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Transformer Overcurrent Protection

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ABSTRACT

During short circuit fault, electrical equipment and power network suffers high stress of fault current which may permanently damage the equipment and the networks. An overcurrent occurs when current exceeds the rating of equipment. For this project, the current relay protection is located between the transmission line and transformer. The current relay is implemented to protect the 220kV power system. The system is designed and simulated using MATLAB software. The output waveforms of before and after the occurrence of a fault were analyzed. The output current waveform for the power system in a normal condition is sinusoidal with the same peak current. When a fault is injected into the system between the transmission line and transformer, the output current waveform increases drastically. The relay will energize and send a trip signal to the circuit breaker. The circuit breaker will disconnect the power system from the transformer, interrupting the current flow in the power system. Hence, no current flows in the system after a fault occurs.

Keywords: Overcurrent, Relay, Transformer, Fault.

1. INTRODUCTION

Nowadays, the modern power system deals with large power network and numbers of associated electrical equipment. During short circuit fault or any other types of electrical fault, the equipment and the power network suffer high stress of fault current that may permanently damage the equipment and networks. In order to protect the equipment and the power networks, the fault current must be cleared from the system as quickly as possible. After the fault is cleared, the system must quickly return to its normal working condition ensuring reliable power supply to consumers. Therefore, the different switching operation is required for proper power system control [1].

During the disconnecting and reconnecting of different parts of the power system network for protection and control; a switching device which can safely operate under overcurrent condition is required. The large arcing between the switching contacts produced during the interruption of a large current should be handled in a safe manner. The circuit breaker is a special device that does all the required switching operations during current carrying condition. This is the basic introduction to circuit breaker [2].

Low load power systems should contain protective devices to prevent injury or damage during failures. The typical protective device commonly used is the fuse. The fuse element melts when the current flows through a fuse exceed a certain threshold value, producing an arc across the resulting gap which interrupts the circuit. Fuses, however, have two problems. The first problem, fuses must be manually replaced after it melts because fuses cannot be reset. This can prove as inconvenient if the fuse is at a remote site or a spare fuse is not available. The second

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problem is that fuses are typically insufficient as a single safety device in most power systems because it allows excess current flows that would be dangerous to human or animal.

An overcurrent exists when current exceeds the rating of conductors or equipment resulted from overload, short circuit, or ground fault. Overload is a condition in which equipment or conductors carry current exceeding their rated ampacity. As for example, when two hairdryers (12.5A and 1.5kW) were plugin into a 20A branch circuit. A short circuit is an unintentional electrical connection between any two current-carrying conductors either line-to-line or line-to-neutral. A ground fault is an unintentional, electrically conducting connection between an ungrounded conductor of a circuit and the equipment grounding conductor, metallic enclosures, metallic raceways, metallic equipment, or earth. Dangerous voltages and abnormally large currents present during a ground fault.

This paper designs current relay protection for the transformer in the three-phase power system. In this paper, the current relay protection is located before the transformer. The current relay is implemented to protect the 220kV power system. It should respond correctly when a fault occurs and send a trip signal to the circuit breaker. The circuit breaker will then disconnect and isolate the system from the faulty area. The system was designed and simulated using MATLAB software. The simulation results in the form of the output waveform of the three-phase were compared before fault and after fault happens.

2. METHODOLOGY

The connection diagram of the overcurrent relay for a three windings transformer with each phase consists of one overcurrent relay and its connection is shown in Figure 1. The current transformer (CT) output is compared with the threshold setting value for each phase of the current transformer.

