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Definite Time Overcurrent Protection Relay of Power Distribution System

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ABSTRACT

This paper discusses multi types of overcurrent protection system relays and focuses on the design of a definite time overcurrent relay for three phase system. The definite time overcurrent relay was designed to provide an accurate and reliable system to efficiently protect the distribution system. Overcurrent protection is one type of protection function mostly used for definite time overcurrent protection. Overcurrent protection was used to determine the peak value of the current signals and detect the difference between the normal operation and abnormal conditions to operate just when a fault occurs and disconnect the faulted areas.

Keywords: Definite Time, Over Current, Protection Relay, Power Distribution.

1. INTRODUCTION

The role of protective relays in a power system is to detect system abnormalities and to execute appropriate commands to quickly isolate only the faulty component from the healthy system. Overcurrent relay has become one of the most important protective devices since the beginning of the age of electricity until today. It has been widely adopted as the main and backup protection of power system due to its characteristics of high reliability, selectivity and cost-effective. Overcurrent protection is a practical application of the magnitude relays because it will be triggered when the magnitude of current exceeds setting value. It also has fast fault clearing times because the operating time of the relay is inversely proportional to the magnitude of the current, which need a shorter operating time to operate for higher faulty current.

Most of the protection relay is located at each feeder of the distribution system network that is formerly located at the substation and is used as the backup protection. The protective relay is coupled with Circuit Breaker (CB) such that it can isolate the abnormal condition from the system. In the interest of reliability and effectiveness of a protection system, some designers of power distribution or power controllers select relay as opposed to electromagnetic circuit breakers as a method of circuit protection.

The power supply interruptions possibly occurred due to improper setting of power protection devices such as built-in tripping, low overcurrent protection and inactive earth fault. The design of power system protection is very important in order to ensure that there is no power supply interruption. One of the most important protection devices in the power system is a relay and the common type of relay that has been used is the electromechanical relay. The electromechanical relay has some disadvantages. Firstly, as time passes by, the spring and linkage inside the relay will become weaker. Eventually, it will make the initial pre-set setting of the relay goes drift, causes system malfunction and leads to false trips. Other than that, the

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electromechanical relay is a non-multifunctional relay, thus the speed of the operation time is limited to the mechanical inertia due to the movement of components. Besides that, a high setting overcurrent relay usually needs a long clearance time. Hence, introducing the risk of damage to the system due to slow clearance time compared to definite time overcurrent relay. This relay will operate at a fast operating time with decreasing faults levels and also gives very fast tripping at high faults level depending on the setting time that has been set.

Electrical power system protection is required for protection of both user and the system equipment itself from fault, hence the electrical power system is not allowed to operate without any protection devices installed. A power system fault is defined as an undesirable condition that occurs in the power system [1]. These undesirable conditions such as short circuit, current leakage, ground short, overcurrent and overvoltage. With the increasing loads, voltages and short-circuit duty in the distribution system, overcurrent protection has become more important today. The ability of the protection system is demanded not only for an economic reason but also to provide a 'reliable' service and satisfy consumers expectation [2].

In a power system protection, a device that can monitor current, voltage, frequency, and power would be required. However, overcurrent protection of an islanded distribution system is still an issue due to the difference in fault current when the distribution system is connected to the grid and when it is islanded [3]. Thus, a device called a Protective Relay (PR) was developed to overcome the issue. The PR is most often coupled with CB such that it can isolate the abnormal condition in the system. In the interest of reliable and effective protection, some designers of power distribution/power controllers select relay as opposed to electromagnetic circuit breakers as a method of circuit protection. Overcurrent protection devices are used to protect conductors from excessive current flow. These protective devices are designed to keep the flow of current in a circuit at a safe level to prevent the circuit conductors from overheating [4].

Overcurrent relays is a type of protective relays which operates when the load current exceeds a pre-set value [5]. In a typical application, the overcurrent relay is used for overcurrent protection by connecting it to a current transformer and calibrated to operate at or above a specific current level [2]. If the input current value exceeds the preset value, the relay detects an overcurrent and send a trip signal to the breaker which then opens its contact to disconnect the protected equipment. When the relay detects a fault, the condition is called fault pickup. The relay can send a trip signal instantaneously after picking up the fault (in the case of instantaneous overcurrent relays) or it can wait for a specific time before issuing a trip signal (in the case of time overcurrent relays). This time delay is also known as the operation time of the relay and is computed by the relay on the basis of the protection algorithm incorporated in the microprocessor [6].

