Design of 330-132-33KV 150MVA Substation

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Abstract: The growing need of continuous power supply in Nigeria cannot be achieved by the number of substations we have today in Nigeria. The Enugu Electricity Distribution Company (EEDC) complains that haphazard development of towns affects its operation because current plans and forecasted load demands are nullified along the processes. A person setting up a small scale industry I an area planned to be residential will really interrupt the load demand operation of EEDC, by not notifying them when the new load is added to the existing one. The consequence of this is that built-in reserve in the network is then quickly used up and slight problem will put everyone into darkness. Thus with the technological advancements and emergence of several sophistications of equipment in power system, this research work studies design of 330/132/33KV, 150MVA substation. Considering the fault levels and then affect on system reliability by incorporating the new technological developments and necessary protections to safeguard the system equipment

Keywords: Design, Dynamically, Electromotive force, Electrical energy, Energy conservation, Mechanical energy, Substation.

1. INTRODUCTION

The general form of power system throughout the world follows the same pattern. Magnitudes of voltage vary from country to country, the difference originating mainly from geographical and historical reasons. The first power station in Nigeria was built in Lagos in 1898 at the present site of National Election Power Authority (NEP A liaison office, Marina, Former NEP A headquarter before the authority relocated to Abuja in 1996.

Before the establishment of NEPA by decree No 24 of April 1972, three principal bodies were responsible for the supply of electricity in the Country. These are National Electric Supply Company (NESCO); The Electricity Corporation of Nigeria (ECN) and the Nigerian Dam Authority (NDA).

Most of the generating stations owned by these separate bodies were concerned solely with electric power supply to their own distribution networks, In September, 1969 the Federal Military Government decided to merge ECN and NDA into a single body to avoid duplication of resources of the two organizations. A year later a Canadian firm of consultants (Shanmont Ltd) was appointed to look into the technical details of the merger. The report was submitted in 1971. Consequently, a decree No 24 of April 1972 integrating the two bodies into a monopolistic management of national Electric Power Authority was established. The decree stipulated and charged the authority with the responsibilities of developing and maintaining an efficient power generation, transmission and distribution to all parts of the Federation.

Nigerian power system consists of a nine-power station. These power stations have a total installed capacity of 6.01 GW, and a total of 79 units interconnection over a network of 330kv transmission lines. Transmission of bulk power to the major load centers (there are twenty-three 330kv substation) is at the 330kv voltage level. Medium load centers are supplied with power at 132kv of which there are a total of eighty-three 132kv substation from which the voltage is still transformed to a further lower levels (33kv, l1kv, 6.6kv, 3.3kv) for distribution.

The nine generating station are made up of three hydro and six thermal. The hydro generating stations are located at Kainji, Jebba and Shirroro, all in Niger State. The thermal stations are at Ogorode-Sapele Delta State, using steam as its fuel. Another at Ughelli Delta State using gas. The one at Afam-Port-Harcourt River State uses both steam and gas, while the station at Egbim Lagos State uses gas. The two obsolete generating stations are Oji-River thermal station in Enugu State and Ijora thermal station in Lagos State. They were both designed to use coal as fuel, and because they are no longer in use, they have been disconnected from the Nation Grid.

Unfortunately, the installed capacity stated above is not readily available for various technical and social reasons. The installed capacity available according to NEPA generation profile in 1988 is 1716MW against installed capacity of 4796.5MW, which is almost less than 35.780/0 of installed capacity. The installed capacity of the present generating stations we have in Nigeria is 6.0 1 GW with installed available capacity of 3.00GW, which is almost 50% less.

Though the available installed capacity is capable of meeting the Nation Power Demand of 2.45 GW. However the installed available capacity of 3.00GW drop at times, occasionally to almost 1.93 GW which is almost 21 % less than the Demand. Due to this drop, the authority embarks on load shedding to avoid total collapse of the system. Load shedding is an unplanned outage or interruption designed temporarily to save the system from collapse or total blackout.

High voltages are generated in most of the generating stations in Nigeria. Example, Kainji and Ogorode generating stations generates 16KV and 15.75KV respectively. These voltages are stepped up to 330KV using step-up transformer before it is fed to the national grid. This voltage is sent to most parts of the Country where it is stepped-down to 132KV, 33KV, and 11KV and finally to 0.415KV for use by the consumers through step-down transformers known as distribution transformers.

Substations are necessary for the change of voltages between generation, transmissions, primary distribution and secondary distribution to provide switching to control network under both normal and fault condition

2. REVIEW

The electrical power system broadly consists of a generation, transmission and a distribution system. Since generating stations are often located far from utilization centers, it becomes imperative that generated electrical energy is transported over a long distance at a minimum cost and reduced voltage drop. This is achieved by transmitting the energy at a very high voltage. The high voltage power transmitted will have to be reduced to considerable energy level before it can be utilized.

For economical and technological reasons, individual generating stations are organized in the form of electrically connected regional grids. Each regional grid operates technically and economically independently, but these are eventually interconnected to form a national grid so that each region is contractually tied to the other regions in respect to certain generation and scheduling features.

Interconnection has the economic advantage of reducing reserve generation capacity in each region. Under condition of sudden increase in load or loss of generation in one region, it is immediately possible to borrow power from adjoining interconnected regions. It also permits the construction of larger and more economical generating units and the transmission of larger and more economical generating units and the transmission of large chunk power from the generating plants to major load centers. In areas having opposing winter and summer requirements, it provides capacity saving by seasonal exchange of power between these regions. It facilitates transmission of off-peak power and gives flexibility to meet unexpected emergency loads.

It is important to note that it is alternating voltages and alternating currents that are generated in this generating station. At the station electrical generators are used in generating the alternating currents and voltages.

An electrical generator is a machine, which converts mechanical energy (or power) into electrical energy (or power). This energy conversion is based on the principle of the production of dynamically (or motional) induced EMF (electromotive-force).

Michael Faraday an English physicist in 1831 found out that whenever a conductor cuts magnetic flux, dynamically induced emf is produced. This emf will cause a current to flow if the conductor circuit is closed. Faraday summed up his facts into two laws known as Faraday's laws of electromagnetic induction:-

i. When the magnetic flux linked with a circuit changes, an emf is always induced in it or whenever a conductor cuts across magnetic lines of flux, an emf is induced in the conductor.
ii. The magnitude of induced emf is equal to the rate of change of flux linkages.

Thus, the value of the voltage generated depends upon the number of turns in the coil, strength of the field and the speed at which the coil or magnetic field rotates. An alternating voltage may be generated by rotating a coil in a magnetic field or by rotating a magnetic field or by rotating a magnetic field within a stationary coil.

According to Faraday's laws of electromagnetic induction, the emf induced in the coil is, given by the rate of change of flux-linkages of the coil. Hence this instant emf at this instant (ie when $\theta = wt$) or the instantaneous values of the induced emf is

$$e = \frac{d}{dt}(N\,\theta) \text{ volt}$$
$$= \frac{N\,d}{d\,t}(\theta_m \cos wt) \text{ volt.}$$
$$= WN\,\theta_m\,(-\text{Sin } wt) \text{ volt.}$$
$$= -\,WN\,\theta_m \sin\theta\,) \text{ volt} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \quad \text{(i)}$$

When $\theta = 90°$ (ie when the coil has turned through 90^o)

Then Sin $\theta = 1$.

Hence e has maximum value, E_m.

From equation (1)

$$E_m = WN\,\theta_m \text{ volt}$$
$$= WN\ Bm\ A \text{ volt}$$
$$= 2\,\pi f\,N\,Bm\,A \text{ Volt}\ldots\ldots\ldots\ldots\ldots\ldots\text{(ii)}$$

Where Bm = maximum flux density in wb/m^2.

A = Area of the coil in M^2 ..

f = Frequency of rotation of the coil in rev/s

Hence we can get the equation of the alternating voltages and current by substituting equation (ii) into equation (i)

$$E = E_m \text{ Sin } \quad E_m \pi w\,t. \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iii)}$$
$$\iota = \text{Im Swt.} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(iv)}$$

The generated powers transmitted at a very high voltage over a long distance are stepped down using transformers at the substation.

Therefore, this calls for the design reliability, flexibility and continuity of service at the lowest cost. To meet these objectives, the design regulation should contain the relevant codes and standards; which includes:-

i. International electro-technical commission (I EC)
ii. British standard
iii. American standard
iv. Institute of electrical and electronic engineers and other standards recognized worldwide.