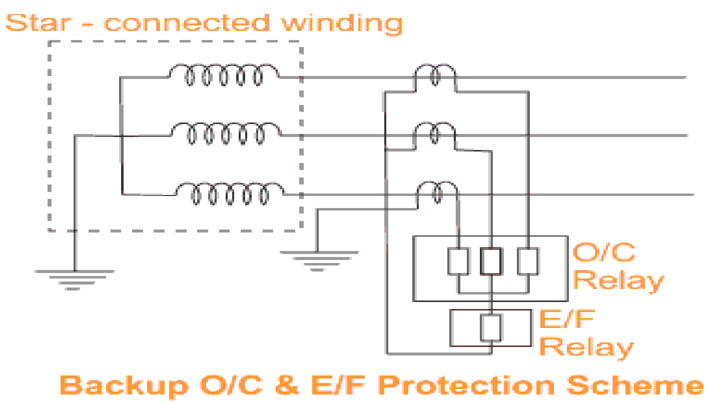

Figure 1. The connection of O/C relays [1].

The transformer used in this research rated as 150MVA. Fuses are used as the overcurrent protection. Time overcurrent relays or instantaneous relays are used for over protection of transformers. In some high power applications, both time overcurrent relays and instantaneous relays are used with instantaneous protection as a backup to the time overcurrent with a higher setting value. The setting of these fuses and overcurrent relays depends on the thermal balance of the transformer core and tank. The relay settings were chosen below the thermal balance of the transformer. In addition, the transformer magnetization current rating is also taken into consideration.

The time over current (IDMT) relay is normally set for operation at about 150% of the rated current of the transformer. The time delay must be long enough to avoid tripping due to the magnetizing inrush current when the transformer is energized. Time selectively must also be achieved between the relays on the primary and secondary side of the transformer.

The instantaneous element has to be set at about 25% above the maximum fault current and above the maximum inrush current. With this setting, instantaneous tripping is only obtained for severe faults on the feeding side of the transformer. The faults on the transformer can be caused by winding close to the bushing, or faults in the circuits between the CTs and the transformer [3].

This paper designs a current relay protection system that will disconnect and isolate the power system when a fault occurs. The flow of this project is shown in Figure 2. This project is divided into several stages where the first stage involves modelling of the basic 220kV power system in MATLAB software. This power system is connected to a transformer in order to step-down the voltage from 220kV to 66kV before it is supplied to a load. In this stage, the 220kV power system is simulated before the fault occurs. The simulation result of this stage will be used as an initial condition where the system operates in a normal condition without fault. The next stage of this project is to design a current relay protection device in order to protect the transformer and power system when the fault occurs. If the current relay does not trip during a fault, the design of the current relay must be modified. However, if the current relay operates according to the desired setting and isolates the power system when a fault occurs, the output result of this stage can be observed and analyzed. Lastly, both results of the output waveform are compared and analyzed.

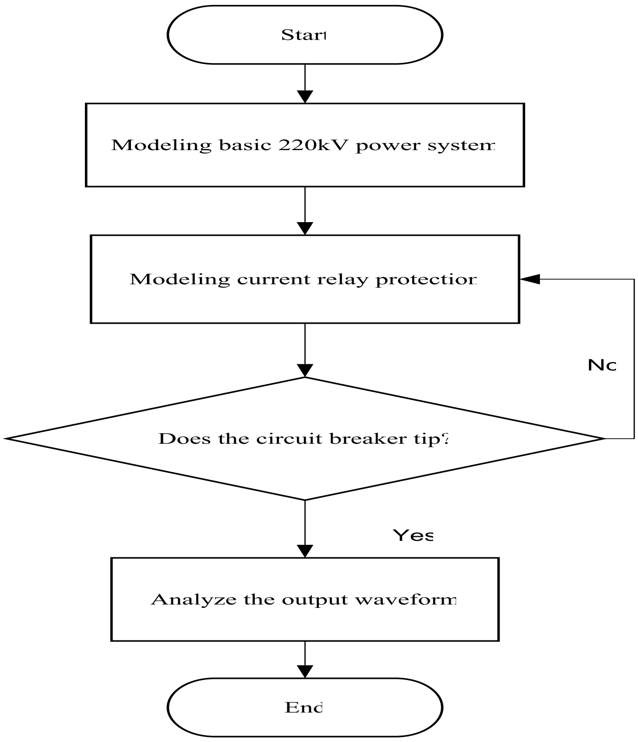

Figure 2. Flowchart of the project.

