Effect on CT Ratio and Circuit Breaker Rating due to nearby New Mega Generating Station

A Dissertation submitted in fulfillment of the requirements for the Degree
of

MASTER OF ENGINEERING
in
Power Systems

Submitted by

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DECLARATION

I hereby certify that the work which is presented in dissertation entitled, "Effect on CT Ratio and Circuit Breaker Rating due to nearby New Mega Generating Station" in partial fulfillment of the requirements for the award of the degree of Master of Engineering in Power Systems, submitted to Electrical & Instrumentation Engineering Department of Thapar University, Patiala is as authentic record of my own work carried under the supervision of Dr. Amrita Sinha. It refers others researcher's work which are duly listed in the reference section. The matter contained in this dissertation has not been submitted, neither in part nor in full to any other degree to any other university or institute except as reported in text and references.

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Certified that the dissertation entitled, "Effect on CT Ratio and Circuit Breaker Rating due to nearby New Mega Generating Station", which is being submitted by Nadhim Garg in fulfillment of the requirements for the award of the Master of Engineering in Power Systems, to Thapar University, Patiala, is a bona-fide record of the candidate's own work carried out by him under my supervision and guidance. The matter contained in this dissertation has not been submitted, neither in part nor in full to any other university or institute for award of any degree.

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TABLE OF CONTENTS

TABLE OF CONTENTS (Continued)

TABLE OF CONTENTS (Continued)

LIST OF TABLE

LIST OF FIGURE

TABLE OF FIGURE (Continued)

LIST OF ABBRIVIATIONS

CT	Current Transformer
CB	Circuit Breaker
AC	Alternating Current
DC	Direct Current
RMS	Root Mean Square
PT	Potential Transformer
MVA	Mega Volt Ampere
TL	Transmission Line

ABSTRACT

This paper presents the effect on the breaking capacity of previously installed circuit breaker due to the upcoming installation of new generating stations in the near vicinity. The MVA capacity of the circuit breaker and current transformer rating needs to be upgraded owing to increase in the symmetrical fault current level. The circuit breaker connected to the older generating station can maloperate. The circuit breaker parameters connected to the smaller generating unit at the generating and grid end have been calculated and tabulated with respect to symmetrical fault without and with the new transmission line connected to the same grid. The more the difference in the rating of the two generating unit the higher is the MVA rating required for circuit breaker upgradation. The current transformers connected at the generating and grid end saturates and affects the secondary output due to the change in fault current level with new generating unit nearby. This results in maloperation of the relay and circuit breaker. The current transformer new rating has been proposed to avoid its saturation and the output is compared with the older rating.

CHAPTER-1

INTRODUCTION

1.1 Overview

The Power demand has augmented manifolds in the recent years due to increase in the consumption. To meet this demand of electricity the generating capacity has been mostly increased in the region where natural resources are available. The new super thermal power plants and large hydro generators have been installed near to the old generating units. The older unit's generating capacity is lesser as compared to the new units installed. The breaking capacity of the circuit breaker is based on symmetrical fault current [1]. The level of the short circuit current for symmetrical fault has been changed for the older generating units due to the upcoming of new mega units in the near vicinity. Therefore, the breaking capacity of the circuit breaker of older generating units needs to be recalculated for faults that may occur in the system.

The circuit breaker failure due to increased fault current has been quantified and the effect of the relative statistical frequency of the different types of faults in the power system distribution analyzed in [2]. Reliability assessment has been also done of over stressed circuit breaker. The short circuit analysis for three phase symmetrical and unsymmetrical fault has been done to calculate the MVA rating of circuit breaker [3].The ratings of existing circuit breaker has been compared with the simulated system and the effect of time delay on its operation has been studied [4]. The interrupting capacity and short time current rating of low voltage circuit breaker have been examined [5] and preventive maintenance of the circuit breaker deduced, based on substation topology to increase the reliability of the electricity supply [6]. Economic analysis has been performed on stress-induced failure of a circuit breaker with or without fault current limiter in [7]. The cost of circuit breaker up-gradation has been evaluated upon the consequence of distributed generator connection. The increase in level of fault current has been different for additional DG being connected at different location in the distribution network [8].

Advance CT sizing concept with transient dimension and X/R ratio factors have been considered for CT performance analysis at different CT Burdens [9]. The influence of CT saturation on over-current protection has been studied during faults for protection devices located far off from it [10]. A method for detection of current transformer saturation effects for low sampling frequencies has been analyzed and for estimation of unsaturated secondary current, a curve fitting algorithm proposed [11].

This dissertation presents the change in circuit breaker rating required on addition of a new generating unit in close vicinity of existing 250MW generating unit. The short circuit current rated interrupting capacity, sub-transient short circuit current, rated short circuit making current have been calculated for symmetrical fault in the transmission line connecting new mega-generating unit and grid station. The circuit breaker of the old generating unit has been found to be overstressed and therefore need to be upgraded. The effect of the current transformer saturation has also been analyzed on the operation of circuit breaker and relay. In 250MW generating station, current transformer (CT1 and CT2) ratings are on the basis of symmetrical fault in the old transmission line. The CT saturation has been analyzed for symmetrical faults in the new TL. New CT rating and the new MVA capacity of CB have been suggested for clearance of faults within prescribed limits.

1.2 Literature Survey

D. P. Kothari *et al.* [1] introduced the breaking capacity of the circuit breaker is based on symmetrical fault current. Short circuit current consist of two component- (a) DC offset current (b) symmetrical short circuit current. The maximum value of dc offset current occurs in that phase whose voltage level is zero at the short circuit (say phase A) because of the time variation of synchronous reactance (X_s) of synchronous generator, the symmetrically short circuit current falls and reaching at steady state position after transient and sub-transient period.

Q. B. Dam *et al.* [2] presented the circuit breaker failure due to increased fault current has been quantified in reliability assessment has been also done of over stressed circuit breaker. Over stressed is the major cause of failure of the circuit breaker. Circuit breaker failure results in the unreliability of the system and simultaneous generator outage.

G. Kaur *et al.* [3- 4] described the short circuit analysis for three phases symmetrical and unsymmetrical fault has been done to calculate the MVA rating of circuit breaker. Now ring main transmission system is installed which result in a decrease in the resistance. Due to this impedance decreases and thus short circuit level is increased. Thus to keep away that problem circuit breaker should be capable short circuit current. Thus, the circuit breaker parameter recalculated with comparing the existing system.

D. D. Roybal [5] presented the interrupting capacity and short time current rating of low voltage circuit breaker has been examined. Interrupting capacity of circuit breaker is defined as a maximum current that breaker can carry without interrupt the supply and short time rating is expressed as R.M.S. value of current that carry by a circuit breaker with a regular increase in temperature with in specific limit.

J. J Meeuwsen *et al.* [6] represented the preventive maintenance of the circuit breaker have been deduced based on substation topology to increase the reliability of the electricity supply. By the preventive maintenance, the failure of the circuit breaker can be reduced, the condition is preventive maintenance is to be carried out carefully. By the preventive maintenance of the circuit breaker, lots of components installed in the substation also protected.

M. R. Haghifam *et al.* [7] introduced the Economic analysis has been performed on the stress-induced failure of a circuit breaker with or without fault current limiter. Fault current passing through the circuit breaker is momentous impact on the circuit breaker failure. when a fault increases above the breaking capacity of the circuit breaker then circuit breaker are subjected to increases the stress which results in failure of the circuit breaker. To reduce this one idea is to increase the breaking capacity of the circuit breaker or circuit breaker replacement. By the use of fault current limiter this problem is solved.

B. Li *et al.* [8] presented the cost of circuit breaker up gradation has been evaluated upon the consequence of distributed generator connection. The increase in fault current is different for additional DG connecting at a different location in the network. This paper proposed a model long run incremental cost pricing, which replicate the cost caused by the change the circuit breaker.

U. A. Bakshi *et al.* [9] described the various components such as bus bar, circuit breaker, instrument transformer, power transformer, measuring instrument are used inside the substation.

P. Jadeja *et al.* [10] presented the idea about whenever symmetrical short circuit fault is occur in the power system network, then due to the consist of both the DC and AC component in the fault current the symmetrical current become asymmetric current because of DC component. DC component is non periodic and decay with time constant L/R. The main focus in this paper is critically operation of circuit breaker at various percentages of DC components with change in tine and decay constant.

D. kaur *et al.* [11] represented the study about to simulate the short circuit fault on different buses of the power system network. They used the both IEEE 11 and IEEE 30 bus system to simulate the study. In this paper estimate the state of the power system network before and after occurrence of fault. When a short circuit fault is occur in system voltage decay to zero and current rises high. To analysis the power system before occurrence of fault it uses a N-R method and to analysis the system after occurrence of fault uses the short circuit current compotation algorithm.

S. Tiwari *et al.* [12] introduced the idea for the accurate operation of the current transformer sizing and saturation characteristics must be adequate with the system current, VA rating, and transient performance .A current transformer is a major part of the power system protection. The main requirement of the current transformer is to translate the primary current in a high voltage system to single level that can be managed by an electronic device. For the current transformer sizing, this paper proposed the concept of K_{TD} and X/R ratio with the performance analysis of current transformer.

L. J. A. Kojovic *et al.* [13] represented the if current transformer rating is not decided as the current flow in the system then the impact occurs when a symmetrical fault occurs in the system the current transformer goes into a saturation state thus the secondary of the current transformer not given the accurate data to relay input, due to this circuit breaker maloperate. One solution solves the problem is increase the rating of the current transformer and another method places the protective device far away from current transformer. Due to this wire resistance is adds with current transformer burden rating which causes the effect of the saturation is less as compare to the protective device close to the current transformer.

P. Stachel *et al.* [14] represented the idea of the current transformer saturation impact even a low sampling frequency. Ideally, a current transformer converts the primary current linearly but in a practical point of view, due to the saturation affect its convert non-linearly output. By the saturation effect current transformer secondary signal destroyed so the protective device such as a relay, circuit breaker operates with some time delay or blocked.

M. M. Eissa [15] introduced a scheme *i.e* based on wavelet transform. It basically distinguishes between the faults at the protective zone to the fault at outside the protective zone. This transform scheme depends on upon high frequency faulted signal, which signal produce current transform saturation. Basically, a saturation of current transformer means a drop of both magnitude and phase shift in the current. Protection of the bus bar is stability and operation is fast.

S. H. Horowitz [16] described the DC component of the fault current cause the increase the flux linkage above the steady state value that results in the saturation of the current transformer. DC component is decay to zero after some time so the effect of the saturation of the current transformer is also decayed to zero after some time according to the circuit parameter. But during the saturation period value of the secondary current of the current transformer not follow the linearly relationship with the primary current of the current transformer, hence the relay which depends on the secondary of the current transformer maloperate during the saturation period .Thus, during the designing of the protective device must consider the effect of the current transformer saturation.

D. REIMERT *et al.* [17] explain the concepts of current transformer rating; according to the accuracy current transformer used for protective relay is C, K, or T type. Current transformer delivers at 20 time's current without exceeding 10% ratio error. Before saturation CT secondary current follow a linear relationship with the primary winding but due to the effect of saturation it follow non linear relationship. Saturation occurs due to the DC component contains in the fault current.

J. H. HARLOW [18] described current transformer always treated as black box. CT always connected in series with the circuit. Current transformer under normal condition, observe the change in load current. The primary winding of current transformer always offers a low impedance loop to the constant current source. CT is not a voltage dependent but it only limits the level of voltage. When current is flow, then by ohm's law voltage is developed and energy dissipated from primary supply thus acts like a shunt. Dissipation results in CT error. According to this, saturation curve is always called a secondary excitation curve, tolerance limit 95% of saturation voltage for any value of excitation current above knee point and 125% of excitation current for any value of voltage below the knee point.

P. Stachel *et al.* [19] described the detection of current transformer (CT) saturation effect for low sampling frequency. Ideally the output of CT is linearly with the output, but due to the saturation occurrence in the CT behaves non linearity at very high input current or high burden. For estimation of saturation effect utilize curve fitting algorithm.

M. Davarpanah *et al.* [20] introduced a hardware technique to prevent the CT saturation. In this technique a rheostat is connected in secondary winding of current transformer which generates a flux opposition to the main flux associated with the decay of DC component of fault current. When a fault is occur in the power system network then CT is more prone to the magnetic core saturation .due to the effect of saturation then it miss coordinate operation with the relay and circuit breaker, due to this stability problems is occur and apparatus associated with the system also damaged.

M. A. Yalcin [21] described the voltage stability is major problem in the power system operation. Main focus on the dynamic voltage stability, because major apparatus of our power system are affect by dynamic voltage stability. Dynamic voltage stability is occurring when tripping of one or more transmission line connected to the network. By such tripping fault impedance is increase, voltage drop and generated reactive is reduce.

S. C. Naghate *et al.* [22] represented demand of electricity continuously increased with time. Thus to fulfill the demand of consumer, it is necessary to increase the transmission line capacity. In this paper various fault (line to line (L-L), Line to ground (L-G), double line to ground (LL-G) simulate and study the effect of these fault in transmission line.

1.3 Objective

- To study the effect on rating of circuit breaker due to the symmetrical fault when a new mega generating station is added to nearby grid station to which a small generating station was previously connected.
- Simulate the effect on CB rating and current transformer saturation of previously installed generating station when a symmetrical fault occurs in the TL connecting to new generating station.
- Simulate the effect on CB rating and current transformer saturation of previously installed generating station when a symmetrical fault occurs in the TL connecting to old generating station.
- Propose the new rating of CB and current transformer of previously installed generating station.

1.4 Organization of Thesis

Thesis is organized in five chapters. The contents of these chapters are as follow:

Chapter 1 discusses the introduction about work and literature survey about thesis work. The main idea in this chapter is discuss the effect of rating of circuit breaker and current transformer when fault is occurs in system and solution of that problem.

Chapter 2 summarizes the substation component.

Chapter 3 discusses about circuit breaker and its rating.

Chapter 4 discusses about current transformer, its rating and saturation.

Chapter 5 simulation work and Implementation of different case study and simulate the parameter of circuit breaker and current transformer.

Chapter 6 summarizes the conclusion and future scope of work.

CHAPTER-2

SUBSTATION

Substation is the assembly of apparatus such as Bus bars, Insulators, Isolating switches, Relay, Circuit breakers, Load interrupting switches, Power transformers, Instrument transformers(current transformer and potential transformer)Indicating and measuring Instrument and so on. This is used to change the supply system characteristics such as voltage level, frequency, rectification and power factors.

2.1 Types of Substations

There are four major types of substation which can be classified as:

- Generating station switchyard
- Customer substation
- System substation
- Distribution substation

Generating station switchyard connects the generator to the utility grid. The main function of the customer substation is to supply electrical power to one particular organization. System substation is basically a switching station that transfer is no power. Distribution substation supplied electrical power directly to the consumer. On the basis of equipment used substation can be classified as:

- Outdoor type with air-insulated equipment
- Indoor type with air-insulated equipment
- Outdoor type with gas-insulated equipment
- Indoor type with gas-insulated equipment
- Mobile substation
- Mining substation

Each substation has its own advantage and disadvantage. During designing the substation cost is the main factor. Mostly substations are outdoor type and where some non-economic factors like public appearance is considered then indoor substation is preferred. Indoor substation handles voltage up to 11 KV. Beyond 66 KV outdoor substation is preferred.

2.2 Substation Equipment

Substation equipments are classified into bus bar, isolating switches, load interrupting switches, power transformer, relay etc. Fig 2.1 depicts the list of various component of substation.