A type of overcurrent relay called definite time overcurrent relay is usually used for backup protection such as back up protection for transmission line where primary protection is distance relay [3]. If the distance relay does not detect a line fault and does not trip the breaker, then after a specific time delay, the overcurrent relay will send a trip command to the breaker. In this case, the overcurrent relay is time delayed by a specific time which is just greater than the normal operating time of the distance relay plus the breaker operation time.

The main objective of this paper is to design a definite time overcurrent relay protection on the three-phase power system. The dependability of the current relay in the system when the fault occurs was observed using MATLAB software. The results of the current waveform are compared between the three-phase power system with and without current relay protection.

2. METHODOLOGY

The definite time overcurrent relay is a type of relay where the delay needs to be manually set. In this simulation, the delay time was set to 0.5 s. Therefore, for every fault that occurs, the relay will trip at 0.5s. Furthermore, in this simulation, the input current of the relay was based on the value of current at full load of the system. Whenever a fault occurs, the value of current at full load will differ from the original. If the value is greater than the input current of the relay, the system will trip.

Figure 1 shows the flowchart of the simulation process. The flowchart presents the detail on the operation of the overcurrent relay. First, the system operates in good condition without any fault. A fault is created in order to test the system. The relay will sense any changes in current that occur in the system. Finally, the information collected result in tripping of the system.

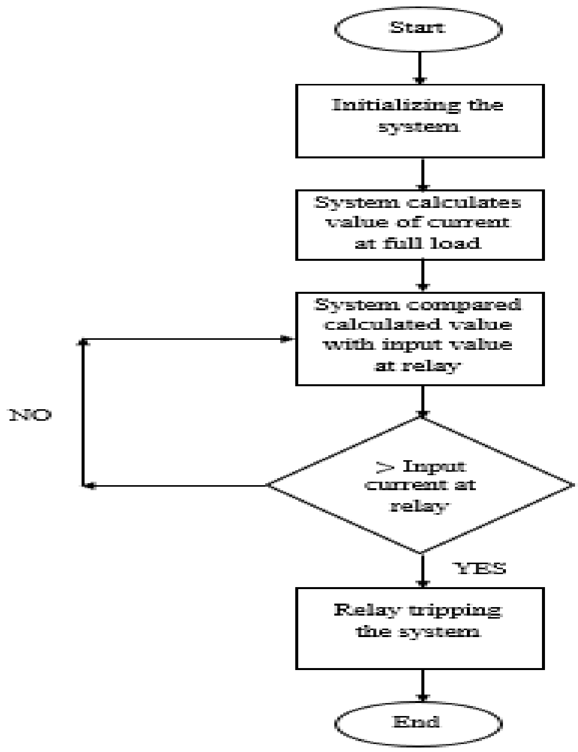

Figure 1. Flowchart of the simulation process.

Figure 2 shows the model of a definite time overcurrent protection relay for the power distribution system. The model consists of a power distribution system and a definite time overcurrent protection relay. The transmitter side of 10 km power distribution is connected to a breaker with a three-phase V-I measurement which is used to measure the value of load current. Meanwhile, at the receiver side of the 10 km power distribution is connected to 10 MW three-phase series RLC load. The main source of the power distribution system is 11 kV, 100 MVA, 50 Hz three-phase generator. The definite time overcurrent protection relay is a type of digital relay that is constructed using Boolean model consisting OR gate and D-Latch flip-flop as shown in Figure 3.

