

Simulator for Overcurrent Phase and Ground Fault Protection with Microprocessor Based Relays

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ABSTRACT

Understanding concepts related to the process for determining the design of protection settings requires practical experience, which can be achieved by repeated trials. The objective of this research has described the design and implementation of a hardware simulator for understanding concepts phase and ground fault protection system, evaluate the maximum of short circuit current prospective in the simulator for safe operation, and describe the mechanism of the relay protection operation related to the symmetrical fault and asymmetrical fault disturbance. This paper presents the methodology of the design and implementation of a simulator for overcurrent phase and ground fault protection with microprocessor-based relays. The microprocessor-based relays are used to operate from symmetrical component quantities to demonstrate that any set of unbalanced three-phase quantities could be expressed as the sum of three symmetrical sets of balanced phasors. The result of evaluating the magnitude of maximum fault current at bus substation is 30.84 ampere, at the middle of the line is 11.75 ampere, at the end of the line is 7.3 ampere. The setting of the Instantaneous should be a maximum is 10 ampere. The phase of over current fault will operate phase relay protection threshold for all symmetrical and asymmetrical fault except for open one phase fault disturbance. For ground fault relay operated at one phase fault and all the asymmetrical fault disturbance.

Keywords: *Simulator, phase fault, ground fault, relay protection*

1. INTRODUCTION

Understanding concepts related to the process for determining the design of protection settings requires practical experience, which can be achieved by repeated trials. This research will develop a simulation of the protection system mechanism related to the symmetrical fault and asymmetrical fault disturbance. The simulator can display the performance of a protection system and test it with direct interference with a short circuit in the network.

Several previous studies related to the simulator for the protection system have been carried out. Develop a design for the Teaching Aid Network Protection System for Medium Voltage Distribution by Supriyanto [1]. Hardware simulator on the high voltage of a 4.8 kV system for simulated ground fault protection with overvoltage relay protection by Heskett and by Mitchell [2] in 2013. A ground fault detection of the earthing system with a floating system to detect disturbance and measure load fluctuations in the delta-delta transformer configuration by Borjas and by Daniela [3]. The reduced of the primary voltage of 20 kV and secondary 380 V to the primary

and secondary at 380 V, using the simulator for the distribution system with floating systems ungrounding system protection with zigzag transformer [4]. Overvoltage with wye open delta[5] and MV network grounding protection [6].

This paper applies the design results for a short circuit study to determine the magnitude of phase and ground fault disturbances, which will be applied to the protection relay settings with microprocessor-based relays that have been written by Celeita [7] and by Carlos [8].

The method of symmetrical components is used to simplify fault analysis by converting a three-phase unbalanced system into two sets of balanced phasors and a set of single-phase phasors, or symmetrical components by Golver [9] and by Durand [10]. In the other case, the method of symmetrical components is used to simplify fault analysis by converting a three-phase unbalanced system into two sets of balanced phasors and a set of single-phase phasors, or symmetrical components by Yin [11]. Implementing high-resistance grounding in mining power systems by Sottile [12]. Residual current-based method for open

phase detection by Charles[13]. The use in study open phase-detection for power transformers using VT by Blake [14].

Study-related to the coordination of overcurrent relays considering different relay characteristics, publish by Ahmadia [15]. The coordination for MV network applications for overload protection of power lines by Hazi [16]. Coordination of the relay protection settings against phase to phase faults in electric power lines 20 kV by Mehmed [17]. The development of virtual relay design for feeder protection testing with online simulation by Montana [18]. The development for fast and secure operation in transient conditions by Lotfi [19], and implementation of an educational real-time platform for relaying automation on smart grids by Celestia [20].

2. METHODOLOGY

2.1. Functional Design

Microprocessor-based relay measurement devices Vamp 40, integrated with sensors for measurement and protection use zero sequence currents from current transformers with star connections on the primary and secondary sides. Zero sequence voltage sensor of the voltage transformer with star relation on the primary side and delta connection on the secondary side [17]. The computerized measurement results will be displayed on a personal computer in the form of phasor diagrams. To verify the performance of this prototype will be tested with a variety of ground disturbances, namely; three-phase short circuit with ground, the two-phase short circuit with ground, one phase short circuit to ground, and one phase cut off. The test results will be compared with calculations using the symmetric component [9], [10].

