a flat panel display, electronic visual display, or video display that uses the light modulating properties of liquid crystals.

4.2.5 relays:

A relay is an electrically operated switch.

Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid-state relays. Relays are used where it is necessary to control a circuit by a low-power signal (with complete electrical isolation between control and controlled circuits).^[7]



Figure 4.2 relay

4.2.6 LED:

A light-emitting diode (LED) is a two-lead semiconductor light source. It is a p–n junction diode, which emits light when activated.

4.2.7 Wires:

To carry current between circuits components.

4.3 Programming language:

A programming language is a formal constructed language designed to communicate instructions to a machine, particularly a computer. Programming languages can be used to create programs to control the behavior of a machine or to express algorithms.

4.4 Results :

After applied some types of faults that could be occur for generator and notice the function of protection in the circuit.

4.3.1 Differential protection:

When changing the value of current the come out of the generator by using the Potentiometer the protection system take action immediately

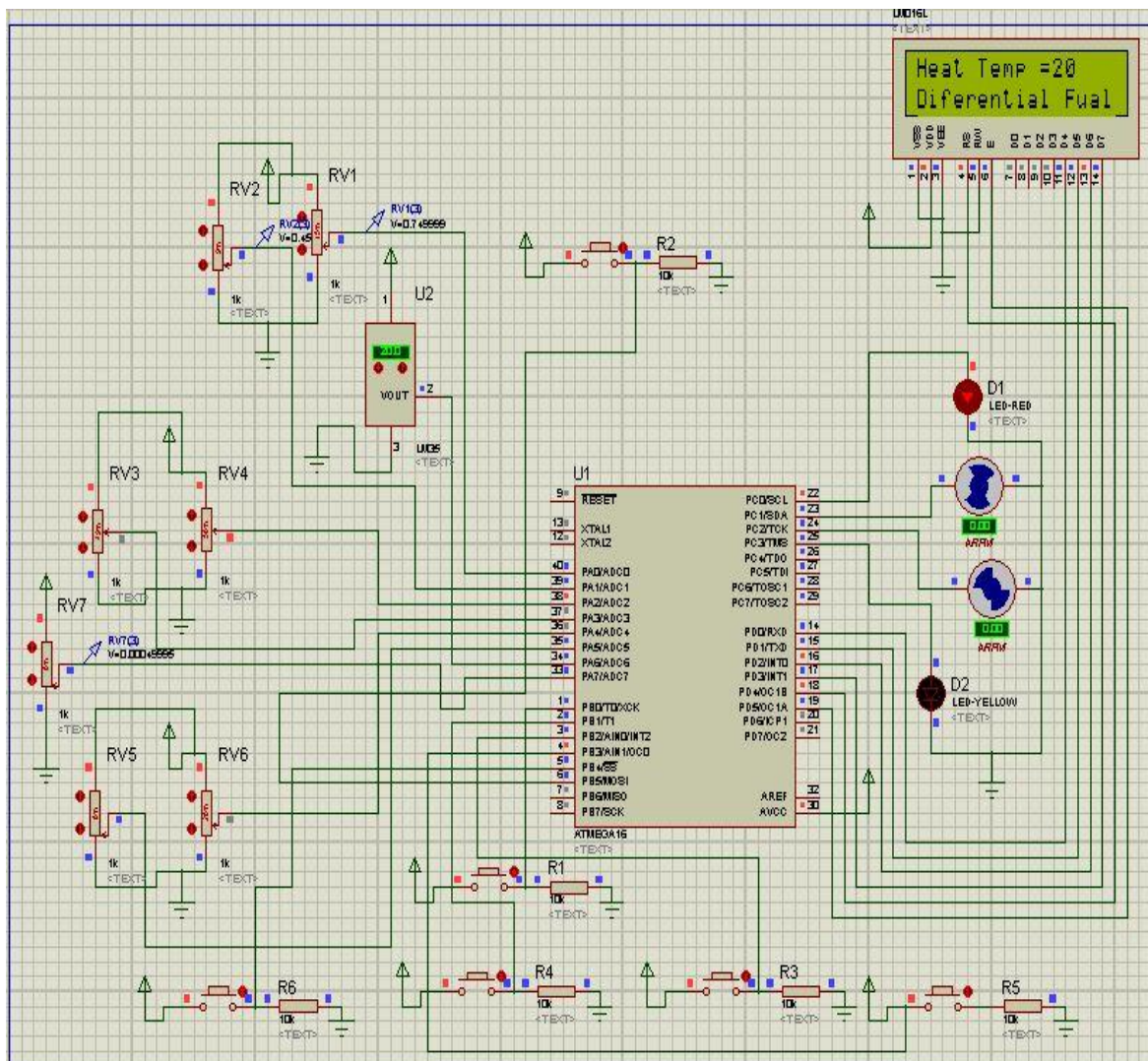


Figure 4.3: differential fault

When the current supplied by the generator exceeds a preset value the protection of over current work