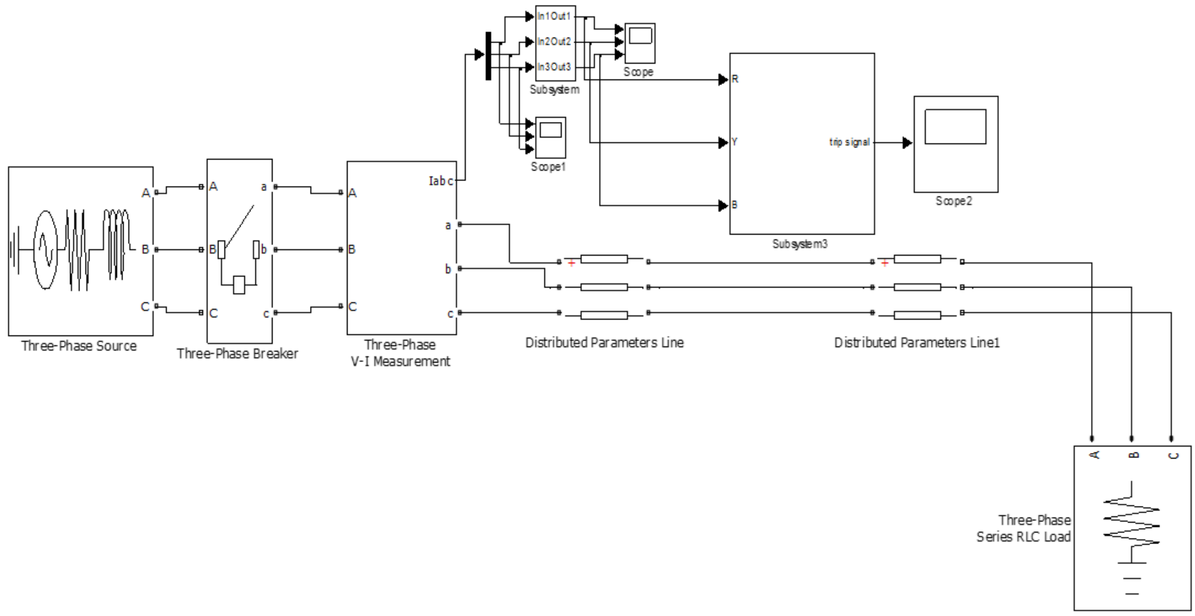

Figure 2. Modelling of the definite time protection relay on the power distribution system.

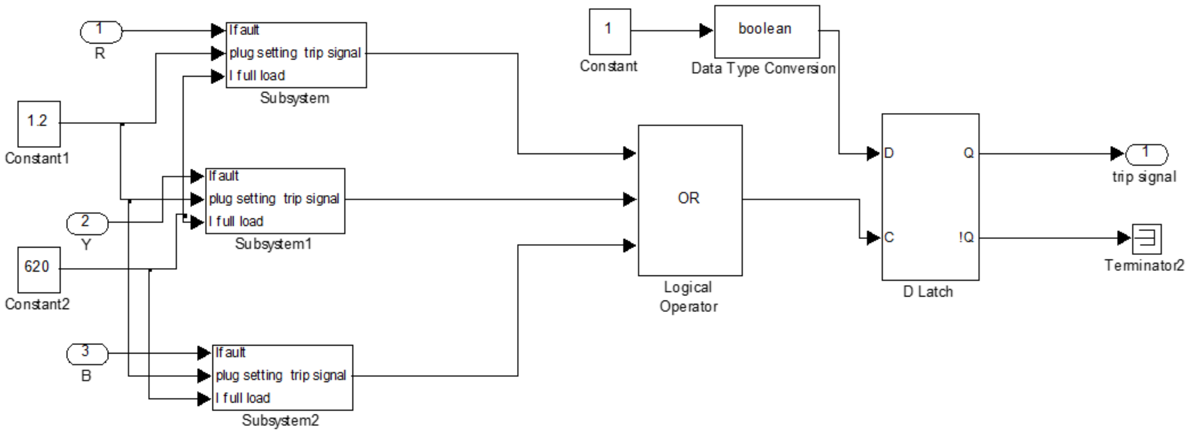

Figure 3. Modelling of the definite time protection relay.

The definite time overcurrent relay works when the current at full load is greater than the pickup current of the relay. Pickup current, I_p is the product of input current and plug setting which is 1.2. The input current of the relay is based on the current at full load when the system at normal condition. Finally, the full complete circuit of the system was shown in Figure 3.
The pickup current, I_p was generated based on the distribution system itself. In this paper, the three-phase source was set to supply 11kV to the load. With the aid of a three-phase V-I measurement, the value of the current at each phase was calculated. The measurement taken at each phase is the RMS value.

3. RESULTS AND DISCUSSION

Figure 4 presents the RMS value of the current at full load when the distribution system is in normal condition. Based on the waveform, the value of the current at full load is approximately 620A. The 620A value will be the input current for the relay. The value of pickup current, I_p of the relay will be 744A. Thus, in order for the system to trip, the value of current at full load should be more than 744A.

