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, comer 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 occurs in the station will eliminate the services from consumer for this reason effective protection action is required to reduce power station outages. The protection of generators is a hard task It involves the consideration of more possible abnormal operating conditions than the protection of any other system element. In unattended stations, automatic protection against all harmful abnormal conditions should be provided. But much difference of opinion exists as to what constitutes sufficient protection of generators in attended stations.

1.3 Objective:

The objectives of the project are to study protection of the power system elements at Garri4 power station specially the generators and analyze different Methods to protect the generators from potential faults.

1.4 Methodology:

In this project the investigation of elements protection will be done using data collection From Garri4 power station and simulation using ETAP program because ETAP is the most comprehensive solution for the design, simulation and analysis of Generation, transmission and distribution. Also protection relays will be used to give practical Results from the laboratory. And we have some task:

Task1: At first gather general information about thermal 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 garri 4 thermal station plant and gathering operation parameters.

Task4: Using ETAP program for simulation.

1.5 Thesis Lay-out:

The project contains five chapters:

Chapter II: It‘s about the types of power station and the equipment of thermal power plant and the points should be considered while selecting site for a thermal 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: will discuss protection system in general way, and we will illustrate the generator protection schemes used in Garri4 power station , with implementation of ETAP will provide the setting calculation used in protection scheme in the generator.

Chapter V: provides the recommendation and conclusion.

CHAPTER TOW

THERMAL 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 emphasized 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 Ranking 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 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 utilizing the heat of coal combustion. The heat of combustion of coal in the boiler is utilized 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.

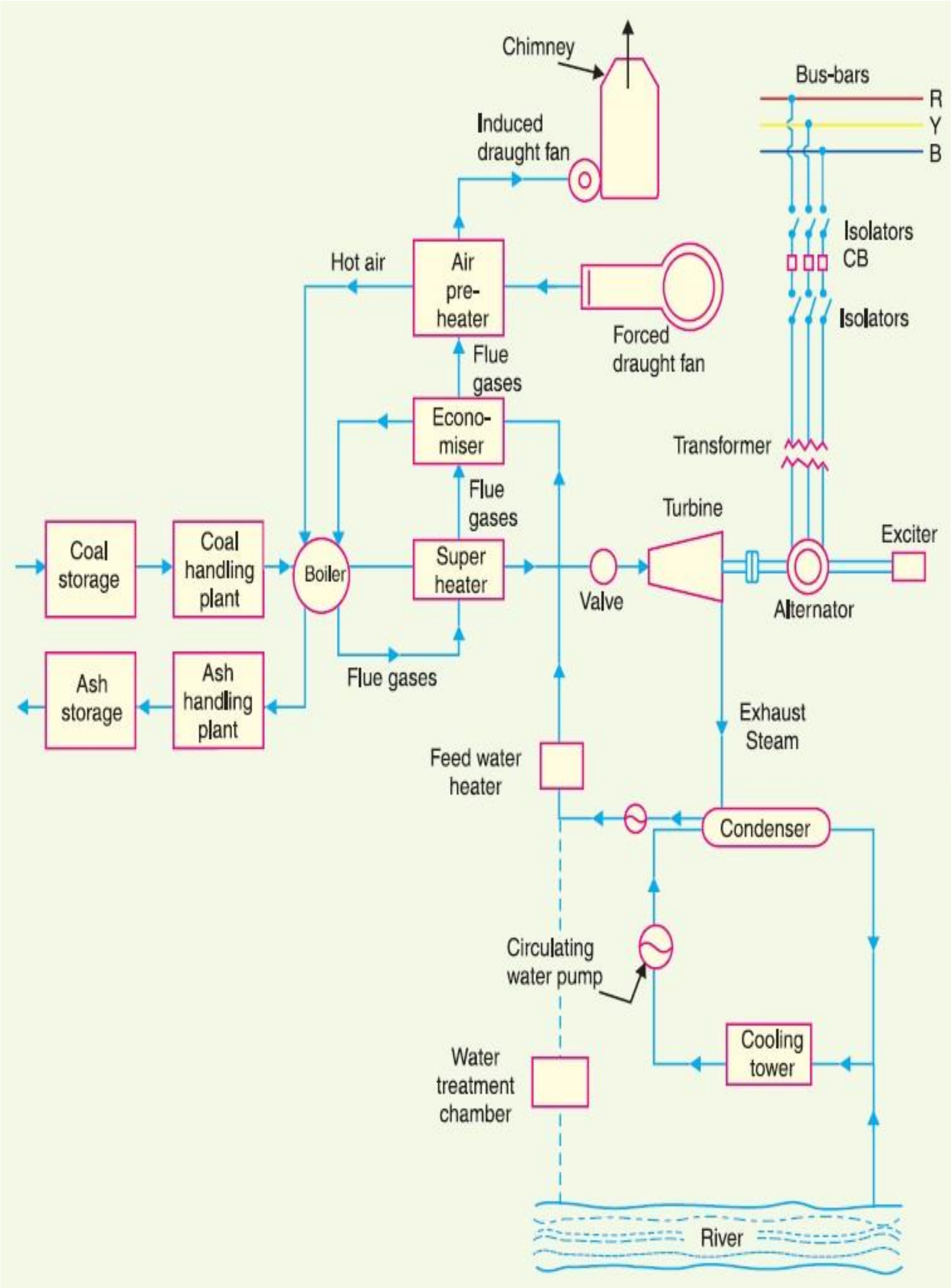


Figure 2.1: schematic arrangement of Steam Power Station

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 :

- **(a)** Plain refractory walls
- **(b)** Hollow refractory walls with an arrangement for air cooling
- **(c)** 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 of 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, dis advantages 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
- Reactions 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.,

(a) main step-up transformers which step-up the generation voltage for transmission of power.

(b) station transformers which are used for general service (e.g., lighting) in the power station.

(c) 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.

2.3.1 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.

2.3.7 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

PROTICTION 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 dam age 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 ill 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 devi ce a nd its application

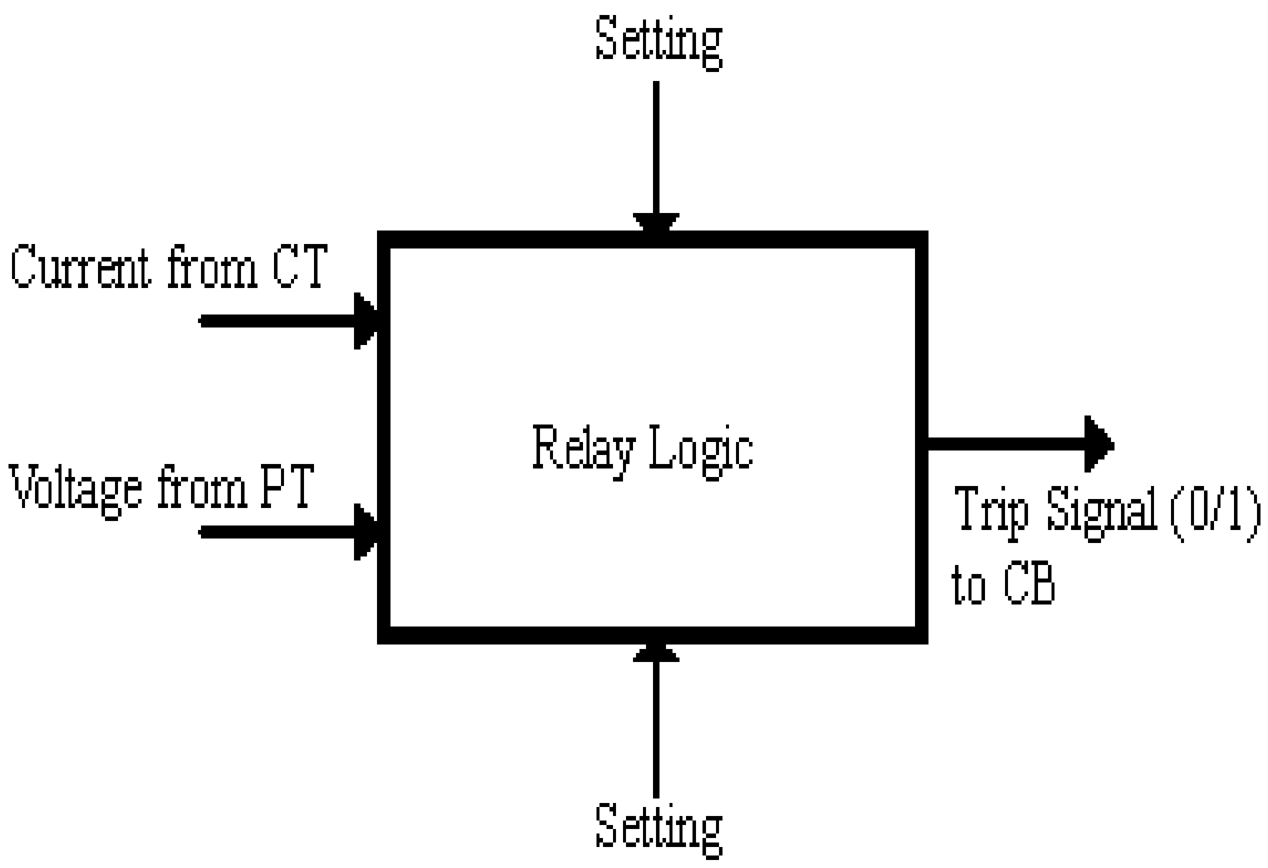


Figure 3. 1. show relay device

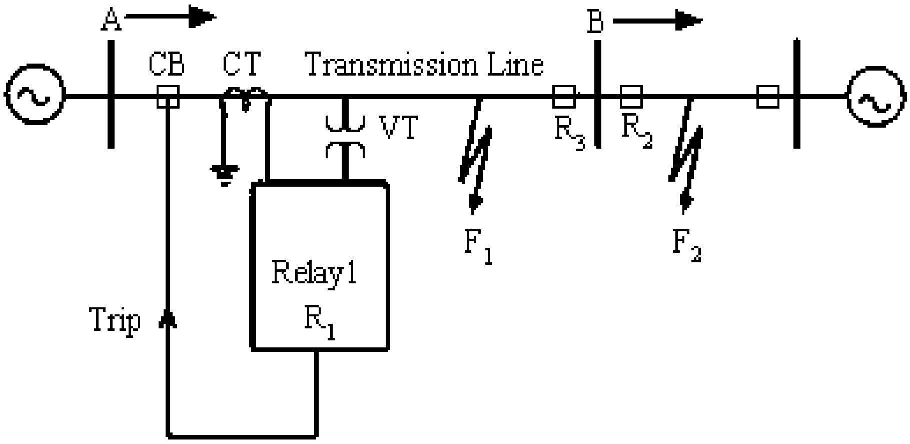


Figure 3. 2 shows relay application

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

It have a lots of advantages such as :

- 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.

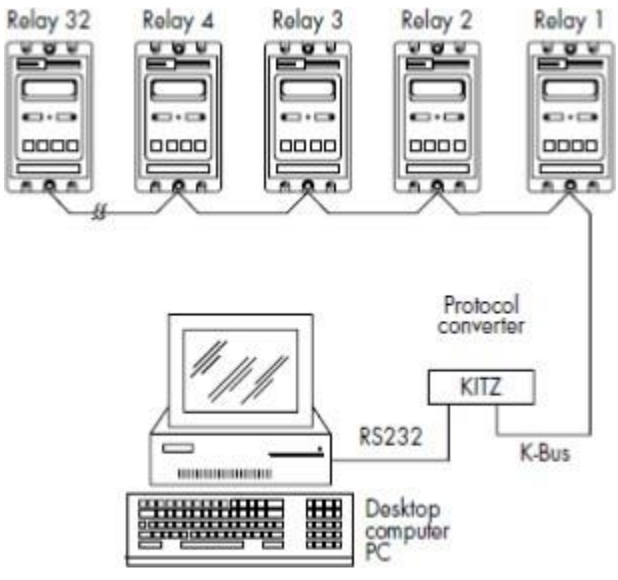


Figure 3.3 serial communication

- 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.

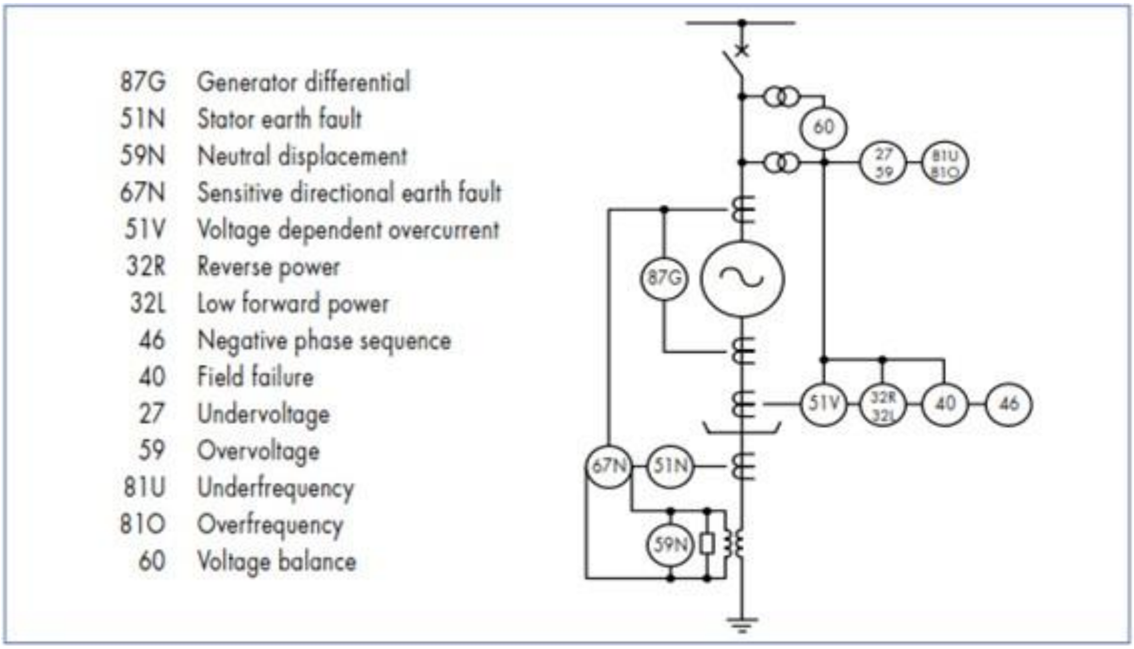


Figure 3.5 : generator protection type

- 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 shorts-circuit currants, 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 resister. 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 than 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 currants 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 same 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 to rotates in opposite direction of the main field and induces e.m.f.‘s. in rotor winding. Thus the unbalances 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 currant 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 is 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 over- heating of the stream 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.

Table (3.1) Some abnormal conditions and protection system

S.NO	Abnormal condition	Effect	Protection
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

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

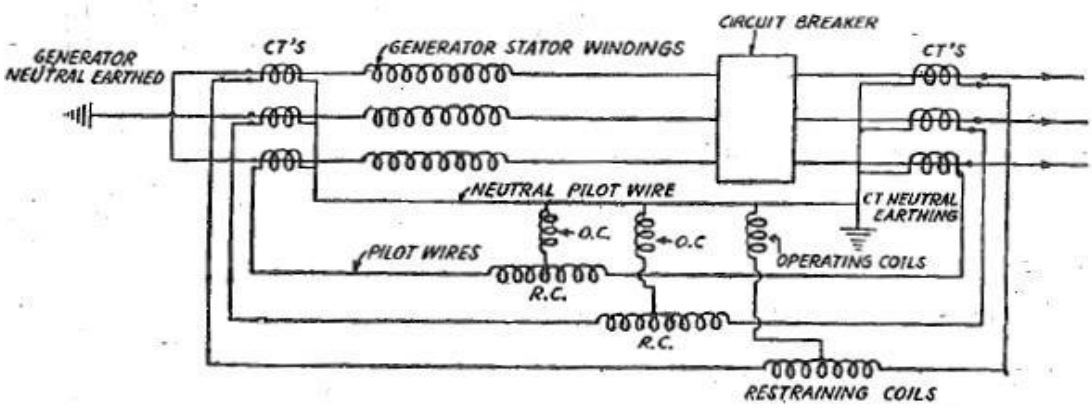


Figure 3.6: Percentage differential relaying of a star connected generator, For phase-phase faults.

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.