Feeders carry current from one substation to another, or to transformer or a feeding point, and are not tapped in between. They are loaded at substations only. Voltage control can be done at the feeding points. Size of the cable conductors is chosen by application a Kelvin's law, which says that the most economical size of conductor will be when the sum of the annual charge on the capital investment and the annual charge due to loss of energy in transmission would be mmimum.

Annual charge on the cost of cable and distribution

$= \quad PI + P2\ A$

Where

A = cross sectional area of the conductor.

P_1 = constant part of the annual charge

P_2 = part of the annual charge dependent on a.

1^2 R x 8760 is the loss in KWh during the year,

where I = current in a 3- phase line.

The cost of the energy loss/year α = p^3/A.

∴ Kelvin's law = Min A ($P_1 + P_2$ A + P_3 /A).

Differentiating with respect to A gives the economic condition as P_2A

$$= \frac{P_2}{A.}$$

Kelvin's law has several limitations and may not give the optimum result. If a certain load is given and the length of line is given, the most economical voltage may be found. The most economical distance between the substations and hence the number of substances in the system, is a function of the distribution voltage used. The primary feeders may have a rating between 500 KV A to 2500KV A. Often a distribution system is designed for total voltage drop of 8 to 10%. The neutral of the distribution system is grounded properly and protection against lightning is provided. The two major components of a substation are the transformer and circuit breaker.

A transformer is a static (or stationary) piece of apparatus by means of which electric power in one circuit is transformed to electric power of the same frequency in another circuit. It can raise or lower the voltage in a circuit but with a corresponding decrease or increase in current. The transformers are selected based on the voltage level and fault level that can be absorbed. The transformers are the most important, expensive and bulkiest component of a substation, which must be well protected against any fault. The circuit breakers in power system provide essential switching flexibility and circuit protection.

The magnitude of fault is usually estimated by calculation and equipment are selected based on the calculation results. Protection for the substation has to be considered from an economic point of view taking into consideration the probability of particular type of a fault, possible consequences of loss of production cost of repair.

The system requirement includes the selection of optimum voltage level, which depends on the load requirements and transmission line distances involved. Many large thermal and hydro power plants are located at great distances from the load centers in order to capitalize on how site cost, ample cooling water supply, economical fuel supply and less stringent

environmental considerations. For these reasons the use of transmission voltages as high as 765KV is becoming more common. The substations used in distribution systems operate at voltage classes from 1.38 to 69KV. Transmission substations serving bulky power sources operate at voltages ranging from 69KV to 765KV.
Voltage classes used in the United States of America for major substations include 69, 115, 138, 161, 230 and 287KV (considered as High voltage or HV class) and 345, 500 and 765KV (considered as "Extra high voltage" EHV class). Even higher voltages now in various stages of designing and construction include 1100 and 1500KV and are referred to as "Ultra high voltage" (UHV class). But here in Nigeria voltages class used for major substations includes 33, 132 and 330KV.

3. Methodology

The advancement of technology has resulted in the need for extra-high voltage substation to be able to meet the increasing load requirement. Thus the aim of this project is to enhance the supplying of electricity at minimum cost and to improve the service of supply to ensure reliability and continuity of service at all time.
This is achieved by using two 330/132/132/33KV autotransformers rated at 150MV A. The vector group of the transformer is star-star-delta. The 33KV side is connected to a 33KV bus bar and from this bus bar a 33/0.415KV distribution transformer is connected to supply the load center around the substation and for the station auxiliaries. This distribution substation is located by the side of the main substation while the 132KV is transmitted further. Two high rated auto-transformers are used because on any system, consideration must be given to the fact that any element of the system may be out of service at any time due to forced outage or some planned maintenance or development work. It is desirable that the outage should not cause any interruption of power supply to consumers, hence there must be an alternate line to ensure reliability and continuity of supply.

Design Objective

As an integral parts of the transmission system the 330/132/33KV substation acts as a connection and switching points for transmission lines, sub-transmission feeders, generating circuits and step up and step-down transformer. The objective of designing such a substation is to provide maximum reliability, flexibility and continuity of supply in order to meet lowest investment cost that satisfies good system requirements.

Design Consideration

Many factors are considered when designing a substation. Such factors include - voltage level, load capacity, environmental consideration, site-space limitation and transmission line right-of-way requirements. There are other design criteria taken into consideration and these varies from system to system in terms of cost of equipment, labour, land, and site treatment since the major substations costs are reflected in the power transformers, circuit breakers and disconnecting switches, the bus layout and switching arrangement selected will determine the number of switches and power circuit breakers required.
Also the choice of insulation levels and co-ordination practices affects cost considerably especially at extra high voltage.

The selection of bus layouts and switching arrangements for a substation to meet system and station requirement requires that the substation must be reliable, economical, safe, and as simple in design as possible. The design should provide a high level of service continuity. It should also provide for further expansion, flexibility of operation and low initial and ultimate costs. The design should also incorporate means for maintaining lines, circuit breakers and isolator without interruption to service or hazard to the personnel. The physical orientation of the transmission line routes often dictates the substations location and bus arrangement. The selection of site is such that convenient arrangements of the lines are accomplished.

Safety

Safety of life and preservation of properties are two important factors that must be firstly considered in designing a substation.

Reliability

The system must be designed in such a way to isolate faults with minimum disturbance and should be able to give maximum dependability and consistency.

Simplicity of Operation

As far as safety and reliability are concerned, this is an important factor because they give room for quick and easy maintenance of the system.

Flexibility

This means the adaptability to development and expansion as well as changes to meet varied requirement during the life time of the substation. Consideration of the Station voltages, equipment ratings, and space for additional equipment and capability for increased loads are very important.

Voltage Regulation

Poor voltage regulation is detrimental to the life and operation of electrical equipments. Voltages at the utilization equipment must be maintained within the tolerance limits of the equipment under any load condition.

Maintenance

The system must include preventive maintenance requirements.

Accessibility and availability for inspection and repair with safety are considered when selecting equipment. Working space must be provided for inspection, adjustments and repair of equipment.

Site Location

This is one of the most important things to be considered and many factors can influence the selection of the site such as environmental consideration, space limitation, transmission line-right- of-way requirement, conducts and cable outlet to provide for present and future requirement, proximity to the load center, and the civil works, such as the cost of grading, clearing, construction of access road and cost of drainage.

Substation Layouts

The substation layout can be in different forms such as:

- (a) Open bus arrangement
- (b) Inverted bus arrangement
- (c) SF6 insulted mini-type metal clad.

Open Bus Arrangement

This involves mainly open bus construction which can be either rigid or strain bus design or combination of both rigid and strain buses. The arrangement can be with double bus arrangement as in double bus single breaker, double breaker, breaker and a half etc.

From the action of arc. For plain break arc, the quenching ability of SF_6 is in order of 100 times that of arc. Other physical properties of SF 6, are its odourless, colourless, inert, non-toxic and incombustible gas.

Substation Buses

These are the most important part of station structure in the sense that they carry high amount of energy confined in a space. Care must be taken on their design so that the construction will provide adequately and economically for the utilization of electric energy generated, and at the same time have sufficient structural strength to with stand the maximum stresses that may be imposed on the conductors or on their structure by heavy current under short circuit conditions. They can be either rigid or strain bus or even combination of both. These are types of buses.

Types of Buses

1.5.2 Rigid Bus: These are buses with simple structures having less steel. The following are the advantages of using rigid buses. Their conduction are not under constant strain. Each of its pedestal-mounted insulators is accessible for cleaning because of their low height and distinct layout, they can be segregated for maintenance and have good physical appearance and low cost. But the disadvantages are that they require more insulators and support, they are sensitive to structural deflection, which may cause misalignment and damage to the bus.
They require more land and are more expensive compared with strain bus.

Strain Bus: These are buses with less structure and more steel. Their advantages are: They require less space of land and are cheaper. The main disadvantages are that they required large structure, hence large foundation, their insulator are not accessible for cleaning and emergency conductor repairs are difficult.
However, for the design of extra-high voltage substations, the bus can be combination of both rigid and strain buses.

Bus Design

The design of station buses depends on the following:

i. Current carrying capacity
ii. The possible short circuit stress expected
iii. Minimum electrical clearance allowed.