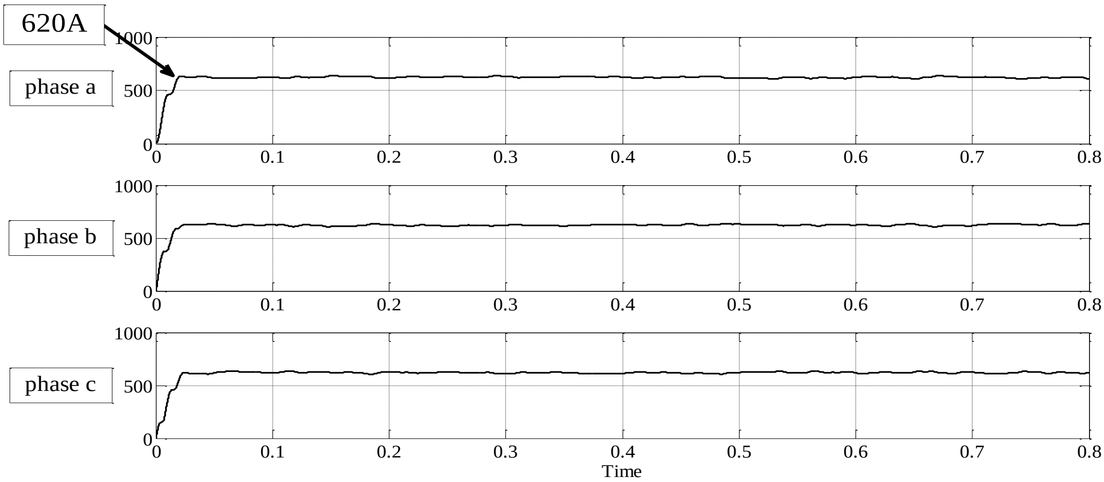

Figure 4. Full load current (RMS) at normal condition.

The simulation involves three types of fault which are three-phase to ground fault, single phase to ground fault, and phase to phase fault. Based on the results, the definite time overcurrent relay performed very well.

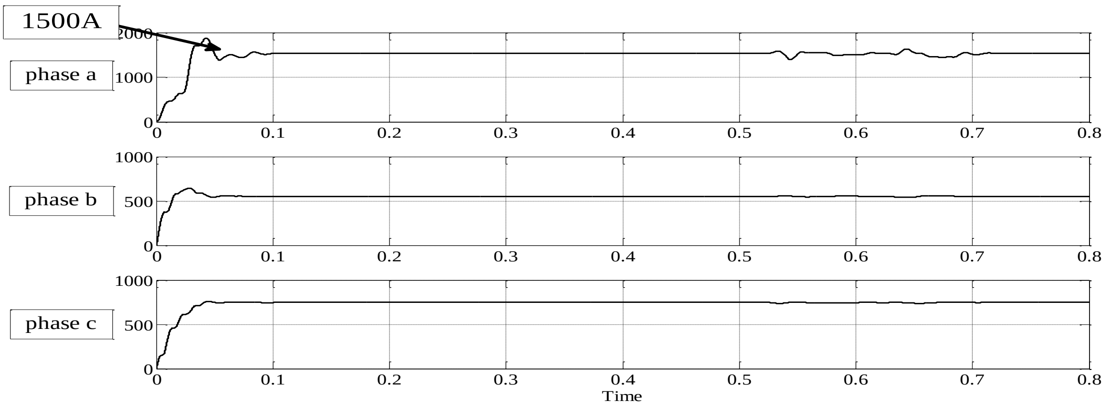

Figure 5. Full load current during single phase to ground fault condition.

The distribution system was first set to undergo single phase to ground fault at phase A. Based on the scope, when a fault occurs, the value of the full load current in RMS suddenly increase to approximately 1500A. The result was shown in Figure 5.

The fault was set using a breaker which is connected to one phase and ground. The switching time of the breaker was set to 0.05s. The overcurrent relay was set to have a delay time of 0.5s. Besides that, the relay system uses an 'or' logic gate resulting in logic '0' for no tripping signal and logic '1' for tripping signal. The tripping process occurred as the relay sense an overcurrent in the system and system tripped at 0.55s. The same goes to phase to phase fault and three phase to ground fault. The value of the full load current in RMS during fault is shown in Figure 7 and 8, respectively. The tripping signal of the system is shown in Figure 6.

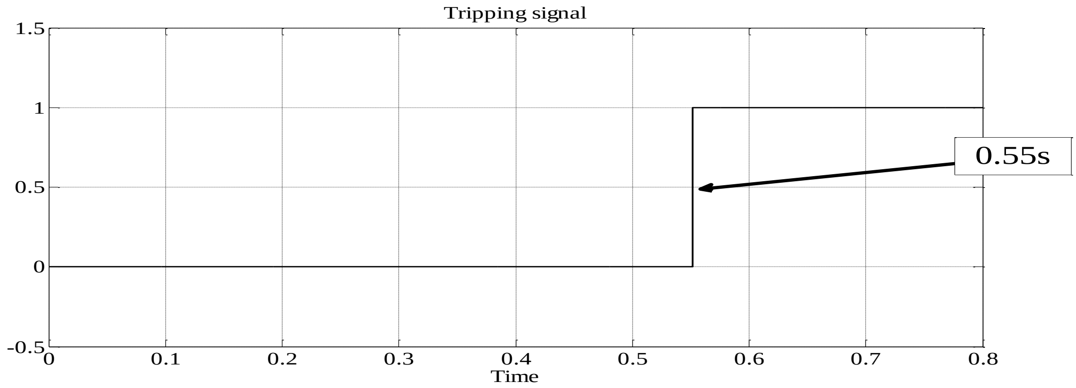

Figure 6. The tripping signal of the system.