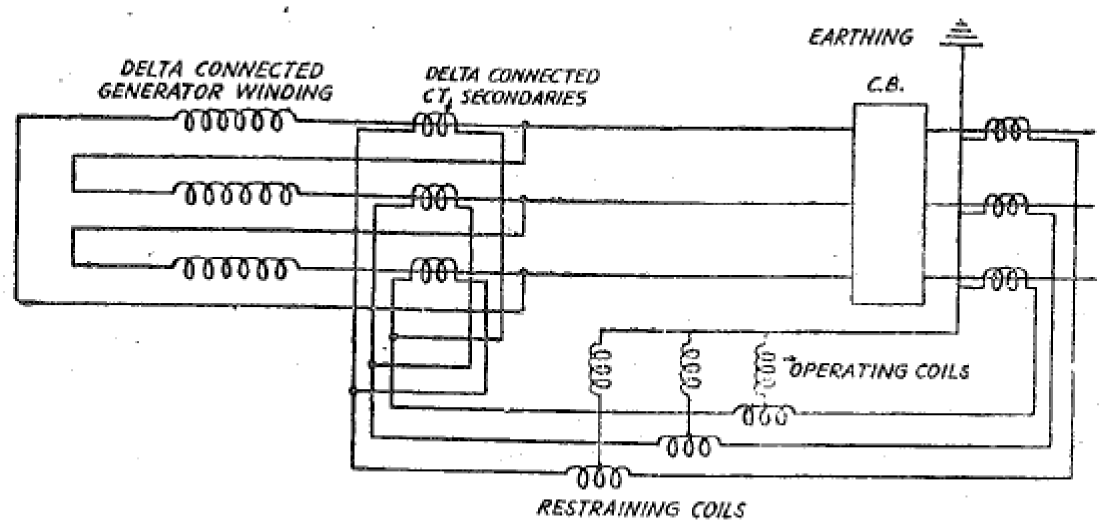


Figure 3.7: Percentage differential relay of a delta connected generator, for phase-phase fault.

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.

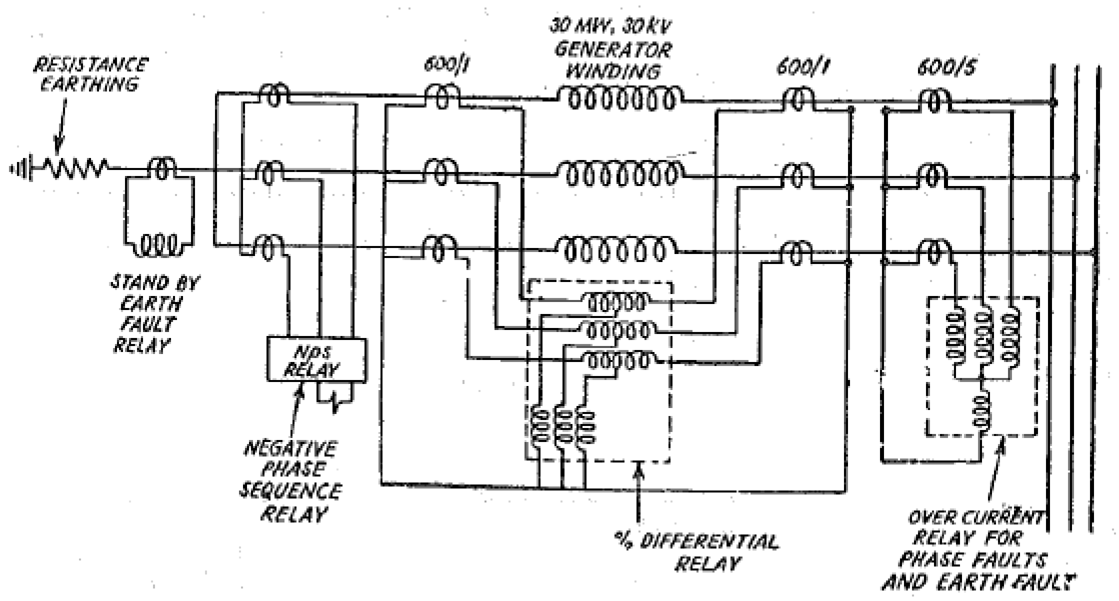


Figure 3.8: Protection of a direct connected generator

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 defferential 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 ratting 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 additional to differential

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

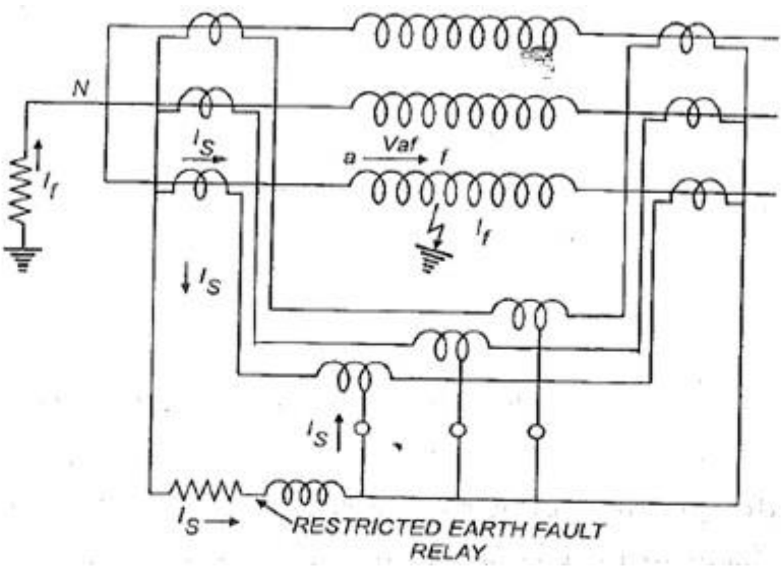


Figure 3.9: Percentage differential with protection Restricted earth fault relay

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 $V_{\alpha f}$ 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 $V_{\alpha f}$ 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.

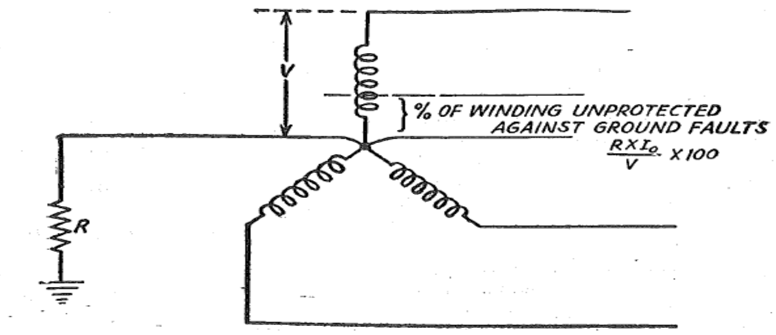


Figure 3.10: Percentage of unprotected winding against phase to ground fault

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.

% of winding unprotected = (R x I_0 x

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).

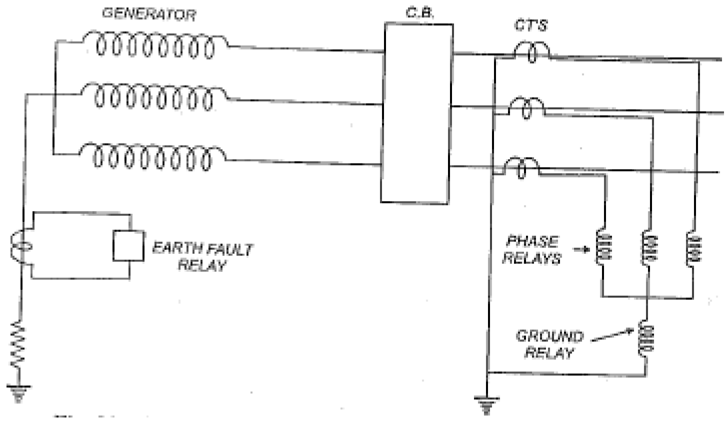
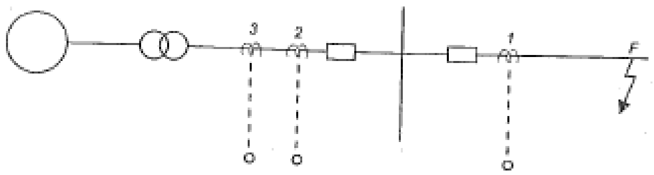


Figure 3.11: Back-up protection by overcurrent protection



Sequence of

operation=1,2,3 1- Line protection. 2-Bus bar

protection.

1- 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).

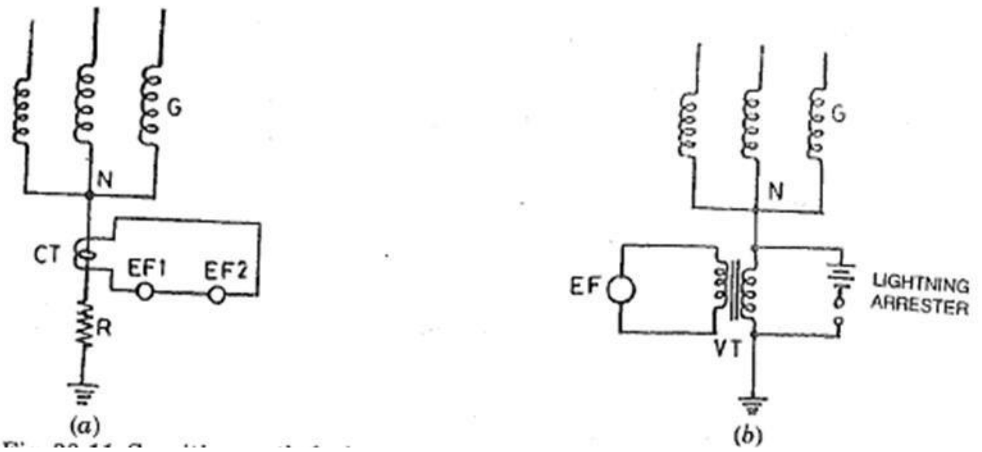


Figure 3.13: sensitive earth-fault protection of generator-transformer unit.

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)).

(a) 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).

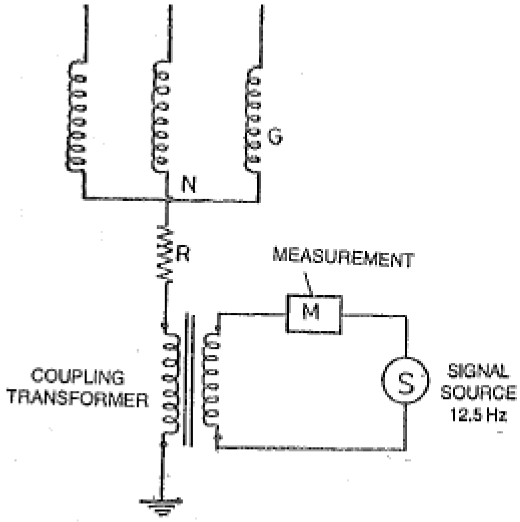


Figure 3.14: 100% Stator earth fault protection by signals through neutral.

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.,

$$V_{RES}=V_{RN}+V_{YN}+V_{BN}=0 \quad (3.1)$$

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

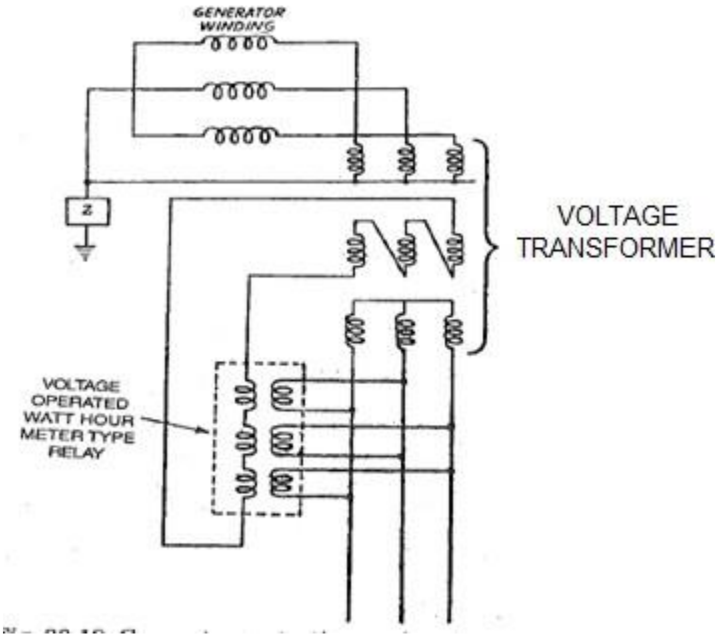


Figure 3.15: Generator protection against inter-turn faults by residual voltage direction.

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

$$V_{RES} = V_{RN} + V_{YN} + V_{BN}\,0 \qquad (3.2)$$

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.

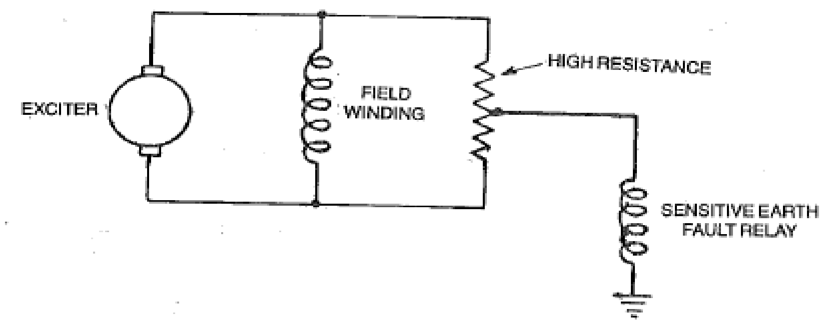


Figure 3.16: Schematic diagram of rotor e.f. protection

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 (which gives a measure of rotor temperature).

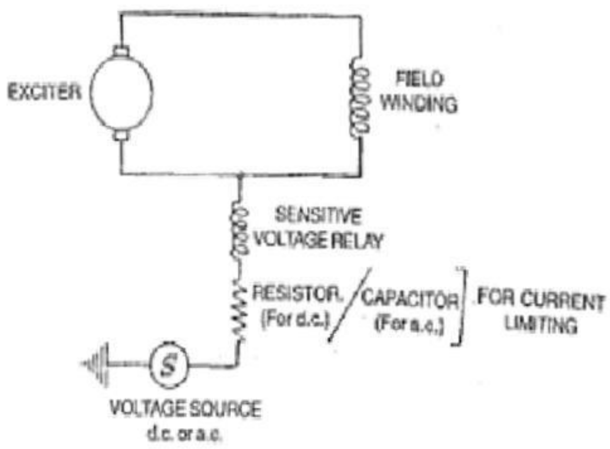


Figure 3.17:principle of d.c/a.c injection Earth fault protection

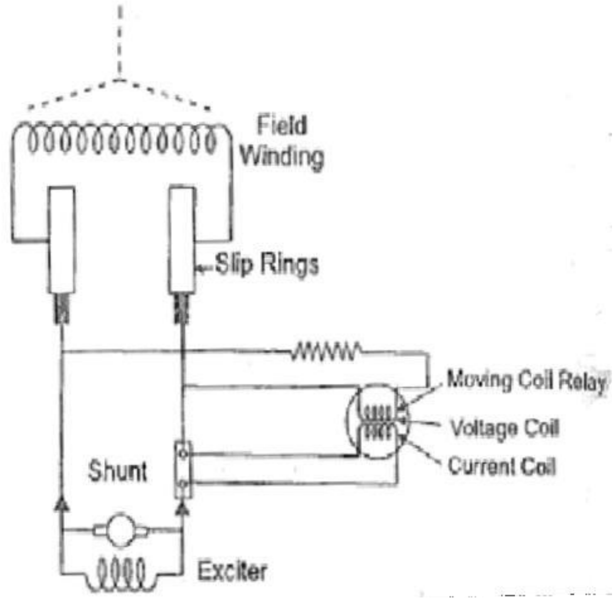


Figure 3.18. Rotor temperature protection by measuring V/I.

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)$_i$ i.e.,

$$\%S = \frac{I_2}{I_n} \times 100 \qquad \text{———————}(3.3)$$

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 would 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)).