Figure 3 shows the block diagram of a 220kV power system with a current relay protection scheme between the transmission line and transformer. This power system is connected to the three-phase circuit breaker. The circuit breaker is controlled by the current relay and used to isolate the power system which is connected with transformer and series RCL load from the fault. The current relay is used to detect the fault and send trip signals to open their associated circuit breakers and isolate the faulted section from the rest of the power system in order to avoid damage to transformer and power system.

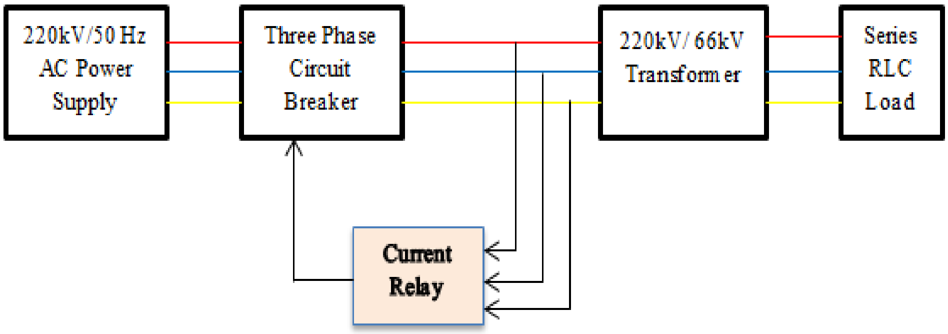

Figure 3. Block diagram of 220kV power system with the current relay protection scheme.

The current relay protection scheme starts with measuring the input current and voltage of the power system without fault. The current that initiates the relay operation is called pickup current. The pickup current of the relay is normally 20% higher than the input current. The calculation of pickup current is shown in Eqn. (1) [4, 5, 6].

$$I_{pickup} = 1.2 \times I_{input} \tag{1}$$

If the input current is larger than the pickup current, the current relay will send a trip signal to the circuit breaker which will interrupt the current flow and trip the system. However, if the input current is smaller than pickup current, the current relay will not operate and circuit breaker will remain in the normal condition. The measurements of the input current and voltage are repeated to continuously monitor the input current.

Figure 4 shows the current relay circuit used in this power system which is based on the digital operating system. The relational operation will compare the input current with the pickup current. In this system, the constant pickup current that had been used in the current relay is 144A. The relational operator is connected to the OR gate in order to analyze its output. The logic gate is then connected to D Latch which also known as D flip-flop. This simple flip-flop was used to “SET” and “RESET” the operation of the relay. The truth table of the D flip-flop is shown in Table 1. The time delay for current relay to trip the circuit breaker is set to 0.1 seconds.