The current capacity of a bus in usually limited to by the heating effect. For rating the bus, the permissible temperature rise without danger of overheating of equipment terminals, but connections and joints are used. The permissible temperature rise for plain copper or Aluminum bus is about 30°C over an ambient temperature of 40°C in order to conform with international standard such as IEEE.
To limit the heating effect, the factors considered in designing a bus are the size and shape of the conductors, surface area of the conductors, skin effect, proximity effect, conductor reactance, ventilation and inductive heating due to proximity to magnetic materials.

Bus Material

For high voltage and extra-high voltages substation Aluminum and copper are generally used as bus material: Hard drawn Aluminum in tubular or rectangular shape are mostly used. Aluminum has the advantage of being about one-third the weight of copper and requires little maintenance. Also proper use of alloys of Aluminum provides the rigidity needed to serve as bus material.

Bus Arrangement
The physical and electrical arrangement switching equipment of any substation is determined by the design scheme adopted. There are different types of bus schemes or arrangement, but in selection the following factors must be taken into consideration:

(i) Reliability
(ii) Economy
(iii) Safety
(iv) Simplicity etc.

The commonly used scheme or arrangement includes:

(i) Single bus
(ii) Double bus, breaker
(iii) Main and transfer bus
(iv) Double bus, single breaker
(v) Ring bus
(vi) Breaker and a half

Modification to any of the adopted scheme is possible by inclusion of bus-tie breaker, bus sectionalizing devices, breaker by pass facilities and extra transfer bus.

Single Bus This type of arrangement fig 1.1 has only one bus and is not normally used in designing a main substation, because failure of the bus or breaker means a serious outage. Also in the event of maintenance or bus extensions; the station must be de-energized to carry out any work. Though, the protective relaying is relatively simple, the single bus scheme is considered inflexible and subject to complete outage.

Double Bus and Double Breaker
Two buses are used in this arrangement fig 1.2. one serves as main and the other as reserve. Two circuit breakers are used for each feeder circuit. Each circuit is connected to both buses or half of each circuit may be operated on each bus in which case bus or breaker failure will only cause loss of half of the circuits. The location of the main is such that it prevents spreading of fault to other healthy bus.
The use of two circuit breakers makes this scheme expensive but it ensures high level of flexibility and reliability of all circuit connected to operate on main and reserve buses.

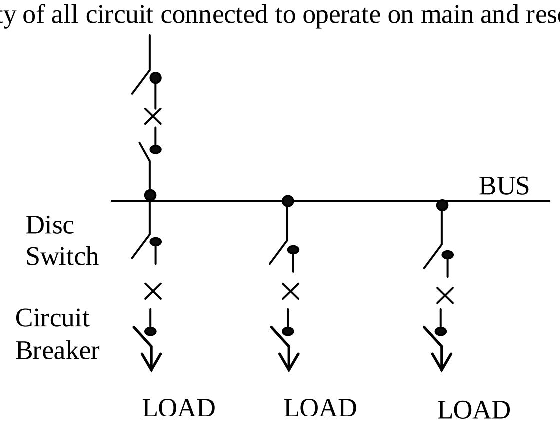
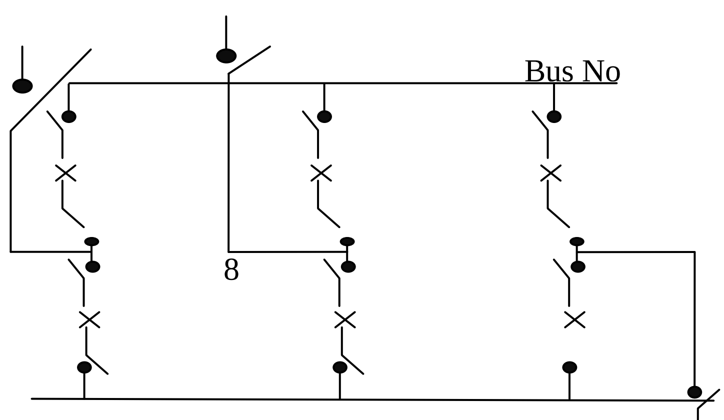


Fig 1.1Single Bus



Bus No 2

Fig1.2. Double bus, double breaker.

Main and Transfer Bus

The addition of transfer bus to the single bus arrangement gives the main and transfer bus, Fig 1.3, extra bus-tie circuit breaker is provided to the main and transfer buses together. The tie bus circuit breaker in used to keep the circuit energized when the circuit breaker is removed for maintenance. The relay sensitivity in this scheme in poor unless the protective relays are also transferred, but the bus and line relaying are not necessarily transferred. If the main bus is taken out for maintenance there will be no circuit breaker to protect any of the feeders and failure of any breaker or the main bus may cause complete loss of service of the substation.

Since the operation of the disconnecting switch in more involving, operators can make mistake, which may result in injury and possible shut down. Though it is cheap but there is no provision for high level of reliability and flexibility.

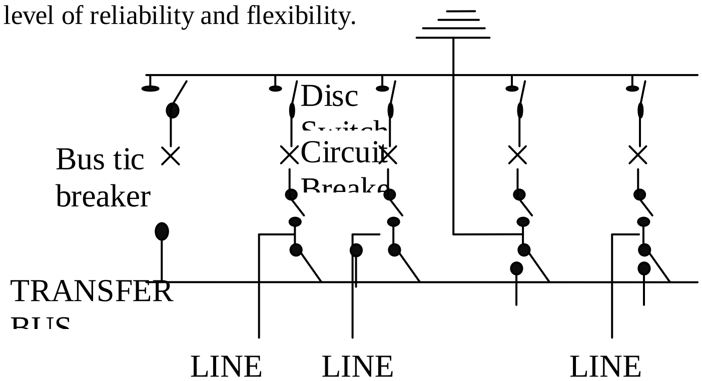


Fig. 1.3 Main Bus

Double Bus-Singe Breaker.

There are two buses in this scheme, Fig 1.4. With each circuit having two-bus selector disconnecting switches. The main and reserve bus are connected to each other by a bus-tie circuit which allows for transfer from one feeder to the other without de-energizing the feeder circuit by operating the bus selector disconnecting switch. The operation is motor driven. It is possible to operate all the circuit on the main bus or half of the circuit on either bus, in which case failure of the bus or breaker takes the station out of service or half of the circuit would be lost.

The circuit can operate on both main and reserve bus with tie- bus the breaker normally closed. In this case a very sensitive bus protective relaying scheme is necessary to prevent complete loss of the station as a result of a fault on either bus. Disconnecting switches are used frequently in this scheme. Thus there is the possibility of mal-operation, injury to personnel and possible shut down. The double bus-single breaker scheme is poor in reliability and is not normally used for important substations.

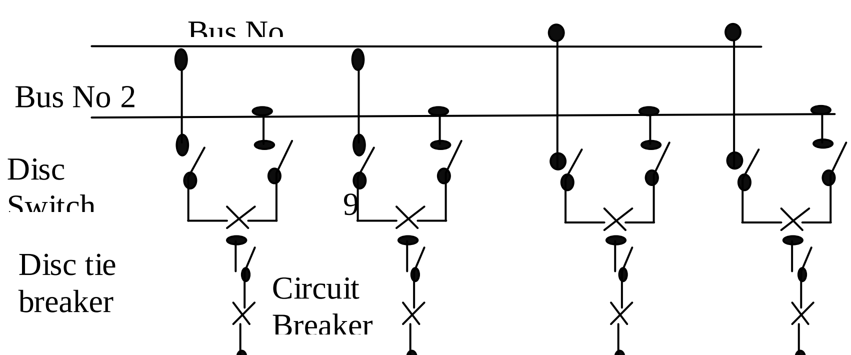


Fig 1.4 Double bus, Single breaker

The arrangement of the breakers here are in a ring with a circuit connected between them Fig 1.5, hence there is equal number of circuits and breakers. During normal operation, all breaker are closed and for any circuit fault, two circuit breakers are tripped but on failure of one the circuit breakers to operate and clear the fault. Additional circuit will be tripped by the operation of breaker failure back up relay.
In the event of breaker maintenance, if the ring is broken all lines still remain in service because the ring connection is just providing an alternative source to the load. The line disconnect switch may be opened for an external circuit outage and the ring closed. The scheme is economical and has good reliability, safe operation and flexibility.