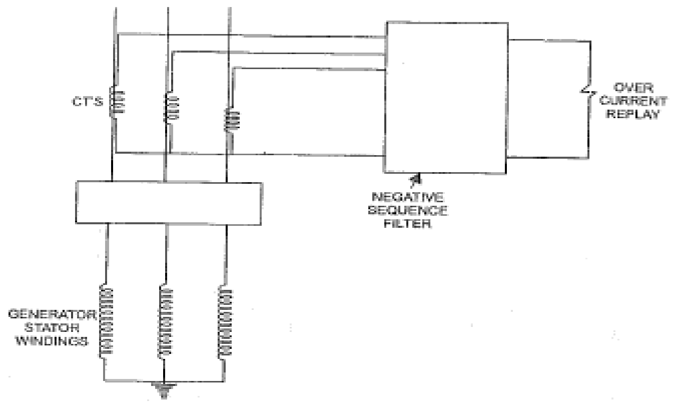


Figure3.19(a): Protection against unbalanced load using negative sequence filter.

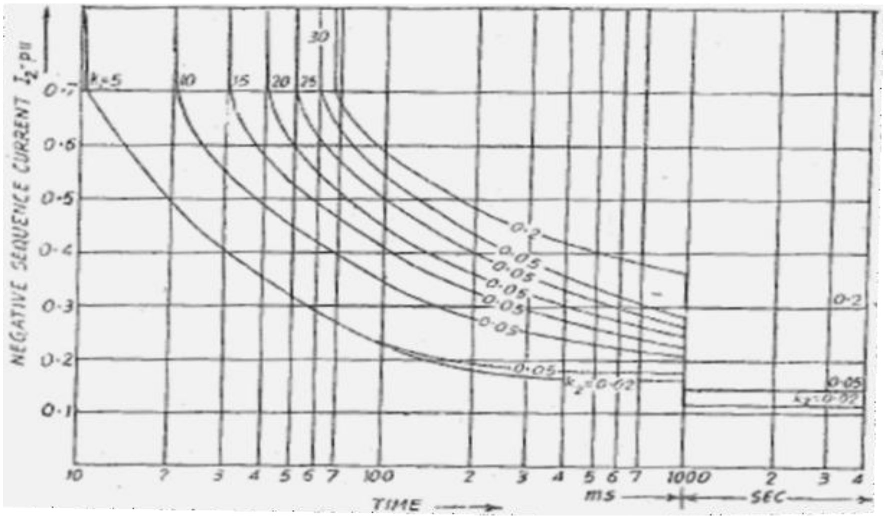


Figure 3.19: (b) Current time characteristics of a static negative phase sequence relay.

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 $I^{2}{}_{2t}$ 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

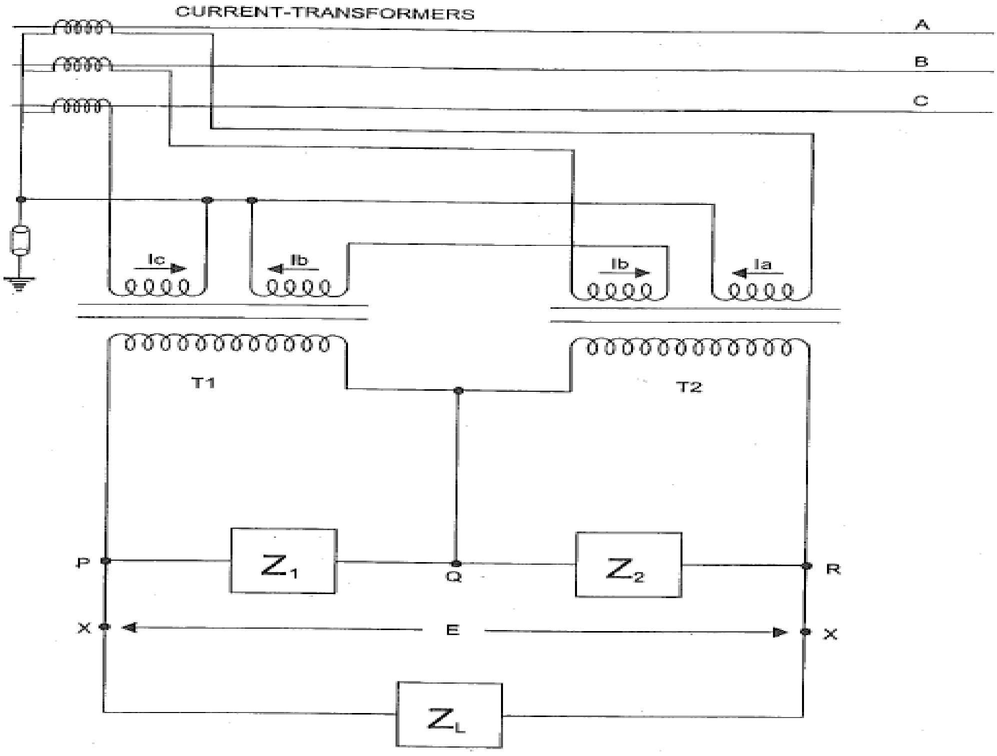


Figure 3.20: Circuit showing principle of negative phase-sequence circuit.

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 - l_c) and that through

T_2 will be (I_a- l_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.

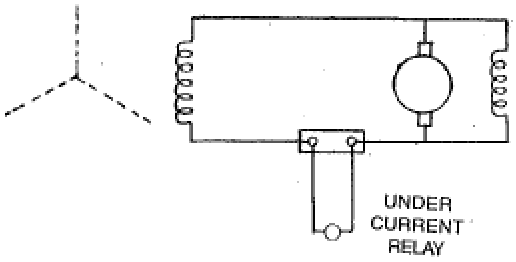


Figure 3.21: Loss of field protection.

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.

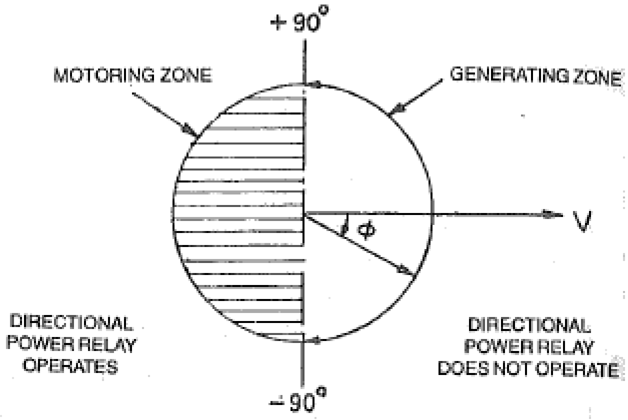


Figure 3.22: Operating characteristic of reverse power protection

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 en tire 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 value 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.

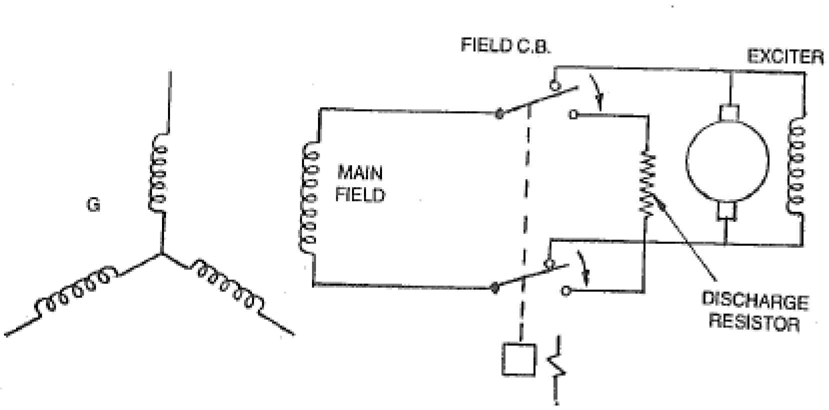


Figure 3.23: Principle of field suppression (The energy in main field is discharged Through resistor by C.B. on to the discharge resistor).

CHAPTER FOUR

GARRI4 STATION OVERVIEW AND ETAP SIMULATION

4.1 Introduction

It is imperative need to install some protective system to protect the expensive elements of modern power system such as generators, transformers, station bus-bar, and transmission lines etc. from different types of faults witch are likely to occur sooner or later. In generating station as a continuous operation of generators is much more necessary so the fault part has to be cleared very quickly for uninterruptable power supply. Unlike other apparatus, opening a breaker to isolate the faulty generator is not sufficient to prevent further damage. The basic electrical quantities those are likely to change during abnormal fault conditions are current, voltage, phase angle and frequency. Protective elements utilizes one or more of these quantities to detect abnormal conditions in a power system for taking further essential steps to isolate the faulty equipment to keep the healthy part in normal working condition.

A modern generating unit is a complex system comprising the generator stator winding, associated transformer and unit transformer that shown in figure 10 (if present), the rotor with its field winding and excitation system, and the prime mover with its associated auxiliaries. Faults of many kinds can occur within this system for which diverse forms of electrical and mechanical protection are required. The amount of protection applied will be governed by economic considerations, taking into account the value of the machine, and the value of its output to the plant owner. Garri thermal power station consist of three planets; Garri one, Garri two and Garri four. Garri one and two are coupled together. Planet one consist of four Gas Turbines Generator (GTG) which capable rating each with an installed capacity of 10.5kV, 38 MW, 50Hz and two Steam Turbines Generator (STG) which capable rating each with an installed capacity of 10.5kV, 36MW, 50Hz. The study carried out planet four which consist of two Steam Turbines Generator (STG) which capable rating with an installed capacity of 11Kv, 60MW, 50Hz. Figure 4.1 represents generator-transformer unit at the plant.

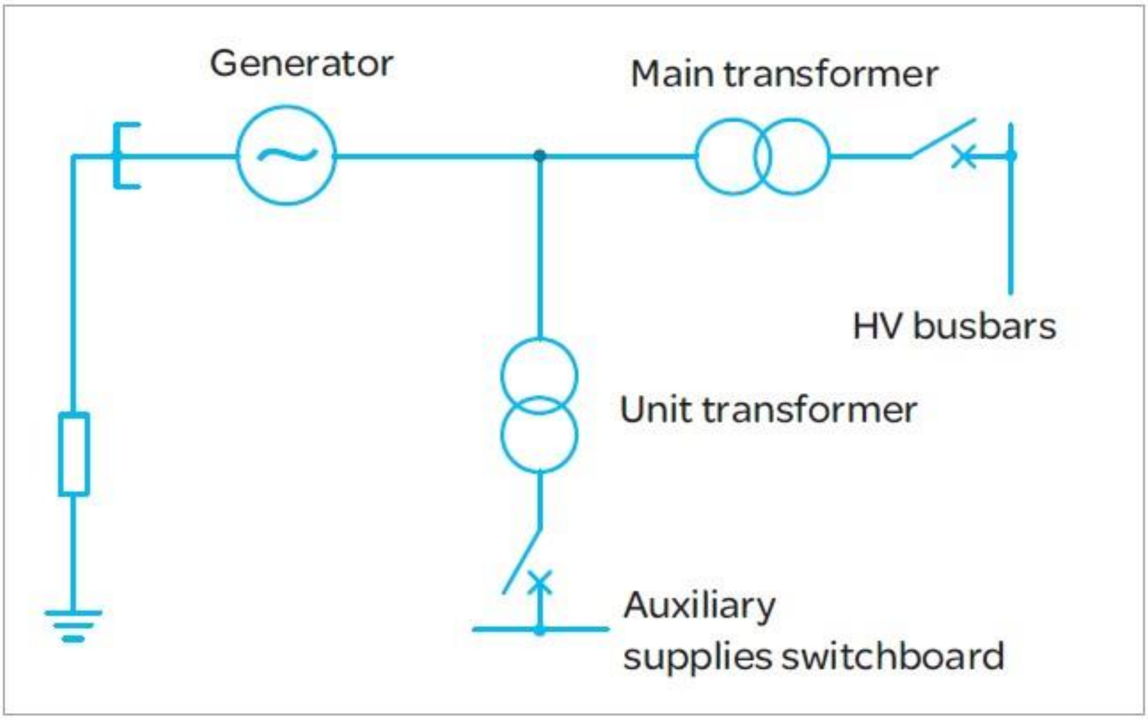


Figure 4.1 Generator-Transformer Unit

4.2 Garri-4 Power Plant Generator:

Garri-4 power plant adopts QF-60-2 type turbo-generator manufactured by Shanghai Turbo-Generator Co., Ltd. With the rated voltage of 11kV, the generator is driven by direct-coupled steam turbine, and is cooled by the enclosed circulating cooling air. The generator is of brushless excitation (by coaxial brushless exciter and permanent magnetism pilot exciter). The voltage of generator is adjusted by micro-computer WLZ-4DW automatic exciting regulator produced by the Hebei Industry University Electrical Factory in China. From the view of steam turbine, the rotating direction of the QF-60-2, 60MW synchronous generator is in clockwise rotation.

4.2.1 Specifications of QF-60-2 Type Turbo-Generator for Garri-4 Power Plant

Generator rating : 60MW, 50HZ, 70.6MVA, 11KV, 370A , 0.85 PF , X'_d =18%,

X_d=166% , X_e=10.7% , CT (5000/1 A) , VT(11/0.11 KV) Type of generator (QF-60-2)

4.3 Generator protection scheme

In the following sections, we consider some prominent abnormal operating conditions shown in figure 4.2 that need to be carefully considered while providing protection to the generator.

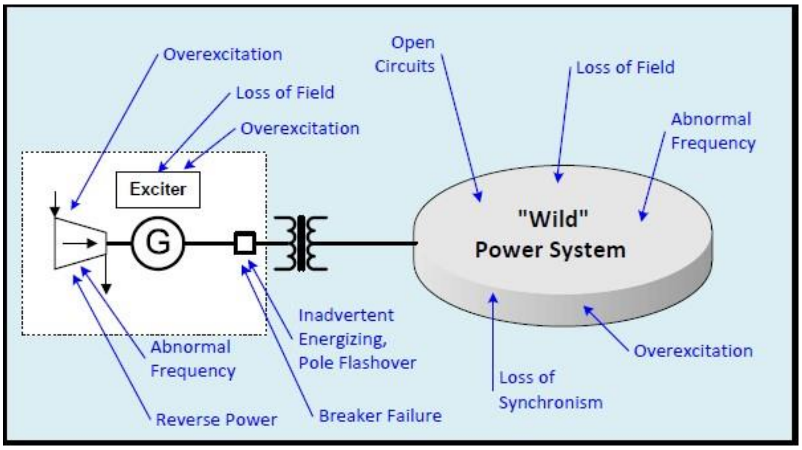


Figure 4.2 Abnormal operation condition

4.4.1 Overvoltage

Over voltage event occurs when the power system loses the load or when the generator is feeding a very small load.

With health voltage regulator (AVR), over voltage should not happened, but it may be caused by the following contingencies:

- Defective operation of the automatic voltage regulator when the machine is in isolated operation.
- Operation under manual control with the voltage regulator out of service. A sudden variation of the load, in particular the reactive power component, will give rise to a substantial change in voltage because of the large voltage regulation inherent in a typical alternator.
- Sudden loss of load (due to tripping of outgoing feeders, leaving the set isolated or feeding a very small load) may cause a sudden rise in terminal voltage due to the trapped field flux and/or over speed.

For these reasons, it is prudent to provide power frequency overvoltage protection, in the form of a time-delayed element, either IDMT or definite time. The time delay should be long enough to prevent operation during normal regulator action, and therefore should take account of the type of AVR fitted and its transient response.

- Setting calculation:

V>1 Voltage Set = 1.15 x 110 = 126.5 V =126 V

V>1 TMS = (1.2 –1) x 2 = 0.4 =0.4 (IDMT)

V>2 Voltage Set = 1.5 x 110 = 165 V

V>2 Time delay = 0.1s =0.1 s

4.4.2 Undervoltage Protection

Undervoltage protection is rarely fitted to generators. It is sometimes used as an interlock element for another protection function or scheme, such as field failure protection or inadvertent energization protection, where the abnormality to be detected leads directly or indirectly to an undervoltage condition. However, it should be addressed by the deployment of ’system protection’ schemes. The generation should not be tripped. The greatest case for undervoltage protection being required would be for a generator supplying an isolated power system or to meet Utility demands for connection of embedded generation In the case of generators feeding an isolated system, undervoltage may occur for several reasons, typically overloading or failure of the AVR. In some cases, the performance of generator auxiliary plant fed via a unit transformer from the generator terminals could be adversely affected by prolonged undervoltage. Where undervoltage protection is required, it should comprise an undervoltage element and an associated time delay.