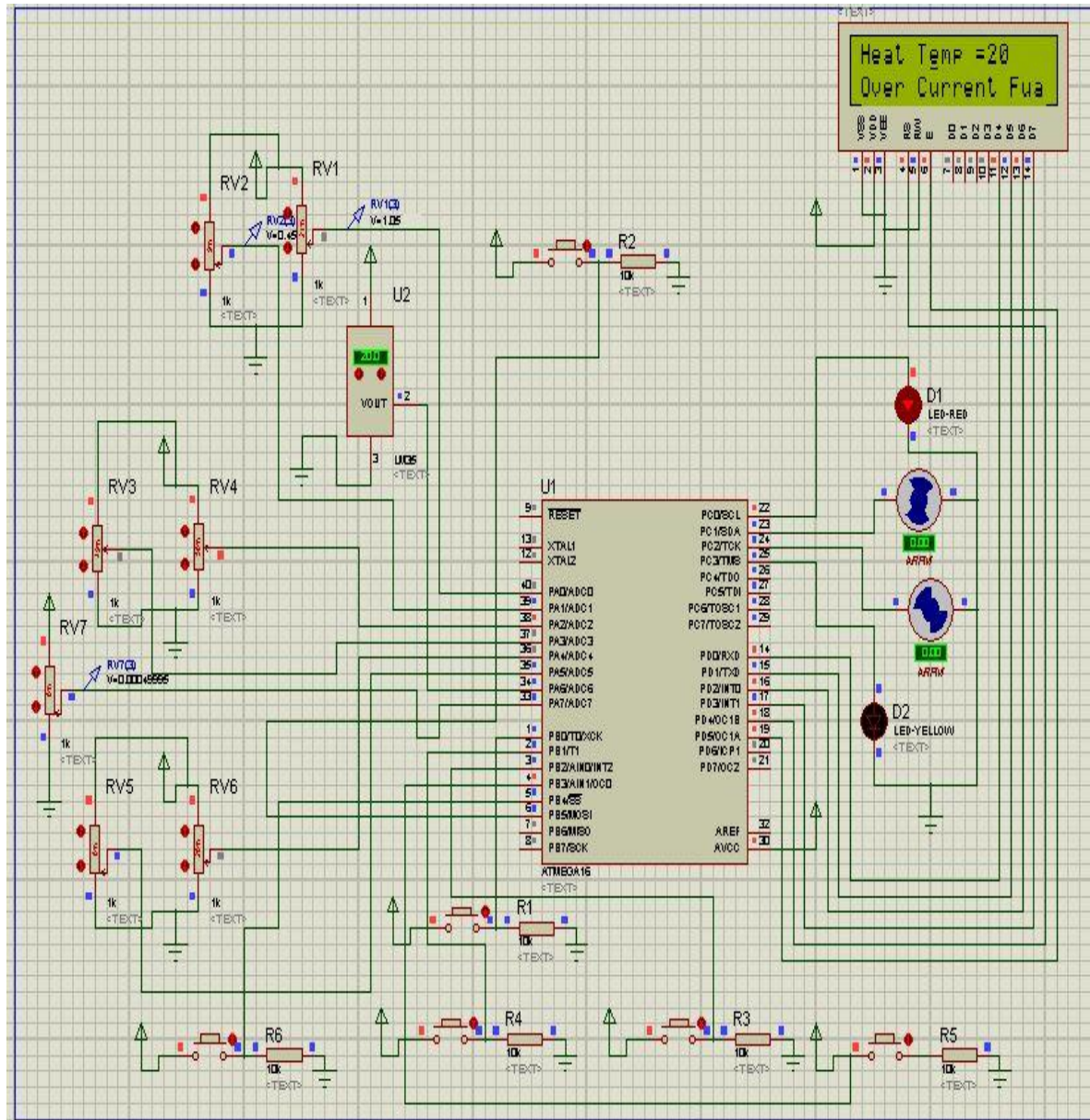


Figure 4.4 Overcurrent fault

4.3.3 Earth fault:

If there is some current flow through the earthed line and that could happen if the summation of three phases are not equal zero.