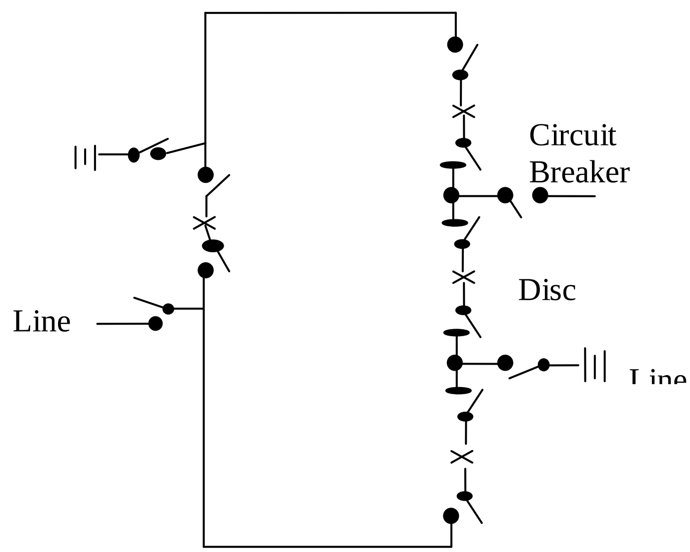


Fig 1.5 RING BUS

Breaker and Half

This has three switching scheme. Fig 1-6. three circuit breaker, which are in series with the main bus, two circuits are connected between three circuit breaker. Under normal working condition the circuit breakers is tapped by the opening of two associated circuit breakers while the tiebreaker failure will trip one additional circuit.

The scheme allows for the maintenance of breakers without loss of service and simple operation of the breaker disconnect. Though it is expensive, but it is reliable, flexible and safe. Protective relaying and automatic re-closing scheme makes it more complex than the others. Bus No 1

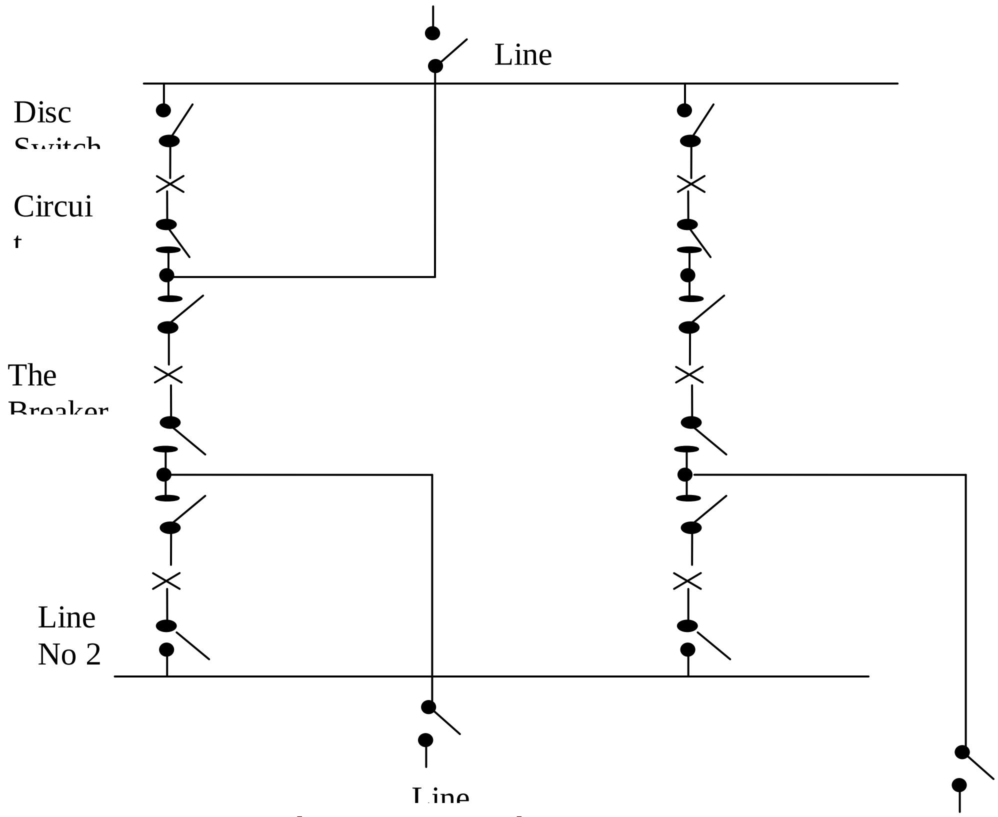


Fig 1.6 Three Circuit Breaker

Components in Substation

These are the components that can be found in a substation. They are used for substation planning and are as follows.

Transformer

This is a device, which transforms alternating voltage and current between two or more windings at the same frequency at different values of voltage and current to a higher or lower value by the principle of electromagnetic induction. Transformers are available in two types i.e. single phase or three phases. In this project, three- phase type is preferred for the following reasons.

i. It occupies less space
ii. No extra support equipment is required to form three phase delta or star connection.
iii. It is cheaper
iv. It can be transported from factory as a compact unit, erected and commissioned at the site quickly.
v. It has a compact on-load tap changing device built in the unit.

Transformers can be installed outdoor or indoor but out-door installation is preferred because of its low cost and inherent weather- proof construction.

Different types of transformers are used in the transmission and distribution of power from the generating station to the point of utilization: These transformers may be classified according to their purpose. The following classification refers to the common type of transformers.

i. Auto transformer
ii. Power transformer
iii. Distribution transformer
iv. Instrument transformer.

Auto Transformers

These are transformers with a common winding for both the primary and secondary. They are used in place of two winding power transformers where the ratio of transformation does not exceed two.

Autotransformer compared with equivalent power rated two winding transformer has reduced losses; smaller size reduced weight and low cost. The Fig 2.1 shows an auto -transformer connection.

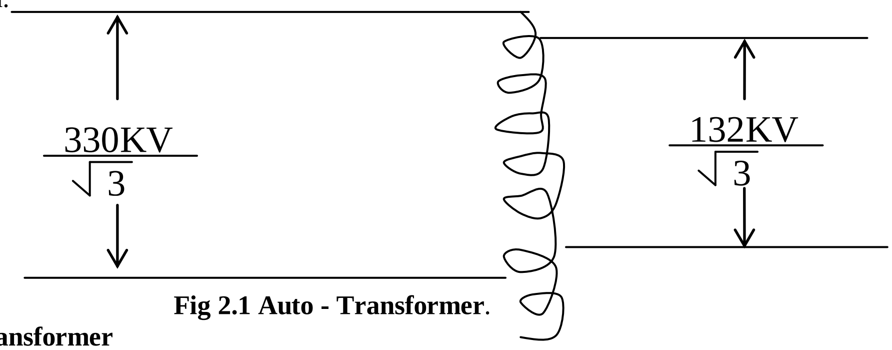


Fig 2.1 Auto - Transformer.

Power Transformer

These are transformers of high rating; generally not less than 7.5 MY A and 33KV. Its rating increase with the voltage rating. They may be of step-up type installed at generating stations or of the step- down type installed at generating substations. They have high utilization factor which make it possible for them to work at a constant load equal to their rating. They are designed to have their maximum efficiency at or near full-load. Power transformers installed in substations are provided with on-load tap changing (LTC) device to regulate the voltage to be within permissible limits during peak load and off-peak load hours.

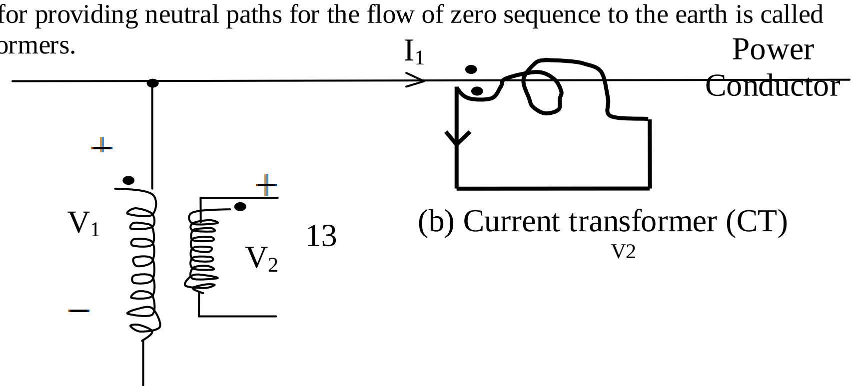
Distribution Transformers

These are transformer installed in high voltage distribution substation to meet voltage requirements of the consumers. They are generally rated at 33KV and below with rating not exceeding 1000KVA. They are characterized by intermittent variable loads, which are considerably less than the full load rating. They are designed to have their maximum efficiency at between half and three -quarter of full load. These transformers are not provided with any on load tap-changing device, but with only of circuit taps.