- Setting calculation:

V<1 Voltage Set = 0.8 x 110 = 88 =88

V<1 TMS = 3 s =3 s (for alarm)

V<2 Voltage Set = 0.7 x 110 = 77 V =77 V

V<2 Time delay = 2 s =2 s

4.4.3 Reverse Power Protection

Protection against revers power is provided for some generators to protect the prime mover Parts which may not be designed to experience reverse torque or they may become damaged through continued rotation after the prime mover has suffered some form of failure. The reverse power protection should be provided with a definite time delay on operation to prevent spurious operation with transient power swings that may arise following synchronization or in the event of a power transmission system disturbance table 4.1 represent the generator reverse power problems.

Table 4.1: Generator reverse power problems

Prime Mover	Motoring Power (% of rated)	Possible Damage	Protection Setting
Diesel Engine	5 - 25	Fire/explosion due to unburned fuel	50% of motoring power
		Mechanical damage to gearbox/shafts	
Gas Turbine	10-15 (split shaft)	gearbox damage	
	> 50% (single shaft)		
Hydro	0.2-2 (blades out of water)	blade and runner cavitation	
	> 2 (blades in water)		
Steam Turbine	0.5 - 6	turbine blade damage	
		gearbox damage on geared sets	

- Setting calculation

Max motoring power for prime mover (IEEE std 242):

For steam turbine 3%

P_{1st} = Generator rating = <u>60 MW</u>

P_{2nd} = Generator rating / (CT Ratio x VT Ratio)

= (60 x 10^6) / (5000 x 100) = <u>120 W</u>

P>1 = 50% x 30% x P_{2nd}

= 0.5 x 0.3 x 120 = <u>1.8 W</u>

Time Delay = <u>8 Sec</u>

4.4.4 Unbalanced Loading

A three-phase balanced load produces a reaction field that, to a first approximation, is constant and rotates synchronously with the rotor field system. Any unbalanced condition can be resolved into positive, negative and zero sequence components. The positive sequence component is similar to the normal balanced load. The zero sequence components produce no main armature reaction.

- Effect of Negative Sequence Current

The resulting reaction field of the negative sequence rotates in the opposite direction to the D.Sc. field system. Hence, a flux is produced which cuts the rotor at twice the rotational velocity, thereby inducing double frequency currents in the field system and in the rotor body. The resulting eddy-currents are very large and cause severe heating of the rotor.

- Setting calculation:

FLC = 60 x 1000 / (√3 x 11 x 0.85) = <u>3704 .92 A</u>

I2therm>1 Set = 0.6 x 0.1 x 3704.92 x (1/5000) = <u>0.0444 A</u>

I2therm>1 Delay = 2s ∴2 s (for alarm)

I2therm>2 Set = 0.7 x 0.1 x 3704.92 x (1/5000) = <u>0.051 A</u>

I2therm>2 K = 15

I2therm>t_{max} =15 / 0.1^2 = <u>1500s</u>

I2therm>t_{min} = <u>5s</u>

4.4.5 Under/Overfrequency and Overfluxing Protection

These conditions are grouped together because these problems often occur due to a departure from synchronous speed.

- Underfrequency

Underfrequency may occur as a result of overload of generators operating on an isolated system, or a serious fault on the power system that results in a deficit of generation compared to load. This may occur if a grid system suffers a major fault on transmission lines linking two parts of the system, and the system then splits into two. Prime movers may have to be protected against excessively low frequency by tripping of the generators concerned. An under frequency condition, at nominal voltage, may result in some over fluxing of a generator and its associated electrical plant. The more critical considerations would be in relation to blade stresses being incurred with high-speed turbine generators; especially steam-driven sets. When not running at nominal frequency, abnormal blade resonance's can be set up that, if prolonged, could lead to turbine disc component fractures.

- Overfrequency:

Over frequency running of a generator arises when the mechanical power input to the alternator is in excess of the electrical load and mechanical losses. The most common occurrence of over frequency is after substantial loss of load. Over frequency protection may be required as a back-up protection function to cater for governor or throttle control failure following loss of load or during unsynchronized running. Moderate overfrequency operation of a generator is not as potentially threatening to the generator and other electrical plant as underfrequency running.

- Setting calculation:

Under/Over frequency protection should be set as per Off-frequency turbine limit but general typical data are considered in this report also these values can be changed as follow customer requirement.

- Under frequency protection

- IEEE standards:

F<1 Setting = 48.0 Hz

Time Delay = 10 s

F<2 Setting = 47.0 Hz

Time Delay = 3 s

F<3 Setting = 46.0 Hz

Time Delay = 2 s

F<4 Setting = 45.5 Hz

Time Delay = 0.1 s

- Over frequency protection

F<1 Setting = 52.0 Hz

Time Delay = 5 s

F<2 Setting = 53.0 Hz

Time Delay = 1s

- Overfluxing

Overfluxing is most likely to occur during machine start up or shut down whilst the generator is not connected to the system. Failures in the automatic control of the excitation system, or errors in the manual control of the machine field circuit, could allow excessive voltage to be generated. Overfluxing occurs when the ratio of voltage to frequency is too high. The iron saturates owing to the high flux density and results in stray flux occurring in components not designed to carry it. Overheating can then occur, resulting in damage. The problem affects both direct-and indirectly-connected generators. Either excessive voltage, or low frequency, or a combination of both can result in overfluxing, a voltage to frequency ratio in excess of 1.05p.u. , normally being indicative of this condition. Excessive flux can arise transiently, which is not a problem for the generator. For example, a generator can be subjected to a transiently high power frequency voltage, at nominal frequency, immediately after full load rejection.

- Setting calculation:

1p.u V/Hz setting = 11000 x 110/11000 / 50Hz= 2.2 V/Hz

V/Hz Alm Set = 2.2 V/Hz x 1.1 = 2.42 V/Hz

Time Delay = 0.5s (for alarm)

V/Hz> 1 set =2.2 x1.1 =2.42 V/HZ

Time Delay =45 Sec

V/HZ > 2 Set = 2.2 X1.15 = 2.53 V/HZ

Time Delay =6 Sec

V/HZ >3 Set =2.2 X 1.2 = 2.64 V/HZ

Time Delay =2 Sec

V/HZ > 4 Set = 2.2 X 1.25 =2.75 V/HZ

Time Delay =1 Sec

4.4.6 Loss of Excitation Protection

A loss of field (LOF) occurs when excitation to the generator field winding fails. This may be a result of equipment failure, inadvertent opening of the field breaker, an open or short circuit in the excitation system, or slip ring flashover. Whatever the cause, this condition poses a threat to the generator and to the power system. The DC current input to the field winding excites the rotor magnetic circuit to establish rotor flux. This flux generates an internal voltage in synchronism with and opposed to the system voltage. When excitation is lost, the rotor current decays at a rate determined by the field circuit time constant. The internal generator voltage will decay at the same rate. If the generator is initially supplying Vars to the power system, the Var output will decrease through zero as the generator draws increasing reactive from the power system to replace excitation formerly provided by the field circuit. Var consumption can exceed the generator MVA rating. The reduction of internal voltage also weakens the magnetic coupling between the rotor and stator. At some point during the decay, the coupling will become too weak to transmit prime mover output power to the electrical system and the generator will lose synchronism.

This is similar to the loss of steady-state stability, to visualize the loss of synchronism following a LOF event; we refer to the power angle equation:

$$Pe = \frac{Eg\,Es}{XT} \sin \delta \qquad (4.1)$$

- Setting calculation:

Z_b = (Base kV2 / Base MVA) x (CT Ratio / VT Ration) =

($11^{\wedge 2}$/ 70.6) x (5000 / 100) = 85.6 Ω

Xd = X′d (Pu) x Zb=0.18 X85.6 =15.408 Ω

Xd Ω =1.66 X 85.6 =142.096 Ω

- Impedance element 1

Ffail -X_{a1} =0.5 X_d =0.5 X 15.408 =7.7 Ω

Ffail- X_{b1} =X_d = 142.96

Ffail Time Delay = 0.5 Sec

- Impedance element

Ffail - X_{a2} =0.5 X'_d =0.5 x 15.408 =7.7 Ω

Ffail - X_{b2} = KV^2 /MVA =85.6 Ω

Ffail Time Delay = 0 Se

4.4.7 Generator Differential Protection

The circulating current differential protection operates on the principle that any current entering and leaving a zone of protection will be equal. Any difference between these currents is indicative of a fault being present in the zone. Figure 4.3 represent the principle of circulating current differential protection.

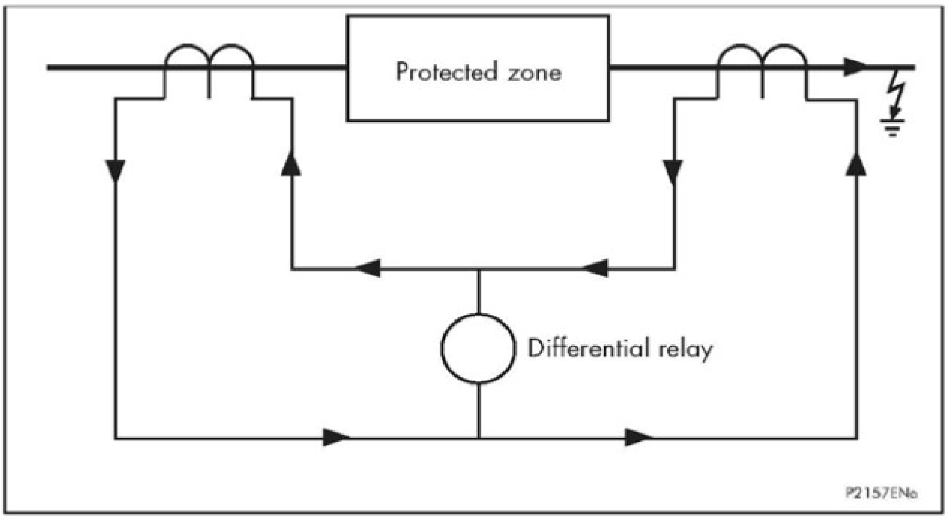


Figure 4.3 Principle of circulating current differential protection

It can be seen that current flowing through the zone of protection will cause current to circulate around the secondary wiring. If the CTs are of the same ratio and have identical magnetizing characteristics they will produce identical secondary currents and hence zero current will flow through the relay. If a fault exists within the zone of protection there will be a difference between the outputs from each CT; this difference flowing through the relay causing it to operate. The calculation is performed on a per phase basis. The differential current is the vector sum of the phase currents measured at either end of the generator. The mean bias current (Ibias) is the scalar mean of the magnitude of these currents.

- Setting calculation:

FLC = 60 x 1000 / (√3 x 11 x 0.85) = 3704.92A

Gen Diff Is1 = 0.1 x 3704.92 x (1/5000) = 0.07 A = 0.1 A

Gen Diff Is2 = 1.2 x 3704.92 x (1/5000) = 0.89 A = 0.9 A

Gen Diff k1 = 10% (IEEE Std. 242 recommendation) = 10 %

Gen Diff k1 = 150% (Manufacture recommendation) = 150%

4.4.8 Stator earth fault protection

Earth fault protection must be applied where impedance earthing is employed that limits the earth fault current to less than the pick-up threshold of the overcurrent and/or differential protection for a fault located down to the bottom 5% of the stator winding from the star-point. The type of protection required will depend on the method of earthing and connection of the generator to the power system.

- Setting calculation:

The maximum generator neutral transformer secondary voltage;

$Vmax$ = (11000/√3) x (0.11/6.3) V = 110.887 V

For 95% protection of the windings, the relay should be set as follows;

IN1>1 Current = 0.05 x (110.887/0.191) x (1/1000) A = 0.029A = 0.03 A

Time Delay = 0.5s = 0.5 s

[Calculation for 100% stator earth fault protection, 3rd harmonic method] 100% St. EF

VN3H = 1% of input voltage

= 0.01 x110.887 V = 1.1088V =1.1 V

Time Delay = 1 s =1 s Existing value 1s should be considered.

4.4.9 over current protection

The system requires discriminative protection designed to disconnect the minimum amount of circuit and load that will isolate the fault. Correct over current relay application requires knowledge of the fault current that can flow in each part of the network. Since large-scale tests are normally impracticable, system analysis must be used, the relay settings are first determined to give the shortest operating times at maximum fault levels and then checked to see if operation will also be satisfactory at the minimum fault current expected thus, the relay farthest from the source has current settings equal to or less than the relays behind it

- Discrimination by current

Discrimination by current relies on the fact that the fault current varies with the position of the fault because of the difference in impedance values between the source and the fault. Hence, typically, the relays controlling the various circuit breakers are set to operate at suitably tapered values of current such that only the relay nearest to the fault trips its breaker. The figure 4.4 illustrates the method

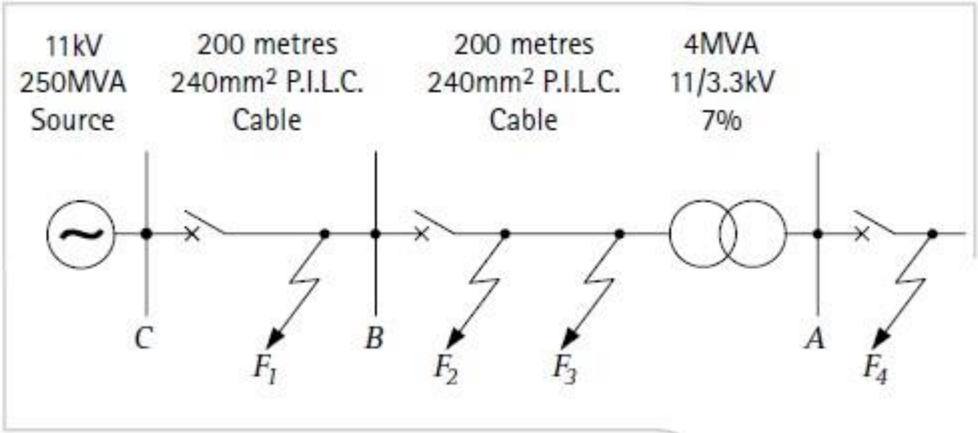


Figure 4.4 Method of Discrimination by Current

The figure illustrates that the relay at zone A trip first, then the relays at zone B, and finally the relay at zone C. it is not practical to distinguish between a fault at F1 and a fault at F2, since the distance between these points may be only a few meters, corresponding to a change in fault current of approximately 0.1%

4.5 SIMULATION AND RESULTS

Protection system was simulated by using power system software program called ETAP (Electrical Transient and Analysis Program).

ETAP power system software is the most comprehensive analysis platform for the design, simulation, operation and automation of generation, distribution and industrial power system.

ETAP offers a suite of fully integrated electrical engineering software solutions including arc flash, load flow, short circuit, transient stability, relay coordination, optimal power flow and more. Its modular functionality can be customized to fit the needs of any company, from small to large power system.

ETAP is developed under an established quality assurance program and is used worldwide as a high Impact software. ETAP is completely localized in seven languages with translated output reports in eight languages. As a fully integrated enterprise solution, ETAP Extends to a Real-Time Power Management System.

To monitor, control, automate, simulate, and optimize the operation of power systems.