Functional design feeder simulation design for a core-type transformer, a phase-to-ground fault can produce more fault current than a three-phase fault when the

fault is on the bus. Where the fault current for the line-to-ground fault is larger than that of the three-phase fault [20]. The core-type transformer with a zero-sequence impedance of 85 percent of the positive-sequence impedance, use for the fault current for a phase-to-ground fault at Test 1(T1) and compare the results with that of a three-phase fault. A core-type transformer has a lower exciting impedance, and the zero-sequence impedance can be 85 to 100 percent of the positive-sequence impedance. In this project a core-type transformer, so $ZT0 = 0.85 \cdot ZT1$. Overhead lines, zero-sequence impedance is considered to be equal to three times the positive sequence impedance [14]. Also, that $ZL1 = ZL2$ and $ZL0 = 3 \cdot ZL1$ [17].

2.2. Hardware Design and Implementation

In this study, the simulator consisted of (1) a Three-phase 380-volt power supply (2) a Secondary wye/wye secondary transformer mounted high resistance grounded (3) a Circuit breaker (4) a Voltage meter (5) a current transformer (6). Potential transformer wye/open delta (7) Relay protection IED Vamp 40 (8) MV Network impedance (9) Load and (10) Short circuit test.

Zero sequence voltage sensors used are 3 voltage transformers with a ratio of 220 V / (100/3), rating 1 ampere. Zero sequences current sensor uses 3 current transformers 30/5 each, 1 VA burden to get a measurement current above 10% loading for primary accuracy CT wrapped around 6 turns so that the ratio of winding decreases to 5/5. The Vamp 40 IED device is used as an overcurrent and overvoltage over-ground protection, this device is also connected to a PC to obtain measurement data in the phasor impact diagram. The above components are configured and assembled into hardware as shown in Figure 1 which shows the hardware simulator (a) the system block diagram (b) the construction of the simulator.

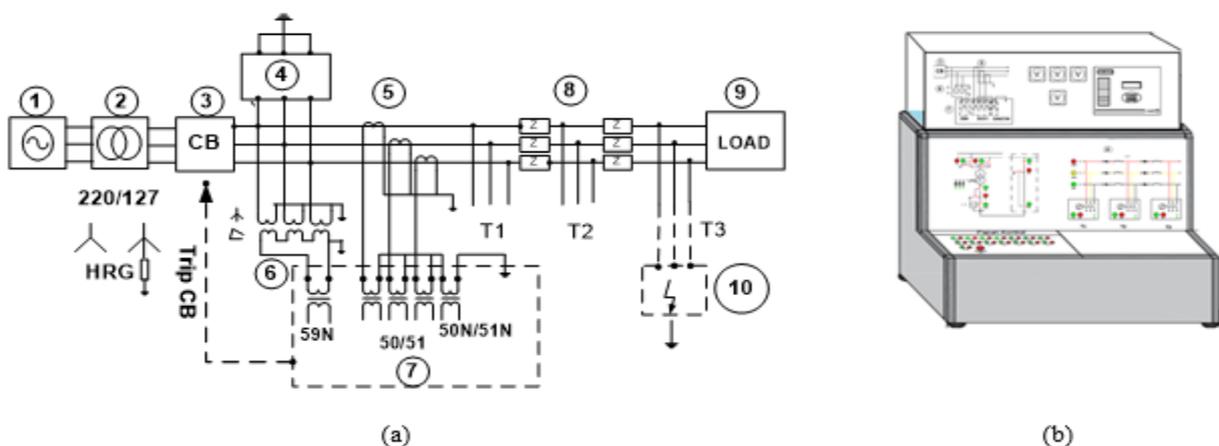


Figure 1 Hardware simulator (a) the system block diagram (b) construction

The design scheme is developed using a Vamp 40 smart device. The sensor for measurement and protection uses zero sequence currents from a current transformer with a star connection on the primary and secondary sides. Zero sequence voltage sensor of the voltage transformer with a star connection on the primary side and delta connection on the secondary side. The computerized measurement results will be displayed on a personal computer in the form of a circular phasor diagram. The phasor diagram display with computerized measurements and the compatibility of the two sensors for use are explained in the Vamp catalog.