Instrument Transformers

This consists of current and voltage transformers. These offer certain distinct advantages for obtaining low-level samples of power system currents and voltages. These include; They are simple, economical and reliable.

They provide electrical insulation from power system voltages they are accurate and would tolerate overloading to some extent. Fig 2.2 shows the representation of voltage transformer (VT) and current transformer (CT) with zero loading. The instrument transformer is also known as auxiliary transformers connected to strategic location for supplying relays, meter etc and the ones for providing neutral paths for the flow of zero sequence to the earth is called grounding transformers.



(b) Current transformer (CT)

Fig 2.2 Representation of Instruction Transformer (a) Voltage Transformer (V T)

Current Transformer:
A current transformer is a transformer intended for measuring or control purpose designed to have its primary winding connected in series with a circuit carrying the current to be measured or controlled.

Voltage Transformer:
The voltage (potential) transformer is used for measuring or control purpose, which is designed to have its primary winding connected in parallel with a circuit, the voltage of which is to be measured or controlled.

Phase Displacement
Phase displacements indicates the angle between high voltage and low voltage vectors and it is normally between O° and 360^0. This is represented by number, which relates the voltage vector group diagram of the high voltage winding and the low voltage winding to a clock face, hence numbers 1 to 12 are used. These numbers multiplied by 30° indicates the angle by which the low voltage winding lags behind the high voltage winding.

However, in this project, the transformers used have the following connections between their primary windings and secondary windings. For the 3301132/33KV, 150VA auto-transformer, the connection is star-star (which means that both the primary and secondary windings are connected in star) with a vector group YNYODII. In a connection of this nature, it is necessary to provide a third winding which is connected in a closed delta to provide a path for the third harmonic voltage and the zero sequence currents. This winding is normally called tertiary or auxiliary winding because it provides substation station-service power to operate station auxiliary equipment.

For 33/0.415KV, 315MV A distribution transformer, the connection is delta at the primary winding and star at secondary winding. The delta connection in the primary will isolate the system with respect to the flow of zero sequence currents resulting from secondary ground fault and may be used whether the primary connection is three wires or four wires while the star secondary winding with external neutral bushing that is grounded provides a convenient neutral point for establishing a system ground or runs a phase conductor per phase to neutral load. The transformer has a phase shift of 150^0 and vector group DYn 5. Thus the neutral point can be load with the rated current and is for local and industrial distribution system.

For 33/0.415 KV 250MV A earthing/auxiliary transformer, the primary winding is connected in zigzag, while the secondary is connected in star. This transformer is connected through load isolating switches to the 33KV side of the 3301132/33KV 150 MY A autotransformer. The 33KV neutral is earthed through a bushing type current transformer feeding a stand by earth fault relay which will cause the main transformer to disconnect by tripping the associated circuit breaker on occurrence of earth fault, if it is not cleared by the relevant 33KV line protection.

Coolings Transformer

When transformers are in operation, some losses are experienced. Majority of these looses are in the magnetic circuit as a result of the variation of alternating flux in the magnetic core in relation to the induced voltages in the windings due to I 2R losses, and eddy currents in relation to the load current. These and other losses result in heating of the corresponding parts of the transformer, hence there is a need to cool the transformer to prevent it from being over heated. Thus, different methods are employed by manufacturers to cool the transformer.
The table 2.2 -2.4 below shows the types of coolants used in cooling transformers, the method of circulating the coolants and common systems.

Table 2.2 Cooling Agent

Coolant	**Symbol**
Mineral Oil	O
Clophen Askarel	L
Gas	G
Water	W
Air	A

Table 2.3 Circulation

Types of circulation	Symbol
Neutral	N
Forced	F
Directed through the winding	D

Fault Analysis in A Power System Substation.

It has been observed that even the best designed electric system occasionally experience short circuit resulting in abnormally high current. Over current protective devices such as circuit breakers and fuses are provided to isolate the faulty section at a given location safely with minimum amount of shut-down of plant operation. Other parts of the system such as conductors, bus duct and disconnecting switches must be capable of withstanding the mechanical and thermal stresses resulting from maximum flow of fault current through them. The magnitudes of faults are usually estimated by calculation and equipment are selected using the calculation results.

The current flow during a fault at any point in a system is limited by the impedance of the circuits and equipment from source to the point of fault and is directly related to the load on the system whether an existing system is expanded or a new system is installed, available fault current should be determined for proper application of over current protective devices.

The analysis provided estimated with reasonable accuracy of minimum and maximum limit of short circuit current. Maximum calculated short circuit values are used for selecting devices of adequate interrupting rating; to check the ability of components of the system to withstand mechanical and thermal stresses and to determine the time current co-ordination of protective relays while minimum short-circuit values are estimated as fraction of maximum values when calculating maximum value of fault current and used to determine the required sensitivity of protective relays.

Design Calculation

Calculation of various fault current, fault level, MVA interruption capacity and momentary current ratings for subsequent sizing of the circuit breakers and line current for isolating sizing.

Below are data obtained from EEDC engineering department.
Power Rating - 150MVA
Transformer Reactance - X ohms

HV - LV	-	0.1124Ω
HV - TV	-	0.1032 Ω
Voltage level	-	330/132/33 KV
Transformer zero sequence		
Impedance - X ohms	-	0.5679 Ω
Fault level MVA	-	10 GVA for 330 KV,

59 VA for 132 KV and 1 GVA for 33 KV

Frequency of operation	-	50H2
Primary winding	-	Star
Secondary winding	-	Star
Tertiary winding	-	Delta.

Below are calculated line parameters, distance of transmission is assumed to be 70KM from the source. This is a short line, hence its distributed capacitance can be ignored. Line impedance is tined by using the formula for inductance of three phase lines.

$$L \quad 2x10^{-7} \text{ Ln } \frac{d}{r} \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where d = spacing of conductor in meter
r = Radius of conductor in mili-meter
But

$WL = 2\pi FL = XL\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$

$= 2 \times 3.142 \times 50 \times 1.468 \text{ X } 10^{-6} \times 70 \text{ X } 10^{3}$

$= 32.26\ \Omega$

$\therefore \quad ZL = 32.26\ \Omega$

While its impedance IS twice positive and negative importance.

Thus $Z_{OL} = 2x\ 23.26$

$= 64.52\ \Omega$

And

$Z_{IL} = Z_{2L}$

Where Z_{2L} = positive sequence impedance

Where Z_{IL} = negative sequence impedance

Fault Level

For 330kv Circuit

Chosen base MVA = S_b = 1000MVA

Chosen base KV = V_b = 330KV

$$\therefore \text{ Base current } = \frac{\text{Base MVA}}{\sqrt{3} \times \text{Base KV}} \qquad \ldots\ldots\ldots\ldots. \ldots.(3)$$

$$\text{Source MVA (P.U)} \quad \frac{\text{source fault level}}{\text{Base MVA}} \qquad \ldots\ldots\ldots\ldots\ldots\ldots.(4)$$

$$\text{Source impedance (P. U)} = \frac{\text{Source voltage (P.U)}}{\text{Source MY A (PU)}} \qquad \ldots\ldots\ldots\ldots..\ldots\ldots(5)$$

$$\text{Source Impedance } (Z_<) \text{ P. U} = \frac{Z_< \text{ohms X } S_b}{Vb2} \qquad \ldots\ldots\ldots\ldots\ldots\ldots. (6)$$

From equation (6)

Line zero impedance (Z_{oL}) PU

$$= \frac{Z_{OL} \text{ ohms x 5b}}{Vb^2}$$

Three phase faults and single phase to ground fault will be calculated because three phase fault gives the maximum fault current while single phase to ground is about the commonest.