4.5.1 The Single Line Diagram Simulation

The following diagram (figure 4.5.1) illustrates a single line diagram of the circuit used to simulate the generator protection system

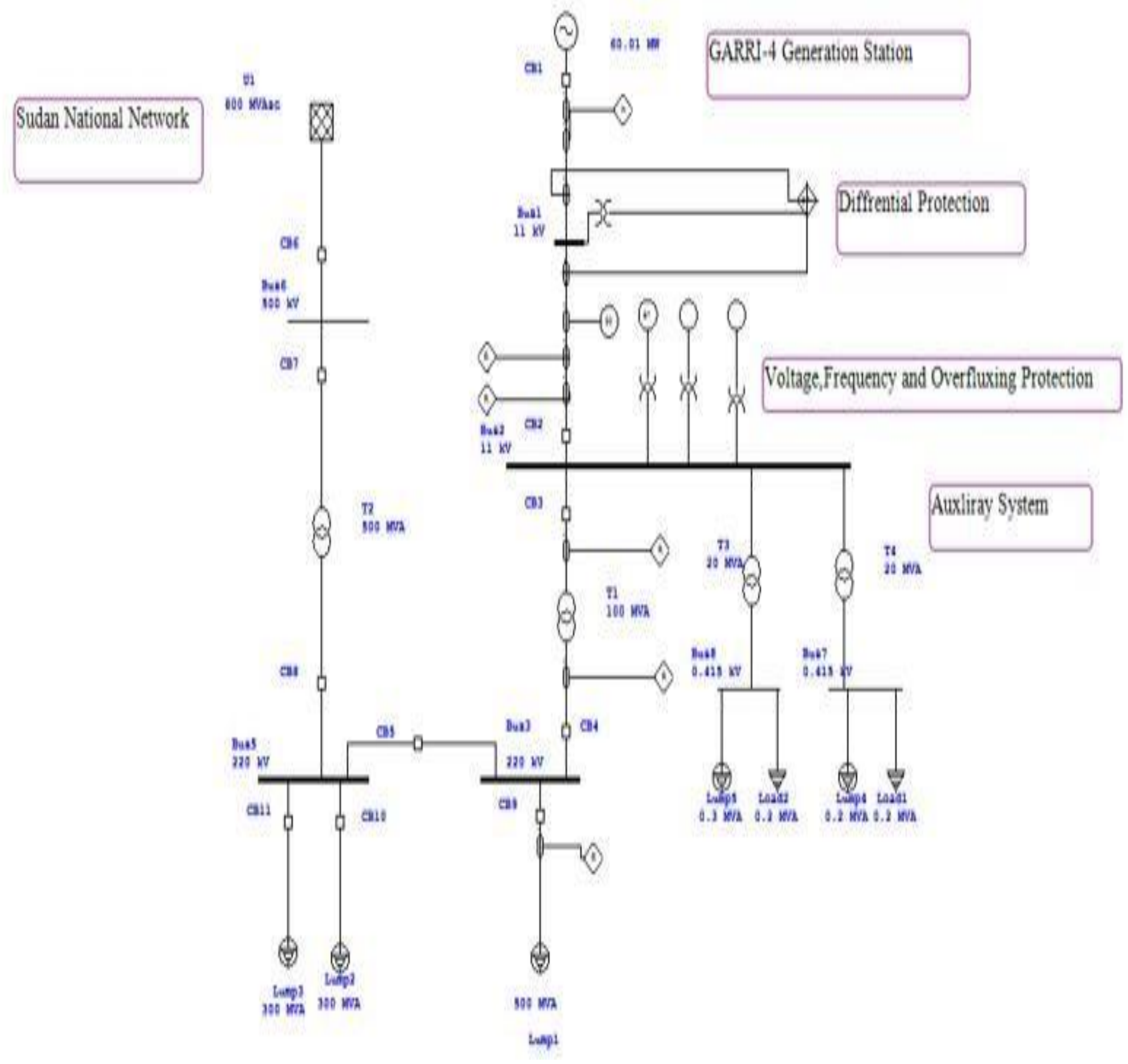


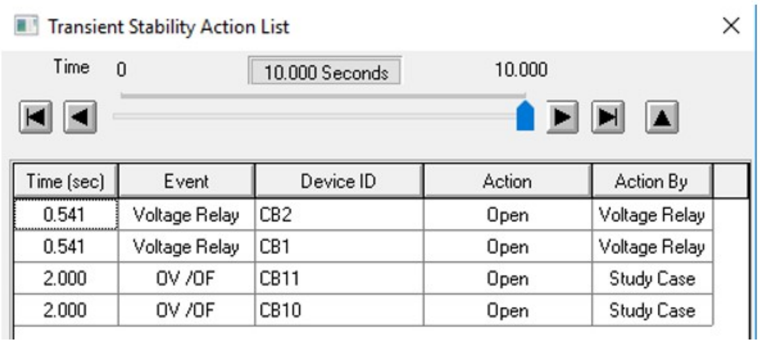
Figure 4.5.1 Single line Diagram of Simulation Circuit

4.5.2 ETAP simulation result

Result are represent as shown:

4.5.2.1 OverVoltage Protection

Figure 4.5.2 illustrates the over voltage action list.



Transient Stability Action List

Time 0 10.000 Seconds 10.000

Time (sec)	Event	Device ID	Action	Action By
0.541	Voltage Relay	CB2	Open	Voltage Relay
0.541	Voltage Relay	CB1	Open	Voltage Relay
2.000	OV /OF	CB11	Open	Study Case
2.000	OV /OF	CB10	Open	Study Case

Figure 4.5.2 Over Voltage action List

- The over voltage scenario was created by opening CB 10 and CB11 to disconnect large loads.

- Bus 1 (generator terminal) voltage reached the relay setting, hence, the voltage relay trips

Figure 4.5.3 represents over voltage (voltage vs. time) graph at bus 1.

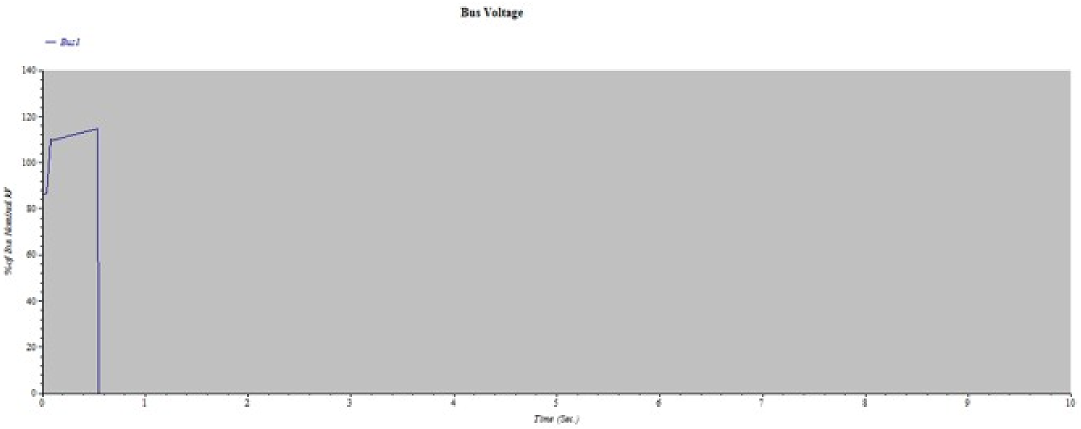
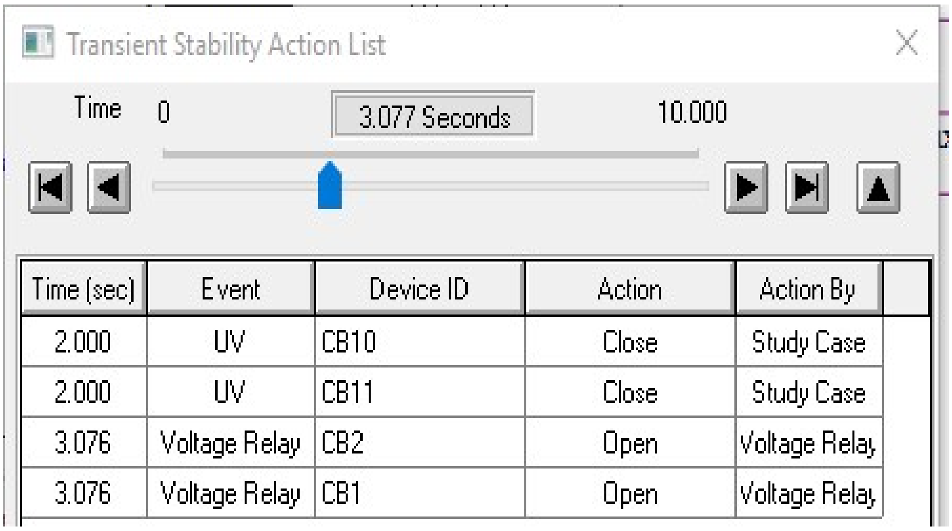


Figure 4.5.3 Over Voltage (Voltage vs. Time) Graph at Bus1

4.5.2.2 Under Voltage protection

Figure 4.5.4 represent under voltage action list.



Time (sec)	Event	Device ID	Action	Action By
2.000	UV	CB10	Close	Study Case
2.000	UV	CB11	Close	Study Case
3.076	Voltage Relay	CB2	Open	Voltage Relay
3.076	Voltage Relay	CB1	Open	Voltage Relay

Figure 4.5.4 Under Voltage Action List

- The under voltage scenario was created by closing CB 10 and CB11 to insert a large loads.
- CB 1 and CB 2 trip after detecting the under voltage fault in Bus 1 (Generator terminal).

Figure 4.5.5 represent under voltage (voltage vs. time) graph at bus1.

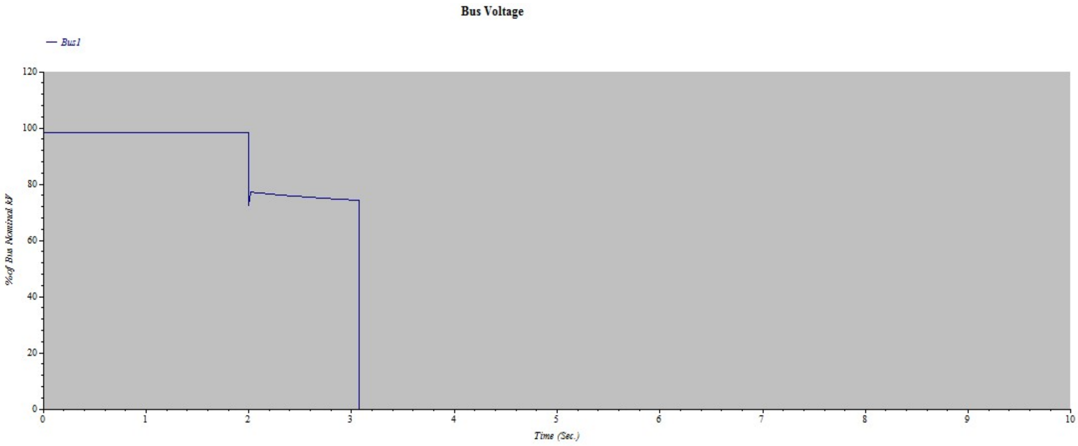


Figure 4.5.5 Under Voltage (Voltage vs. Time) Graph at Bus1

4.5.2.3 Loss of Field

Figure 4.5.6 represent loss of field (generator reactive power vs. time) graph.

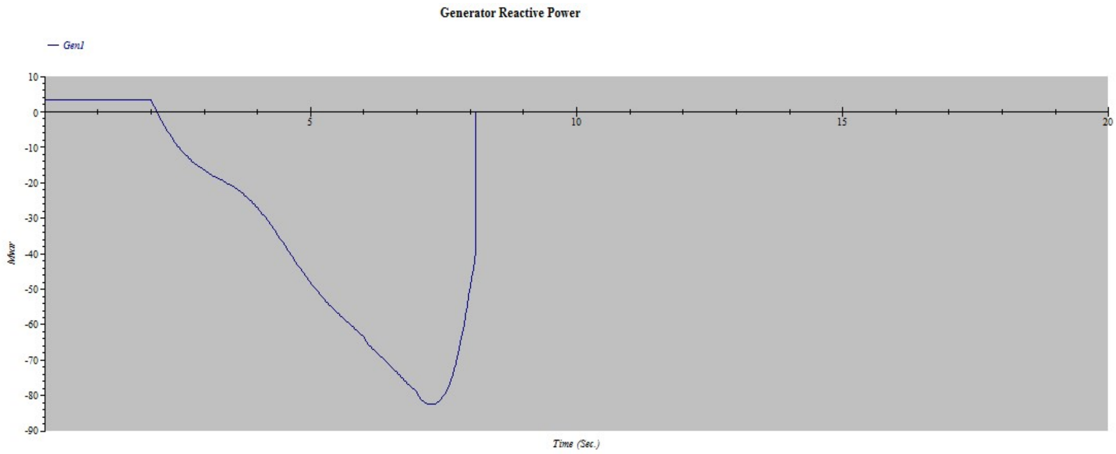


Figure 4.5.6 Loss of Field (Generator Reactive Power Vs. Time) Graph

- It is created by choosing loss of excitation option from transient stability analysis.

- The reactive power draw from the system before the condition is detected by the relay and then trip.

4.5.2.4 Reverse Power Protection

Figure 4.5.7 represent the reverse power action list.

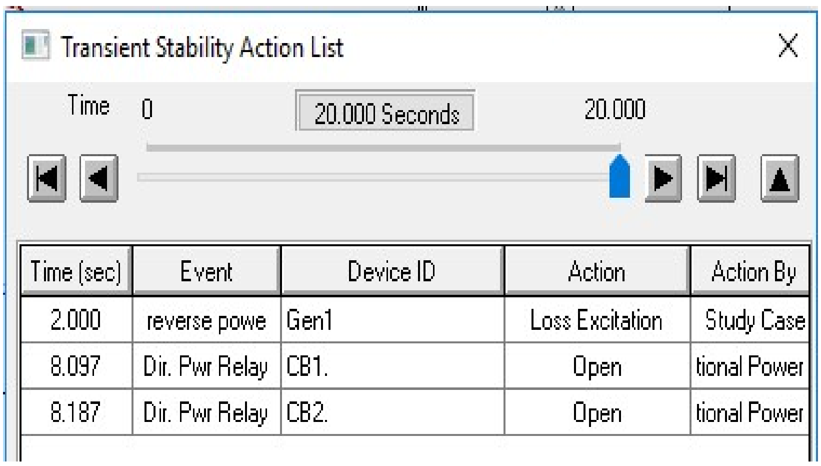


Figure 4.5.7 Reverse Power action List

- The relay waits 8 seconds then trips.

Figure 4.5.8 represent the reverse power (generator active power vs. time) graph.

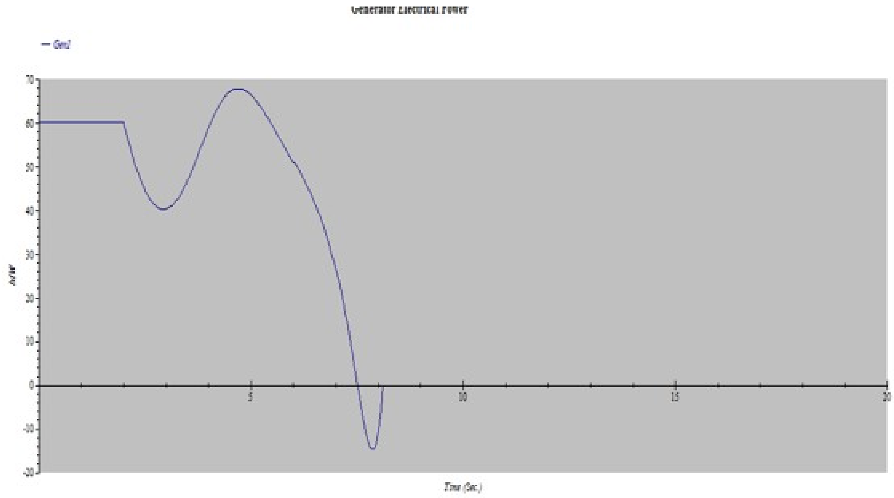


Figure 4.5.8 Reverse Power (Generator Active Power vs. Time) Graph

- It is created by choosing loss of excitation option from transient stability analysis.

- The direction of the real power reverses before the relay detects the condition.

