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Review of Power System Faults

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***Abstract*—Fault in a power system is an abnormal condition that interrupts the stability of the system and causes a high current to flow through the equipment. In this paper the causes, effects and methods to overcome the power system faults will be discussed.**

Keywords—Power system; power system faults; power system protection; circuit breaker; relay

I. INTRODUCTION

A power system is always a huge system that spreads over a large geographical area, it is connecting the whole country, and sometimes more than one country to the system. It consists of several equipment such as generators, that converts the mechanical energy into electrical energy to produce the power. Transformers that changes the level of the generated voltage to different levels based on the needed application. Transmission lines to transfer the electrical energy from one end of the system to the other. And many other equipment such as relays and circuit breakers which are used for protection against faults.

Faults are an unwanted connection between two different conductors. There are several causes of faults, weather conditions, human error and equipment failure are some examples of it. Faults in the power system can be severe and damage an equipment, or the whole power system sometimes. It also causes fires and affects the operating personnel and might cause death [1] [2].

This paper provides a review of the power system faults, the effects of the faults and some prevention methods to protect the power system and increase its stability and reliability by sensing and clearing the faults and isolating the faulted zone. The structure of the paper is as follows, the second section will discuss the causes of faults. The types of faults will be introduced in the third section. Some effects of the faults will be presented in the fourth section. Furthermore, methods to overcome these faults are discussed in the fourth section, and the last section will be a conclusion.

II. CAUSES OF FAULTS

Faults are an unwanted condition of the power system. And to prevent this situation, the causes of faults need to be avoided if possible. There are several causes of power system faults. In this section some of those causes will be introduced.

- Environmental conditions
  Weather conditions is one cause of the power system faults that cannot be avoided. It includes lightning, rain, snow and other conditions. Such weather conditions hinder the operation of the power system and causes faults in the transmission lines especially.
- Human errors
  Another cause of electrical faults is human error. Inaccurate calculations lead to improper selection of electrical devices and equipment such as relays, circuit breakers. Moreover, delaying maintenance schedules may also affect the equipment performance which leads to reducing its performance and eventually malfunctioning and causing faults in the power system.
- Failure of equipment
  The performance of electrical equipment usually reduces with age. Also, insulation failures usually occur. This reduction of performance and malfunctioning may lead to short circuit faults in the system. Which leads to the flow of abnormal current through the lines to the equipment, which further damage them.

III. TYPES OF FAULTS

Different types of faults are classified into several types. The major types of faults are short circuit fault. Short circuit fault is an unwanted connection between two elements of the system, it might occur between one phase and ground, two phases, or three phases. This in turn might damage equipment, the lines and human beings as well. The other types are not considered major faults, such as open circuit faults and other faults [3] [4].

A. Symmetrical fault

Symmetrical fault is a fault that affects all three phases equally, it causes an abnormal current to flow in the lines with the same magnitude, but different phase angle with a shift of 120 degrees. It is also called balanced three phase fault. Three phase fault is the least to happen among all types of faults with a 2%-3% only [5].

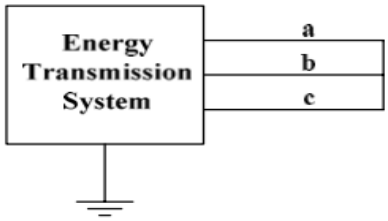

Fig. 1. Schematic representation of three phase short circuit fault in power system

B. Asymmetrical fault

Asymmetrical fault is a fault that does not affect all three phases equally. There are three different types of

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asymmetrical faults that can occur in the power system. These are described below.

- Phase to phase fault (L-L)
  Phase to phase fault is a short circuit that takes place between any two phases of the system. This is the second least fault happens in a power system with a percentage of 8%-10%.

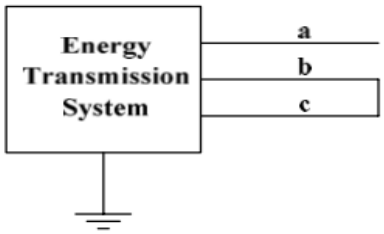

Fig. 2. Schematic representation of phase to phase short circuit fault in power system

- Phase to phase to ground fault (L-L-G)
  Phase to phase to ground fault takes place between any two phases of the system and ground. This is the second most common fault in power system with 10%-17%.

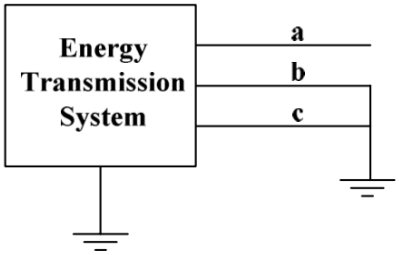

Fig. 3. Schematic representation of phase to phase to ground short circuit fault in power system

- Single phase to ground (L-G)
  Single phase to ground fault is a fault that takes place between any phase of the system and ground. It is the most common type of faults that happens in the power system, it happens with a 70%-80%. And this results primarily from lightning-induced transient high voltage, tree branches and falling trees [5] [6].