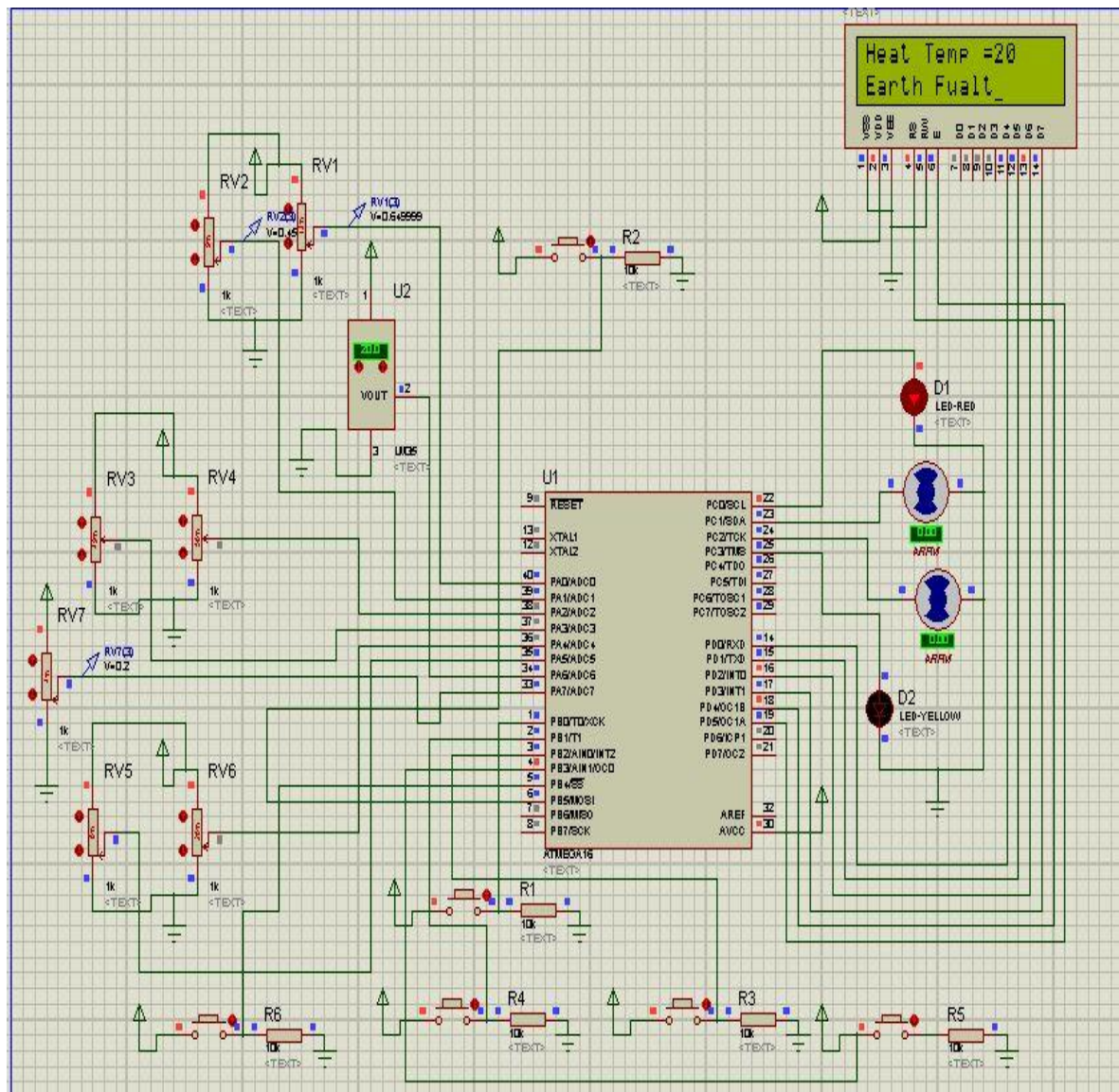


Figure 4.5 Earth fault

4.3.4 Overheating:

Heat above certain value could cause a lot of problems for the machine. In the circuit the first fan will work if the temperature reach 30° if not reduced and keep increasing the second one will work after 35° after that the machine will trip .