4.8.1.1 Three Phase Fault

One line diagram is shown in fig 4.4

$$I_f = \frac{E_a}{Z_1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(7)}$$

where I_f Fault current
E_a Source voltage in P.U
Z_1 Positive sequence impedance in P.U
z_{st} Source impedance in P.U
$Z_<$ Line impedance in P. U

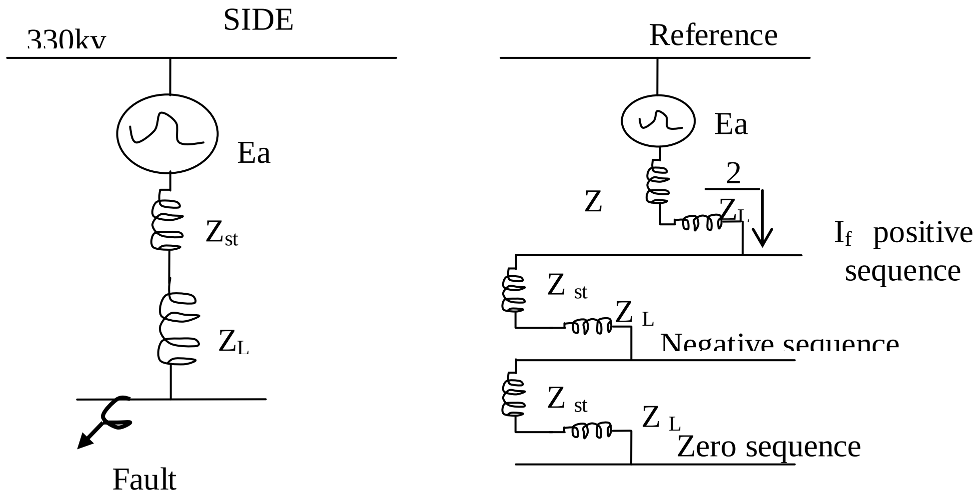


Fig 3.1 One line diagram for 3. Fault.

Z_I = Z_{st} x $Z_<$ …………………. (8)
Actual Fault current = I_F X I_b ……………………(9)
Actual fault level = I_f x base MVA …………..(10)

Single Phase to Ground Fault

Z_1 = Positive sequence impedence
Z_2 = negative sequence impedance
Z = zero sequence impedance

$$I_{a1} = \frac{E_a}{Z_I + Z_2 + Z_0} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(11)}$$

Where I_{a1} = I_{a2} = F_{a0} ……………………..……. (12)
I_F = 3 Ia_1 ………………………….(13)
Z_1 = $Z_{st} + Z_{1L}$ …………………… ……. (14)
Z_1 = Z_2
Z_0 = Z st + Z_{OL} ………………..………….(15)

Thus using equation…………. (11)

$$I_{a1} = \frac{1.0}{0.3692 + 0.3692 + 0.6925}$$

From Equation (12)

$$I_f = 3I_{a1}$$

Equation (9) and (10) give actual fault current and fault level as

Actual fault current $I_f \times I_b$

$= 2.02 \times 1.7495 \times 103$

Actual fault level ^{I}f x base MVA $= 2.02 \times 1000$ MVA

$= 2020$MVA

for 132 K V Circuit

Base MVA = 1000 MVA

Base KV = 132KV

From Equation (3)

$$\text{Base current} = \frac{1000\ \text{MVA}}{\sqrt{3} \times 132\text{KV}}$$

$= 4.374 \times 103$ A

For transformers T_1 and T_2

$$XPU = X\,\text{ohm} \times \frac{\text{base MVA}}{\text{Old MVA}} \times \left(\frac{\text{old KV}}{\text{Base KV}}\right)^2 \qquad \text{………………. (16)}$$

Three Phase Fault

$Z_{st} = 0.1$, $Z_L = Z_{2L} = 0.2962$

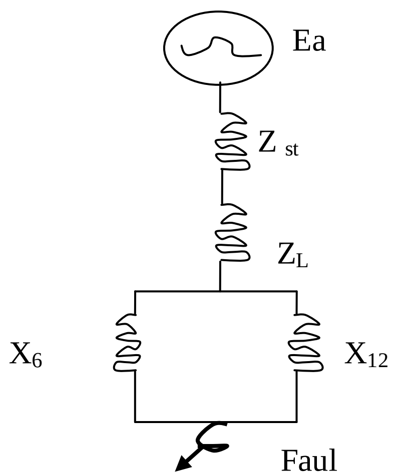


Fig 3.2 One line diagram for 3-4 Fault

$Z_{st} = 0.1$

$Z_{iL} = Z_{2L}$

$XTI = XT2$

$Z1 = Z_{st} \times Z_l \times X_T // XT_2$

$$X_{TI} // X_{T2} = \frac{X_{TI} // X_2}{X_{TI} // X_{T2}} \qquad \text{………………….. (17)}$$

from equation (9) and (10)

Actual fault current = I_F x 1_b

Actual fault level = 1.2855 x 4.374 KD

= 5.623 KA

Actual fault level = I_F x base MVA

= 1.2855 X 1000 MVA

= 1286 MVA

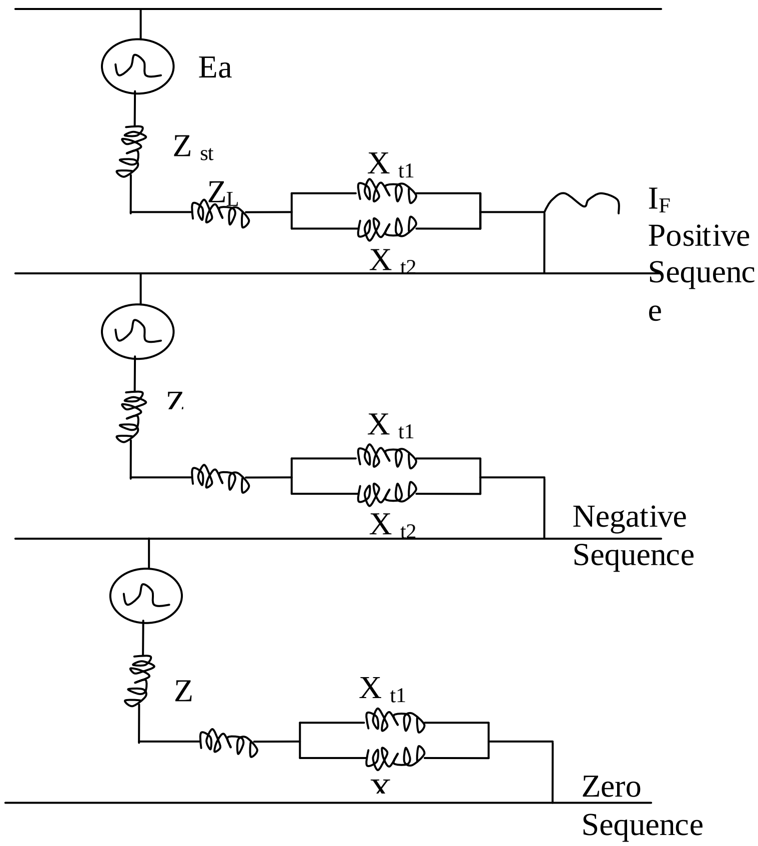


Fig 3.3 Single Phase to Ground Fault

$Z_{st} = 0.1$ PU

$X_{T1} = X_{T2}$

$Z_{IL} = Z_{2L}$

$Z_{OL} = 0.5925$PU

$X_{OTl} = X_{OT2}$

$$XOT = 0.5679 \times \frac{1000MVA}{150MVA} \times \left(\frac{132KV}{150\ MVA\ 132\ KV}\right)^2$$

$$Z_1 = Z_{st} + Z_{OL} + X_{Tl} // X_{T2} \quad \ldots\ldots\ldots 17$$

But $Z_I = 0.7779$ P U

$$Z_O = Z_{st} + Z_{OL} + X_{OT1} // X_{OT2} \quad \ldots\ldots\ldots 18$$

$$XO_{T1} // X_{OT2} = \frac{X_{OTl} \cdot X_{OT2}}{X_{OTl} + X_{OT2}}$$

From equation (11)

$$F_{a1} = \frac{E_a}{Z_1 + Z_2 + Z_0}$$

From equation (13)

$I_f = 3Ia_l$

= $3 \times 0.2415 =$ 0.72445

From equation (9) and (10)

Actual fault current $I_f \times I_b$

= $0.7244 \times 4.373 \times 10^3$

= 3.169×10^3 A = 3.169 K A

Actual fault level I_f x base MVA

= 0.7244 x 1000 MVA = 724.4MVA

For 33 K V Circuit

Base MVA = 1000MVA

Base KV = 33KV

From equation (3)

$$\text{Base current} = \frac{1000\ MVA}{\sqrt{3} \times 33KV}$$

= 17.495KA.