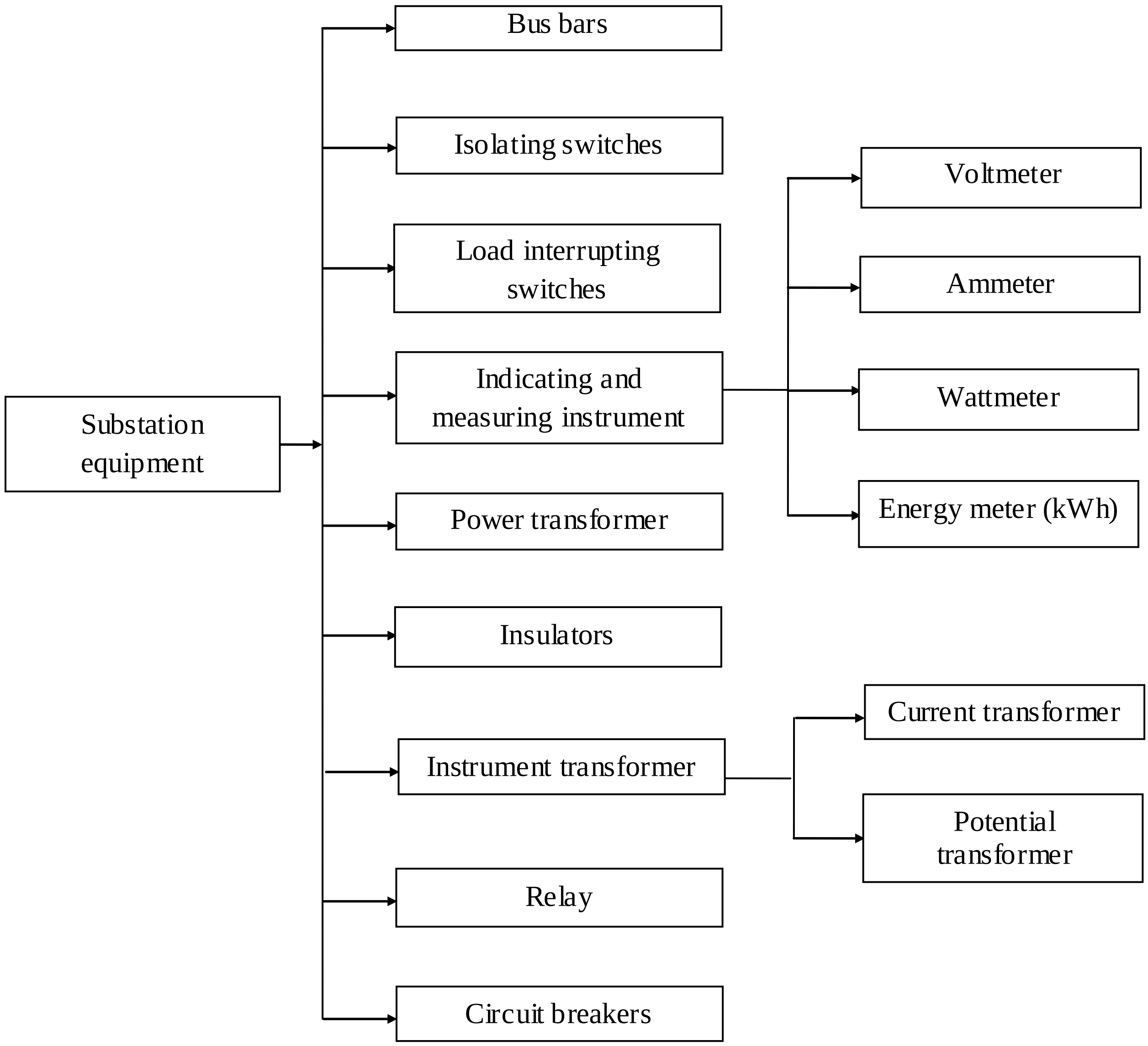


Fig 2.1 List of various component of substation

2.2.1 Bus Bars and Arrangement

Bus Bar is the nerve center of the power system, where various electrical components such as circuit breaker, isolator, isolating switch, instrument transformer are connected i.e. operating at same voltage level directly. Bus bars are two types:

- Rigid type
- Strain type

In rigid type pipes are used as bus bars. Two types of material are used to manufacturing the bus bars:

- Copper
- Aluminum

But due to numerous advantage of aluminum over copper such as lower cost, highly conductivity on weight basis thus aluminum is preferred. Aluminum pipes are used as a material in case of formation of rigid type bus bar. Size of AL pipes are required according to their voltage level is shown in Table 2.1.

Table 2.1 Size of aluminum pipe according to the voltage level

S.No.	Voltage	Size
1.	33 KV	40 mm
2.	66 KV	65 mm
3.	132 KV	80 mm
4.	220 KV	80 mm
5.	400 KV	100 mm

Bus Bar Arrangement**:** There are numerous bus bars arrangement as shown in Fig.2.2. The factors considered while selection of bus bar arrangement are flexibility, reliable supply, cost, system voltage. There are some point also considers bus bar arrangement:-

1) Arrangement of Bus Bar should be simple.
2) During abnormal conditions maintenance of line should be possible without interruption of supply.
3) Layout should be accommodating in such a way that the future expansion is possible with increase in load demand.

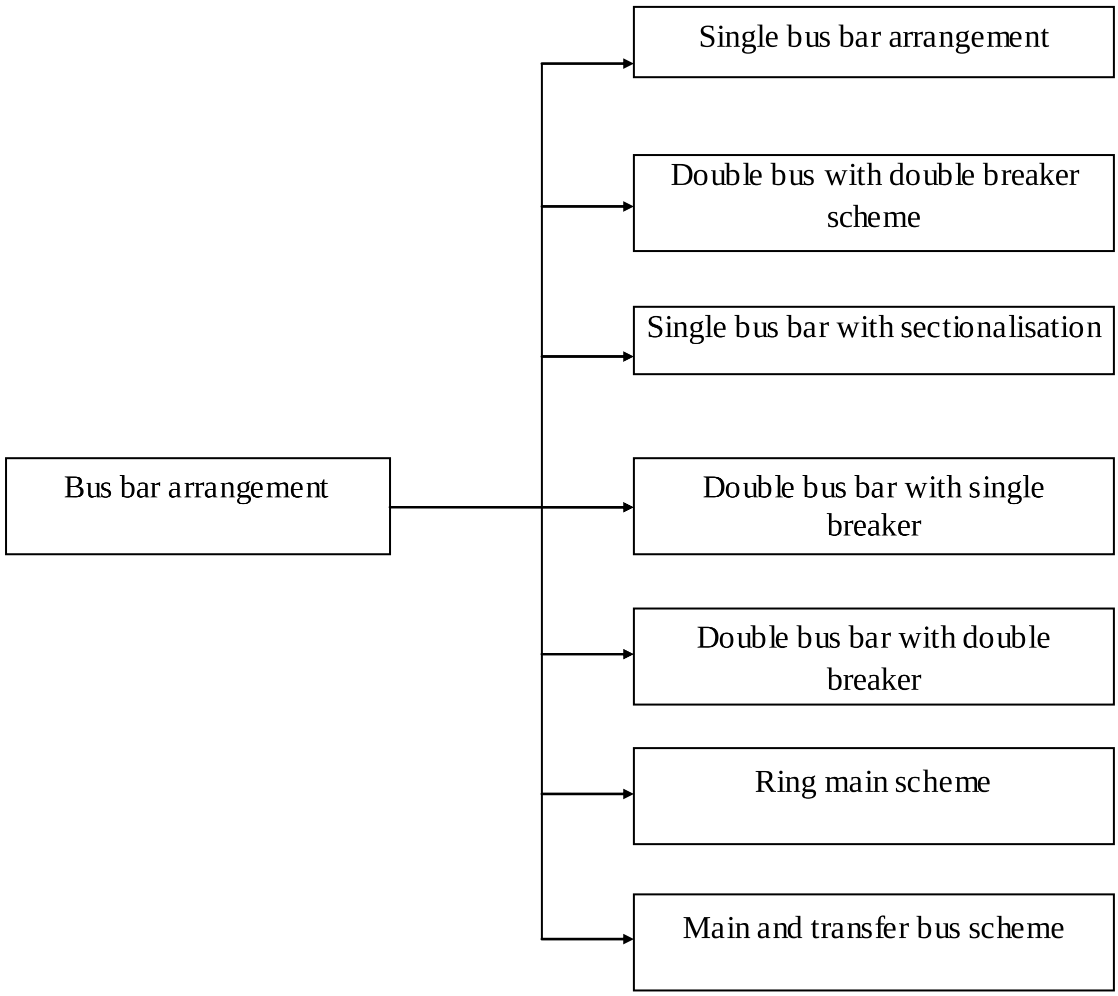


Fig 2.2 List of various bus bars arrangement

Now mostly ring main (mesh scheme) bus bar arrangement is used because in ring main system whole supply is not interrupted whenever a fault occurs in any transmission line, thus, reliability is increased.

2.2.2 Insulator

Insulator is generally providing insulation to the live parts. It does not allow the flow of electric current through it. Insulators are generally used to support the bare conductor of the transmission line. Materials used for manufacturing the insulator are porcelain, glass and a composite polymer material (steatite). Various types of insulator are:

- Pin type
- Suspension type
- Strain type

- Shackle type
- Egg or stay type

According to the voltage level the insulator are used as shown in Table 2.2.

Table 2.2 Type of insulator according to voltage level

S.No.	Type	Voltage
1.	Pin type	≤ 33kV
2.	Suspension type	≥ 33kV
3.	Strain type	Dead ends, sharp corners

2.2.3 Circuit Breaker

Circuit breaker is the primary component that is installed within the switchgear enclosure to interrupt the fault current (normally twice the normal circuit current). Circuit breaker can be designed by:

- Manually operated
- Automatic controlled

Automatic controlled CB done following duties

1. It carries full load current continuously without damage or overheating.
2. It open or close the circuit under no load.

Under normal operating condition circuit breaker operates manually and when severe fault is occur in the transmission line circuit breaker operate automatically. Fig 2.3 depicts the list of various types of circuit breaker and their operating voltage level. When a fault is occurs in the system then contact of circuit breaker separate in an insulating medium serve as two functions:

1) Extinguished the arc formation between the contacts forms when the contacts are separate to each other.
2) Provide insulation between the contacts.

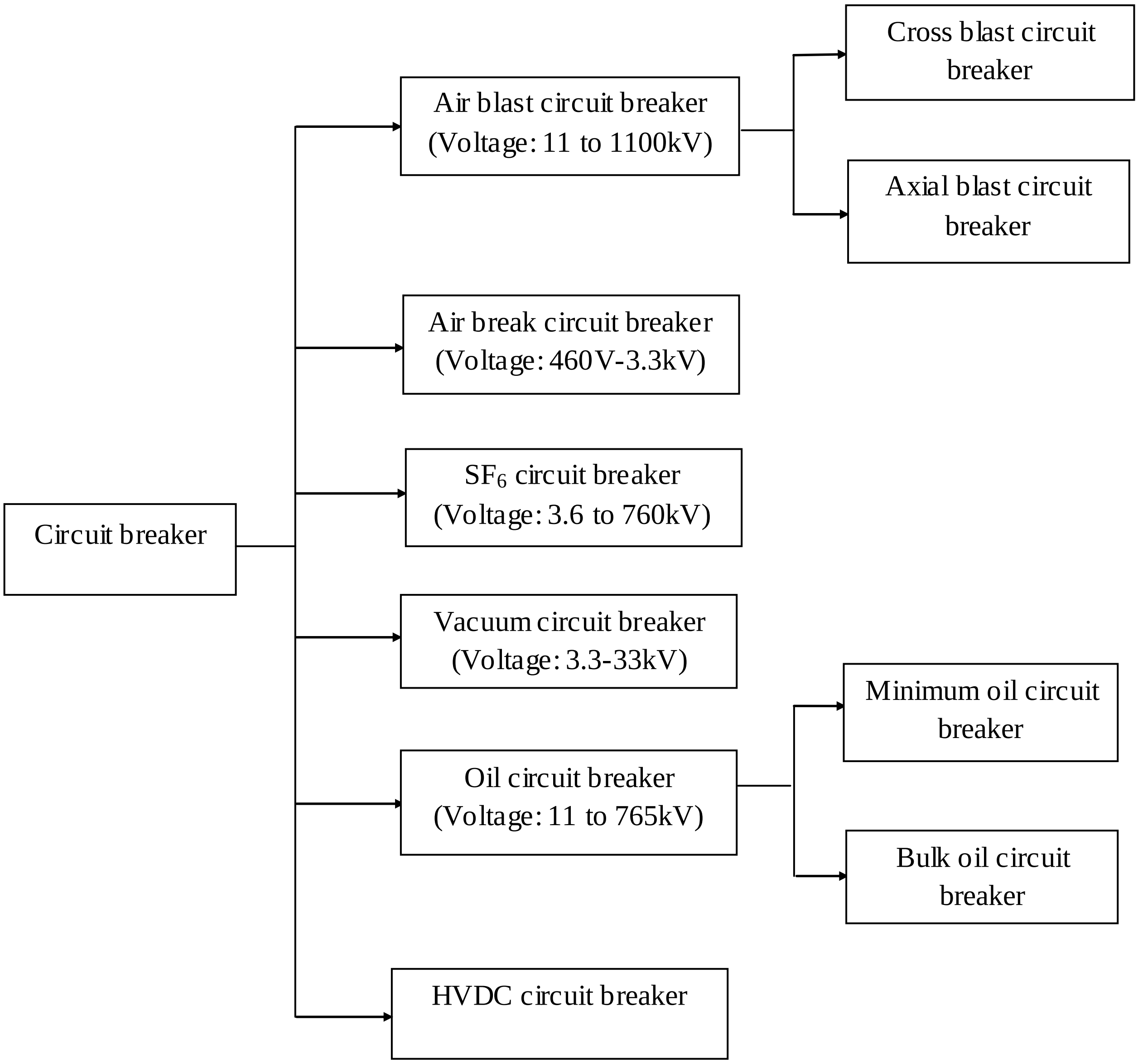


Fig 2.3 List of various types of circuit breaker and their operating voltage level

2.2.4 Power Transformer

Power transformer performs two functions:

- Step up voltage($V_{output}>V_{input}$)
- Step down voltage($V_{output}<V_{input}$)

At the generating end, its function is to step up the voltage and at substation/load end its function is to step down the voltage. Fig 2.4 shows ideally representation diagram of transformer.

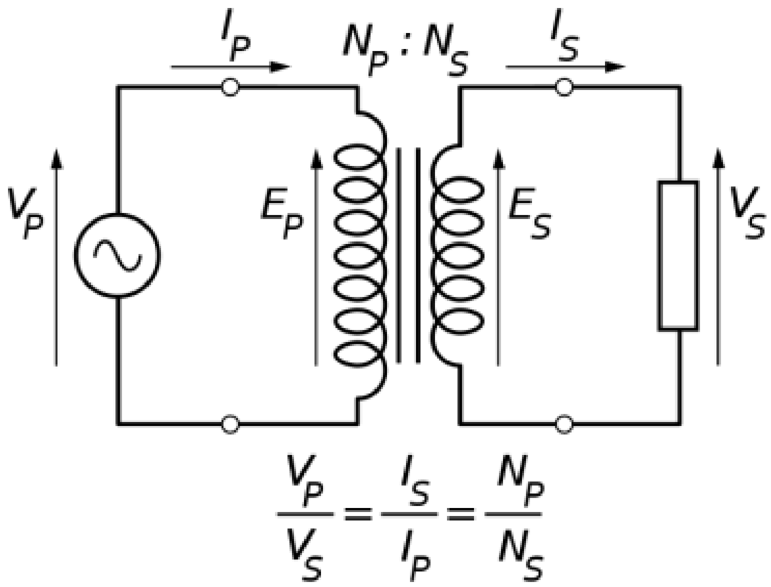


Fig 2.4 Representation diagram of transformer [23]

Power transformer rating is above 200MVA. Efficiency of a power transformer is about 99%. For cooling of power transformer, we use forced oil, water cooling and air blast, etc.

2.2.5 Instrument Transformer

Due to high magnitude of voltage and current carried by power lines the measuring instruments cannot be used for direct measurement due to the cost of equipment and safety of the person working. Instrument transformer is used to measure a voltage and current carried by the power lines.

Instrument transformers are classified as two types:

- Current transformer (CT)
- Potential transformer (PT)

Current transformer: current transformer is a step up transformer, it reduce the current by its known ratio call as transformation ratio (ratio of primary current to the secondary current). In current transformer weight of the secondary is more than the primary. If the current transformer having transformation ratio 200/5, thus current flow in primary side is 200 where as current in the secondary winding is 5, thus conversion factor is 40.