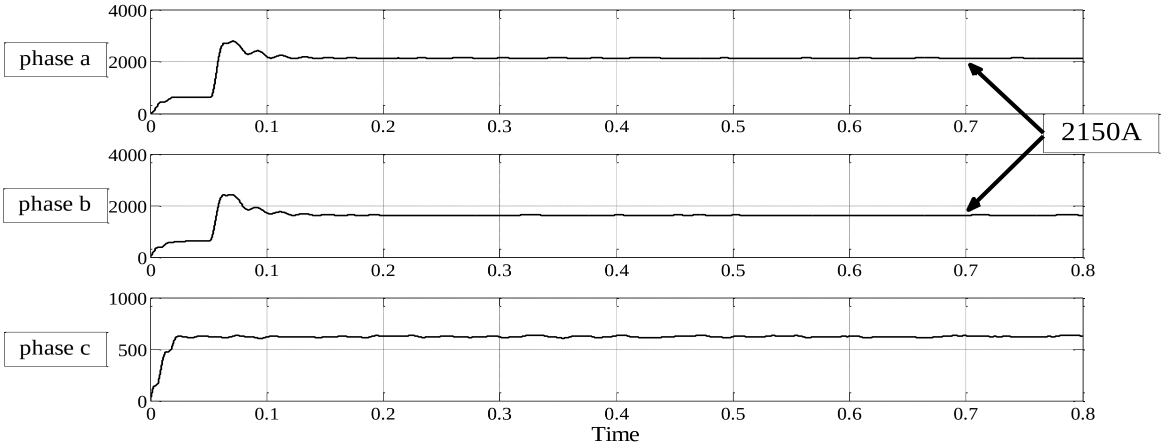

Figure 7. Full load current (RMS) waveform during phase to phase fault.

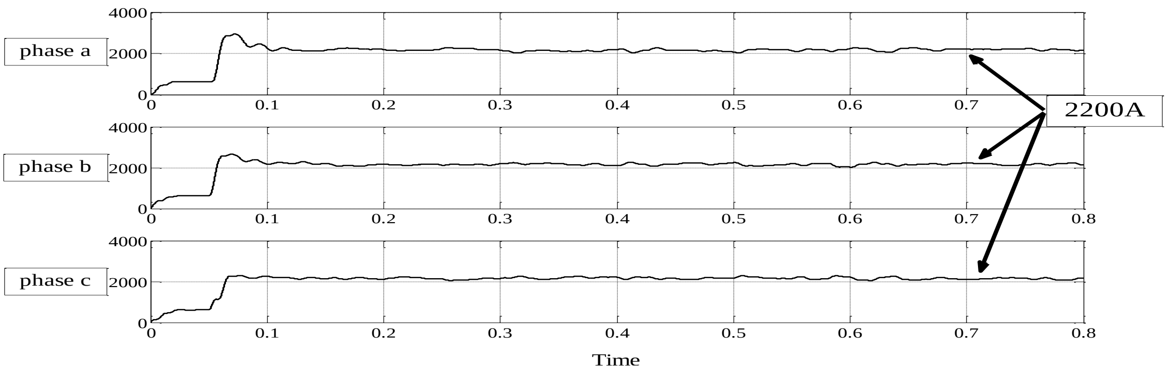

Figure 8. Full load current (RMS) waveform during three-phase to ground fault.

Both Figure 7 and 8 show the output of the full load current waveform (RMS) for each phase. Phase to phase fault result in only two phases has increasing current value compared to the current at normal condition. Unlike three-phase to ground fault, it affects all phases. Fortunately for the system, the overcurrent relay able to sense all three types of fault and allows the tripping process to occur.

4. CONCLUSION

Based on results and discussions, it can be concluded that when the fault occurred in a power distribution system, one of the effects is a drastic increase in full load current value. The drastic increase in full load current value may cause fires or electrical equipment failures. In order to avoid such consequences, the power distribution system requires a protection system. Overcurrent protection relay is the most suitable device to prevent overcurrent in the system caused by faults.

This paper proves the effectiveness of a definite time overcurrent relay in detecting and protecting the distribution system from a single line to ground fault, phase to phase fault and three phase to ground fault.

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