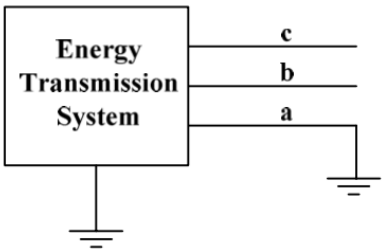

Fig. 4. Schematic representation of single phase to ground short circuit fault in power system

IV. EFFECTS OF FAULTS

Each type of faults affect the power system operation in a different manner, some faults are severe and might cause a blackout. Others might damage an equipment and so on. In this section, some of the effects of faults are mentioned

- Flow of abnormal current, when short circuit fault occurs, it creates a very low impedance path for current flow. This results in huge current to be drawn from the supply, this fault current might reach up to 10 times the normal current, which might damage the insulation of an equipment [2].
- Loss of equipment, due to the high current passing to the equipment, it might damage it. It could burn the insulation and windings of motors and transformers, which leads to improper working of the equipment. So, a properly working relaying system must be implemented [2] [5] [7].
- Loss of component, applying a well-designed protection system to clear the fault results in loss of component. Since the faulted zone will be isolated, the components in that zone are lost, and hopefully not damaged. Losing the components leads to another several problems in the power system, therefore weakens the system. These encountered problems could be an overvoltage, undervoltage and overload [5] [2].
- Power system stability issues, a power system is designed to involve exchanging of power between the generators and the loads. Having a fault interrupts this operation, hence, causes the power system to be unstable by changing the parameters of the system and the power transmission capabilities [5].
- Danger to employees, Faults endanger personnel as well since it might cause shocks to workers, these shocks differ in its severeness. Depending on the magnitude of current and voltage at the fault location. It can cause death in some cases [2].
- Disturbs interconnected active circuits, A fault occurring in a location usually does not only affect the fault location, it also affects nearby interconnected zones as well. These nearby interconnected circuits contribute in the fault current also [8] [2].
- Electrical fires, Short circuit faults cause the huge sparks and flashovers, which in turn ionizes the air between the conductors, and this sometimes leads to fires [2].

V. METHODS TO OVERCOME FAULTS

Electric systems suffer from short circuits from time to time which results in flow of abnormal currents. To protect the power system from these faults, the faulted area should be isolated from the rest of the system. Protection system should sense and isolate the faulted zone as fast as possible to minimize the severity of the fault and protect both the equipment and the system. Usually, the protection devices, such as circuit breakers as well as relays, are selected based on estimated calculations. In this section, these protection devices will be introduced, as well as one of the most efficient protection technique, differential protection [5] [1] [9].

A. Relay

A relay is an electrical device that is designed to respond to input conditions in a prescribed manner, and after specified conditions are met. Usually, the relay is described as the brain of the protection system. Since it takes the voltage or current as an input, compare it to a preset value and then takes action

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if needed. The action that a relay takes is that it sends a trip signal to the associated circuit breaker to either open or close, to isolate a faulted zone [5] [1].

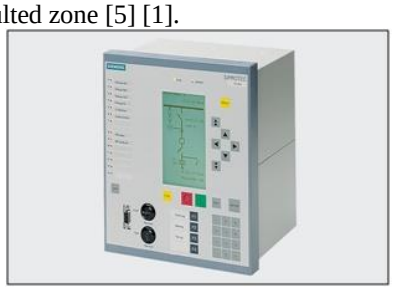

Fig. 5. Numerical relay

B. *Circuit Breaker*

Relays, as mentioned above, serves as the brain of the protection system, but it is a low energy device, which obstructs it from opening and isolating a faulted area. Circuit breakers are one of the best examples and most commonly used devices to serve as the muscles of the protection system, the relays send the trip signal to the circuit breaker, and it interrupts the faulted area to isolate it from the rest of the system [5].

Fig. 6. Circuit breaker

C. *Instrument transformer*

Instrument transformer is divided into two different types, current transformers and voltage transformers. These are used to provide the input signal to the relays, since the power system values are much larger than what a relay withstands. Instrument transformers are used to provide smaller magnitude of the power system values to the relays, it also serves for isolation as well since it isolates the relays from the power system [5].

D. *Differential protection*

For more than fifty years, differential protection is considered as the best protection technique. The electrical quantities entering and leaving the protected area are monitored and compared by current transformers. If the summation of the two compared values are zero, then it is assumed that the system is working properly. Otherwise, the relay senses the difference and sends a trip signal to the associated circuit breakers to open and isolate the faulted zone [5].

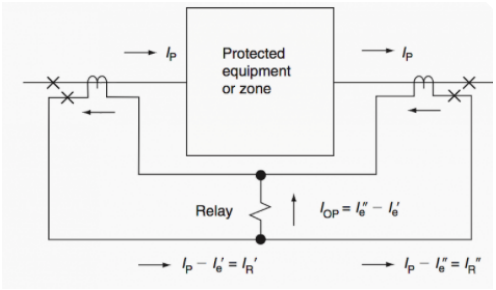

Fig. 7. Differential protection scheme

E. *Directional Overcurrent protection*

Directional overcurrent relay is one of the various types of relays. It is the type used in directional overcurrent protection. This technique is usually used for parallel transmission lines. For this protection approach, three parameters are needed, voltage, current and the phase angle between the voltage and current. The current could flow either way in the relay, but, the relay detects the fault current through the phase angle and direction of flow. Then, it sends a trip signal to the associated circuit breaker to trip the faulted area [10].

F. *Distance protection*

Distance protection is one of the most popular approaches used to detect the fault location in a power system, especially in long transmission lines. A distance relay is used for this protection technique. This relay measures the impedance of the line where the fault is located, then compares it to a set value. If the measured value is less than a set value, then, the fault is within the relay's protected zone, in this case the distance relay sends a trip signal to the associated circuit breaker [10].

VI. CONCLUSION

Power system faults are considered as the major hindrance to the stability, sustainability and reliability of the power system. In this paper, the faults that interrupts the proper operation of the system has been briefly discussed as well as its effects, to the system and the operating personnel, and the methods to overcome this interruption.

In order to have a reliable power system, there must be a properly implemented protection system, which needs accurate studies and calculations as well as well conditioned, highly accurate protection devices.

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