4.5.2.5 Unbalanced Loading Protection

Figure 4.5.9 represents Protection Operation of Unbalanced Loading Fault

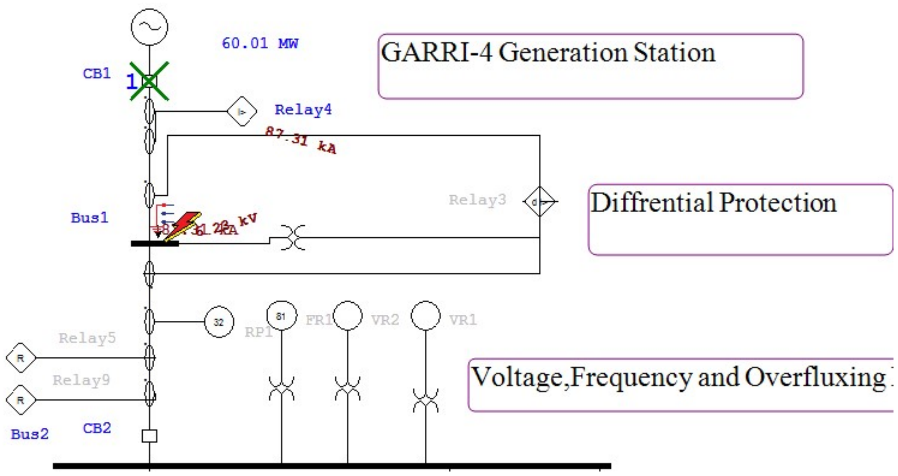
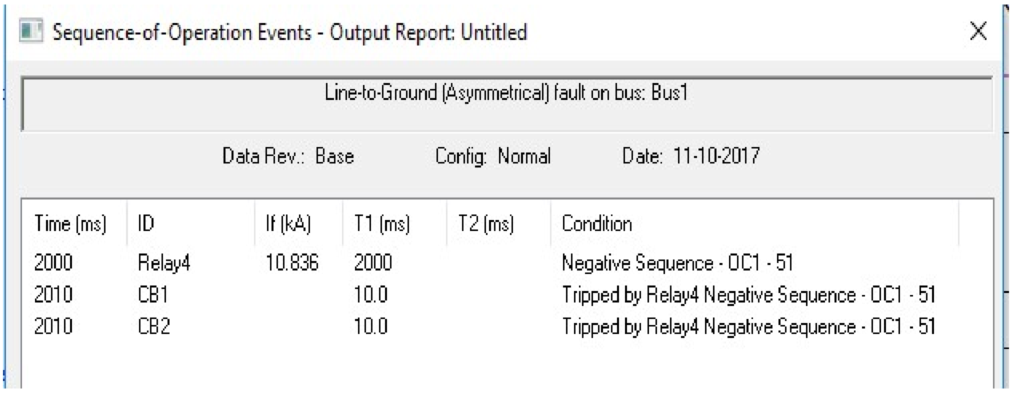


Figure 4.5.9 Protection Operation of Unbalanced Loading Fault

- In the normal condition positive sequences are applied to the system.

- Negative sequence event created by choosing line to ground fault at Bus1 since the fault occurs. Negative sequence current will appear in the system .Figure 4.5.10 Negative sequence event recorder.



Sequence-of-Operation Events - Output Report: Untitled

Line-to-Ground (Asymmetrical) fault on bus: Bus1

Data Rev.: Base   Config: Normal   Date: 11-10-2017

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
2000	Relay4	10.836	2000		Negative Sequence - OC1 - 51
2010	CB1		10.0		Tripped by Relay4 Negative Sequence - OC1 - 51
2010	CB2		10.0		Tripped by Relay4 Negative Sequence - OC1 - 51

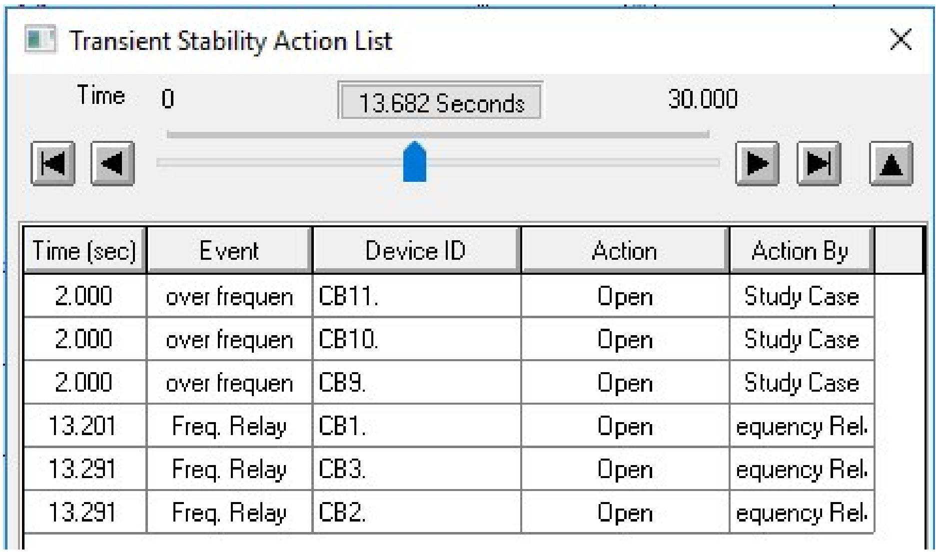
Figure 4.5.10 Negative Sequence Event Recorder

- The Multifunction relay used as negative sequence current protection relay to detects the faulty condition.

- CB1 and CB2 trips after 0.01 second from the detected fault.

4.5.2.6 Over frequency protection

Figure 4.5.11 represents the over frequency action list.



Transient Stability Action List

Time 0   13.682 Seconds   30.000

Time (sec)	Event	Device ID	Action	Action By
2.000	over frequen	CB11.	Open	Study Case
2.000	over frequen	CB10.	Open	Study Case
2.000	over frequen	CB9.	Open	Study Case
13.201	Freq. Relay	CB1.	Open	equency Rel.
13.291	Freq. Relay	CB3.	Open	equency Rel.
13.291	Freq. Relay	CB2.	Open	equency Rel.

Figure 4.5.11 Over Frequency Action List

- The over frequency scenario was created by opening CB 9, CB 10 and CB11 to disconnect large loads.

- Bus 1 (generator terminal) frequency reached the relay setting, hence, the frequency relay trips

Figure 4.5.12 represents the over voltage (voltage vs. time) graph at bus1.

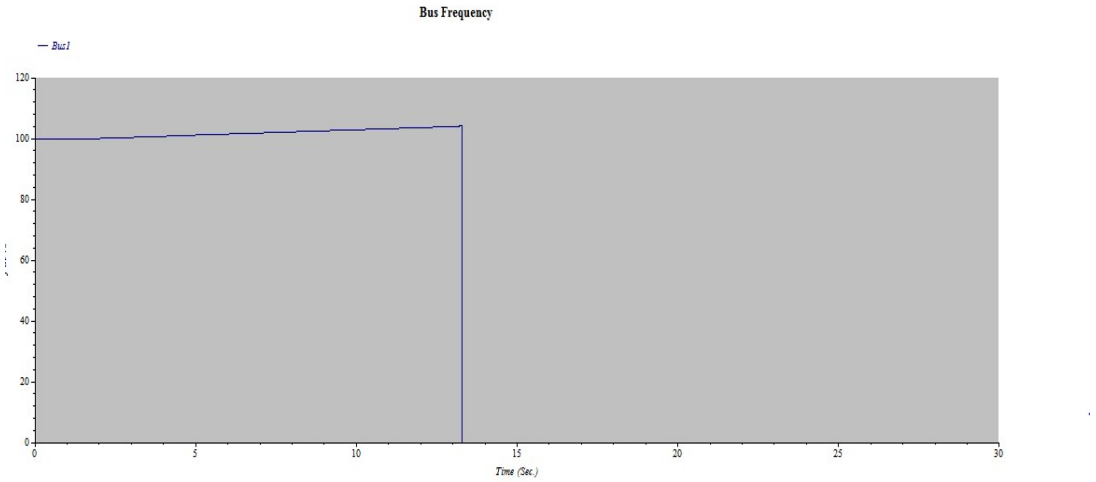
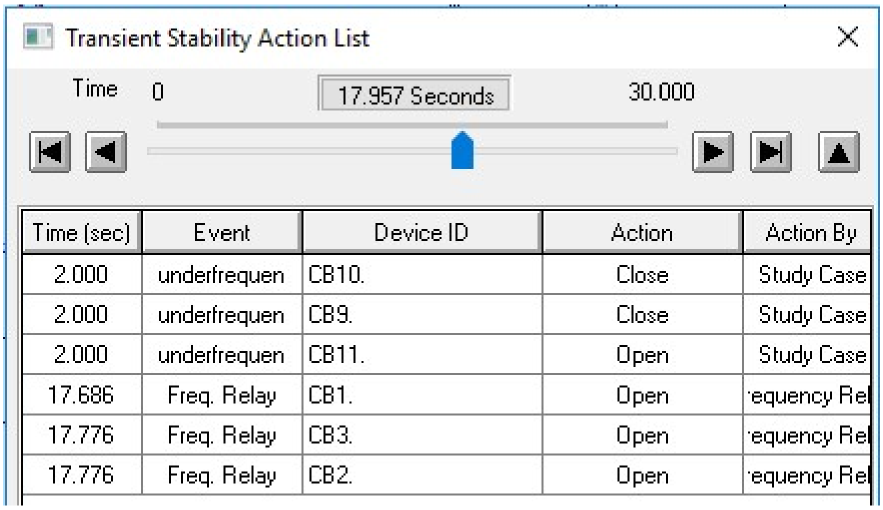


Figure 4.5.12 Over Voltage (Voltage vs. Time) Graph at Bus1

4.5.2.7 Underfrequency Protection

Figure 4.5.13 represents the Under Frequency Action list.



Transient Stability Action List

Time 0 17.957 Seconds 30.000

Time (sec)	Event	Device ID	Action	Action By
2.000	underfrequen	CB10.	Close	Study Case
2.000	underfrequen	CB9.	Close	Study Case
2.000	underfrequen	CB11.	Open	Study Case
17.686	Freq. Relay	CB1.	Open	equency Rel
17.776	Freq. Relay	CB3.	Open	equency Rel
17.776	Freq. Relay	CB2.	Open	equency Rel

Figure 4.5.13 Under Frequency Action list

-The under frequency scenario was created by closing CB 9, CB 10 and CB11 to insert a large loads.

Figure 4.5.14 represent under frequency (frequency vs. time) graph at bus1.

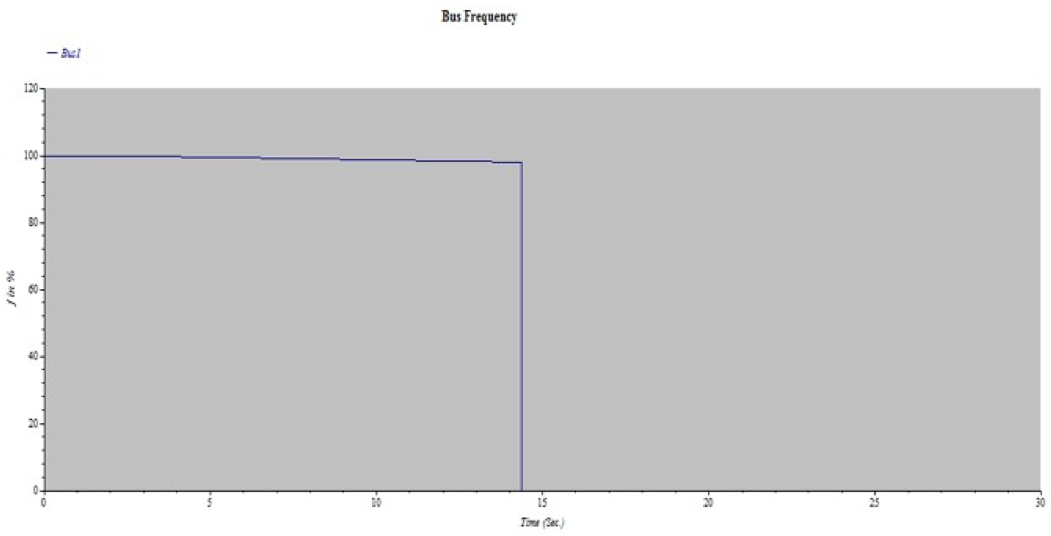
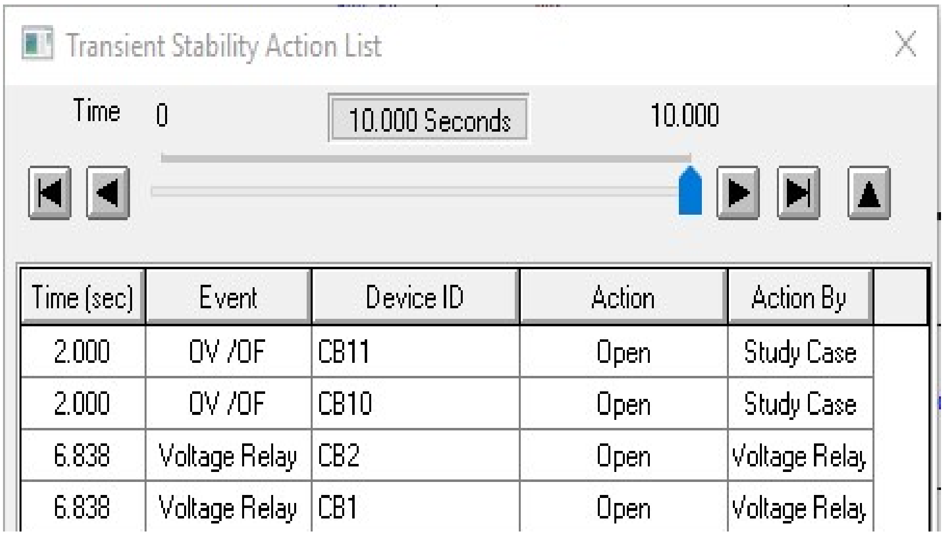


Figure 4.5.14 Under Frequency (Frequency vs. Time) Graph at Bus1

- Bus 1 (generator terminal) frequency reached the relay setting frequency after 15 seconds from event occurring.

4.5.2.8 Overfluxing Protection

Figure 4.5.15 represents the over fluxing action list.



Time (sec)	Event	Device ID	Action	Action By
2.000	OV /OF	CB11	Open	Study Case
2.000	OV /OF	CB10	Open	Study Case
6.838	Voltage Relay	CB2	Open	Voltage Relay
6.838	Voltage Relay	CB1	Open	Voltage Relay

Figure 4.5.15 Over fluxing Action List

- The over fluxing scenario was created by disconnecting large loads from the system by opening CB10 and CB11.

Figure 4.5.16 represents over fluxing (v/f vs. time) graph bus1.

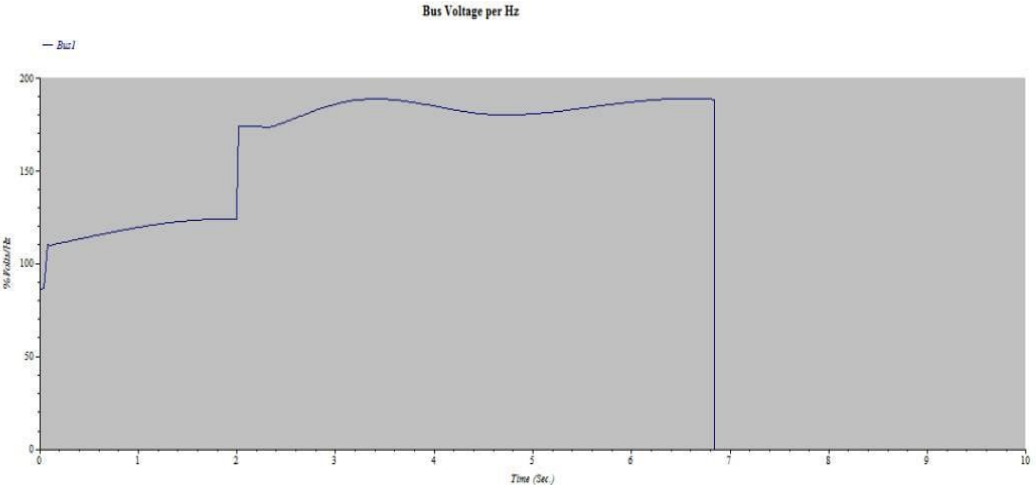


Figure 4.5.16 Over Fluxing (V/F vs. Time) Graph at Bus1

- CB1 and CB2 trips after Bus1 voltage over frequency ratio reached the relaying siting.

4.5.2.9 Differential Protection

Figure 4.5.17 represents the internal fault.