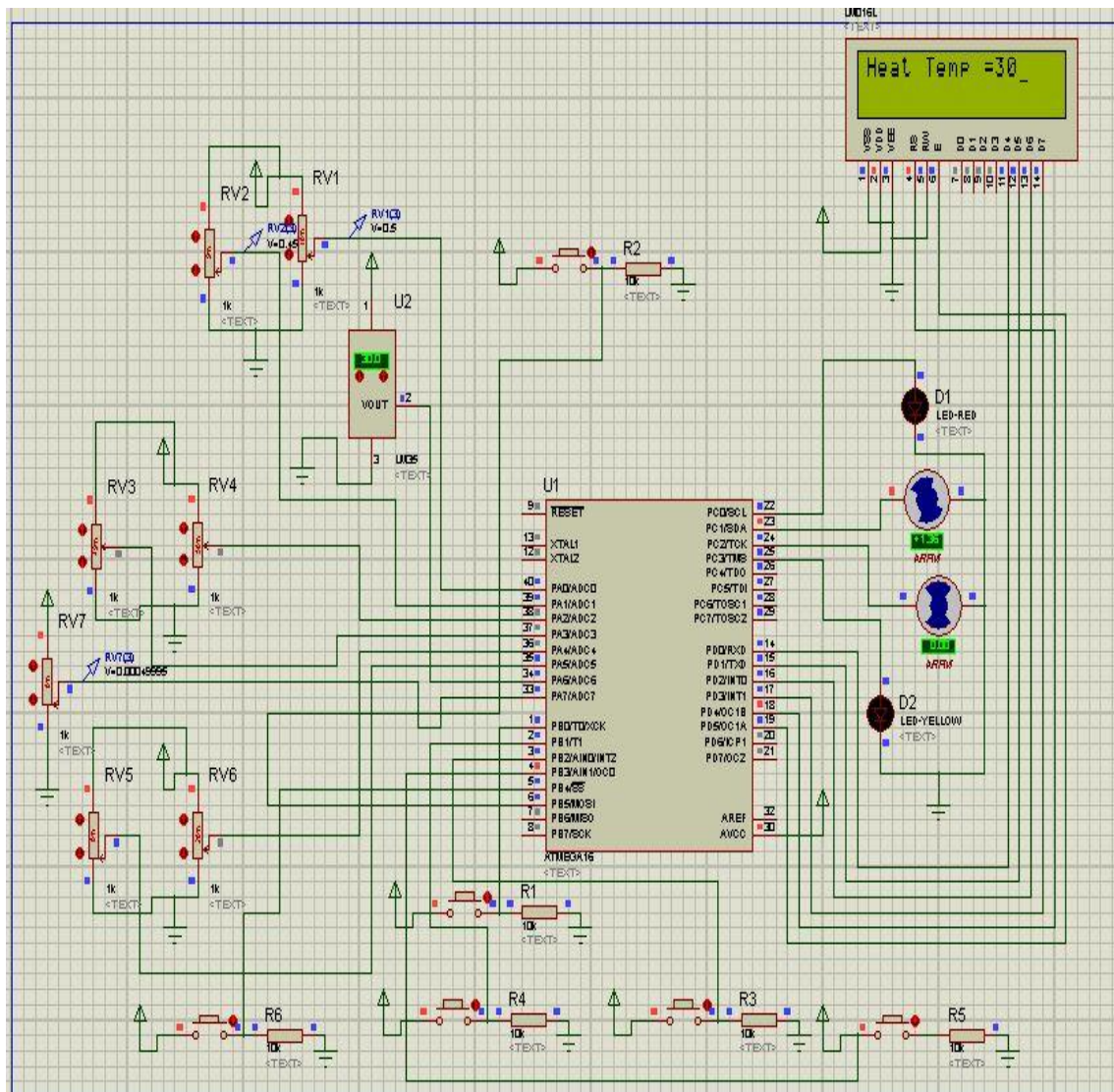


Figure 4.6 Overheating

CHAPTER FIVE

CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion:

Throughout the project and with looking deep in the important of the power plant its clear the protection for the power plant should put in priority for all power plant equipment, steam power plant has the some vital equipment such as synchronous generator and this has some faults may happened on it , but good protection with save the machine

From the project find that there are a lot of protection techniques could be applied for protect synchronous generator form most faults so power plant could keep supplied serveries to consumers

And we can use some kind of digital relays to ensure fast response and accurate result.

5.2 Recommendation:

The concluded recommendations are:

- 1- Use matlab for Simulink and test the network under fulty condition and see the response of protective relays.
- 2- Include modern devises such as digital relay help to improve protection reliability.
- 3- Give protection system more intention for it importance.

Reference:

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- [5] Sunil S. Rao Switchgear Protection and Power System (Theory, Practice And Solved Problems), Khanna Publishers, 1999.
- [6] Atmega 16 data sheet
- [7] Mason, C. R. "Art & Science of Protective Relaying, Chapter 2, GE Consumer & Electrical", Retrieved October 9, 2011.

APPENDEXE A:

\$regfile "m16def.dat"

\$crystal = 1000000

Config Porta = Input

Config Portc = Output

Config Portb = Input

Config Adc = Single , Prescaler = Auto , Reference = Avcc

Config Timer1 = Timer , Prescale = 1024

Config Lcd = 16 * 2

Config Lcdpin = Pin , Db4 = Portd.0 , Db5 = Portd.1 , Db6 = Portd.2 , Db7 = Portd.3 , Rs = Portd.4 , E = Portd.5

Dim Cap As Word , Cas As Word , Cbp As Word , Cbs As Word , Ccp As Word , Ccs As Word

Dim Iap As Single , Ias As Single , Ibp As Single , Ibs As Single , Icp As Single , Ics As Single

Dim Iopa As Single , Iopb As Single , Iopc As Single , Iresa As Single , Iresb As Single , Iresc As Single

Dim Idef As Single , K As Single , Ipich As Single , Delayp As Single , A As Single , B As Single , C As Single , Tms As Single , Tp As Single

Dim Tripa As Bit , Tripb As Bit , Tripc As Bit , Trip As Bit , T As Bit , A1 As Bit , A2 As Bit , Hx As Integer

Dim B1 As Bit , B2 As Bit , C1 As Bit , C2 As Bit , Trip1 As Bit , Trip2 As Bit , Trip3 As Bit , T1 As Bit , Tripn0 As Bit

Dim Ra1 As Bit , Ra2 As Bit , Rb1 As Bit , Rb2 As Bit , Rc1 As Bit , Rc2 As Bit , T2 As Bit , T3 As Bit , T4 As Bit , T5 As Bit , T6 As Bit

Dim M1 As Bit , Ht As Word , D As Single , Heat As Single , M2 As Bit , M3 As Bit , M4 As Bit , Triph As Bit , Tripm As Bit