2.2.6 Measuring Instrument

Various instrument is used in the system to measure the different parameter such as ammeter (measure the circuit current), voltmeter (measure the circuit voltage), wattmeter (measure the power), kWh (to measure the energy consumed by the system), Kvar meter, frequency meter etc.

2.2.7 Relay

Relay is used as a sensing device which senses the any disturbance occur in the system when ever any disturbance occur in the system. Operation of relay shows in Fig 2.5. When fault is occur in the system, relay sense the fault and send a trip signal to the circuit breaker and finally circuit breaker remove the faulty section. Fig 2.6 shows a various types of relay.

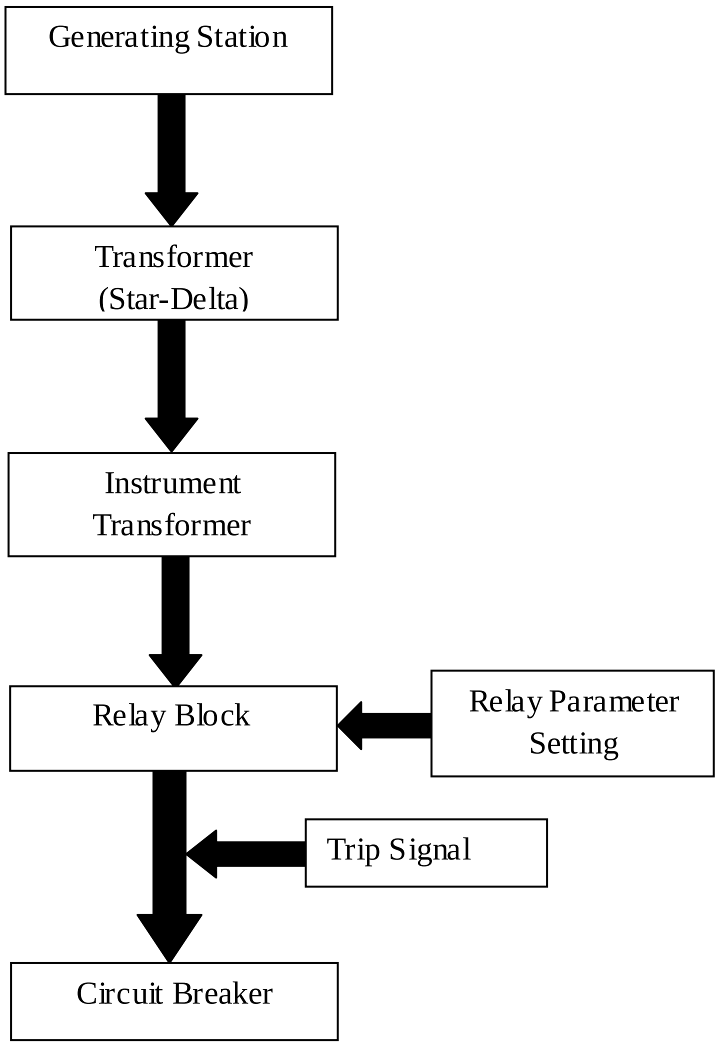


Fig 2.5 Relay operation

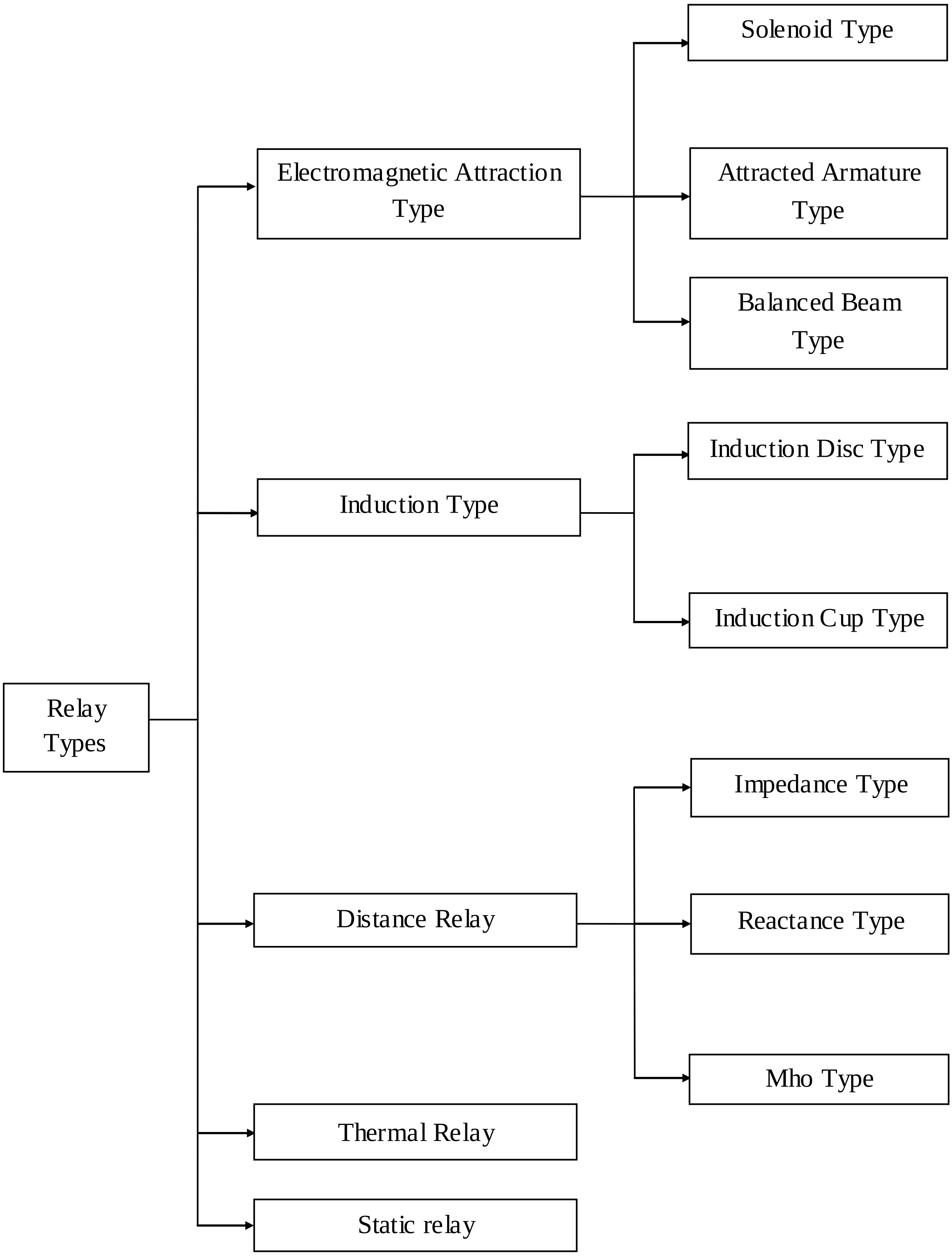


Fig 2.6 Lists of different types of relays

2.2.8 Miscellaneous Equipment

With addition to all above equipment explained some addition equipment is also used in substation such as fuses and control cable. Fuses are used to protection up to 66kV.

CHAPTER-3

CIRCUIT BREAKER

3.1 Introduction

Circuit breaker is an electromechanical device which can make or break the contact of the circuit breaker under normally and faulty condition. The main function of the circuit breaker, under faulty condition/abnormal condition it isolates the faulty section of the power system. Basic circuit diagram of CB is shown in Fig 3.1.Circuit breaker consists of two contacts:

1. Fixed contact
2. Moving contact

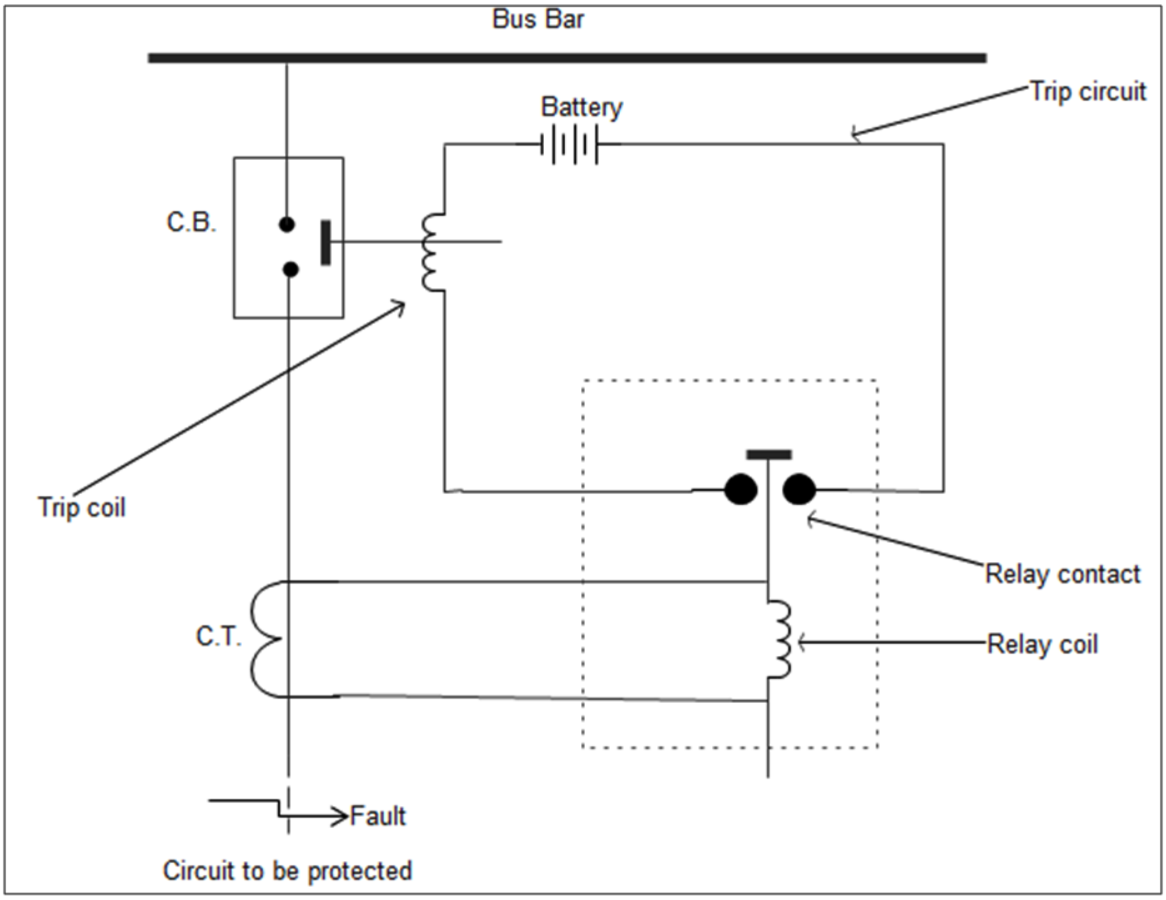


Fig 3.1 Circuit diagram of Circuit breaker

Under normal condition both fixed contact and moving contact is closed to each other and when fault is occurring in the system, current flowing in the primary winding of the current transformer is sufficiently very high, that current induces emf in the secondary of the current transformer which energizes the relay coil and contacts of relay is closed and the circuit of the battery is complete and coil energizes and circuit breaker open.

Power system stability means when the system again comes into a steady state position after the disturbance is occur in the system. This disturbance is occurring due to the fault is occurring in the system. Faults are classified as two types:

- Symmetrical fault
- Unsymmetrical fault

Symmetrical fault is further classified as:

1. Line to line to line to ground (L-L-L-G)
2. Line to line to line (L-L-L)

Unsymmetrical fault is classified as:

1. Line to Ground fault (L-G)
2. Line to Line fault (L-L)
3. Double line to ground (LL-G)

List of various types of fault occurs in the system and their percentage of occurrence shown in Table 3.1. From Table 3.1 clearly indicates most of the fault occurrence in power system is single line to ground fault.

Table 3.1 Various types of fault and their percentage of occurrence

S. No.	Type of Fault	Percentage of occurrence
1.	Line to ground	75%-80%
2.	Line to line	5%-7%
3.	Double line to ground	10%-12%
4.	Line to line to line to ground	8%-15%
5.	Line to line to line	8%-15%

To remove the fault in the system two methods is used:-

- One method is to remove the fault with the help of circuit breaker and shift the load to other section due to this interruption of supply is not occur.
- Second method is shut down the system and repair the faulty part, by this process interruption of supply takes place that is why this method is not used now days.

When the contacts are moving apart to each other due to occurrence of the fault, an arc is formed between the contacts, to interrupt the arc various method is used as shown in Table 3.2. Now mostly SF_6 is used because it is easy to install and maintenance required is less. According to the voltage level circuit breakers are selected shown in Table 3.3.

Table 3.2 Various types of circuit breaker and their voltage level

S. No.	Type	Arc quenching medium	Voltage range	Breaking capacity
1.	Miniature circuit breaker	Air at atmosphere pressure	400-600V	For small current rating
2.	Air break circuit breaker	Air at atmosphere pressure	400V-11kV	5-750MVA
3.	Minimum oil circuit breaker	Transformer oil	3.3kV-220kV	5-200MVA
4.	Vacuum circuit breaker	Vacuum	3.3kV-33kV	250-2000MVA
5.	SF_6 circuit breaker	SF_6 at 5kg/cm^2 pressure	3.3kV-765kV	1000-50,000MVA
6.	Air blast circuit breaker	Compressed air at high pressure(20-30 kg/cm^2)	66kV-1100kV	2500-60,000MVA

Table 3.3 Selection of circuit breaker according to the voltage level

S. No.	Rated voltage	Choice of circuit breaker	remarks
1.	< 1kV	Air-break circuit breaker	
2.	3.3kV-33kV	Vacuum circuit breaker, minimum oil circuit breaker, SF_6 circuit breaker.	Vacuum circuit breaker is preferred
3.	132kV-220kV	SF_6 circuit breaker, minimum oil circuit breaker, air blast circuit breaker	SF_6 circuit breaker is preferred.

3.2 Arc Interruption

Two methods are used for interruption of arc in circuit breaker:

- High resistance interruption method
- Low resistance interruption method

3.2.1 High Resistance Method

For interruption of arc by this method, arc resistance is increase in such a way that it can reduce the current of a value insufficient to maintain the arc. The value of arc resistance can be increased by:

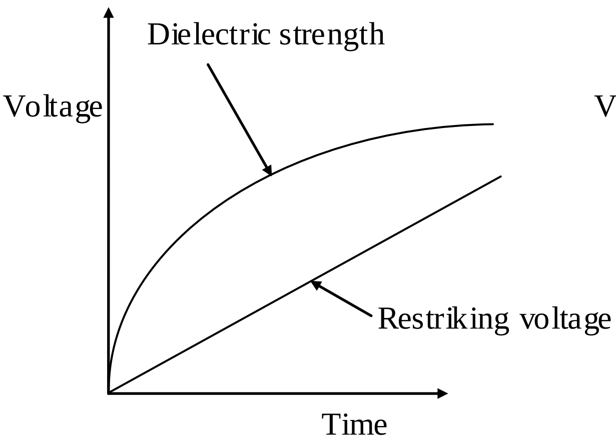
1. Lengthening of arc
2. Cooling of arc

3.2.2 Low Resistance Method

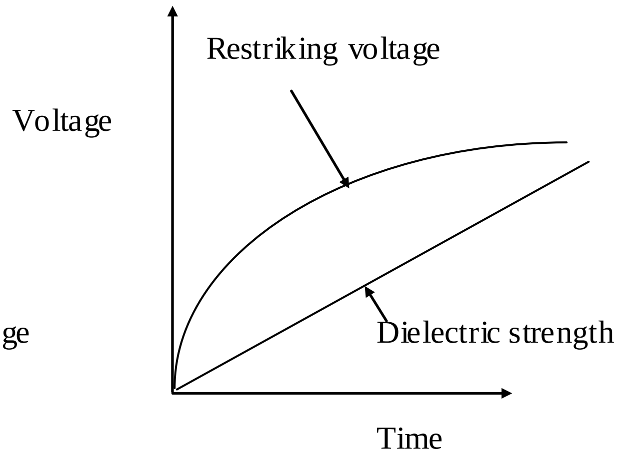
This is valid only for ac circuit breaker. In ac supply, current wave passes through zero value after one alternation. This characteristic of ac is utilized in low resistance method for interruption of the arc. Two methods for interruption of arc:

- Recovery rate theory
- Energy balance theory

Recovery rate theory**:** The arc between the gaps of the circuit breaker contact is due to the ionized gasses. Thus, ions and electron are immediately removed after the current reaches at zero instant, to extinguish the arc.