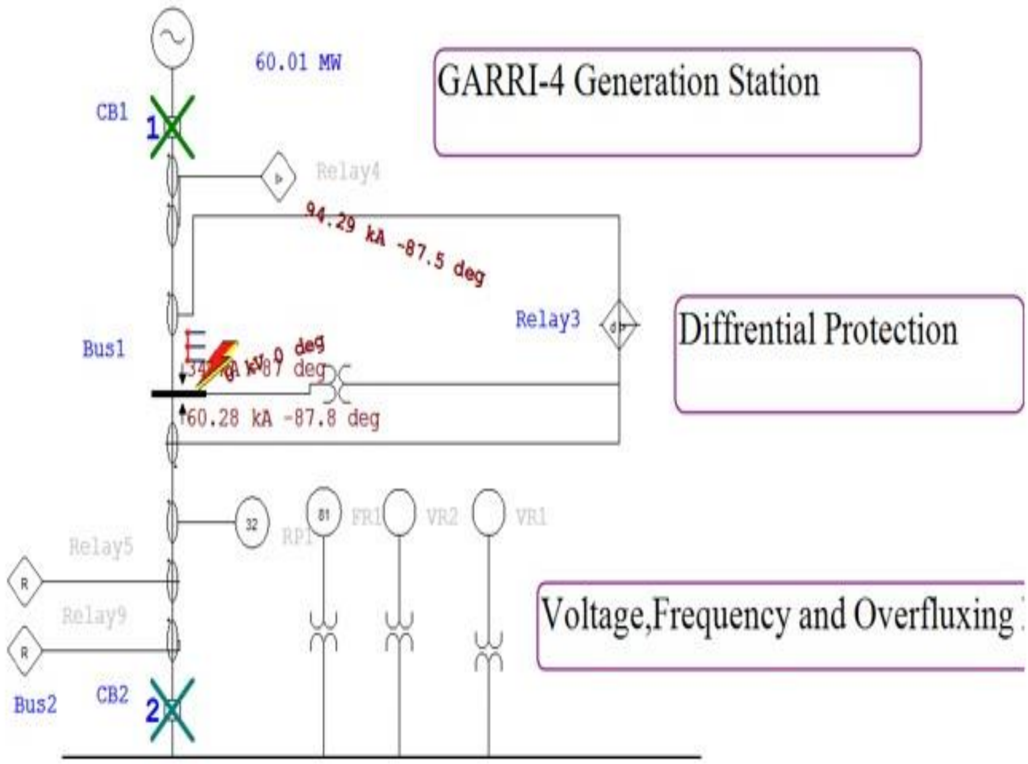
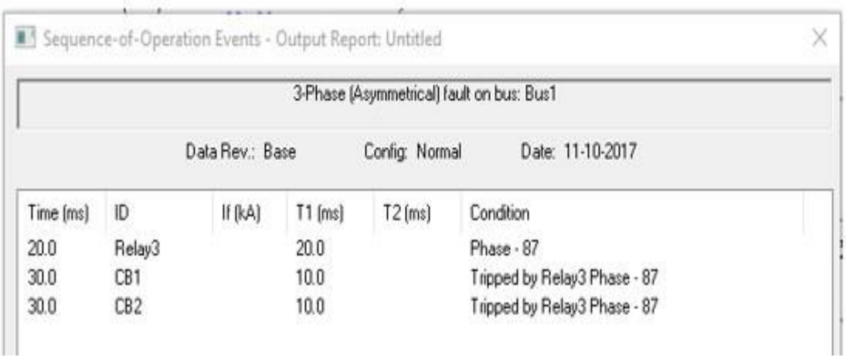


Figure 4.5.17 Internal fault

- Unit protection for Bus1 was applied by using two current transformers CT 20 and CT 21 with opposite polarity.
- In this case 3 phase fault occurred in the protected zone (Bus 1).

Figure 4.5.18 represents differential protection event recorder.


Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Asymmetrical) fault on bus: Bus1

Data Rev.: Base Config: Normal Date: 11-10-2017

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
20.0	Relay3		20.0		Phase - 87
30.0	CB1		10.0		Tripped by Relay3 Phase - 87
30.0	CB2		10.0		Tripped by Relay3 Phase - 87

Figure 4.5.18 Differential Protection Event Recorder

- CB1 and CB2 trips after 0.01 second from detecting the fault by differential relay.

Figure 4.5.19 represents external faults.

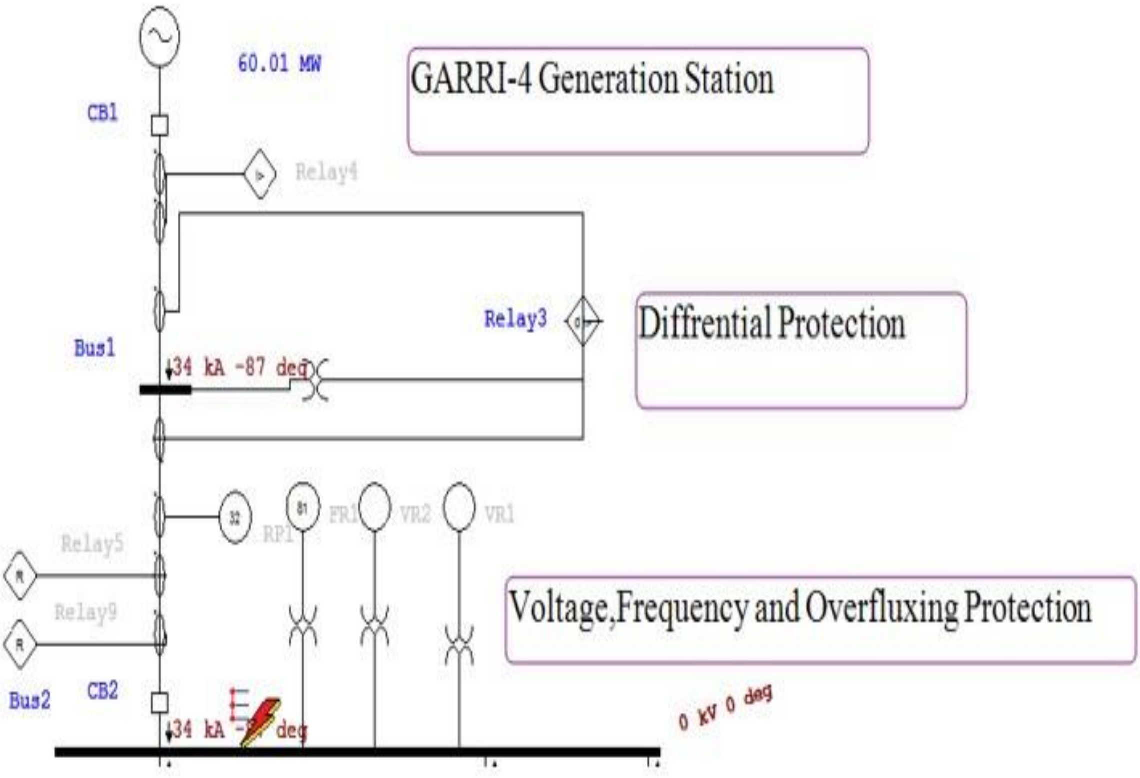


Figure 4.5.19 External Fault

- The fault occur outside the protected zone bus 1 with the same polarity of CT.

4.5.2.10 Stator Earth Fault Protection

Figure 4.5.20 represents protection operation of stator earth fault.

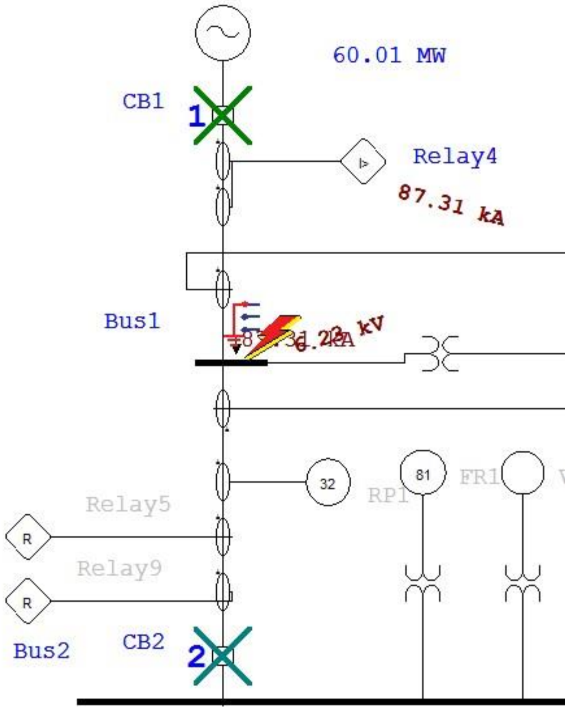


Figure 4.5.20 Protection Operation of stator Earth Fault

- Stator earth fault event created by choosing line to ground option at bus1 since the fault occurs. Figure 4.5.2 represents stator earth fault event recorder.

Sequence-of-Operation Events - Output Report: Untitled

Line-to-Ground (Asymmetrical) fault on bus: Bus1

Data Rev.: Base Config: Normal Date: 11-10-2017

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
500	Relay4	87.314	500		Ground - OC1 - 51
510	CB1		10.0		Tripped by Relay4 Ground - OC1 - 51
510	CB2		10.0		Tripped by Relay4 Ground - OC1 - 51

Figure 4.5.21 Stator Earth Fault Event Recorder

- Multifunction relay was used to detects the faulty condition

- CB1 and CB2 trips after 0.01 second.

4.5.2.11 OverCurrent Protection

Figure 4.5.22 represents protection operation of over current.

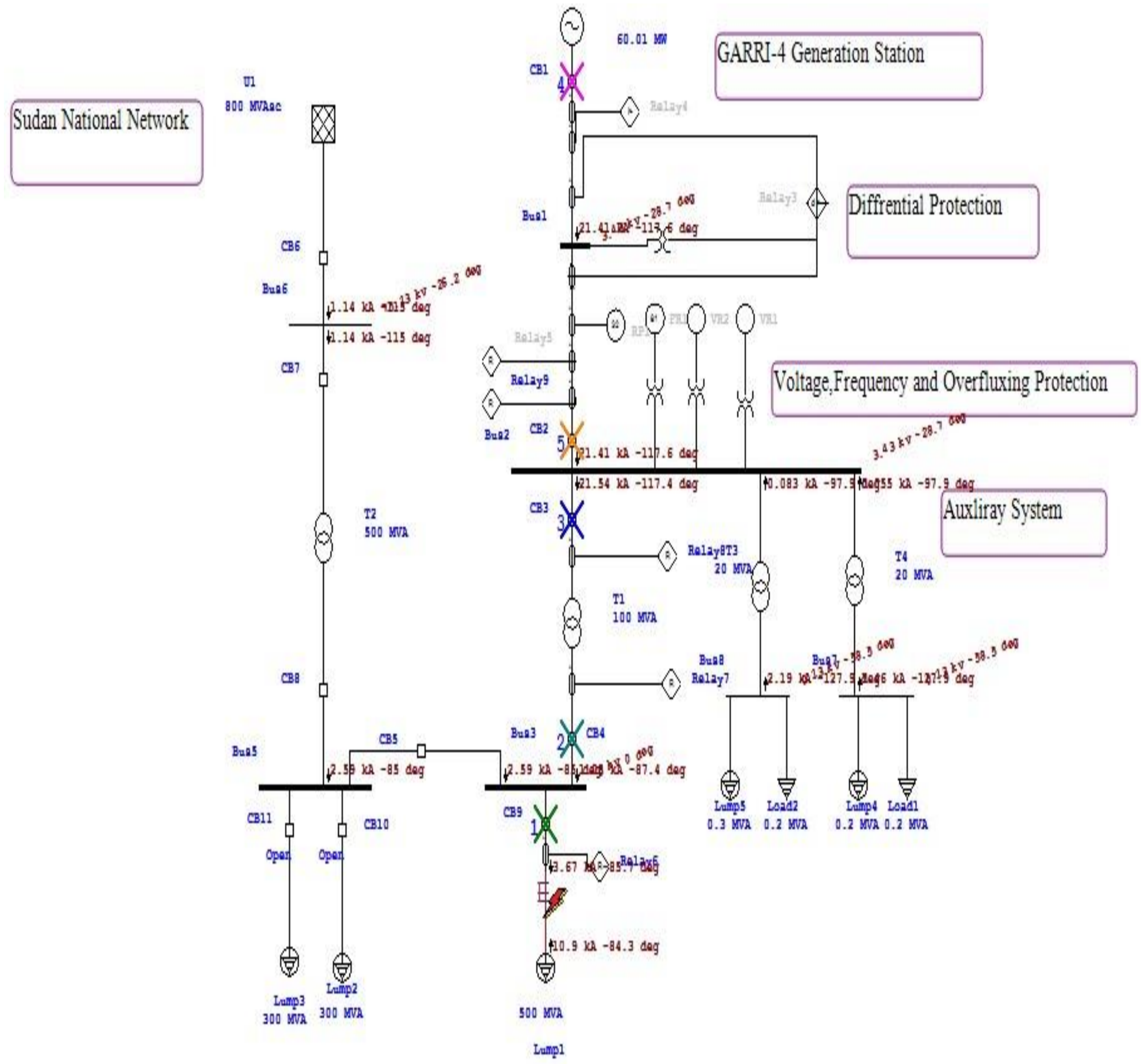


Figure 4.5.22 Protection operation of Over Current

- For over current protection four relays and CT were used

Figure 4.5.23 represents the overcurrent record.

Sequence-of-Operation Events - Output Report: Untitled

3-Phase (Asymmetrical) fault on connector between CT8 & Lump1. Adjacent bus: Bus3

Data Rev.: Base Config: Normal Date: 11-10-2017

Time (ms)	ID	If (kA)	T1 (ms)	T2 (ms)	Condition
305	Relay6	3.668	305		Phase - OC1 - 51 - Forward
315	CB9		10.0		Tripped by Relay6 Phase - OC1 - 51 - Forward
497	Relay7	1.077	497		Phase - OC1 - 51
507	CB4		10.0		Tripped by Relay7 Phase - OC1 - 51
750	Relay8	21.538	750		Phase - OC1 - 51
760	CB3		10.0		Tripped by Relay8 Phase - OC1 - 51
1009	Relay9	21.408	1009		Phase - OC1 - 51
1019	CB1		10.0		Tripped by Relay9 Phase - OC1 - 51
1019	CB2		10.0		Tripped by Relay9 Phase - OC1 - 51

Figure 4.5.23 Over Current Event Record

- CB4, CB3, CB2 and CB1 trip in a sequence order.

4.5.3 Summary

- The generators starts withdraw reactive power from the system in the event of loss of filed. The event will be detected by the revers power relay which trip the Circuit Breaker. This event is designed using ETAP transient stability analysis by loss of excitation event.

- In reverse power event the direction of the active power reverses. The reverse power relay detects this event and trip the Circuit Breaker. This event was implemented using ETAP by activating loss of excitation for transient stability analysis

- The generator frequency drops when the system is overloaded. Relay measures the frequency of voltage signal given through VT. Under frequency relay detects this event and trip the Circuit Breaker. This event was implemented using ETAP by activating Under Frequency for transient stability analysis.

- Over Frequency event appears when the load is lost or when the generation excessed the load. Relay measures the frequency of voltage signal given through VT, over frequency relay trip the Circuit Breaker when the frequency of the system rises above the set value. This event was implemented using ETAP by activating Over Frequency for transient stability analysis.

- Over fluxing event appears when disconnecting a high load. If the percentage V/F increased above the set value the over fluxing relay trips the Circuit Breaker. This event was implemented using ETAP by activating Over Fluxing event for transient stability analysis.

- Overvoltage event appears when the load is suddenly lost. Relay measures the voltage s through VT, over voltage relay trip the Circuit Breaker when the voltage of the system rises above the set value. This event was implemented using ETAP by activating over voltage for transient stability analysis.

- Under voltage event occurs when the system is overloaded, so, the generator delivers larger current and the voltage of the system drops. Under voltage relay operates when the voltage of the system goes below the set value. This event is designed using ETAP transient stability analysis by adding a high load.

- The generator voltage drops when the system is overloaded. Relay measures the voltage signal given through VT. Under voltage relay detects this event and trip the Circuit This event is designed using ETAP transient stability analysis by removing a high load

CHAPTER FIVE

CONCLUSION AND RECOMMINDATION

5.1 Conclusion

Generators are the most important and expensive unites in power system grid. Thus, generator protection must be taken in the consideration.

A real time implementation of multifunctional digital relaying scheme in ETAP for scaled generator is presented in this project. The 3-phase power circuit simulation and prototype implementation of various protection schemes applicable to generator has been carried out.

This project presents a real time implementation of multifunctional digital relaying scheme in ETAP for scaled generator. The 3-phase power circuit simulation and prototype implementation of various protection schemes applicable to generator has been carried out

The developed model is capable of eliminating various type of normal and abnormal faulty condition of generator. Faults protection scheme is designed and implemented to detect all types of faults.

Various type of generator protection was implemented successfully by ETAP programmer with satisfactory result.