Dim P1 As Bit , P2 As Bit , P3 As Bit , P4 As Bit , P5 As Bit , N0 As Word , In0 As Single , N As Single ,
Tmsn As Single , Ipichn As Single

Start Adc

M4 = 0

Do

Ipich = 1

Ipichn = .07

Idef = 1.857

K = .35

Tms = .03

Tmsn = .05

Cap = Getadc(0) 'read adc out put

Cas = Getadc(1)

Cbp = Getadc(2)

Cbs = Getadc(3)

Ccp = Getadc(4)

Ccs = Getadc(5)

Ht = Getadc(6)

N0 = Getadc(7)

Iap = Cap * 5 'change to value

Iap = Iap / 1023

Ias = Cas * 5

Ias = Ias / 1023

$$lbp = Cbp * 5$$

$$lbp = lbp / 1023$$

$$lbs = Cbs * 5$$

$$lbs = lbs / 1023$$

$$lcp = Ccp * 5$$

$$lcp = lcp / 1023$$

$$lcs = Ccs * 5$$

$$lcs = lcs / 1023$$

$$ln0 = N0 * 5$$

'change to value

$$ln0 = ln0 / 1023$$

$$lopa = lap - las$$

$$lopb = lbp - lbs$$

$$lopc = lcp - lcs$$

$$lresa = lap + las$$

$$lresa = lresa / 2$$

$$lresb = lbp + lbs$$

$$lresb = lresb / 2$$

$$lresc = lcp + lcs$$

$$lresc = lresc / 2$$

$$ldef = ldef - 1$$

$$ldef = ldef * 2.45$$

$$ldef = ldef / 7$$

If Iresa <= 1 Then 'diferential protection

If Iopa >= .3 Then

A1 = 1

A2 = 1

End If

End If

If Iresa > 1 Then

Ra1 = 1

End If

If Iresa <= 8 Then

Ra2 = 1

End If

If Iresa > 8 Then

Ra2 = 0

End If

If Ra2 = 0 Then

Iopa = 5.55 + Iopa

If Iopa >= Iresa Then

A1 = 1

A2 = 1

End If

End If

If Ra1 = 1 And Ra2 = 1 Then

Iresa = Iresa - 1

Iresa = Iresa * K

If Iopa >= Iresa Then

A1 = 1

End If

If Iopa >= Idef Then

A2 = 1

End If

End If

If A1 = 1 And A2 = 1 Then

Tripa = 1

End If

If Iap > 1 Then 'over current protuction from phase a

Start Timer1

Delayp = Timer1

A = Iap / Ipich

A = A ^ .02

A = A - 1

A = 0.14 / A

Tp = Tms * A

Tp = Tp * 976

If Delayp > Tp Then

Trip1 = 1

End If

End If

If Iresb <= 1 Then

If lopb >= .3 Then

B1 = 1

B2 = 1

End If

End If

If Iresb > 1 Then

Rb1 = 1

End If

If Iresb <= 8 Then

Rb2 = 1

End If

If Iresb > 8 Then

Rb2 = 0

End If

If Rb2 = 0 Then

$I_{opb} = 5.55 + I_{opb}$

If $I_{opb} \geq I_{resb}$ Then

B1 = 1

B2 = 1

End If

End If

If $R_{b1} = 1$ And $R_{b2} = 1$ Then

$I_{resb} = I_{resb} - 1$

$I_{resb} = I_{resb} * K$

If $I_{opb} \geq I_{resb}$ Then

B1 = 1

End If

If $I_{opb} \geq I_{def}$ Then

B2 = 1

End If

End If

If B1 = 1 And B2 = 1 Then

Tripb = 1

End If

If $I_{bp} > 1$ Then

'over current protuction from phase B

Start Timer1

Delayp = Timer1

$B = I_{bp} / I_{pich}$

$B = B^{.02}$

$B = B - 1$

$B = 0.14 / B$

$T_p = T_{ms} * B$

$T_p = T_p * 976$

If Delayp > T_p Then

Trip2 = 0

End If

End If

If I_{resc} <= 1 Then

If I_{opc} >= .3 Then

C1 = 1

C2 = 1

End If

End If

If I_{resc} > 1 Then

Rc1 = 1

End If

If I_{resc} <= 8 Then

Rc2 = 1

```
End If

If Iresc > 8 Then

Rc2 = 0

End If

If Rc2 = 0 Then

lopc = 5.55 + lopc

If lopc >= Iresc Then

C1 = 1

C2 = 1

End If

End If

If Rc1 = 1 And Rc2 = 1 Then

Iresc = Iresc - 1

Iresc = Iresc * K

If lopc >= Iresc Then

C1 = 1

End If

If lopc >= Idef Then

C2 = 1

End If

End If

If C1 = 1 And C2 = 1 Then
```