Arc extinguish



Arc does not extinguish

Fig 3.2 Low resistance method for arc interruption in circuit breaker

Thus, arc will be extinguished only when the dielectric strength is more than the restriking voltage.

Energy balance theory: Arc between the gaps of the circuit breaker contact is due to the ionized gasses and finite value of resistance. Thus to extinguish the arc gap is completely de-ionized and value of resistance is high (infinitely).

3.3 Voltage Across CB: Arc voltage is in phase with the current as shown in Fig 3.3.

3.3.1 Restriking Voltage

The transient voltages that appear across the circuit breaker contact at zero current during arc period is called restriking voltage.

3.3.2 Recovery Voltage

The normal frequency RMS voltage that appears across the circuit breaker contact after the arc is completely extinguished and transient oscillation dies out.

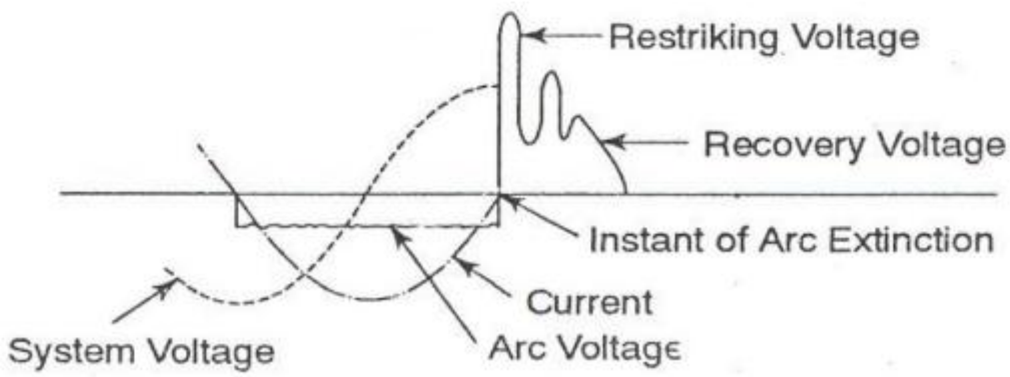


Fig 3.3 Restriking voltage and recovery voltage [24]

3.4 Rating of Circuit Breaker

In accumulation to the rated current, rated voltage, frequency, circuit breaker having three important rating as shown below:

1. Interrupted capacity or Breaking capacity
2. Rated short circuit making current
3. Rated short circuit making current
4. AC component of short circuit current
5. DC component of short circuit current
6. Rated duration of short circuit current

3.4.1 Interrupted Or Breaking Capacity: The rated interrupting capacity of the circuit breaker is defined as the maximum current a circuit breaker can safety interrupted. The rated short-circuit current is expressed as RMS symmetrical amperes and is specified by current magnitude only. The following expressions have been used to calculate the various parameters of the circuit breaker:

Rated interrupting capacity = $\sqrt{3}\times V\times I\times 10^{-6}$ (MVA)--------------(3.1)

Where V is line voltage in volts, I is rated breaking current in amperes

Interrupting capacity or breaking capacity of CB shown in Fig.3.4. Interrupting capacity of a circuit breaker is of two types:

1) Symmetrical breaking capacity 2) Asymmetrical breaking capacity

- **Symmetrical Breaking Current:** It is the RMS value of fault current, that contain only AC component. That RMS value of fault current is capable or breaking by circuit breaker under a specific condition.
- **Asymmetrical Breaking Current:** It is the RMS value of the fault current that contains both AC and DC component. It generally expressed in MVA.

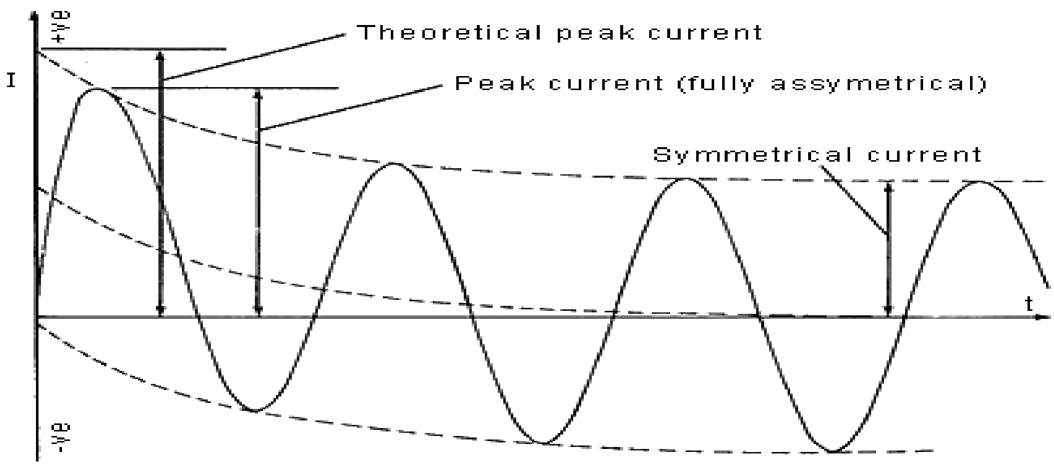


Fig 3.4 Interrupting capacity of circuit breaker [25]

3.4.2 Sub- Transient Short Circuit Current: The sub transient short circuit current or rated current in CB defined as the RMS value of current which CB carry at rated voltage and rated frequency.

Sub transient short circuit current = $\frac{rapturing\ capacity}{\sqrt{3}\times rated\ voltage}$ (kA)------------(3.2)

3.4.3 Making Capacity or Rated Short Circuit Making Current: It is defined as the peak value of current (addition to DC component) in the first cycle at which breaker can be closed.

Making capacity = $\sqrt{2} \times 1.8 \times$ sub-transient short circuit current ------------------------ (3.3)

3.4.4 AC Component of Short Circuit Current: AC component of short circuited current consist of normal current.

AC component of short circuit current =$\sqrt{2}\times$sub-transient short circuit current -------- (3.4)

3.4.5 DC Component of Short Circuit Current: DC component in short circuit current is due to the Inductance and Capacitance consists in fault current.

DC component of short circuit current = 0.5 times AC component of short circuit current. ------------------ (3.5)

3.4.6 Rated Duration of Short Circuit Current: rated duration of short circuited current is the square root of both the square of sub-transient short circuited current and DC component of short circuited current.

Rated duration of short circuit current = $\sqrt{}$ [(sub-transient short circuit current)^2 + (DC component of short circuit current)^2] --------------------(3.6)

3.6 Design of Circuit Breaker

It is necessary to design the circuit breaker in such a way that it can remove the faulty section as quickly as possible. By the use of high-speed circuit then it decease the damage of line conductor and their insulation. Due to the less damage line put in service quickly. Now 5-cycle and 3-cycle breaker are more common due to their speed.

CHAPTER 4
CURRENT TRANSFORMER AND SATURATION

4.1 Introduction

Current transformer normally called a black box. Before saturation, output current in current transformer secondary is proportional to the current flowing in primary of the current transformer, but due to occurrence of a fault in transmission line current in a secondary winding not proportional to the primary winding current as shown in Fig 4.1. Fault current consist of both AC and DC component. Saturation occurs due to the DC component present in the post fault current signal and decays with time depending on the time constant of the system. The output of the CT being fed to the relay affects the sensing of the fault and it's clearing time. For appropriate operation of current transformer the effect of saturation should be reduced by its proper designing of core.

$$I = I_m[e^{-t/\tau} - \cos(\omega t)] \qquad \text{--} (4.1)$$

Where I = CT primary current, I_m = CT secondary current, τ = L/R time constant of primary circuit.

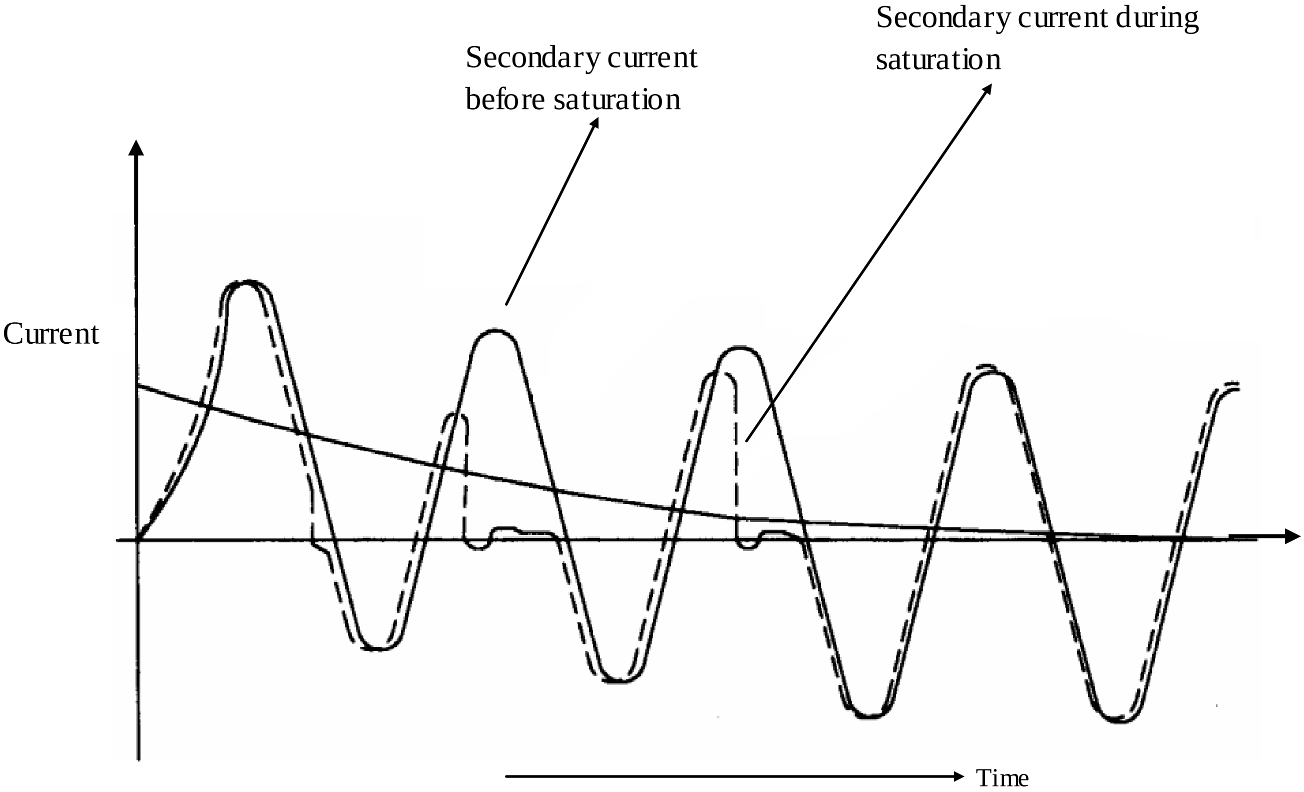


Fig 4.1 Effect of CT saturation on secondary output [26]

CT consists of only one or very few turns as its primary winding and many turns consist in secondary winding. Primary winding can be either a single flat turn, a coil of heavy duty wire wrapped around the core or just a conductor or bus bar placed through a central hole. Magnetic flux density in CT is very low. The cross sectional area of the secondary winding is smaller depending upon the current rating. The standard rating of the secondary of CT is usually 1Amp or 5Amp. When the secondary winding of open circuited the iron core of the transformer operates at a high degree of saturation produce an abnormally large secondary voltage and damaged the insulation or cause electrically shock if the CT's terminal are accidentally contacted.

Replication of AC current component in the secondary circuit requires a creation of a sinusoidal secondary voltage and sinusoidal core flux. Alternating positive and negative rates of flux changes generate this AC voltage. The directional reversal limits the flux magnitude for each cycle. Replication of the DC current component requires a DC voltage and unidirectional rate of flux change until the DC component dissipate.

4.2 Current Transformer Types

Three basic types of CT are:

I. Wound type CT
II. Toroidal type CT
III. Bar type CT

Major categories:

a) Protection CTs
b) Metering CTs

Table 4.1 Measuring current transformers limits of error for accuracy classes 0.1 to 1.

S. No.	Class	± percentage current (ratio) error at %age of rated current shown below			Phase displacement at rated percentage of rated current shown below in minutes		
		10 to 20	20 to 100	100 to 120	10 to 20	20 to 100	100 to 120
1.	0.1	0.25	0.2	0.1	10	8	5
2.	0.2	0.5	0.35	0.2	20	15	10
3.	0.5	1	0.75	0.5	60	45	30
4.	1	2	1.5	1	120	90	60

4.3 CT Ratio

The number of turns in the primary winding of the CT is one or two turns whereas secondary winding consist of several hundred turns. Assume current rating of the primary winding is 100A and secondary winding is 5A. Thus ratio of the CT is 100:5 or 20:1.means current flow in primary winding is 20 times more than the secondary winding.

CT ratio can be changed by modifying the primary turns through the ct's window. One primary turn is equal to one pass through the window results in the electrical ratio being modified.

4.4 Characteristics of CT

Various characteristics of CT are-Rating factor, Thermal short time rating, Mechanical short time rating, Relay factor accuracy rating.

4.4.1 Rating factor

Multiple numbers of primary amperes rating at which CT operate continuously without exceeding rated temperature rise.

4.4.2 Thermal Short Time Rating

Symmetrical RMS primary current for one second with secondary short circuited without exceeding the rated temperature.

4.4.3 Mechanical Short Time Rating

Maximum RMS asymmetrical current CT can carry without mechanical damage.

4.4.4 Relay Factor Accuracy Rating

The voltage delivers at 20 time's current without exceeding ratio error by 10%.

4.5 CT Core Magnetizing

Fault current contain DC component. When a fault current is passes through the CT due to the DC component will magnetize the core. Due to magnetizing the core output of the CT gets affected and shows less current as compare to the actual current which affects the performance of the functioning of the relay.

Process for demagnetize the core: Connect a large resistance across the secondary winding and inject rated current. Slowly cut off resistance till full ratio current obtained in secondary.

CHAPTER 5

SIMULATION WORK AND IMPLEMENTATION

Though symmetrical faults are very rare, this generally leads to most severe fault current flow against which the system must be protected. There may be two situations- all the three phases may be short-circuited to the ground or they may be short-circuited without involving the ground. Since the network remains electrical balanced during this type of fault, it is also known as balanced fault. Because the network is balanced, the three phases carry identical currents except for the phase shift.

A power system network comprises a synchronous generator, transformer, transmission lines and loads. Load can be neglected during the fault, as voltage dips very low and so current drawn by the loads can be neglected in comparison to the fault current. The system must be protected against flow of heavy short circuit current by disconnecting faulty part of the system with the help of circuit breaker operated through protective relay. In a modern large interconnected power system, heavy current flowing during a fault must be interrupted much before the steady state condition has been established. The mechanical forces that act on circuit breaker components and the maximum current that the breaker has to carry momentarily must also be determined. For selecting a circuit breaker we must therefore, determine the initial current that flows on occurrence of a short circuit and also the current in the transient that flows at the time of circuit interruption.

When a fault occurs at a point in a power system, the corresponding fault MVA is referred to as the fault level at that point referred to a 3-phase symmetrical fault. The fault levels provide the basis for specifying interrupting capacities of circuit breakers. The MVA rating required for a circuit breaker is estimated on a 3-phase symmetrical fault because it the most severe fault and the worst case. Hence, the circuit breakers rated breaking capacity in MVA must be equal to or greater than, the 3-phase fault level MVA.

The three-phase symmetrical fault on a line causes collapse of the system voltage accompanied by an immediate reduction of power transmission capability to naught. On the other hand, unsymmetrical faults partially cripple the line.