From equation (16) we can obtain the per unit for transformer T, and T2

$$XP.U = X\ ohms \times \frac{base\ MVA}{Old\ MVA} \times \left(\frac{old\ KV}{base\ KV}\right)^2$$

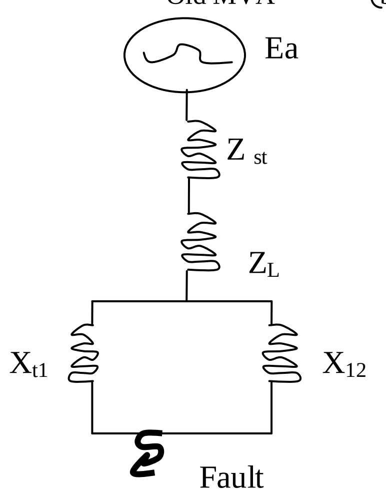


Fig 3.4: Three Phase Fault

Z_{st} = 0.1 PU

Z_{1L} = 0.2962 P U

X_{TI} = 0.688 P U

From equation 18

$Z_1 = Z_{st} + Z_2 + XT_I // X_{T2}$

Using equation 17

$$X_{TI} // X_{T2} = \frac{X_{T1} \cdot X_{T2}}{X_{T1} + X_{T2}}$$

From equation 18

Z_1 $Z_{st} + Z_2 + X_{TI} // X_{T2}$

From equation (7)

$1_f = \frac{E_a}{0.7402}$ 1.351PU

From equation 9 and 10

Actual Fault current = $I_f \times I_b$
= 1.351 x 17.495 KA = 23.636 KA

Actual Fault level = I_f x base MVA
= 1.351 x 1000 MVA KA = 1351 MVA

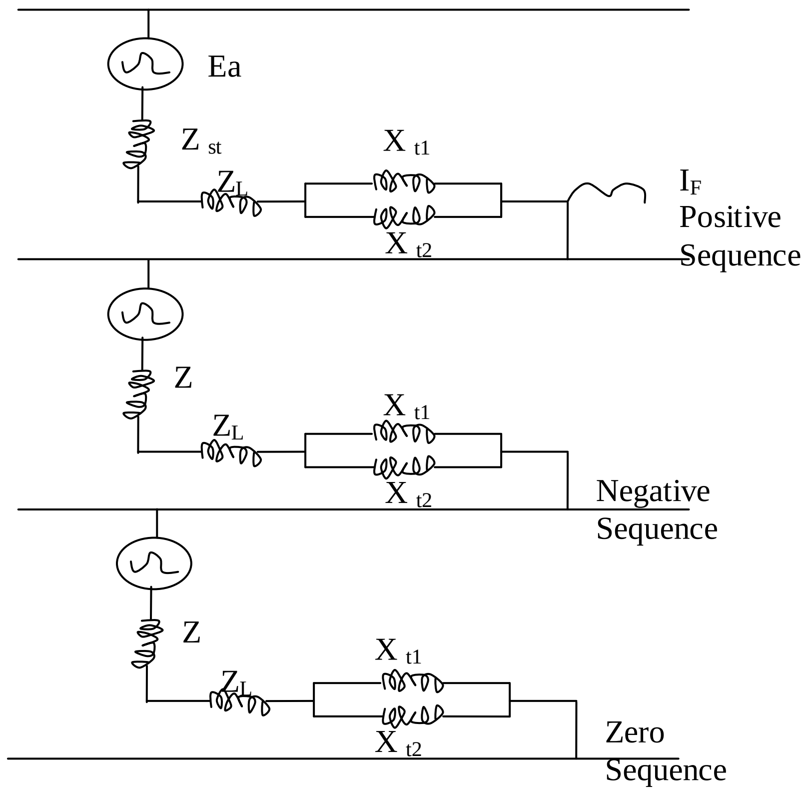


Fig 3.5 Single Phase to Ground Fault

Z_{st} = 0.1 PU
Z_{IL} = Z_{2L}
Z_{OL} = 0.5925PU
X_{T1} = X_{T2}
X_{OTl} = X_{OT2}

From equation (15)

$X_{OT} = 0.5679 \times \frac{1000MVA}{150MVA} \left(\frac{33 \times 0}{33 \text{ kv}}\right)^2$

From equation 18

$Z_1 - Z_{st} + Z_{IL} + X_{TI} // X_{T2}$

$X_{OT1} // X_{oT2} = X_{O1} . X_{OT2}$

$$\overline{\qquad\qquad}$$
$$X_{OT1} + X_{OT2}$$

From equation 11

$$I_{a1} = \frac{E_a}{Z_1 + Z_2 + Z_0}$$

From equation 13

I_f = $3I_{al}$
= 3 x 0.246
= 0.738

From equation 9 and 10

Actual fault current I_f x I_b
= 0.738 x 17.495 = 12.91 K A

Actual fault level = I_f x base MVA
= 0.738 x 1000 MVA = 738 MVA

From the above calculations, three-phase fault current and levels are chosen by virtue of their higher values compared with fault levels and currents in single phase to ground in rating the circuit breaker.

330kv Circuit Breaker

Choosing fault current of three-phase fault, which is 4.415 KA, then the momentary current rating is 1.6 x I_F..................20

For circuit breakers above 5 KV

:. Monetary current rating = 1.6 x 4.415 K A
= 7.064 KA

Interrupting capacity = $\sqrt{3}$ X V_{LL} x I^f x 10_6 ………… 21
= 2425 MVA.

The calculated fault level of three phases for 330 KV circuit is 2524 MVA but circuit breakers are available in standard sizes or rating. Therefore the nearest standard rating of 3000 MVA has been used. Using single phase circuit breaker

MVA per phase = $\frac{\text{Total MVA}}{3}$

$\frac{3000}{3}$ = 1000 MVA

The rating should be as follows

Type = S_{F6}

Frequency 50 H_2

Rated voltage = 330KV

MVA per phase rating = 1000 MVA

Rated opening and closing voltage = 110 d.c

Rated lightning impulse withstand voltage = 1050 KV

Rated short circuit breaking current = 20 KA

132 KV Circuit Breaker

Choosing a fault current of three phase is 5.623 K A

From equation …………… (20)

The momentary current rating = 1.6 X I_F
= 1.6 x 5.623
= 8.997 KA

From equation………………(21)
The interrupting capacity = $\sqrt{3} \times V_{LL} \times I_F \times 10^{-6}$ = 1286 MVA.
Fault level of three phase for 132 K V circuit is 1286 MVA, the nearest standard ratings of 1500 MVA has been used.
Using single phase circuit breaker
From equation……………………. (22)
∴ MVA per phase = $\frac{1500}{3}$
= 500MVA
The rating should be as follows

Type	-	SF6
Frequency	-	50Hz
Rated voltage	-	132 KV
MVA per phase rating	=	500MVA
Rated opening and closing voltage	=	110 d . c
Rated lightning impulse withstand voltage	=	650KV
Rated short circuit breaking current	=	20KA

33 KV Circuit Breaker
Choosing a fault current of three phases, which is 23.636 KA.
From equation ……………………..(20)
The momentary current rating = $I^f \times 1.6$
= 1.6 x 23.63 KA
= 37.82 KA
From equation (21)
The interrupting capacity = $\sqrt{3} \times V_{LL} \times I^f \times 10^{-6}$
= 1.6 x 23.636 KA 10^{-6}
= 1351MVA.
Fault level of three phases for 33 K V circuit is 1351 KVA; the nearest standard rating of 1500 MVA has been used.
Used single-phase circuit breaker.
∴ MVA per phase = $\frac{1500}{3}$
= 500MVA
The rating should be as follows

Type	-	SF6
Frequency	-	50H2
Rated voltage	-	33 KV
MVA per phase rating	-	500 MV A
Rated opening and closing voltage	-	1l0dc
Rated lighting impulse with stand voltage	-	170 KV
Rated short circuit breaking current	-	40KA

Current Transformer Ratio
Calculation for selection of current Transformers
Load current = $\frac{\text{Rated MVA}}{\sqrt{3} \times \text{Rated KV}}$ …………………..(23)
Then load current at 330 KV
Load current = $\underline{150 \times 10^6 \qquad}$

$\sqrt{3} \times 330 \text{ X } 103$

= 2624 A

Load current at 132 KV

$= \dfrac{150 \times 10^6}{\sqrt{3} \times 132 \times 10^3} = 656\text{A}$

Load current at 33 KV

$= \dfrac{150 \times 106}{\sqrt{3} \times 33 \times 10^3}$

= 875 A

Therefore line current transformer ratio at 330 KV = 300 / 1 A
Line current transformer ratio 132 KV = 800 / I A
Line current transformer ratio at 33 K V = 1000/1 A
From equation 23 we have
Current at 33 KV corresponding to 150 MVA

$= \dfrac{150 \text{ X } 10^6}{\sqrt{3} \times 33 \text{ x}l0^3} = 2624.3\text{A}$

Secondary current from 330 KV line current transformer corresponding to 150 MVA is

$262 \times \dfrac{1}{300} = 0.8733 \text{ A}$

Therefore ratio of required star! delta interposing current transformers is 0.8733/ $1/\sqrt{3}$
Secondary current from 132 KV line current transformer corresponding to 150 MVA is

$656 \times \dfrac{1}{800}$

0.82A.