Trip_c = 0

End If

If I_{cp} > 1 Then 'over current protuction from phase C

Start Timer1

Delay_p = Timer1

C = I_{cp} / I_{pich}

C = C ^ .02

C = C - 1

C = 0.14 / C

T_p = T_{ms} * C

T_p = T_p * 976

If Delay_p >= T_p Then

Trip₃ = 1

End If

End If

If I_{n0} > .1 Then 'nutral point

Start Timer1

Delay_p = Timer1

N = I_{n0} / I_{pichn}

N = N ^ .02

N = N - 1

$N = 0.14 / N$

$T_p = T_{msn} * N$

$T_p = T_p * 976$

If Delayp > T_p Then

Tripn0 = 1

End If

End If

$T1 = \text{Tripa Or Tripb}$

$T2 = \text{Tripc Or Trip1}$

$T3 = \text{Trip2 Or Trip3}$

$T4 = \text{Triph Or Tripn0}$

$T5 = T1 \text{ Or } T2$

$T6 = T4 \text{ Or } T3$

$T = T6 \text{ Or Tripm}$

$\text{Trip} = T \text{ Or } T5$

$\text{Portc.0} = \text{Trip}$

$D = H_t * 5$

$D = D / 1023$

$\text{Heat} = D * 100$

If Heat < 45 Then

If Heat > 30 Then

M1 = 1

End If

If Heat < 30 Then

M1 = 0

End If

If Heat > 35 Then

M2 = 1

End If

If Heat < 35 Then

M2 = 0

End If

If Heat > 40 Then

M3 = 1

End If

End If

If Heat > 45 Then

M4 = 1

End If

If Trip = 1 Then

M1 = 0

M2 = 0

End If

If M4 = 1 Then

Triph = 1

Portc.1 = 0

Portc.2 = 0

End If

If M1 = 1 And M4 = 0 Then

Portc.1 = 1

End If

If M2 = 1 And M4 = 0 Then

Portc.2 = 1

End If

If M3 = 1 And M4 = 0 Then

Portc.3 = 1

End If

If M1 = 0 And M4 = 0 Then

Portc.1 = 0

End If

If M2 = 0 And M4 = 0 Then

Portc.2 = 0

End If

Trip_m = 0

Cls

End If

If Pin_b.1 = 1 Then

P1 = 1

End If

If P1 = 1 Then

Trip_m = 1

End If

If Pin_b.2 = 1 Then

P2 = 1

End If

If P2 = 1 Then

Port_c.3 = 1

End If

If Pin_b.5 = 1 Then

P5 = 1

End If

If P5 = 1 Then

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End If

'*****

Hx = Heat

Locate 1 , 1

Lcd "Heat Temp =" ; Hx

If Iap > 1 Then

If Trip1 = 1 Then

Locate 2 , 1

Lcd "Over Current Fualt"

End If

End If

If Ibp > 1 Then

If Trip2 = 1 Then

Locate 2 , 1

Lcd "Over Current Fualt"

End If

End If

If Icp > 1 Then

If Trip3 = 1 Then

Locate 2 , 1

Lcd "Over Current Fualt"

End If

End If

If Iap < 1 Then

If Tripa = 1 Then

Locate 2 , 1

Lcd "Diferential Fualt"

End If

End If

If Tripb = 1 Then

Locate 2 , 1

Lcd "Diferential Fualt"

End If

If Icp < 1 Then

If Tripc = 1 Then

Locate 2 , 1

Lcd "Diferential Fualt"

End If

End If

If Tripn0 = 1 Then

Locate 2 , 1

Lcd "Earth Fualt"

End If

Loop

'*****

Manual:

Do

If Pinb.1 = 1 Then

P1 = 1

End If

If P1 = 1 Then

Portc.0 = 1

End If

If Pinb.2 = 1 Then

P2 = 1

End If

If P2 = 1 Then

Portc.3 = 1

End If

If Pinb.3 = 1 Then

P3 = 1

End If

If P3 = 1 Then

Portc.1 = 1

End If

If Pinb.4 = 1 Then

P4 = 1

End If

```

If P4 = 1 Then

Portc.2 = 1

End If

If Pinb.5 = 0 Then

P5 = 0

End If

If P5 = 0 Then

Return

End If

If Pinb.0 = 1 Then                                'reset switch

Portc.0 = 0

Portc.1 = 0

Portc.2 = 0

Portc.3 = 0

Portc.4 = 0

P1 = 0

P2 = 0

P3 = 0

P4 = 0

Cls

End If

Loop

```

APPENDEXE A:

\$regfile "m16def.dat"

\$crystal = 1000000

Config Porta = Input

Config Portc = Output

Config Portb = Input

Config Adc = Single , Prescaler = Auto , Reference = Avcc

Config Timer1 = Timer , Prescale = 1024

Config Lcd = 16 * 2

Config Lcdpin = Pin , Db4 = Portd.0 , Db5 = Portd.1 , Db6 = Portd.2 , Db7 = Portd.3 , Rs = Portd.4 , E = Portd.5

Dim Cap As Word , Cas As Word , Cbp As Word , Cbs As Word , Ccp As Word , Ccs As Word

Dim Iap As Single , Ias As Single , Ibp As Single , Ibs As Single , Icp As Single , Ics As Single