Fault analysis determines the value of voltage and current at different location of the system during the fault. It also includes determination of the required rating of the circuit breakers and selection of the protective relay scheme.

5.1 Simulation Work

5.1.1 CB Rating Calculation for Old Generating Unit

A 250MW, 11kV generating unit has been stepped upto 220kV at the generating station and connected to the substation shown in Fig 5.1. This is further stepped upto 400kV at nearby station for transmitting the power through grid station. By varying the distance of symmetrical fault occurrence on transmission line having total length is 20kM the circuit breaker rating has been calculated. The short circuit current has been simulated for breaker CB1 and breaker CB2 using MATLAB Simulink and the calculated parameters have been tabulated in Table 5.1 and Table 5.2 respectively.

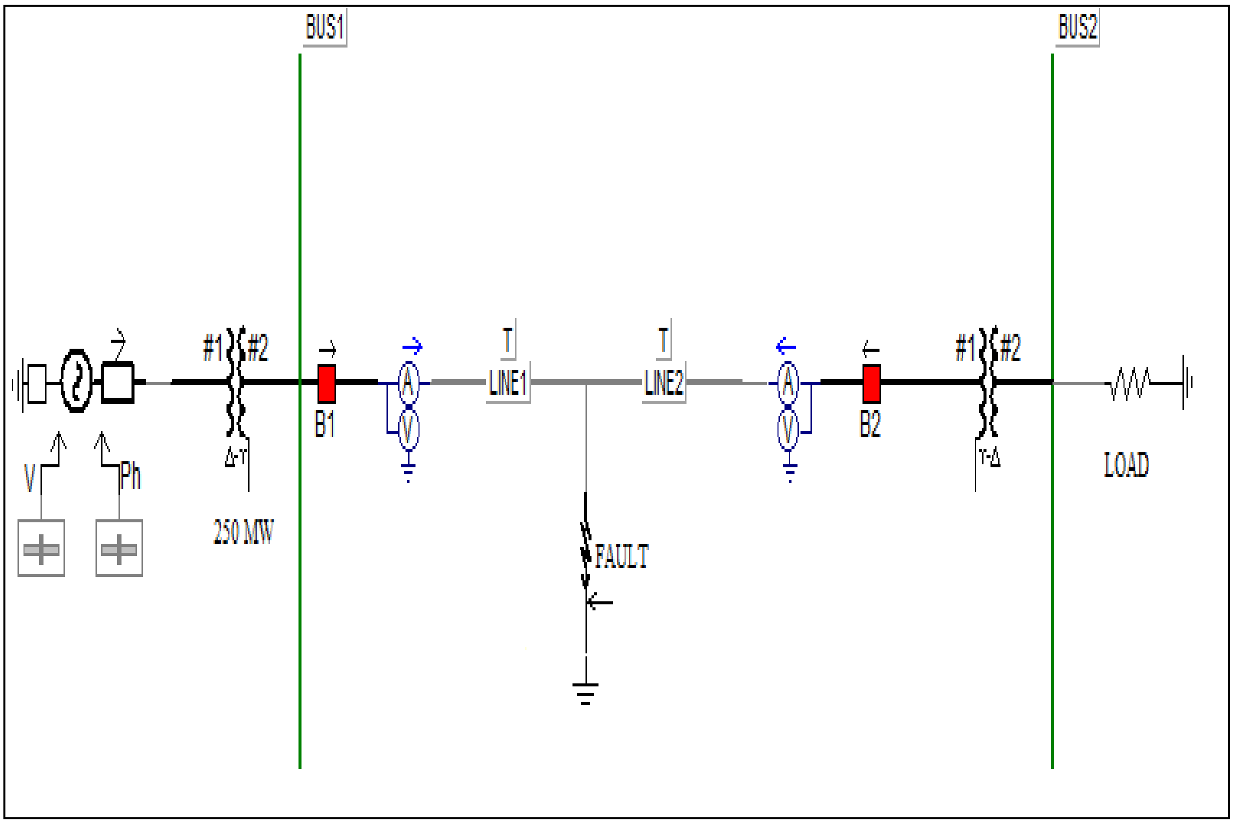


Fig. 5.1 250MW capacity power plant

Table 5.1 Circuit breaker (CB1) parameters for symmetrical faults in old TLs

Fault from source (km)	Short circuit current (kA)	Rated interrupting capacity (MVA)	Sub transient short circuit current(kA)	Rated short circuit making current(kA)	AC component of short circuit current(A)	DC component of short circuit current(A)	Rated duration of short circuit current(kA)
L-1	8.4079	657.7477	3.4764	8.8648	4.9164	2.4582	4.2577
L-5	8.0608	650.6398	3.4437	8.7814	4.8701	2.4351	4.2177
L-10	7.6746	635.3465	3.3676	8.5874	4.7625	2.3813	4.1245
L-15	7.3183	607.7891	3.2240	8.2212	4.5594	2.2797	3.9486

Table 5.2 Circuit breaker (CB2) parameters for symmetrical faults in old TL

Fault from source (km)	short circuit current (kA)	Rated interrupting capacity (MVA)	Sub transient short circuit current(kA)	Rated short circuit making current(kA)	AC component of short circuit current(A)	DC component of short circuit current(A)	Rated duration of short circuit current(kA)
L-1	2.7922	249.9311	1.4112	3.5686	1.9957	0.9979	1.7284
L-5	2.7932	250.0339	1.4773	3.7671	2.0892	1.0446	1.8093
L-10	2.7924	250.3740	1.3093	3.3387	1.8516	0.9258	1.6035
L-15	2.7925	243.4727	1.4456	3.6863	2.0444	1.0222	1.7705

5.1.2 CB Rating Calculation Connected To Old Generating Unit for Fault in Both TLs

A 1000MW, 21kV mega generating unit has been stepped upto 440kV at the generating station and connected to the grid station via 20km transmission line as shown in Fig 5.2. This generating station is in close vicinity of 20km from the 250MW, 11kV generator. By varying the distance of symmetrical fault occurrence on new and old transmission lines (TLs) of 440 kV and 22 kV connected to the new and old generating units respectively, the circuit breaker rating at both ends of 220kV old TL has been calculated. The short circuit current has been simulated for breaker CB1 and breaker CB2 connected to older generating station of 250MW and the calculated parameters have been tabulated in Table 5.3 and Table 5.4 respectively. The results show that the magnitude of fault current of Circuit breaker CB1 and CB2 has increased by an substantial amount and needs to be upgraded with the new ratings as shown in column 4 in (Table 5.3 and Table 5.4). The old CB operation can lead to failure due to the increased maximum value of instantaneous short circuit current, rated interrupting capacity and sub transient short circuit current.

The changes in the rated interrupting capacity (MVA) of CB1 and CB2 has been compared with the old rating for symmetrical faults at 1 km from the source in new and old transmission lines connected to the grid has been represented graphically in Fig. 5.3 and Fig. 5.4 respectively.

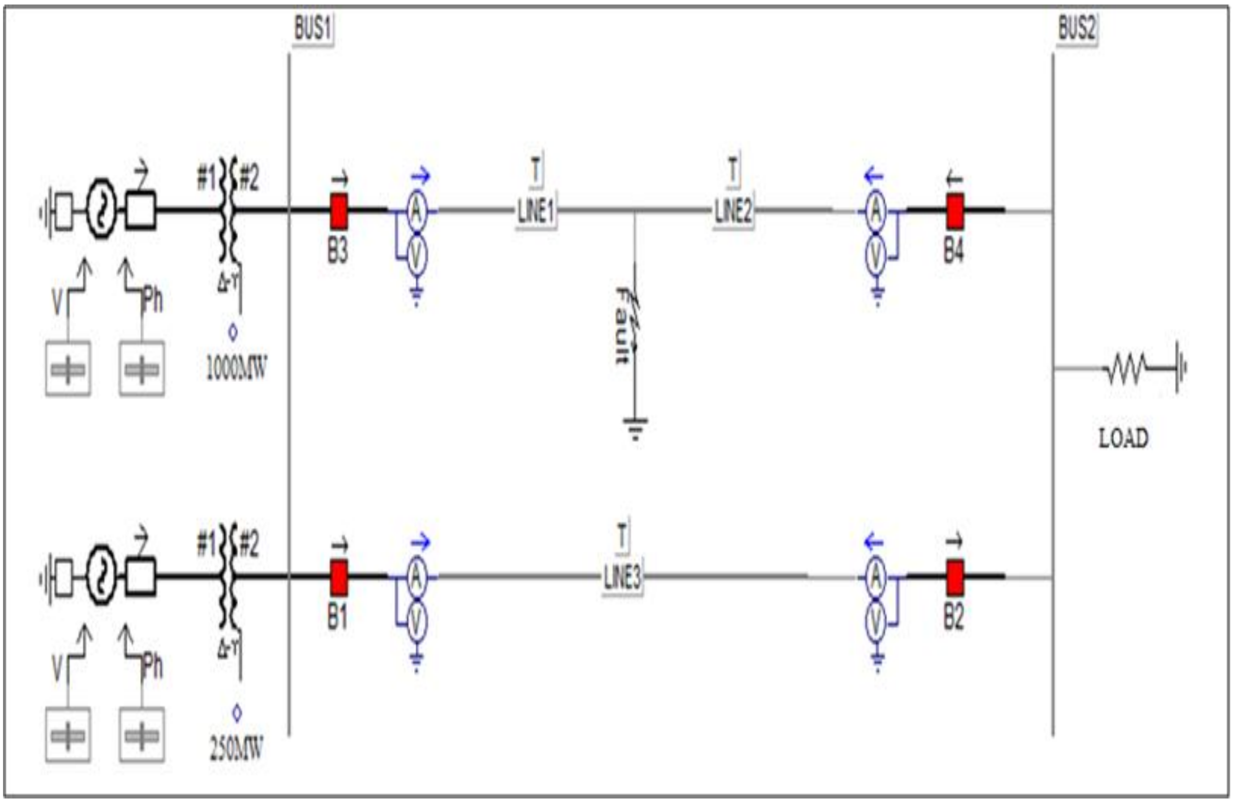


Fig. 5.2 1000MW capacity new power plant connected to same grid as old generating unit

Table 5.3 Circuit breaker (CB1) parameters for symmetrical faults in both TLs

Case	Fault from source (km)	short circuit current (kA)	Rated interrupting capacity (MVA)	Sub transient short circuit current(kA)	Rated short circuit making current(kA)	AC component of short circuit current(A)	DC component of short circuit current(A)	Rated duration of short circuit current(kA)
Fault location in new TL (length from new generating station)	L -1	3.3277	682.0894	2.0759	5.2935	2.9358	1.4679	2.5425
	L -5	3.3278	682.7764	2.0780	5.2989	2.9387	1.4694	2.5450
	L -10	3.3276	683.6213	2.0788	5.3009	2.9399	1.4699	2.5459
	L -15	3.3275	684.4497	2.0817	5.3083	2.9439	1.4719	2.5495
Fault location in old TL (length from old generating station)	L -1	10.4663	1416.0970	6.3544	16.2037	8.9865	4.4933	7.7825
	L -5	10.1292	1371.5263	6.1544	15.6937	8.7036	4.3518	7.5375
	L -10	9.7388	1319.9496	5.9230	15.1036	8.3764	4.1882	7.2542
	L -15	9.3779	1272.8753	5.7117	14.5648	8.0775	4.0387	6.9953

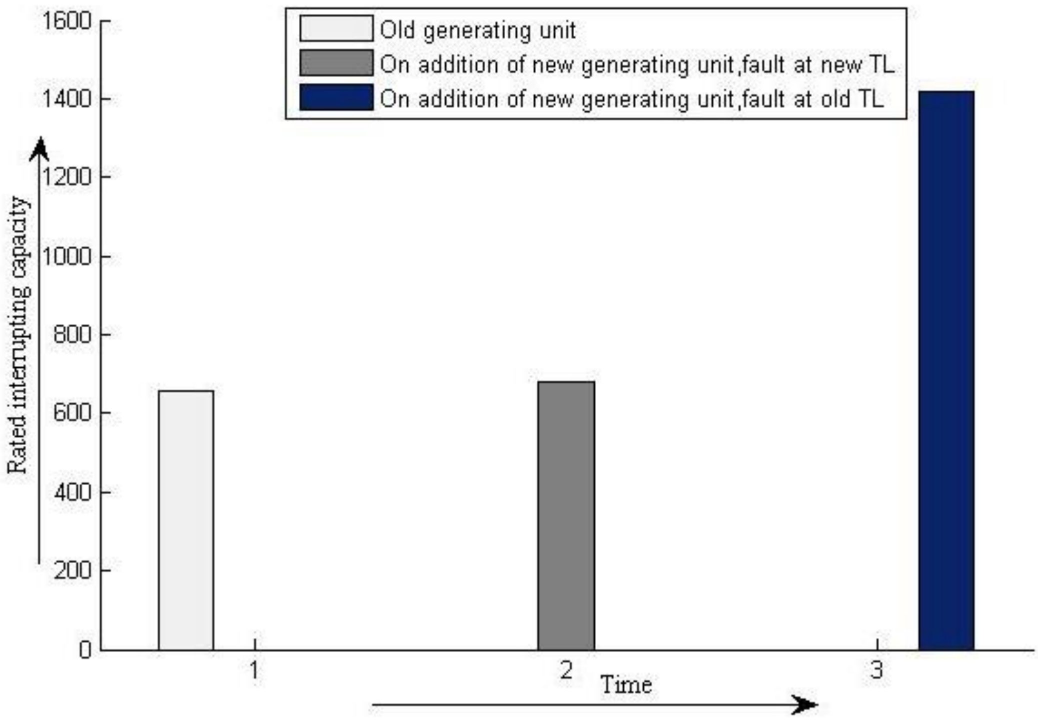


Fig 5.3 Comparison of rated interrupting capacity of CB1 for L-1km

Table 5.4 Circuit breaker (CB2) parameters for symmetrical faults in both TLs

Case	Fault from source (km)	short circuit current (kA)	Rated interrupting capacity (MVA)	Sub transient short circuit current(kA)	Rated short circuit making current(kA)	AC component of short circuit current(A)	DC component of short circuit current(A)	Rated duration of short circuit current(kA)
Fault in new TL (length from new generating station)	L -1	3.3300	701.0351	2.0854	5.3177	2.9492	1.4746	2.5541
	L -5	3.3301	701.7389	2.0867	5.3211	2.9510	1.4755	2.5556
	L -10	3.3298	702.5837	2.0904	5.3305	2.9563	1.4782	2.5602
	L -15	3.3299	703.4526	2.0929	5.3369	2.9598	1.4799	2.5633
Fault in old TL (length from old generating station)	L -1	2.9577	459.0163	2.0295	5.1752	2.8701	1.4350	2.4856
	L -5	3.0554	459.0139	2.0294	5.1749	2.8700	1.4350	2.4855
	L -10	3.1551	460.6748	2.0368	5.1938	2.8805	1.4403	2.4946
	L -15	3.2676	471.6356	2.0853	5.3175	2.9491	1.4746	2.5540

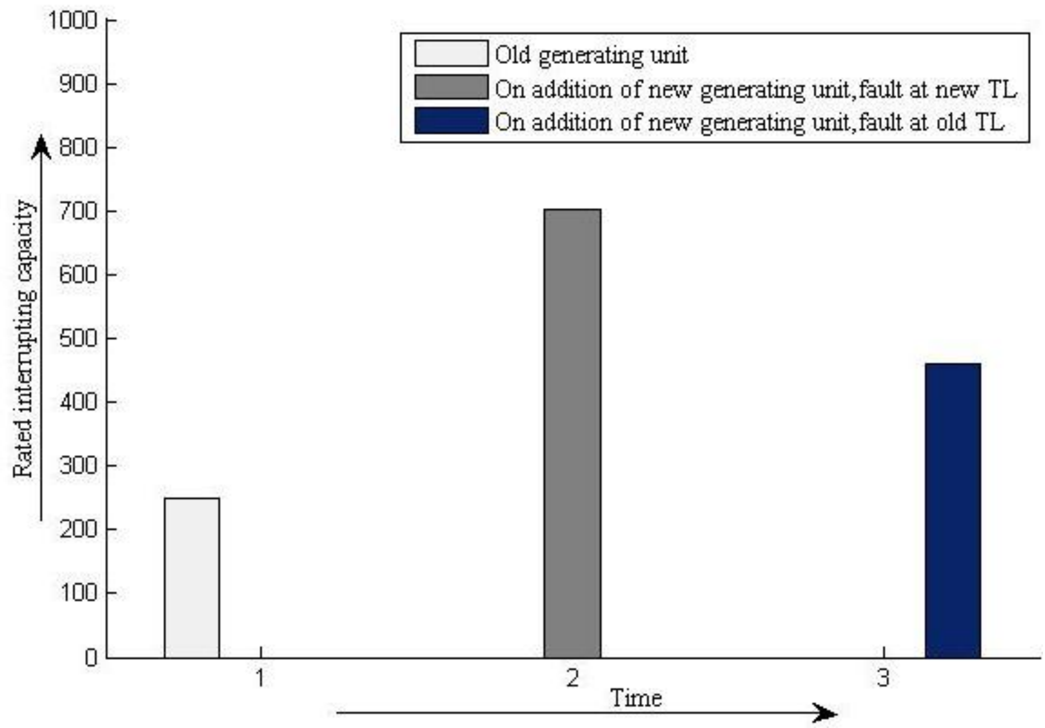


Fig 5.4 Comparison of rated interrupting capacity of CB2 for L-1km

5.1.3 CB and CT Rating of Old Generating Unit

A 250MW, 11kV generating unit has been stepped up to 220kV at the generating station and connected to the substation by a transmission line of length 20 km. This is further stepped up to 400kV at nearby station for transmitting the power through grid station as shown in Fig 5.5 By varying the distance of symmetrical fault occurrence on transmission line the circuit breaker rating has been calculated using (3.1-3.6). The short circuit current has been simulated for breaker CB1 and CB2 using MATLAB/Simulink and the calculated parameters have been tabulated in Table 5.5 and Table 5.6 respectively. Current transformers CT1 and CT2 having a rating of 8500/5 and 3000/5 respectively are decided according to the symmetrical fault occurrence in the connected transmission line and load. The current transformer expected output as per the transformation ratio has been compared with the simulated result and tabulated in Table 5.7.