Table 1 Truth table of D flip-flop

C	D	Q
0	0	No Change
0	1	No change
1	0	0 = RESET state
1	1	1 = SET state

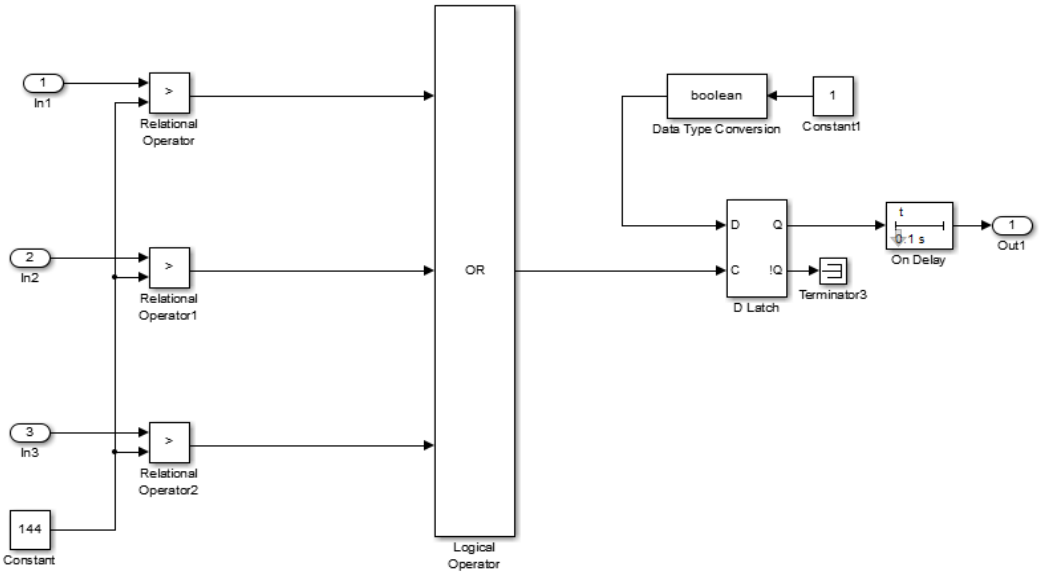

Figure 4. Current relay block diagram using Matlab.

Figure 5 shows the design circuit for the 220kV power system. The three-phase fault can be connected and disconnected in order to analyses the output waveforms. When the three-phase fault is connected between the transmission line and transformer, low resistance is injected into the power system. Low resistance and a high voltage will give a very high input current to the system. The parameters of the system are shown in Table 2.

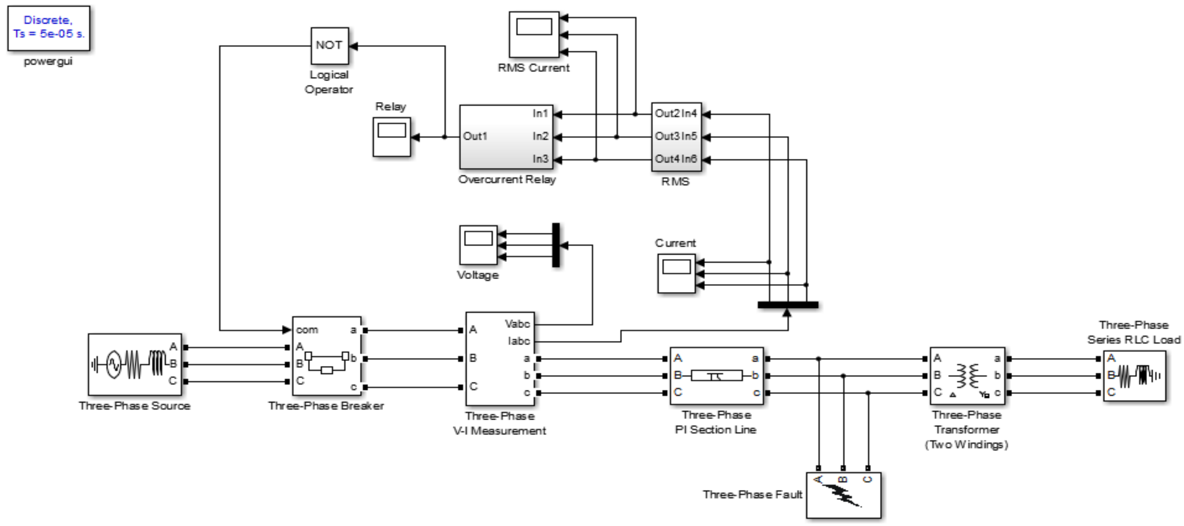

Figure 5. The design of the block diagram for the 220kV power system.