Dim Iopa As Single , Iopb As Single , Iopc As Single , Iresa As Single , Iresb As Single , Iresc As Single

Dim Idef As Single , K As Single , Ipich As Single , Delayp As Single , A As Single , B As Single , C As Single
, Tms As Single , Tp As Single

Dim Tripa As Bit , Tripb As Bit , Tripc As Bit , Trip As Bit , T As Bit , A1 As Bit , A2 As Bit , Hx As Integer

Dim B1 As Bit , B2 As Bit , C1 As Bit , C2 As Bit , Trip1 As Bit , Trip2 As Bit , Trip3 As Bit , T1 As Bit ,
Tripn0 As Bit

Dim Ra1 As Bit , Ra2 As Bit , Rb1 As Bit , Rb2 As Bit , Rc1 As Bit , Rc2 As Bit , T2 As Bit , T3 As Bit , T4 As
Bit , T5 As Bit , T6 As Bit

Dim M1 As Bit , Ht As Word , D As Single , Heat As Single , M2 As Bit , M3 As Bit , M4 As Bit , Triph As
Bit , Tripm As Bit

Dim P1 As Bit , P2 As Bit , P3 As Bit , P4 As Bit , P5 As Bit , N0 As Word , In0 As Single , N As Single ,
Tmsn As Single , Ipichn As Single

Start Adc

M4 = 0

Do

Ipich = 1

Ipichn = .07

Idef = 1.857

K = .35

Tms = .03

Tmsn = .05

Cap = Getadc(0) 'read adc out put

Cas = Getadc(1)

Cbp = Getadc(2)

Cbs = Getadc(3)

Ccp = Getadc(4)

Ccs = Getadc(5)

Ht = Getadc(6)

N0 = Getadc(7)

lap = Cap * 5 'change to value

lap = lap / 1023

las = Cas * 5

las = las / 1023

lbp = Cbp * 5

lbp = lbp / 1023

lbs = Cbs * 5

lbs = lbs / 1023

lcp = Ccp * 5

lcp = lcp / 1023

lcs = Ccs * 5

lcs = lcs / 1023

ln0 = N0 * 5 'change to value

ln0 = ln0 / 1023

lopa = lap - las

lopb = lbp - lbs

lopc = lcp - lcs

lresa = lap + las

Ra2 = 0

End If

If Ra2 = 0 Then

lopa = 5.55 + lopa

If lopa >= Iresa Then

A1 = 1

A2 = 1

End If

End If

If Ra1 = 1 And Ra2 = 1 Then

Iresa = Iresa - 1

Iresa = Iresa * K

If lopa >= Iresa Then

A1 = 1

End If

If lopa >= Idef Then

A2 = 1

End If

End If

If A1 = 1 And A2 = 1 Then

Tripa = 1

End If

```

If Iap > 1 Then                                'over current protuction from phase a

Start Timer1

Delayp = Timer1

A = Iap / Ipich

A = A ^ .02

A = A - 1

A = 0.14 / A

Tp = Tms * A

Tp = Tp * 976

If Delayp > Tp Then

Trip1 = 1

End If

End If

'*****

*****

If Iresb <= 1 Then

If Iopb >= .3 Then

B1 = 1

B2 = 1

End If

End If

If Iresb > 1 Then

Rb1 = 1

```

```
End If

If Iresb <= 8 Then

Rb2 = 1

End If

If Iresb > 8 Then

Rb2 = 0

End If

If Rb2 = 0 Then

lop = 5.55 + lop

If lop >= Iresb Then

B1 = 1

B2 = 1

End If

End If

If Rb1 = 1 And Rb2 = 1 Then

Iresb = Iresb - 1

Iresb = Iresb * K

If lop >= Iresb Then

B1 = 1

End If

If lop >= Idef Then

B2 = 1
```

End If

End If

If B1 = 1 And B2 = 1 Then

Tripb = 1

End If

If Ibp > 1 Then 'over current protuction from phase B

Start Timer1

Delayp = Timer1

B = Ibp / Ipich

B = B ^ .02

B = B - 1

B = 0.14 / B

Tp = Tms * B

Tp = Tp * 976

If Delayp > Tp Then

Trip2 = 0

End If

End If

If Iresc <= 1 Then

If Iopc >= .3 Then

C1 = 1

```
C2 = 1

End If

End If

If Iresc > 1 Then

Rc1 = 1

End If

If Iresc <= 8 Then

Rc2 = 1

End If

If Iresc > 8 Then

Rc2 = 0

End If

If Rc2 = 0 Then

lopc = 5.55 + lopc

If lopc >= Iresc Then

C1 = 1

C2 = 1

End If

End If

If Rc1 = 1 And Rc2 = 1 Then

Iresc = Iresc - 1

Iresc = Iresc * K
```