5.2 Recommendation

The lack of main and reliability back-up protection schemes in the event of abnormalities and faults, the lack of comprehensive monitoring, the occurrences of abnormalities and faults without protecting the supply units from them is the main reason for instability of power supply.

To make a comprehensive and effective protection for the generation units at GARRI 4, generator protection design scheme must also take into account some additional considerations to increase the performance of the protection scheme, such as Scheduling maintenance for generation units to avoid frequent outage of the electrical supply, in the event of very sever fault the relay must trip the Circuit Breakers in very short time like what happened in the transient study of over frequency by using ETAB implementation .

Also Study and simulation for generation unit (both generator and its step-up transformer) could be done using protection relays of ETAP software besides online relay testing.

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10. GARRI4 MANUAL . 2008.

APPENDIX A

Voltage Relay Setting

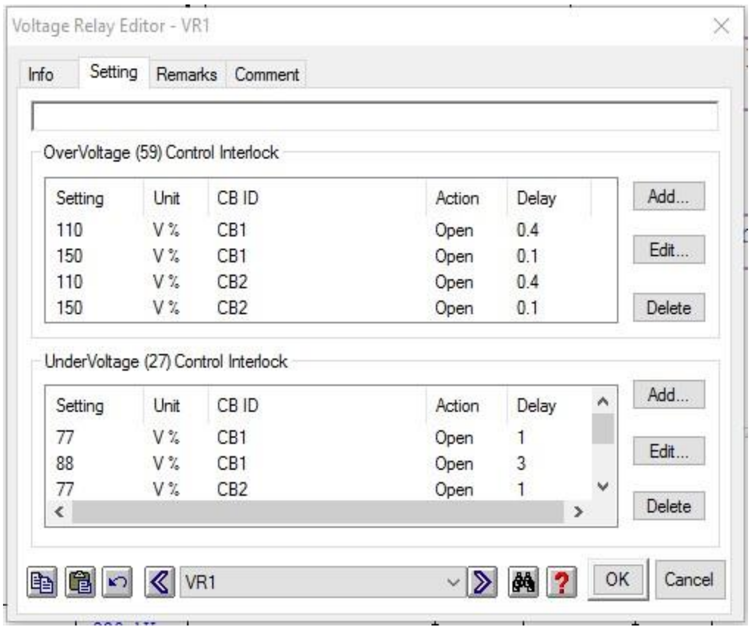

Figure A-1

Reverse Power Relay Setting

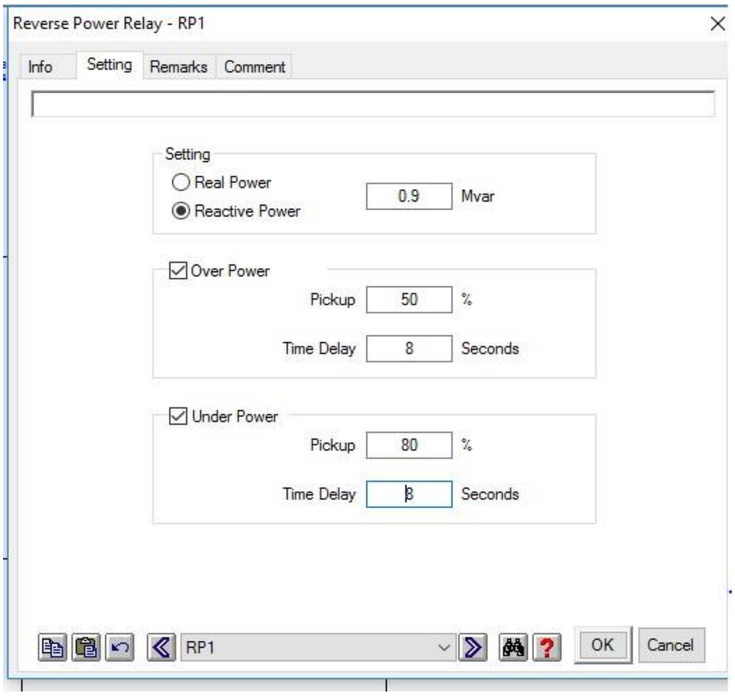

Figure A-2

Negative Sequence setting

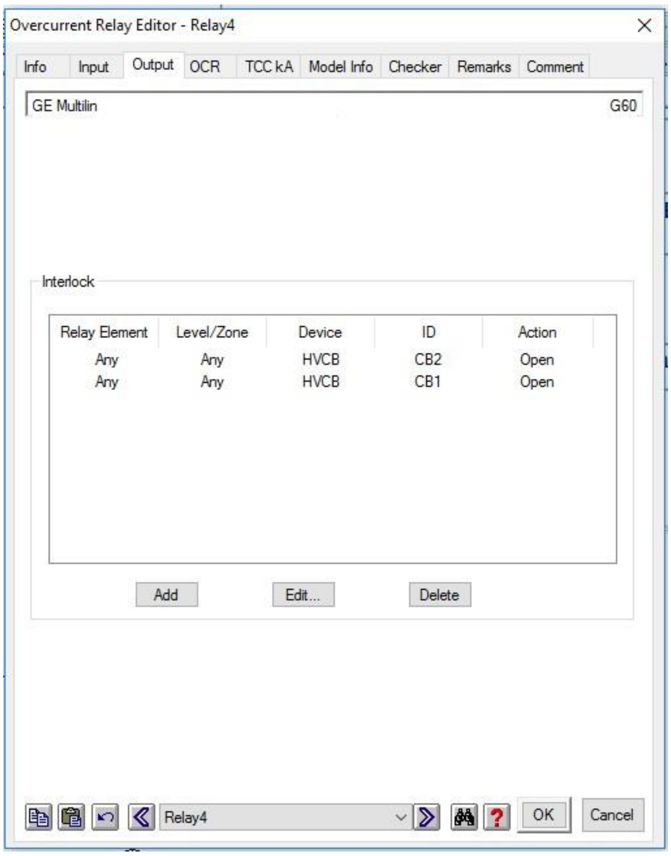

Figure A-3

Negative Sequence Relay Setting

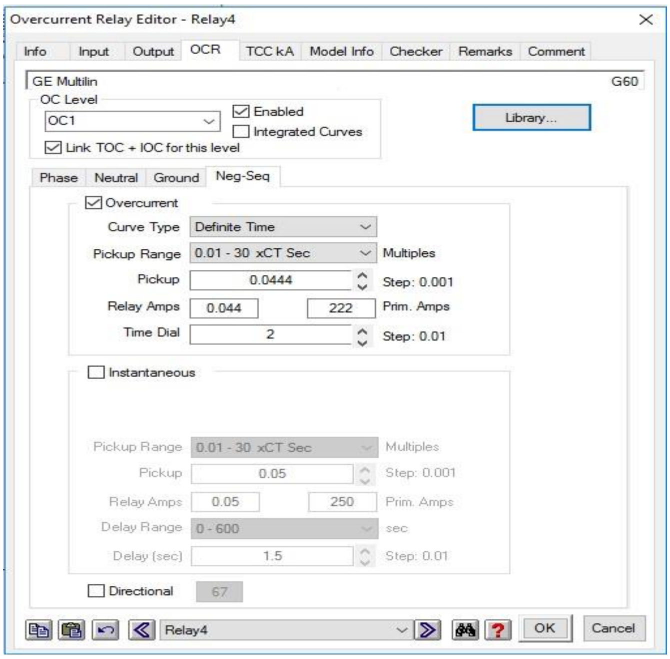

Figure A-4

Over fluxing Setting

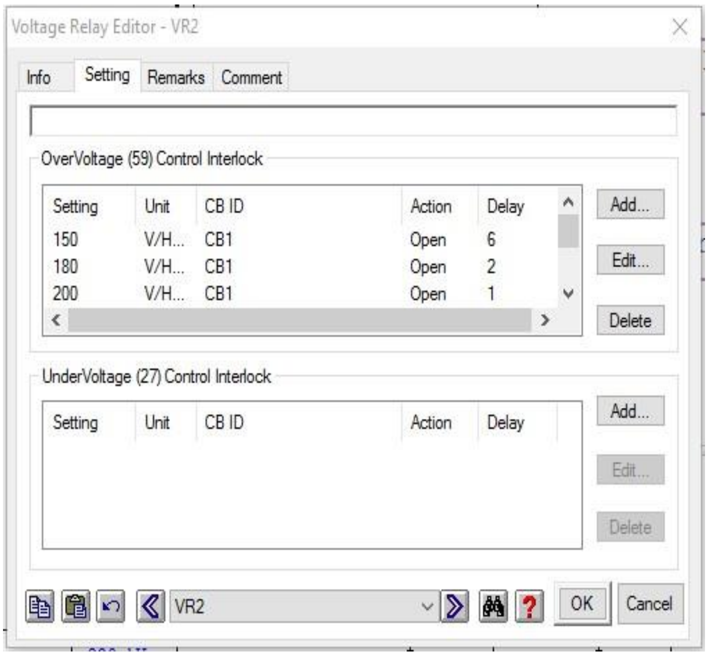

Figure A-5

Differential Relay Setting

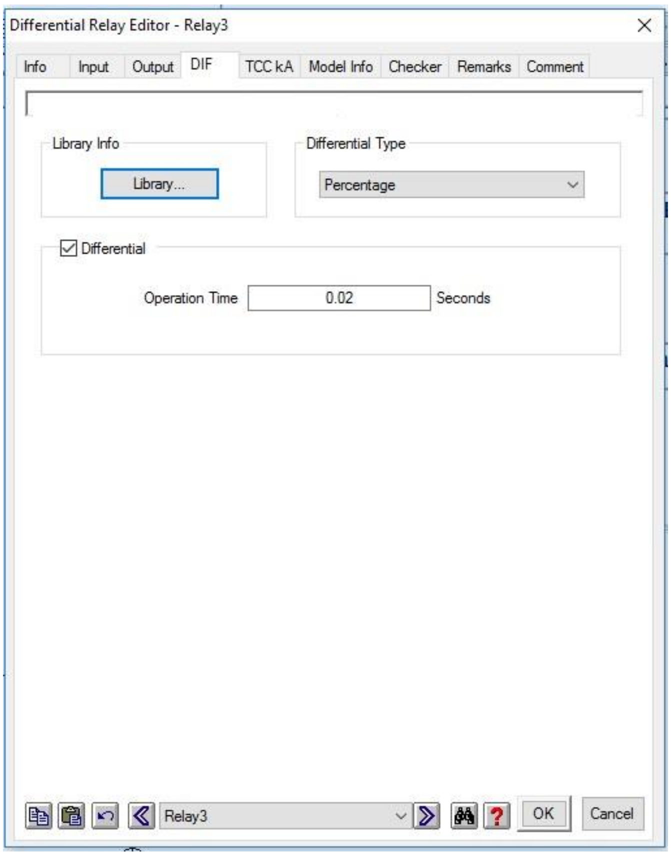

Figure A-6

Frequency Relay Setting

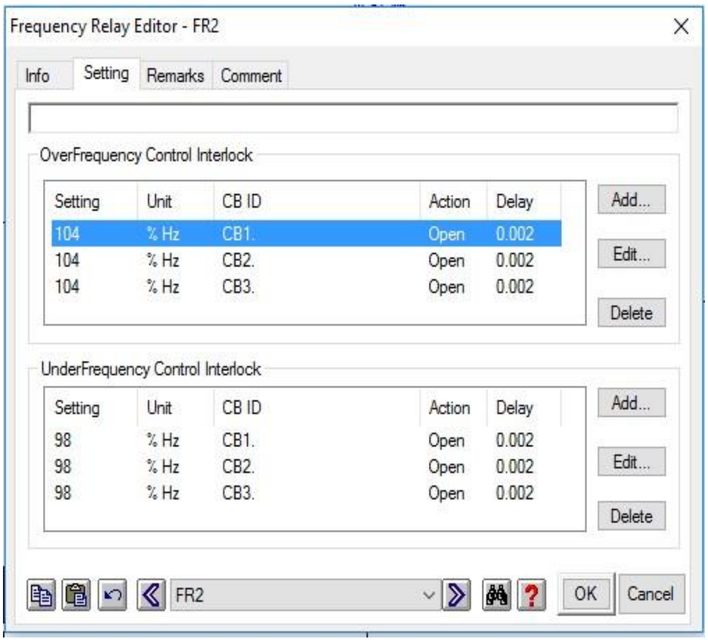

Figure A-7

Stator Earth Fault Relay Setting

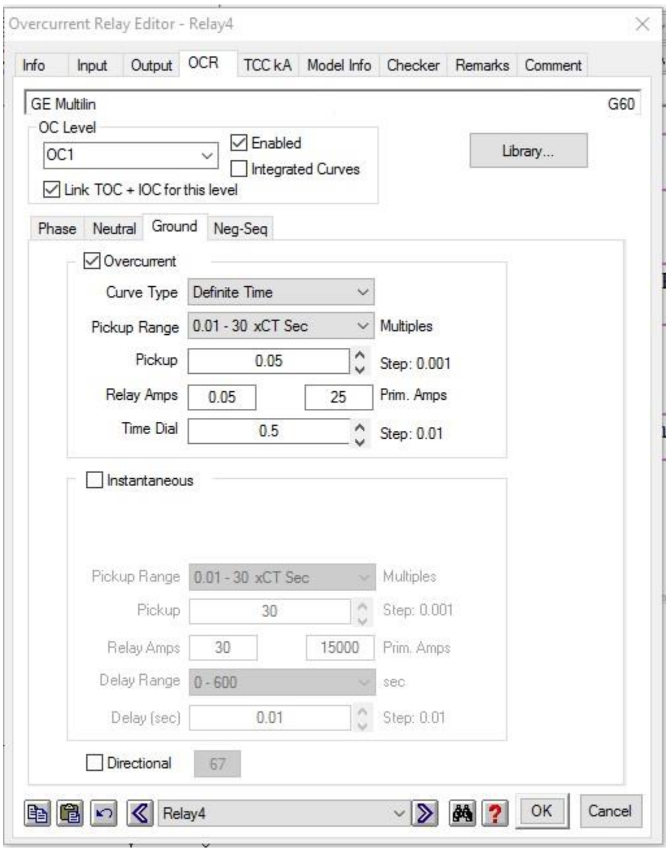

Figure A-8

Stator Earth Fault Setting

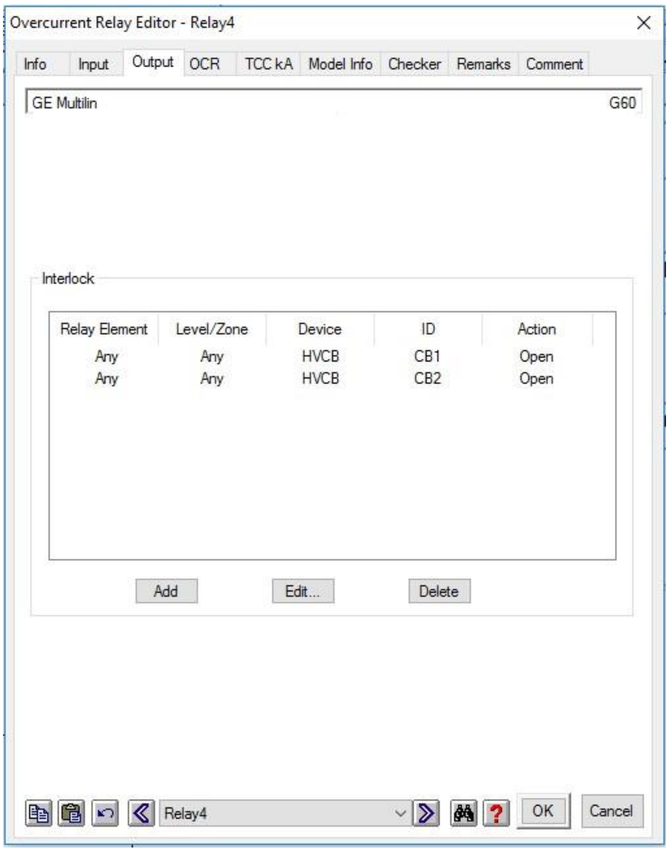
Overcurrent Relay Editor - Relay4
Info
Input
Output
OCR
TCC kA
Model Info
Checker
Remarks
Comment
GE Multilin
G60
Interlock
Relay Element
Level/Zone
Device
ID
Action
Any
Any
HVCB
CB1
Open
Any
Any
HVCB
CB2
Open
Add
Edit...
Delete
Relay4
OK
Cancel

Figure A-9