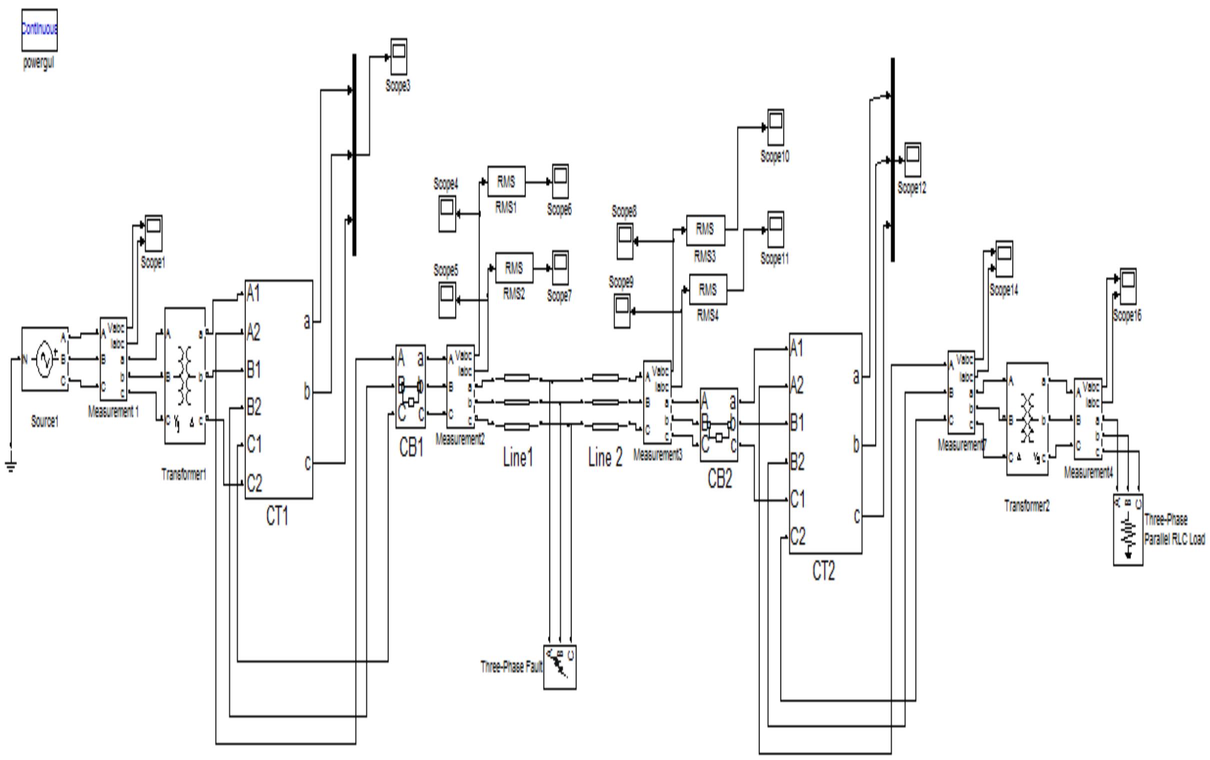


Fig 5.5 250MW capacity power plant with current transformer

Table 5.5 Calculated parameters of circuit breaker CB1 for symmetrical faults in old generating unit

Fault from source at length (km)	Short circuit current (kA)	Rated interrupting capacity (MVA)	Sub transient short circuit current(kA)	Rated short circuit making current(kA)	AC component of short circuit current(A)	DC component of short circuit current(A)	Rated duration of short circuit current(kA)
L1-2	8.3629	692.5348	4.8767	12.4358	6.8968	3.4484	7.7108
L1-6	8.1408	693.9498	4.7508	12.1147	6.7187	3.3594	7.5117
L1-10	7.7421	665.7849	4.5134	11.5091	6.3829	3.1915	7.1363
L1-14	7.5278	651.3086	4.4019	11.2248	6.2252	3.1126	6.9599

Table 5.6 Calculated parameters for circuit breaker CB2 for symmetrical faults in old generating unit

Fault from source at length (km)	short circuit current (kA)	Rated interrupting capacity (MVA)	Sub transient short circuit current(kA)	Rated short circuit making current(kA)	AC component of short circuit current(A)	DC component of short circuit current(A)	Rated duration of short circuit current(kA)
L1-2	2.3734	237.9534	1.7059	4.3502	2.4125	1.2063	2.4587
L1-6	2.3738	235.6971	1.7052	4.3484	2.4116	1.2058	2.0884
L1-10	2.3732	228.8565	1.7044	4.3462	2.1731	1.0865	2.4296
L1-14	2.3734	225.6386	1.7035	4.3440	2.4091	1.2045	2.0863

Table 5.7 Comparison of simulated output of CT1 and CT2 with expected output (as per CT ratio) for symmetrical faults in old generating unit

Fault from source at length(km)	Primary Current (CT1)	Secondary Actual Output (CT1)	Expected output (CT1)	Primary Current (CT2)	Secondary Actual Output (CT2)	Expected output (CT2)
L1-2	8352.548	4.7732	4.9133	2719.102	4.4659	4.5318
L1-6	8033.989	4.5916	4.7259	2709.673	4.4659	4.5161
L1-10	7653.596	4.3743	4.5021	2700.876	4.4659	4.5015
L1-14	7301.226	4.1727	4.2948	2710.193	4.4659	4.5169

5.1.4 CB and CT Rating Calculation Connected To Old Generating Unit for Fault in Both TL

A new mega-generating station has been installed in close vicinity of grid station which is 20km from the old generating station. To transfer the power from new generating unit of 21KV to the grid station, the voltage has been stepped up to 400KV shown in Fig 5.6. The capacity of the new mega generating station has been varied as 500MW, 750MW, 1000MW and 1250MW, and its distance from the grid station as 5km, 10km, 15km and 20km. The short circuit current has been simulated for breaker CB1 and breaker CB2 connected to older generating station of 250MW for symmetrical fault in occurs in new and old transmission lines connecting the generating station and grid. The circuit breaker parameters for CB1 and CB2 have been tabulated in Table 5.8 and Table 5.9 respectively for varying new generator capacity and varying length of TL connecting to grid when a symmetrical fault is occur in new TL.

By varying the distance of symmetrical fault occurrence on new and old transmission lines (TLs) connected to the grid, the circuit breaker rating at both ends of 220kV TL has been calculated. The faults near to the grid station has more effect on the rating of circuit breakers of old transmission line as compare to faults near to new generating station. The results show that the Circuit breaker rating of CB1 and CB2 has increased by an substantial amount and needs to be replaced with the new ratings or else can lead to the failure of operation of the same. The fault current level for faults in new transmission line does not affect CB1 but it does effect if a fault occurs in old TL. The MVA rating of CB2 is depended on the new generating station capacity and needs to be upgraded accordingly. Table 5.8 and Table 5.9 reflect the required changes in CB1 and CB2 rating with varying generating capacity of new station and its distance from grid station for symmetrical faults in new TL and Table 5.11 and Table 5.12 reflect the required changes in CB1 and CB2 rating with varying generating capacity of new generating unit.

In this case of fault occurence on 440kV TL connected mega unit, it not only affects the rating of the circuit breaker CB1 and CB2 but also affects the current transformer CT2.The actual output of the CT1 (8500/5) and CT2 (3000/5) have been compared with the expected output as per transformation ratio and tabulated in Table 5.10. But if fault occurence on 220kV TL connected mega unit, it not only affects the rating of the circuit breaker CB1 and CB2 but also affects the current transformer CT1 andCT2.The actual output of the CT1

(8500/5) and CT2 (3000/5) have been compared with the expected output as per transformation ratio and tabulated in Table 5.13 and Table 5.14. The variation of generating capacity and its distance from grid station has also been considered for symmetrical faults near the grid as this has maximum affect on CT1 and CT2 output. The existing CT core saturates due to the fault in the TL and the actual secondary output deviates from the expected output. The relay connected to the CTs may maloperate and the fault may persist in the system. The CT1 and CT2 secondary output are about 15% less than the expected output due to core saturation as shown in Fig 5.7. The effect of the symmetrical fault current for faults occurring in new transmission line is not significant for the CT1 installed near the old generating unit. However the change in the fault current is quite significant for CT1 and CT2 for fault in old TL and its rating needs to be upgraded. The rating of the new CT1 and CT2 should be chosen such that the saturation of the core does not occur. The new rating of CT1 and CT2 has been recommended to 10000/5 and 4000/5 as per the simulated results and existing ratings available. The secondary output of CT1 and CT2 with recommended rating has been simulated and compared with expected output as shown in Table 5.10.Comparison of rated current and actual current in shown in Fig 5.8. The new recommended CTs output can be used for relay setting and maloperation being avoided.

Fig 5.9 and Fig 5.10 shows a comparison of rated interrupting capacity of CB1 and CB2 by varying the generating capacity of the newly added generating unit for symmetrical fault at 19km from the old generating station. Fig 5.11 and Fig 5.12 shows a bar graph comparison of actual current and expected current CT1 and CT2 by varying the generating capacity of the newly added generating unit as 500MW and 1250MW at 5km distance from grid and for symmetrical fault at 19km from the source.

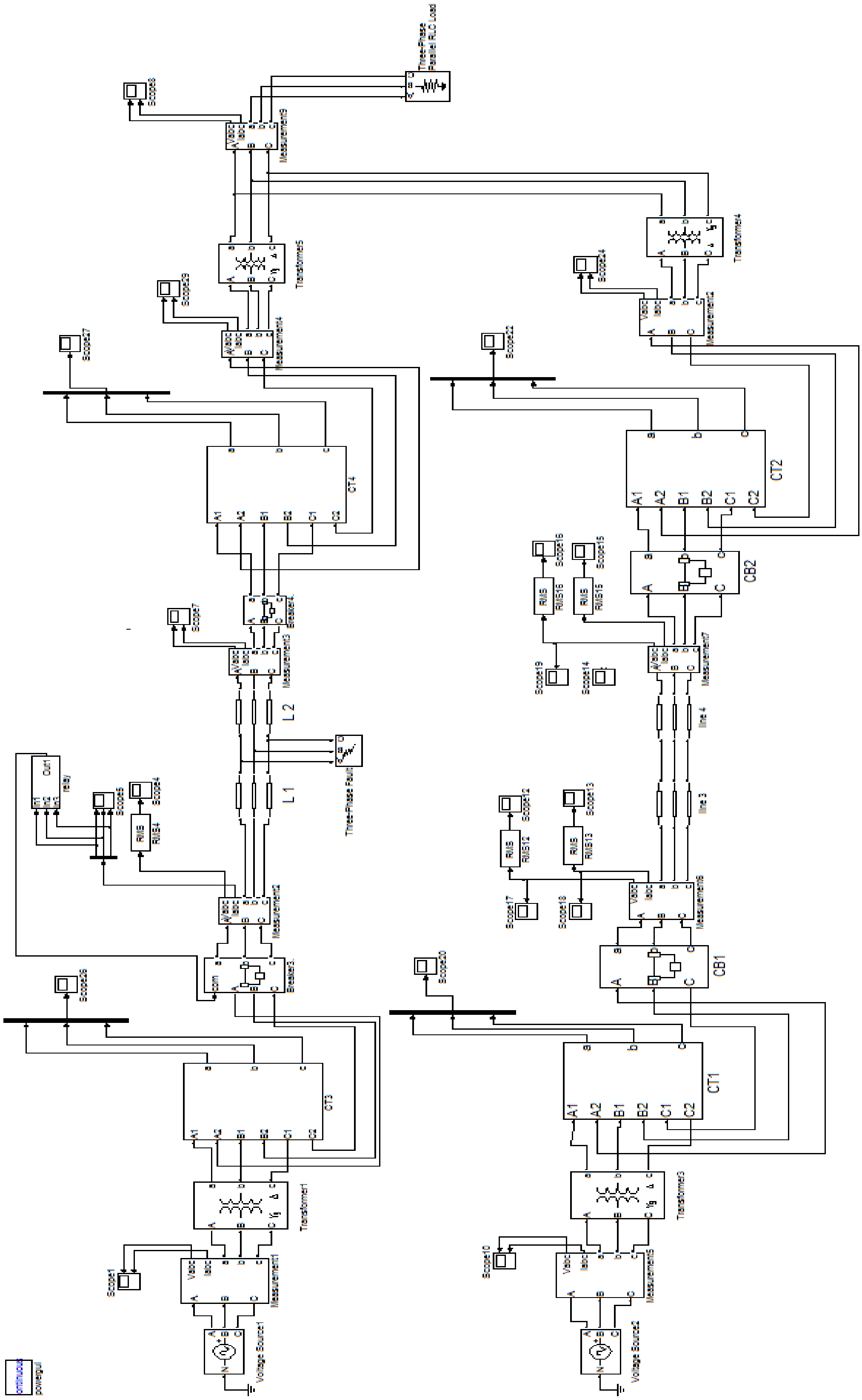


Fig.5.6. New Generating unit installed with Old unit generating, fault at 440KV TL.

