A Review on Power System Faults and Overcurrent Protection of Distribution Transformer

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Abstract— An electrical fault is the deviation of voltages and currents from nominal values. Power system equipment or transmission lines carry normal voltages and currents which results in smooth operation of the system. But when a fault occurs, it causes very high current to flow through the equipment and can damage the equipment. This paper provides the causes, effects and methods to overcome the faults of power system.

Keywords— Power system; Current; Short Circuit; Faults; Power system protection; Equipment; Circuit breaker; Relay

I. INTRODUCTION

The power system is a network consisting of generation, transmission and distribution of power. The main objective of power system is to maintain continuous supply of power with an acceptable quality, to all the consumers in the system without any interruption. Faults are an unwanted connection between different phases of conductors or conductors and ground. Faults occur due to bad weather conditions, falling of tree branches onto conductors, human errors and equipment failures. Faults in the power system causes very high current to flow through the equipment and can damage the equipment [1] [12].

This paper describes the different types of power system faults, the causes, the effects of the faults and protective methods to protect the power system and increase its reliability. The structure of the paper is as follows, the second section will describe the causes of faults. The third section will describe the effects of the faults. The types of faults are introduced in the fourth section. The fifth section will discuss the methods to overcome these faults, and the final section will be a conclusion.

II. CAUSES OF FAULT

Faults in a power system are caused mainly due to the following.

- **Bad weather conditions**

Weather conditions include lighting over voltages, heavy rains, cyclones, snow and ice formation on transmission lines, etc. These environmental conditions interrupt the power supply and can also damage electrical equipment [1] [9].

- **Failure of electrical machines and devices**

Electrical machines like generators, motors and devices like transformers, reactors, etc. causes short circuit faults due to malfunctioning, insulation failure of cables, and winding. Due to these failures very high currents will flow through the machines and devices which can damage them [9].

- **Human errors**

Electrical faults are also caused due to human errors by improper selection of rating of equipment or devices. Not installing electrical conducting parts after servicing or maintenance [9].

- **Switching operations**

Due to switching operations switching surges are produced. Some of the causes for switching surges are switching of an unloaded line or open line and reactor switching.

III. EFFECTS OF FAULTS

Based on the type of fault each fault will affect the power system operation in a different way, some faults are severe and might cause interruption to power transmission. While some faults can damage an electrical equipment. Some of the effects of faults are listed below

• Flow of short circuit current, when fault occurs will create a very low impedance path for current flow, which results in drawing of huge current from the supply, and it can be in the order of 10 times the rated current, which can damage the insulation of equipment. Faults can also cause shocks to operating personnel [1] [2].

• Arcing faults can cause fire in devices like transformers as well as circuit breakers.

• Due to switching of an unloaded line cause switching surges due to travelling wave phenomenon by sudden application of voltage in the line as soon as the circuit breaker is closed at the sending end. The successive reflection of the voltage wave causes over voltages in the line.

• When a circuit breaker is made to interrupt low inductive currents such as currents due to no load magnetising current of a transformer, it interrupts even before current actually passes through zero value. This breaking of current before it passes through the natural zero is called as current chopping. Current chopping results in the production of high voltages across the circuit breaker contacts.

• Indirect lightning strokes such as lightning discharge near the transmission line can result in inducing over voltages.

IV. TYPES OF FAULTS

Faults can be classified as:

1. Open circuit faults (Series faults).

2. Short circuit faults (Shunt faults).

1) Open circuit faults (Series faults)

The most common causes of these faults include joint failures of cables and overhead transmission lines, and also due to melting of conductor or fuse in one or more phases [8]. When circuits are protected by fuses or circuit breaker which does not open all three phases during fault condition, one or two phases of the circuit may be opened while the other phases or phase is closed. These types of faults are called series faults. These faults may also occur with one or two broken conductors [4].

Series faults are characterised by increase in voltage and frequency but decrease in current in the faulty phases. These are unbalanced or unsymmetrical type of faults [4]. Although open circuit faults can be tolerated for longer periods than short circuit faults, these must be cleared as early as possible to reduce the further damage to the power system.