If $I_{opc} \geq I_{resc}$ Then

$C1 = 1$

End If

If $I_{opc} \geq I_{def}$ Then

$C2 = 1$

End If

End If

If $C1 = 1$ And $C2 = 1$ Then

$Trip_c = 0$

End If

If $I_{cp} > 1$ Then

'over current protuction from phase C

Start Timer1

$Delay_p = Timer1$

$C = I_{cp} / I_{pich}$

$C = C^{.02}$

$C = C - 1$

$C = 0.14 / C$

$T_p = T_{ms} * C$

$T_p = T_p * 976$

If $Delay_p \geq T_p$ Then

$Trip3 = 1$

End If

End If

```
If In0 > .1 Then 'neutral point
```

Start Timer1

Delayp = Timer1

$$N = I_{n0} / I_{pichn}$$
$$N = N^{.02}$$
$$N = N - 1$$
$$N = 0.14 / N$$
$$T_p = T_{msn} * N$$
$$T_p = T_p * 976$$

If Delayp > Tp Then

Tripn0 = 1

End If

End If

T1 = Tripa Or Tripb

T2 = Tripc Or Trip1

T3 = Trip2 Or Trip3

T4 = Triph Or Tripn0

$$T5 = T1 \text{ Or } T2$$

$T6 = T4 \text{ Or } T3$

$T = T6 \text{ Or } \text{Tripm}$

$\text{Trip} = T \text{ Or } T5$

$\text{Portc.0} = \text{Trip}$

$D = Ht * 5$

$D = D / 1023$

$\text{Heat} = D * 100$

If Heat < 45 Then

If Heat > 30 Then

M1 = 1

End If

If Heat < 30 Then

M1 = 0

End If

If Heat > 35 Then

M2 = 1

End If

If Heat < 35 Then

M2 = 0

End If

If Heat > 40 Then

M3 = 1

End If

End If

If Heat > 45 Then

M4 = 1

End If

If Trip = 1 Then

M1 = 0

M2 = 0

End If

If M4 = 1 Then

Triph = 1

Portc.1 = 0

Portc.2 = 0

End If

If M1 = 1 And M4 = 0 Then

Portc.1 = 1

End If

If M2 = 1 And M4 = 0 Then

Portc.2 = 1

End If

If M3 = 1 And M4 = 0 Then

Portc.3 = 1

End If

If M1 = 0 And M4 = 0 Then

Portc.1 = 0

End If

If M2 = 0 And M4 = 0 Then

Portc.2 = 0

End If

If M3 = 0 And M4 = 0 Then

Portc.3 = 0

End If

'*****

If Pinb.0 = 1 Then 'reset switch

Portc.0 = 0

M4 = 0

M3 = 0

A1 = 0

A2 = 0

B1 = 0

B2 = 0

C1 = 0

C2 = 0

```
Tripa = 0

Tripb = 0

Tripc = 0

Trip1 = 0

Trip2 = 0

Trip3 = 0

Tripn0 = 0

Triph = 0

Tripm = 0

Cls

End If

If Pinb.1 = 1 Then

P1 = 1

End If

If P1 = 1 Then

Tripm = 1

End If

If Pinb.2 = 1 Then

P2 = 1

End If

If P2 = 1 Then

Portc.3 = 1
```

End If

If Pinb.5 = 1 Then

P5 = 1

End If

If P5 = 1 Then

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End If

Hx = Heat

Locate 1 , 1

Lcd "Heat Temp =" ; Hx

If Iap > 1 Then

If Trip1 = 1 Then

Locate 2 , 1

Lcd "Over Current Fualt"

End If

End If

If Ibp > 1 Then

If Trip2 = 1 Then

Locate 2 , 1

Lcd "Over Current Fualt"

End If

```
End If

If Icp > 1 Then

If Trip3 = 1 Then

Locate 2 , 1

Lcd "Over Current Fualt"

End If

End If

If Iap < 1 Then

If Tripa = 1 Then

Locate 2 , 1

Lcd "Diferential Fualt"

End If

End If

If Tripb = 1 Then

Locate 2 , 1

Lcd "Diferential Fualt"

End If

If Icp < 1 Then

If Tripc = 1 Then

Locate 2 , 1

Lcd "Diferential Fualt"

End If
```

End If

If Tripn0 = 1 Then

Locate 2 , 1

Lcd "Earth Fualt"

End If

Loop

'*****

Manual:

Do

If Pinb.1 = 1 Then

P1 = 1

End If

If P1 = 1 Then

Portc.0 = 1

End If

If Pinb.2 = 1 Then

P2 = 1

End If

If P2 = 1 Then

Portc.3 = 1

End If

If Pinb.3 = 1 Then

P3 = 1

End If

If P3 = 1 Then

Portc.1 = 1

End If

If Pinb.4 = 1 Then

P4 = 1

End If

If P4 = 1 Then

Portc.2 = 1

End If

If Pinb.5 = 0 Then

P5 = 0

End If

If P5 = 0 Then

Return

End If

If Pinb.0 = 1 Then 'reset switch

Portc.0 = 0

Portc.1 = 0

Portc.2 = 0

Portc.3 = 0

Portc.4 = 0

P1 = 0

P2 = 0

P3 = 0

P4 = 0

Cls

End If

Loop