Table 5.8 Recalculated parameter of Circuit Breaker (CB1) for fault in new TL after addition of new generating station

Capacity of new generating station	Steps total length (Km)	Fault from source at length (km)	short circuit current (kA)	Rated interrupting capacity (MVA)	Sub transient short circuit current (kA)	Rated short circuit making current (kA)	AC component of short circuit current(A)	DC component of short circuit current(A)	Rated duration of short circuit current (kA)
500MW	5	L1-4	2.83363	544.7010	2.4638	6.2827	3.4843	1.7421	3.0175
	10	L1-9	2.8360	544.0069	2.4617	6.2774	3.4814	1.7407	3.0150
	15	L1-14	2.8353	543.33	2.4597	6.2723	3.4785	1.7393	3.0125
	20	L1-19	2.8341	542.6945	2.4578	6.2675	3.4759	1.7379	3.0102
750MW	5	L1-4	2.8576	559.4211	2.5075	6.3942	3.5461	1.7730	3.0710
	10	L1-9	2.8566	558.5570	2.5052	6.3882	3.5429	1.7714	3.0682
	15	L1-14	2.8559	557.6674	2.5026	6.3818	3.5393	1.7696	3.0650
	20	L1-19	2.8552	556.8177	2.5003	6.3758	3.5359	1.7679	3.0622
1000MW	5	L1-4	2.8651	567.5594	2.5301	6.4519	3.5781	1.7890	3.0987
	10	L1-9	2.8648	566.5210	2.5273	6.4447	3.5742	1.7871	3.0953
	15	L1-14	2.8642	565.5561	2.5248	6.4382	3.5706	1.7853	3.0922
	20	L1-19	2.8638	564.5725	2.5221	6.4314	3.5668	1.7834	3.0889
1250MW	5	L1-4	2.8686	572.6468	2.5436	6.4861	3.5972	1.7986	3.1152
	10	L1-9	2.8683	571.5473	2.5407	6.4788	3.5931	1.7965	3.1117
	15	L1-14	2.8676	570.5150	2.5381	6.4721	3.5894	1.7947	3.1085
	20	L1-19	2.8673	569.4784	2.5354	6.4653	3.5855	1.7928	3.1052

Table 5.9 Recalculated parameter of Circuit Breaker (CB2) for fault in new TL after addition of new generating station

Capacity of new generating station	Steps total length (Km)	Fault from source at length (km)	Short circuit current (kA)	Rated interrupting capacity (MVA)	Sub transient short circuit current (kA)	Rated short circuit making current (kA)	AC component of short circuit current (A)	DC component of short circuit current(A)	Rated duration of short circuit current (kA)
500MW	5	L1-4	2.840	551.8430	2.458	6.294	3.4906	1.7453	3.0147
	10	L1-9	2.839	551.0731	2.466	6.288	3.4877	1.7438	3.0205
	15	L1-14	2.839	550.3252	2.464	6.283	3.4849	1.7424	3.0179
	20	L1-19	2.837	549.6145	2.462	6.278	3.4822	1.7411	3.0157
750MW	5	L1-4	2.861	568.1600	2.511	6.405	3.5524	1.7762	3.0764
	10	L1-9	2.860	567.1894	2.509	6.399	3.5489	1.7744	3.0794
	15	L1-14	2.859	566.1930	2.507	6.392	3.5455	1.7727	3.0704
	20	L1-19	2.859	565.2436	2.504	6.387	3.5421	1.7711	3.0676
1000MW	5	L1-4	2.868	577.2569	2.534	6.462	3.5843	1.7921	3.1041
	10	L1-9	2.868	576.0916	2.531	6.455	3.5803	1.7901	3.1006
	15	L1-14	2.868	576.0033	2.529	6.449	3.5767	1.7884	3.0975
	20	L1-19	2.867	573.0898	2.526	6.442	3.5729	1.7865	3.0943
1250MW	5	L1-4	2.872	582.9804	2.547	6.497	3.6032	1.8016	3.1204
	10	L1-9	2.872	581.7404	2.545	6.489	3.5992	1.7996	3.1169
	15	L1-14	2.871	580.5715	2.542	6.483	3.5955	1.7977	3.1138
	20	L1-19	2.870	579.4009	2.539	6.476	3.5917	1.7958	3.1104

TABLE 5.10 CT2 output for symmetrical fault in new adjacent transmission line

Capacity of new generating station	Total length (Km)	Fault from source at length (km)	Primary Current (CT2)	Before change rating (3000/5)		After change rating (4000/5)	
				Secondary actual output	Expected output	Secondary actual output	Expected output
500MW	5	L1-4	3.1458	4.3866	5.2447	3.8584	3.9361
	10	L1-9	3.1407	4.3855	5.2345	3.8574	3.9347
	15	L1-14	3.1243	4.3577	5.2072	3.8163	3.8918
	20	L1-19	3.1237	4.3571	5.3101	3.8553	3.9327
750MW	5	L1-4	3.1861	4.4374	5.2440	3.8452	3.9207
	10	L1-9	3.1446	4.3844	5.2410	3.8619	3.9388
	15	L1-14	3.1625	4.4133	5.2709	3.8861	3.9644
	20	L1-19	3.1451	4.3844	5.2419	3.8599	3.9367
1000MW	5	L1-4	3.1735	4.4222	5.2893	3.8671	3.9435
	10	L1-9	3.1655	4.4147	5.2759	3.8733	3.9499
	15	L1-14	3.1718	4.4206	5.2863	3.8659	3.9423
	20	L1-19	3.1647	4.4138	5.2745	3.8711	3.9477
1250MW	5	L1-4	3.1752	4.4245	5.2919	3.8750	3.9516
	10	L1-9	3.1746	4.4240	5.2911	3.8753	3.9519
	15	L1-14	3.1740	4.4234	5.2900	3.8736	3.9502
	20	L1-19	3.1722	4.4218	5.2870	3.8738	3.9504

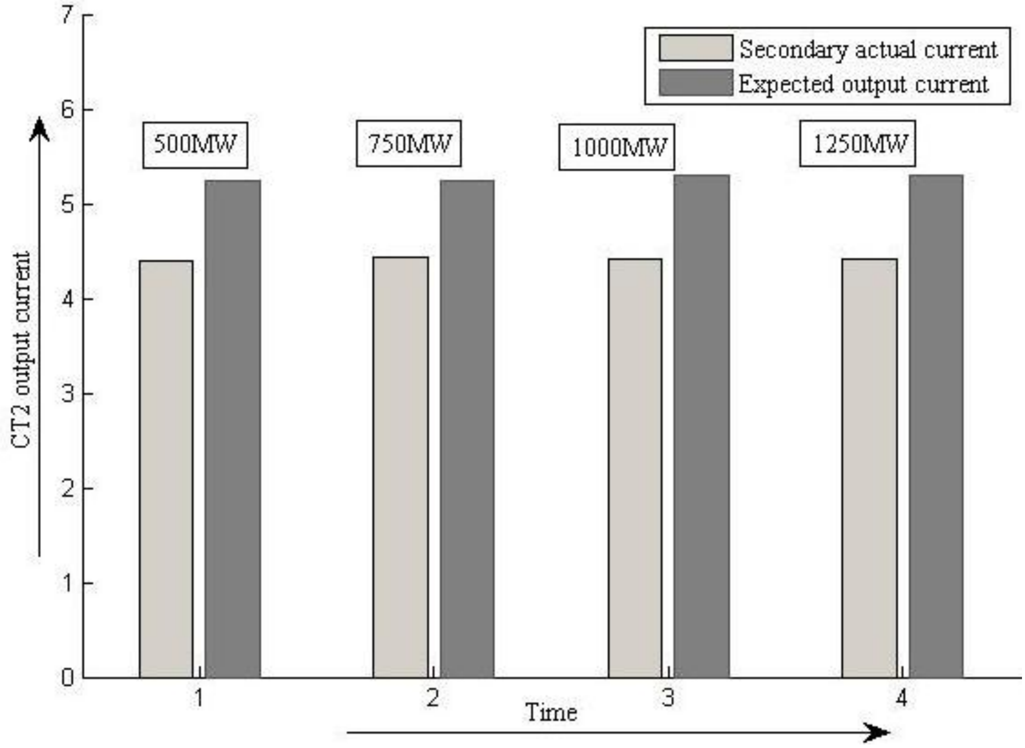


Fig 5.7 Comparison of actual current and expected current for 500MW, 5KM of CT2 before changed rating, fault in new TL

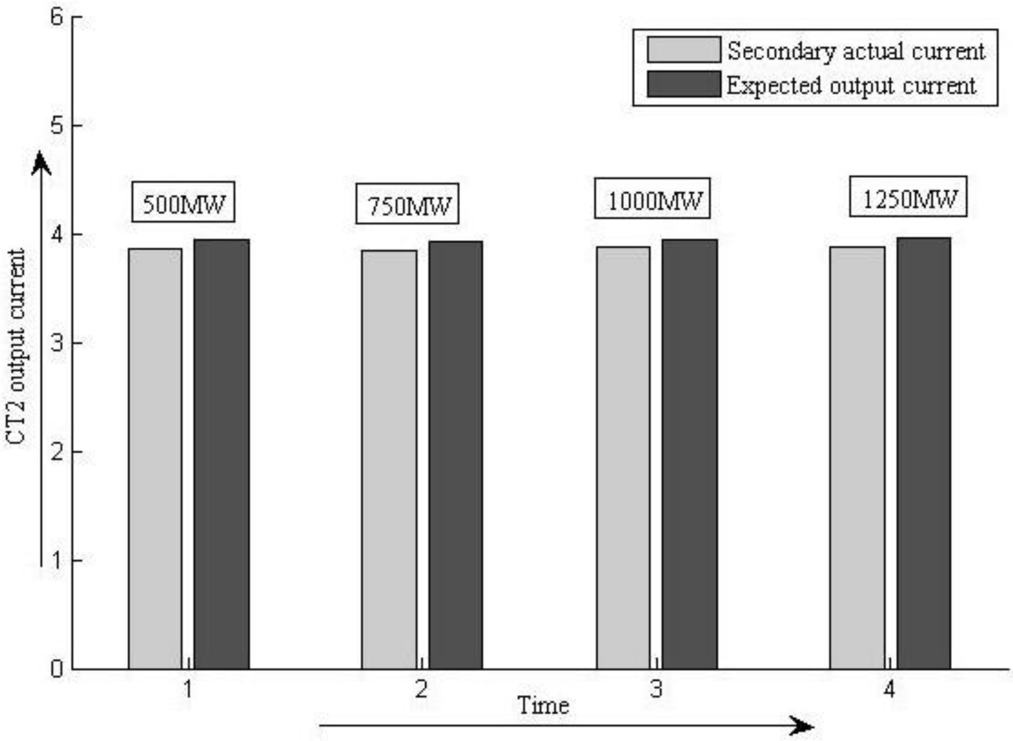


Fig: 5.8 Comparison of actual current and expected current for 500MW, 5KM of CT2 after changed rating, fault in new TL

Table 5.11 Recalculated parameter of Circuit Breaker (CB1) for fault in old TL after addition of new generating station

Capacity of new generating station	Total length of TL (Km)	Fault from source at length (km)	short circuit current (kA)	Rated interrupting capacity (MVA)	Sub transient short circuit current (kA)	Rated short circuit making current (kA)	AC component of short circuit current(A)	DC component of short circuit current(A)	Rated duration of short circuit current (kA)
500MW	5	L1-19	9.0405	1210.4400	5.4974	14.0184	7.7745	3.8872	6.7329
	10	L1-19	9.0980	1209.488	5.4954	14.0132	7.7716	3.8858	6.7304
	15	L1-19	9.0360	1208.6026	5.4937	14.0089	7.7693	3.8846	6.7283
	20	L1-19	9.0333	1207.6486	5.4915	14.0032	7.7661	3.8831	6.7256
750MW	5	L1-19	9.0911	1230.4350	5.5393	14.1254	7.8337	3.9168	6.7842
	10	L1-19	9.0877	1229.0953	5.5365	14.1180	7.8298	3.9148	6.7808
	15	L1-19	9.0845	1227.8095	5.5339	14.1115	7.8261	3.9130	6.7776
	20	L1-19	9.0814	1226.5409	5.5313	14.1048	7.8224	3.9112	6.7744
1000MW	5	L1-19	9.1209	1242.4757	5.5641	14.1884	7.8688	3.9344	6.8146
	10	L1-19	9.1170	1240.8962	5.5608	14.1801	7.8642	3.9321	6.8105
	15	L1-19	9.1132	1238.0095	5.5516	14.1567	7.8511	3.9255	6.7992
	20	L1-19	9.1094	1237.8368	5.5545	14.1640	7.8552	3.9276	6.8028
1250MW	5	L1-19	9.1406	1250.5061	5.5804	14.2300	7.8918	3.9459	6.8345
	10	L1-19	9.1363	1248.7473	5.5768	14.2208	7.8868	3.9433	6.8301
	15	L1-19	9.1321	1247.0317	5.5733	14.2119	7.8818	3.9409	6.8258
	20	L1-19	9.1280	1245.3614	5.5699	14.2033	7.8770	3.9385	6.8217

Table 5.12 Recalculated parameter of Circuit Breaker (CB2) for fault in old TL after addition of new generating station

Capacity of new generating station	Total length of TL (Km)	Fault from source at length (km)	short circuit current (kA)	Rated interrupting capacity (MVA)	Sub transient short circuit current (kA)	Rated short circuit making current (kA)	AC component of short circuit current(A)	DC component of short circuit current(A)	Rated duration of short circuit current (kA)
500MW	5	L1-19	2.9057	447.2450	2.008	5.1215	2.8397	1.4199	2.4593
	10	L1-19	2.8854	446.8859	2.0079	5.1201	2.8395	1.4197	2.4591
	15	L1-19	2.8654	446.5252	2.0073	5.1187	2.8387	1.4194	2.4584
	20	L1-19	2.8461	446.1936	2.0068	5.1175	2.8380	1.4190	2.4578
750MW	5	L1-19	3.2516	467.6858	2.0764	5.2950	2.9364	1.4682	2.5430
	10	L1-19	3.2265	464.9915	2.0660	5.2685	2.9217	1.4608	2.5303
	15	L1-19	3.2014	462.2891	2.05557	5.2417	2.9070	1.4535	2.5175
	20	L1-19	3.1768	459.6695	2.0454	5.2158	2.8926	1.4463	2.5050
1000MW	5	L1-19	3.4530	490.4928	2.1630	5.5156	3.0589	1.5295	2.6491
	10	L1-19	3.4242	487.2319	2.1505	5.4838	3.0413	1.5206	2.6338
	15	L1-19	3.3963	484.1079	2.1386	5.4534	3.0244	1.5122	2.6192
	20	L1-19	3.3685	481.0049	2.1267	5.4231	3.0076	1.5038	2.6046
1250MW	5	L1-19	3.5836	505.7880	2.2204	5.6621	3.1401	1.5700	2.7194
	10	L1-19	3.5530	502.2288	2.2069	5.6278	3.1210	1.5605	2.7028
	15	L1-19	3.5228	498.7353	2.1937	5.5940	3.1023	1.5511	2.6867
	20	L1-19	3.4928	495.2870	2.1806	5.5605	3.0838	1.5419	2.6707

TABLE 5.13 CT1 outputs for symmetrical fault occurs in old transmission line

Capacity of new generating station	Total length (Km) of new transmission line)	Fault from source at length (km)	Primary Current (CT1) (KA)	Before change rating (8500/5)		After change rating (10000/5)	
				Secondary actual output	Expected output	Secondary actual output	Expected output
500MW	5	L1-19	9.0405	4.3726	5.3179	4.4194	4.5203
	10	L1-19	9.0980	4.4002	5.3518	4.4056	4.5490
	15	L1-19	9.0360	4.3635	5.3152	4.3666	4.5180
	20	L1-19	9.0333	4.3619	5.3137	4.3737	4.5166
750MW	5	L1-19	9.0911	4.3298	5.3477	4.3819	4.5455
	10	L1-19	9.0877	4.3339	5.3457	4.4012	4.5438
	15	L1-19	9.0845	4.3288	5.3438	4.3911	4.5422
	20	L1-19	9.0814	4.3265	5.3420	4.3895	4.5407
1000MW	5	L1-19	9.1209	4.4176	5.3652	4.4176	4.5604
	10	L1-19	9.1170	4.4180	5.3629	4.4245	4.5585
	15	L1-19	9.1132	4.4095	5.3607	4.4051	4.5566
	20	L1-19	9.1094	4.4073	5.3584	4.4153	4.5547
1250MW	5	L1-19	9.1406	4.4258	5.3768	4.4270	4.5703
	10	L1-19	9.1363	4.4233	5.3743	4.4166	4.5682
	15	L1-19	9.1321	4.4240	5.3718	4.4356	4.5661
	20	L1-19	9.1280	4.4181	5.3694	4.4206	4.5640