2) Short circuit faults (Shunt faults)

Short circuit is defined as an abnormal connection of very low impedance between two points of different potential. These are the most common and severe type of faults, resulting in the flow of abnormal currents through the equipment or transmission lines. If these faults are allowed to persist even for a short period, it leads to the damage of the equipment.

Short circuit faults can also be known as shunt faults. Shunt type of faults involve conductor or conductors to ground or short circuit between conductors. Falling of trees and tree branches onto conductors can cause line-to-ground or double line-to-ground fault. Shunt faults are characterised by increase in current and decrease in voltage and frequency [4] [8] [11]. The major types of faults are shunt faults. These faults may damage equipment, the healthy phases and human beings as well. Here we will discuss only shunt type of faults. Shunt type of faults are classified as

i. Line-to-ground fault (LG fault)
ii. ii. Line-to-line fault (LL fault)
iii. iii. Double line-to-ground fault (LLG) and

iv. iv. Three-phase fault (LLL or LLLG fault)

In these, LG, LL, LLG are considered as unsymmetrical faults or unbalanced faults as the symmetry is disturbed in one or two phases.

Whereas LLL or LLLG fault isconsidered as symmetrical fault or balanced fault.These faults will be analysed using symmetrical components.

• Line-to-ground fault (LG fault)

Line-to-ground fault will occur between any phase of the system and ground. It is the most common type of faults that occurs in the power system. Around 70%-80% of faults are of these type. Falling of trees and tree branches onto conductors are the most common cause of these faults [1].

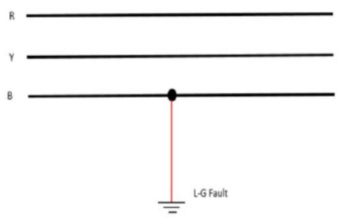

Fig. 1. Schematic representation of LG fault

• Line-to-line fault (LL fault)

Line-to-line fault will occur between any two phases of the system. Around 8%-10% of faults are of these type.

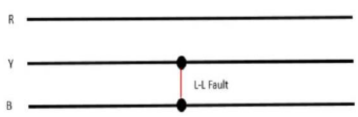

Fig. 2. Schematic representation of LL fault

• Double line-to-ground fault (LLG)

Double line-to-ground fault will occur between any two phases of the system and ground. Around 10%-15% of faults are of these type [12].

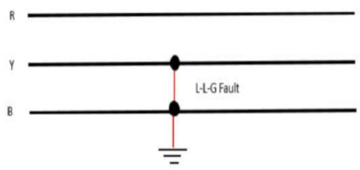

Fig. 3. Schematic representation of LLG fault

• Three-phase fault (LLL or LLLG fault)

Three-phase fault will occur due to short circuit of all three phases or between three phases and ground. These faults are least occurring faults among all types of faults but these faults are severe compared to all other faults. Around 2%-3% of faults are of these type [10] [12].

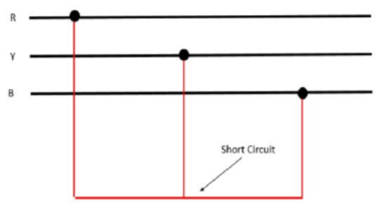

Fig. 4. Schematic representation of LLL fault

V. METHODS TO OVERCOME FAULTS

Power system can be protected by isolating the faulty section from healthy system. This can be achieved by using protective devices, such as circuit breakers, relays and lightning arrester. Protective system employed should be able to detect the fault and isolate the faulty section from healthy system as early as possible to minimize the severity of fault and to reduce the further damage to the power system. In this section, protective devices and some protective techniques will be introduced [1].

A. Relay

A protective relay is a switchgear device that detects the fault and initiates the operation of the circuit breaker to isolate the defective element from healthy system [4].

They are compact and self-contained devices which can detect fault conditions. Protective relays detect the faults in the electrical circuits by constantly measuring the electrical quantities which are different under normal and fault conditions. The electrical

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quantities which can change under fault conditions are voltage, current, frequency, and phase angle.

After detecting the fault, the relay operates to close the trip circuit of the circuit breaker. This results in the opening of the breaker contacts and disconnection of the faulty circuit from healthy system. [4]

A typical relay circuit is shown in the below figure. For simplicity this diagram shows one phase of a 3-phase system.