Therefore ratio of required star/star interposing current transformers = 2624 /1

Voltage Transformer Ratio Calculation

The voltage ratio for 330 KV voltage transformers will be as follows;

$\dfrac{330000\text{V}}{\sqrt{3} \times 330}$

$= \dfrac{110 \text{ V}}{\sqrt{3}}$

The voltage ratio for 132 KV voltage transformers will be.

$\dfrac{132000\text{V}}{\sqrt{3} \times 132} \quad \dfrac{110 \text{ U}}{\sqrt{3}}$

Isolator Rating Calculation Line
Current Isolator Sizing.

The 330 KV transmission line capacity is about 1000 MVA and the 132 KV transmission line capacity is about 300 MVA while the 33 K V transmission line capacity has about 40 MVA. That is six 150 MV A substations can be fed from a single 330 MV A transmission line.
From equation 23
The primary load current I_{Lp} will be;

$I_{Lp} = \dfrac{1000 \text{ MVA}}{\sqrt{3} \times 330\text{KV}}$

$$= \frac{1000 \times 10^6}{\sqrt{3} \times 330 \times 10^3}$$

$= 1749.5$ A

The secondary current on 150MV A 330 / 132 transformer

$$I_{LT} = \frac{300 \times 10^6}{\sqrt{3} \times 1132 \times 10^3}$$

$= 1312.2$ A

While the current on the 33 K V tertiary side is

$$ILT = \frac{40 \times 10^6}{\sqrt{3} \times 33 \times 10^3}$$

$= 629.84$ A

Thus, the isolator ratings can be classified as follows;

The 330 KV line current will be calculated with respect to + 10% tolerance but a lower limit is chosen since the current is the maximum it can carry.

Hence 330 KV line current - 10 %

Tolerance gives; 1749.5A - 174.95 A

= 1574.55 A.

The nearest isolator standard rating of 1600 A is chosen.

For 132 KV line current - 10 % tolerance gives;

1312.2 A - 131.22 A = 1180.98 A.

The nearest isolator standard rating of 1250 A is chosen.

For 33 KV line current - 10 % tolerance given;

699.82 A - 69.982 A = 629.84 A

The nearest standard rating of 800 A is chosen.

Conductor Rating

Selection of connector size requires consideration of load current to be carried and loading cycle, emergency over loading requirement and duration fault clearing time and interrupting capacity of the conductor over current protection or source capacity and voltage drop for particular installation.

The load current to be carried can be determined as follows

For 330 KV circuit

Using equation 23 we have

$$\text{Load current} = \frac{MVA}{\sqrt{3} \times KV}$$

$$= \frac{150 \times 10^6}{\sqrt{3} \times 330 \times 10^3}$$ where $MVA = 150 \times 10^6$, $KV = 330 \times 10^3$

$= 262.43$ A

But consideration has to be given for over load 'hence allowance of 20 % is given.

The maximum permissible current that will flow

$$= \frac{120}{100} \times 262.43 \text{ A}$$

$= 314.92$ A.

for 132 KV circuit

Equation 23

$MVA = 150 \times 10^6$

KV = $132 \text{ X } 10^3$

Load current = $\frac{150\text{x } 106}{\sqrt{3}\text{x } 132 \text{ X } 10^3}$ = 656.08 A

Given an allowance of 20% over load given

$\frac{120}{100}$ x 656.08

= 787.3 A

For 33 KV circuit

From equation 23

MVA = $25 \text{ x } 10^6$

KV = $33 \text{ X } 10^3$

Load current I_L = $\frac{25 \text{ X } 10^6}{\sqrt{3}\text{x } 33 \text{ X } 103}$

= 437.39 A.

Given an allowance of 20% overload gives

$\frac{120}{100}$ x = 4.37.39

= 524.86 A

Now for the conductor rating, they are rated as follows with load current they can carry.

For 330KV circuit

Load current = 314.92 A

Conductor size = 100/ 15 mm^2

For 33 KV circuit

Load current = 524.86 A

Conductor size = 212 / 50mm^2

Commission

All installations must be thoroughly tested before they are commissioned to ensure that proper connections are made and all equipments work according to specification before the station is energized.

Overall Requirements

Conductors to which high voltage tests are applied shall be isolated from live conductors at system voltage by either isolating a circuit breaker or by opening appropriate switching devices to obtain two isolating gaps in series.

High voltage test shall be conducted in accordance with standard safety rules. The equipments to be tested in the substation include; the transformers, the circuit breakers and other accessories associated as auxiliary equipments.

4. INSULATION RESISTANCE TEST

A poor insulator has a comparatively low insulation value and vice-versa. For this reason conductor and apparatus insulation resistance is expressed in mega-ohms (106) Dampness is a major use of low insulation. The moisture, which is absorbed by the insulation, produces in the equipment leakage current, which flows outwards through the insulation and may be taken to form parallel paths. The insulation level of equipment under test shall be measured with insulation resistance tester (MEGGAR) before and after the application of a high voltage test.

Earth Resistance Test

Earth testers may also measure soil resistivity) four metal spikes are driven into the ground up to a depth of 1 m and not exceeding one twentieth of their separation, in a straight line with typical dimensions.

This method is used extensively in refinery geological surveys and for confirming the presence of mineral deposits.

Equipment Testing

Transformer Testing

The following tests should be carried out on each transformers and their accessories.

i. Winding resistance
ii. Voltage ratio
iii. No load loss current at main and extreme traps
iv. Load loss
v. Induced over voltage withstand
vi. Mechanical strength
vii. Dielectric strength insulation medium
viii. Temperature rise
ix. Full wave impulse voltage withstand voltage
x. Short circuit and open circuit
xi. Zero impedance

Circuit Breaker Testing

These are the tests to be carried out on a circuit breaker.

i. Temperature rise
ii. Operation and mechanical endurance
iii. Making capacity
iv. Impulse voltage withstand
v. Over head line switching
vi. Switching transformer on no load

Current Transformer Testing

Tests are to be carried out on current transformers to certain the following:

i. Impulse voltage
ii. Short time current
iii. Temperature rise
iv. Error saturation factor
v. Accuracy
vi. Verification of terminal marking

Voltage Transformer Testing

The tests to be carried on voltage transformers are ;

i. Verification of terminal making
ii. Temperature rise
iii. Impulse voltage
iv. Power frequency at both primary and secondary winding.

Lightning Arrester Testing

Lightning arresters are to be tested to ensure the following:

i. Voltage withstand on arrester insulation

ii. Power frequency spark over
iii. Front-of- wave impulse spark over
iv. Residual voltage
v. Impulse current withstand.
vi. Operating duty.

Relays Testing

The following tests are to be carried out on relays.

i. Limits of error test
ii. Resetting values test
iii. Insulation test
iv. Operating test
v. Over load test
vi. Temperature test
vii. Contactrating test

Conclusion

The substation is fed by 330KV line. It is designed to produce 132KV and 33KV outputs.

In this research appropriate equipment selection is given special attention. As equipment interfacing must be conformed to reduce miss-match and consequent instability. Protection system was designed to protect important components of the substation such as transformers, circuit breakers and bus bars.

The protecting devices used are surge arresters (thyrite arresters and commercial arresters is value type and expulsion arresters), restricted earth-fault protection, over voltage relay, breaker failure detector relays and reactor. Gaps are also used as surge arrester.

Fault analysis in power system substation was also considered to estimate the maximum magnitude of fault in a substation to assist in selection of appropriate equipment.

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