TABLE 5.14 CT2 outputs for symmetrical fault occurs in old transmission line

Capacity of new generating station	Total length (Km) of new transmission line	Fault from source at length (km)	Primary Current (CT4)	Before change rating (3000/5)		After change rating (4000/5)	
				Secondary actual output	Expected output	Secondary actual output	Expected output
500MW	5	L1-19	2.9057	4.1101	4.8428	3.5439	3.6321
	10	L1-19	2.8854	4.0885	4.8090	3.5467	3.6068
	15	L1-19	3.0695	4.0548	4.7756	3.5369	3.5818
	20	L1-19	2.8461	4.0227	4.7435	3.4972	3.5576
750MW	5	L1-19	3.2516	4.6997	5.4193	4.0206	4.0645
	10	L1-19	3.2265	4.6448	5.3775	3.9296	4.0331
	15	L1-19	3.2014	4.6158	5.3357	3.9154	4.0017
	20	L1-19	3.1768	4.5654	5.2946	3.8845	3.9710
1000MW	5	L1-19	3.4530	4.9589	5.7550	4.2113	4.3162
	10	L1-19	3.4242	4.8867	5.7070	4.1018	4.2802
	15	L1-19	3.3963	4.9208	5.6605	4.1871	4.2454
	20	L1-19	3.3685	4.8936	5.6142	4.1264	4.2106
1250MW	5	L1-19	3.5836	5.0859	5.9727	4.3287	4.4795
	10	L1-19	3.5530	5.0798	5.9216	4.3670	4.4413
	15	L1-19	3.5228	5.1114	5.8713	4.2713	4.4035
	20	L1-19	3.4928	5.0753	5.8213	4.2872	4.3660

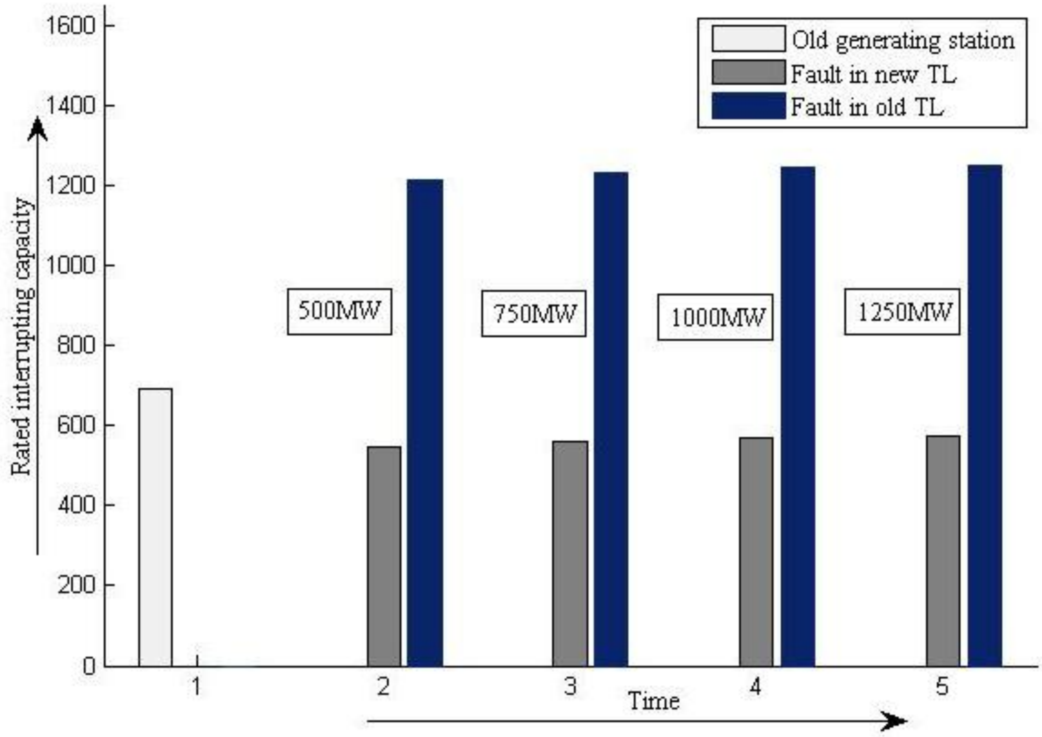


Fig: 5.9 Comparison of rated interrupting capacity of CB1 for L-1km

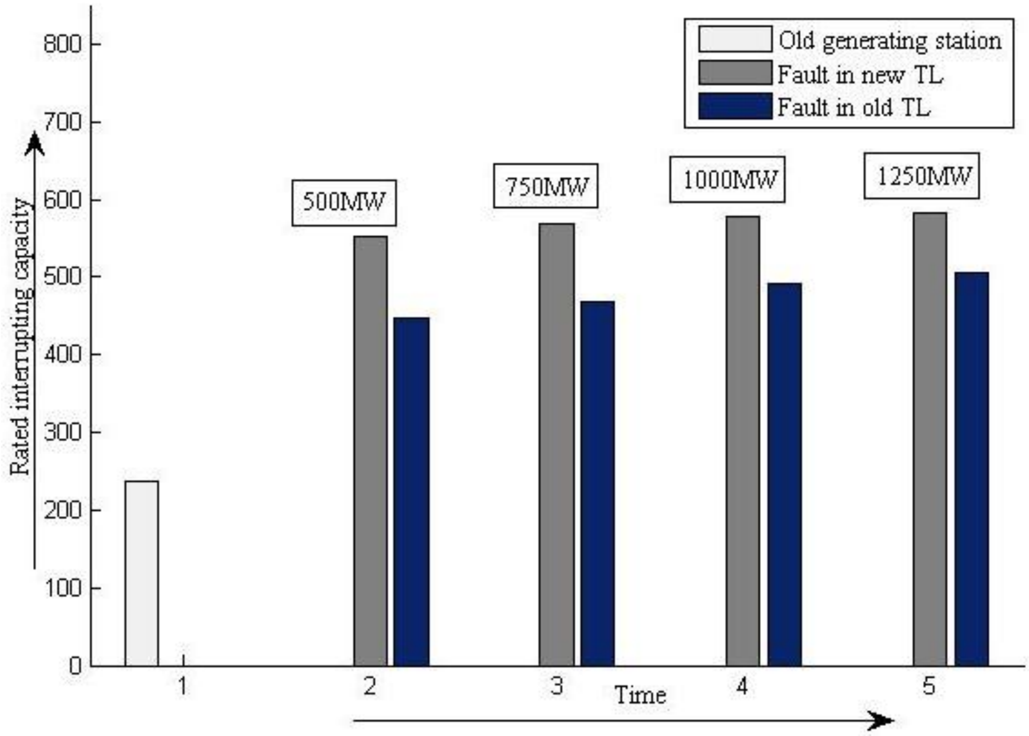


Fig: 5.10 Comparison of rated interrupting capacity of CB2 for L-1km

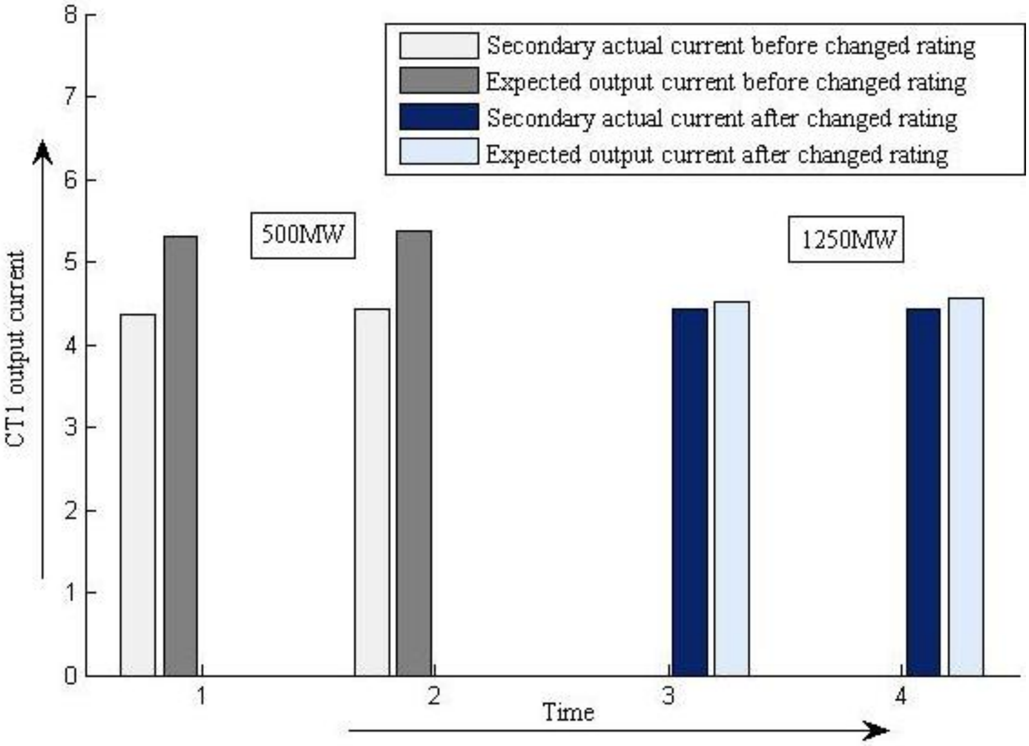


Fig: 5.11 Comparison of actual current and expected current for 500MW, 5KM of CT 1 before changed rating, fault in old TL

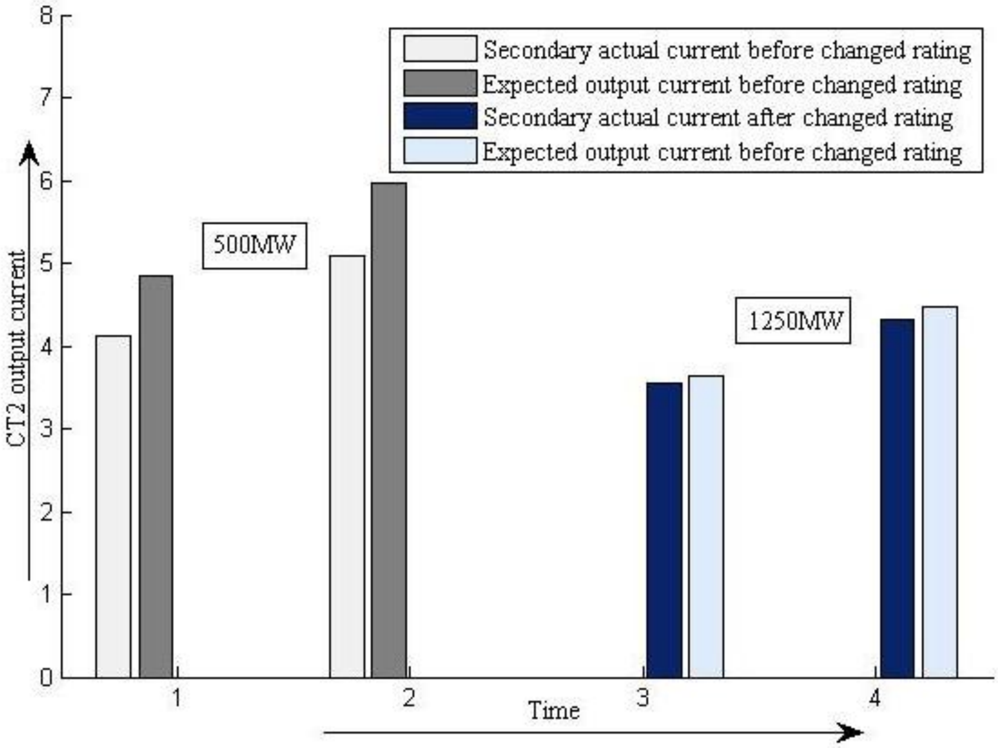


Fig: 5.12 Comparison of actual current and expected current for 500MW, 5KM of CT2 after changed rating, fault in old TL

CHAPTER-6

CONCLUSION AND FUTURE SCOPE

6.1 Conclusion

The circuit breaker and CT connected to the generating station of smaller capacity needs to be upgraded when much larger generating unit is connected to the same grid. The increase in the magnitude of current due to symmetrical fault on the same transmission line or other TL connected to the same grid can harm the CBs and CTs connected to the older generating station. The current transformer gets saturated due to increased fault current and leads to relay mal-operation. Therefore, the CT parameters are recalculated to avoid saturation under most severe fault condition. The change in the circuit breaker rating due to above stated condition has been calculated for the symmetrical fault with varying generating capacity of new unit and its distance from grid. This situation arises only after the new mega-generating unit comes into vicinity of old smaller generating unit. The new rating of the CBs and CTs has been proposed for proper functioning of the older generating unit with changed operating condition.

6.2 Future Scope

- Implementation on Ring main system.
- Consider this, before design of Generating station.

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[1] N. Garg and A. Sinha, "Effect of Previously Install Circuit Breaker due to the Upcoming New Generating Station," Presented in IEEE First International Conference on Power Electronics, Intelligent Control and Energy Systems (ICPEICES), Delhi Technical University, New Delhi, 4^{th}-6^{th} July 2016.

[2] Garg, Nadhim and Sinha, Amrita: "Effect on CT Ratio and Circuit Breaker Rating due to nearby New Generating Station", IET Generation, Transmission & Distribution (Communicated- 2016).

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Technical Skills

Basic Fundamental of Computer, Hardware & software. Visual Basic.

I am having a good command in Testing of Distribution Transformers.

Working on "MATLAB"software for Designing & Controlling of linear and non-linear electrical networks.

Experience & Trainings

2 year Experience in "Garg Electrical", Kotkapura.
June2012 to June 2014.

work as a testing of transformer engineer.

6 Weeks summer Training at J.K Electricals
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Underwent a course in manufacturing & testing of distribution transformers in J.K Electricals. Where i handled the testing of distribution transformer which is to be done with the latest technology equipments and control panel.

6 Months Industrial Training at Technology Products, Gurgaon.
Dec 2011 – May 2012
Where I am undergoing a course in designing, manufacturing and testing of the electrical control lab equipments.

Special Training:

First aid training organised by St. John Ambulance Association

We underwent a training to learn how we can save the life of a person in the industry during the critical situations like in case of fire or in case of any accident etc and which type of medicines and procedures should be adopted at the site. Also we learnt that how we can save a life of a person during accidental situation by using the resources which are available at that movement.

Achievements

Won first prize in presentation on “Generation of Electrical Energy by Wind Turbines”.

First runner up in presentation on Distribution Transformers in Volta-2010 held at GZSCET Bathinda

Stood second position in Group Discussion at Tarrannum-2010 in GZSCET Bathinda.

Worked as Vice president of Library club from 2010 to 2012.

Won first prize in Literary events in technical fest held at GZSCET Bathinda.

Publication In International Conference

2016

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Language Known

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Declaration

I do here by confirm that the above information furnished above is true to the best of my Knowledge and belief.

Date: NADHIM GARG

Appendix-A

1) For CT Rating

Appendix A.1 for CT rating Calculation

At rated primary current IPN	Thermal strength	VA Rating
2x 125 A 2x 150 A 2x 200 A 2x 250 A 2x 300 A 2x 400 A 2x 500 A 2x 600 A	100 x IPN	5
2x 100 A	150 x IPN	5
2x 75	200 x IPN	5
2x 50 A 2x 60 A	300 x IPN	5
2x 40 A	400 x IPN	5
2x 25 A 2x 30 A	500 x IPN	10
2x 20 A	800 x IPN	5

2) For CB Rating

Appendix A. 2 for CB rating Calculation

CB AMP Rating	10,000 RMS Sym Interrupting Rating		14,000 RMS Sym. Interrupting Rating		18000 RMS Sym. Interrupting Rating	
	I_p	I_{RMS}	I_p	I_{RMS}	I_p	I_{RMS}
15A	7200	5100	8700	6100	9300	6600
20A	8900	6300	11,400	8100	12,600	8900
25A	10,700	7500	14,200	10,100	16,500	11,700
30A	10,700	7500	14,200	10,100	16,500	11,700
40A	11,700	8300	16,000	11,300	19,200	13,600
50A	11,700	8300	16,000	11,300	19,200	13,600
60A	12,500	8800	17,300	12,200	21,300	15,100
70A	13,000	9200	18,100	12,800	22,600	16,000
80A	13,000	9200	18,100	12,800	22,600	16,000
90A	13,200	9300	18,300	12,900	23,000	16,300
100A	13,200	9300	18,300	12,900	23,000	16,300

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