Table 2 Parameter setting for power system

Parameter	Value
Three-phase source	220kV
Three-phase fault resistance	0.001 ohm
Three-phase transformer	220kV/ 66kV
Nominal power	150MVA

The designed system was simulated using MATLAB software. The results of output current waveform for power system between normal condition without fault and condition with fault were compared. If the measured input current does not exceed the relay pickup current, the breaker will not trip the system. But, if the measured input current exceeds the relay pickup current, the current relay will send a trip signal to the three-phase breaker. The breaker will disconnect and isolate the fault from the power system.

3. RESULTS AND DISCUSSION

After the circuit was successfully designed, it needs to be tested and analyzed in term of the current relay dependability. Therefore, in this section, the waveform from the simulation are shown in Figure 6 and 7.

Figure 6 shows that the three-phase current waveform for the 220kV power system in a normal condition which means without fault. The output current waveforms for every phase are sinusoidal with the same peak current, 120A. During this time, the input current is lower than current relay pickup current.

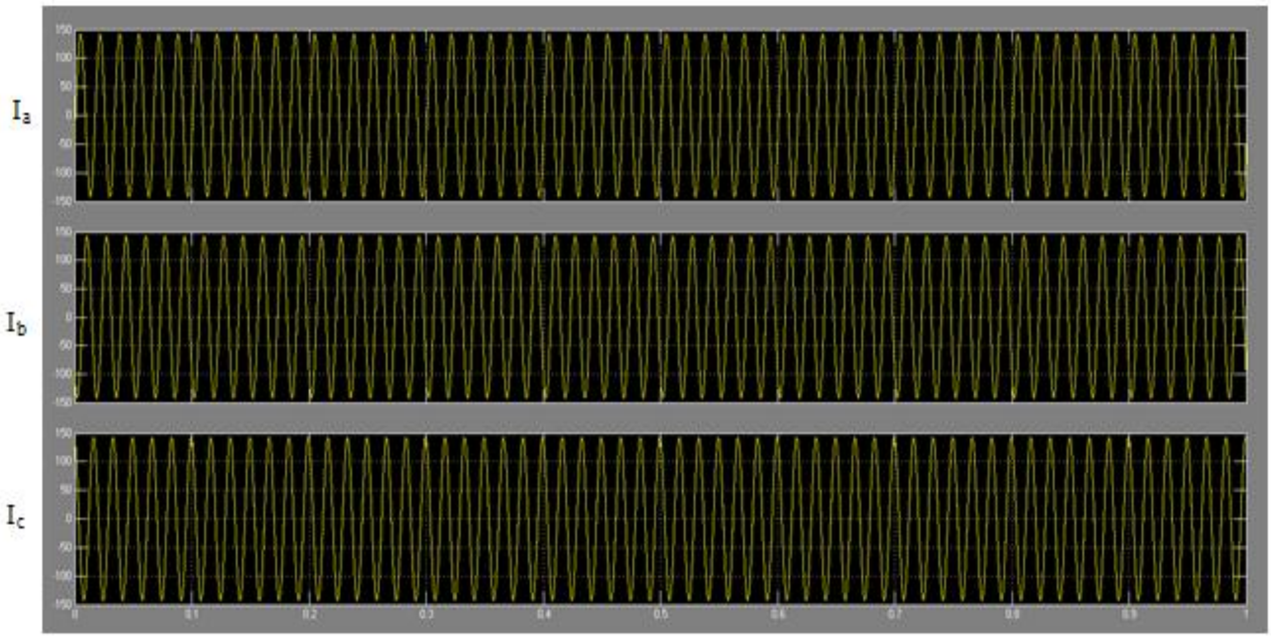

Figure 6. Output current waveforms in normal condition.

Figure 7 shows the three-phase current waveform for 220kV power system when a fault occurs. The fault is injected into the system between the transmission line and transformer at 0.5 seconds and the output current waveform suddenly increases drastically up to 500A. During this time, the input current is higher than current relay pickup current. The relay was energized and send a trip signal to the circuit breaker. The circuit breaker then disconnects the power system from the transformer. The time delay for the fault to trip is 0.1 second. The current flow in the power system was interrupted, thus no current flows in the system after a fault occurs. The design of the current relay protection system is reliable only if the relay trips when it is expected to trip. Dependability is the degree of certainty that the relay will operate correctly where it is operating reliably when fault conditions occur [7, 8, 9].