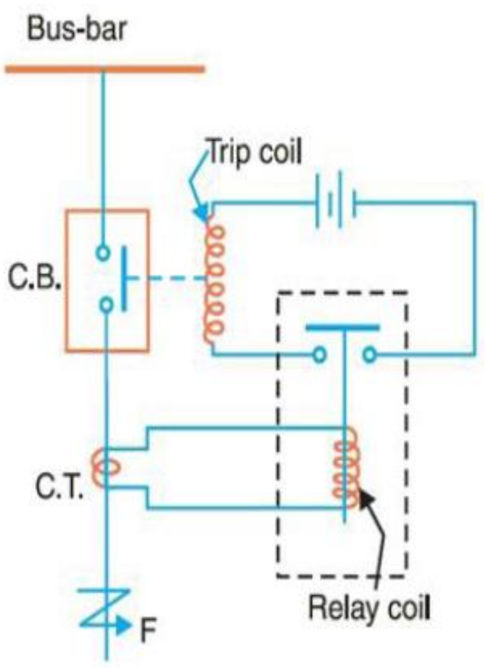

Fig. 5. Typical Relay Circuit Diagram

Fig. 6. Relay

B. Circuit Breaker

An electrical circuit breaker is a switching device which is used to break the circuit either manually or automatically when fault occurs for protecting an electrical power system.

When relay sends a trip signal to the circuit breaker the breaker contacts get opened and the faulty section is isolated from healthy system.

Fig. 7. Circuit breaker

C. Instrument Transformer

The protective relays are normally not connected directly to the power system but these are connected through instrument transformers [4].

Instrument transformers are of two types, current transformer (CT) and potential transformer (PT). As the power system values are much higher than relay ratings, instrument transformers provide smaller magnitude of voltage or current values to the relays. They are also used to provide electrical insulation from power system voltages [1].

D. Lightning Arrester

A lightning arrester is a device used in power system to protect the insulation and conductors of the power system from the damaging effects of lightning. The lightning arresters will protect against surges caused by indirect lightning strokes. The protection of overhead transmission lines from direct lightning strokes is done by running one or more ground wires above the overhead transmission lines [8].

E. Differential protection

A differential relay is an overcurrent relay operating on the difference of currents at the two ends of a protected element. Differential protection scheme is used for internal fault conditions. It cannot be used for inter-turn faults because the currents at the two ends of the winding of protective element remain same. Differential protection is very commonly used protection for protecting transformers and generators from internal faults [7].

Differential relays are very sensitive to the faults occurred within the zone of protection but they are least sensitive to the faults that occur outside the protected zone or through fault. Relay operates to protect the element when $k|I1 - I2|$ is not zero [3].
where k is current transformation ratio of the two CTs.

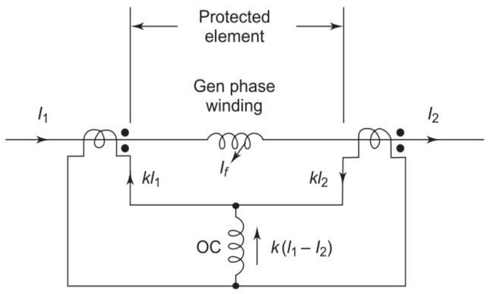

Fig. 8. Differential protection scheme

F. Directional Overcurrent protection

Directional overcurrent relay responds to excessive current flow in a particular direction in the power system. They are mainly used for the protection of parallel feeders [7].

Directional overcurrent relays are generally used on incoming line circuit breakers on buses which have more than two sources. They are connected to trip an incoming line circuit breaker when fault current flows back to the source, so that a fault on one source is not fed by other sources.

G. Distance protection

A distance relay is mainly used for the protection of transmission lines. These types of relays can detect ground faults and phase faults.

Distance relays are of three types, reactance relay, impedance relay and mho relay. Reactance relay is used for the protection of short transmission line. Impedance relay is used for the protection of medium transmission line and mho relay is used for the protection of long transmission line.

VI. CONCLUSION

Faults in a power system can cause severe damage to the equipment, create stability problems, and can make power system unreliable. In this paper, the faults that interrupts the power system operation has been discussed as well as the causes, the effects of the faults and protective methods to protect the power system are described.

Power system reliability can be improved by using highly accurate protection devices which can detect and clear the fault as early as possible.

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