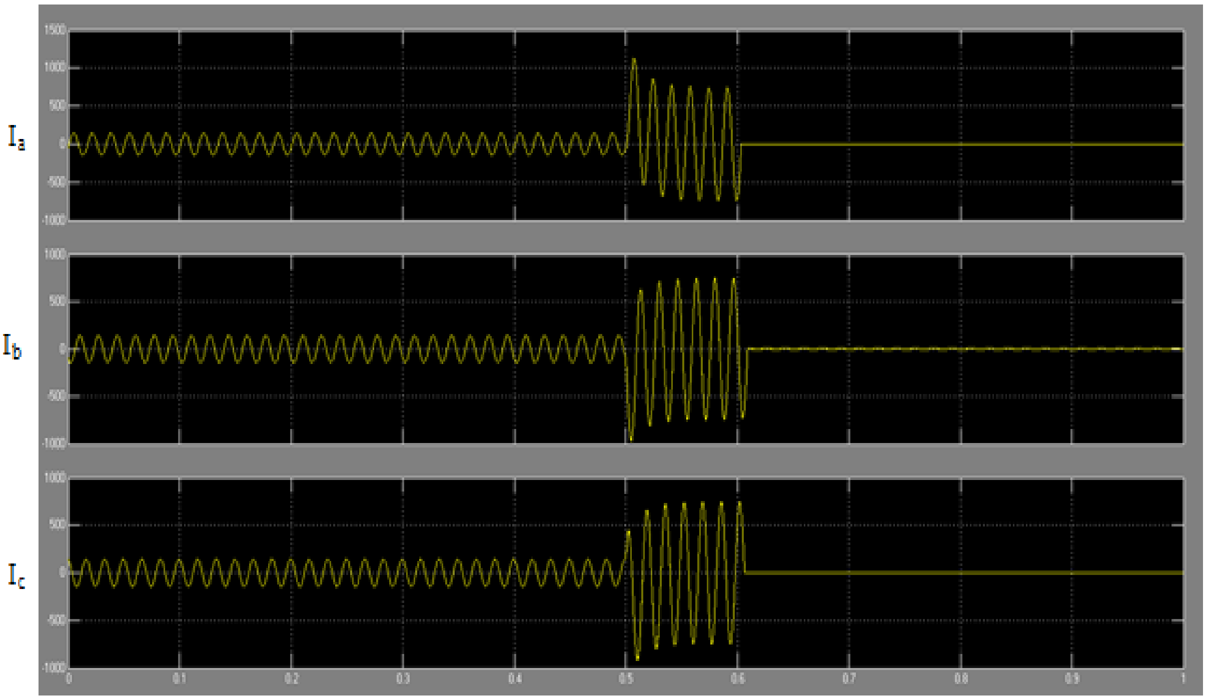

Figure 7. Output current waveform in a fault condition.

4. CONCLUSION

In this paper, a dependable overcurrent relay protection for the transformer in the three-phase power system is designed using MATLAB SimPowerSystems. The 220kV power system is protected from fault by the overcurrent relay protection scheme. The overcurrent relay is able to send trip signals to the circuit breaker when the input current is higher than the pickup current of the overcurrent relay. The circuit breaker received a trip signal from overcurrent relay and interrupt the current flow by disconnecting its contactor. Thus, the system will trip and the equipment will stay protected within the protection area when a three-phase fault occurs. In another word, the overcurrent relay protection system design is considered dependent when the relay able to trips only when it is expected to trip. The current waveform between phase power system with and without current relay protection are compared using MATLAB software. From the comparison, the power system without protection system is proven unreliable compared to the system with the protection system.

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