The Microprocessor-based relay measurement devices integrated with sensors for measurement and protection use zero sequence currents from current transformers with star connections on the primary and secondary sides. The zero-sequence voltage sensor of the voltage transformer with star relation on the primary side and delta connection on the secondary side. The computerized measurement results will be displayed on a personal computer in the form of phasor diagrams. To verify the performance of this prototype will be tested with a variety of ground disturbances, namely; three-phase short circuit with ground, the two-phase short circuit with ground, one phase short circuit to ground, and one phase cut off. The test results will be compared with calculations using the symmetric component.

2.3. The maximum of the short circuit current design

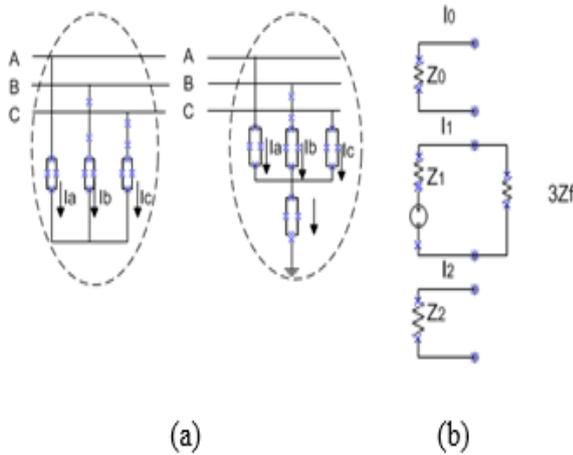


Figure 2 Three-phase fault (a) Phase connections (b) Sequence connections

The faults are classified into symmetrical and asymmetrical parts. The major feature of these faults is the large value of the negative component, such that there are the theoretical following cases. Fig.2 shows for three-phase fault and three-phase-ground fault. The maximum of the three-phase fault and three-phase - ground fault, there are no negative sequence or zero

sequence currents are present, and therefore, only the positive-sequence network is used.

$$I_0 = I_2 = 0; I_A = I_1 = V_f/Z_1 \tag{1}$$

The three-phase current consist of three components in sequence space which are related to each other according to equation (2) as follows::

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_1 \\ I_1 \\ 0 \end{bmatrix} \tag{2}$$

Figure 3 shown the single line to ground fault.

$$I_0 = I_1 + I_2 = I_2 = V_f/(Z_0 + Z_1 + Z_2 + 3Z_f) \tag{3}$$

Z_0 is the zero component impedance, Z_1 is the positive component impedance, Z_2 is the negative component impedance, and Z_f is the fault impedance between the line and ground. Three components in sequence space which are related to each other according to equation (4) as follows:

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_0 \\ 0 \\ 0 \end{bmatrix} \tag{4}$$

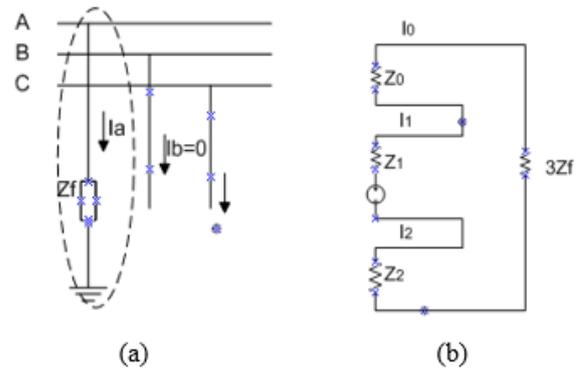


Figure 3 Single line to ground fault (a) Phase connections (b) Sequence connections

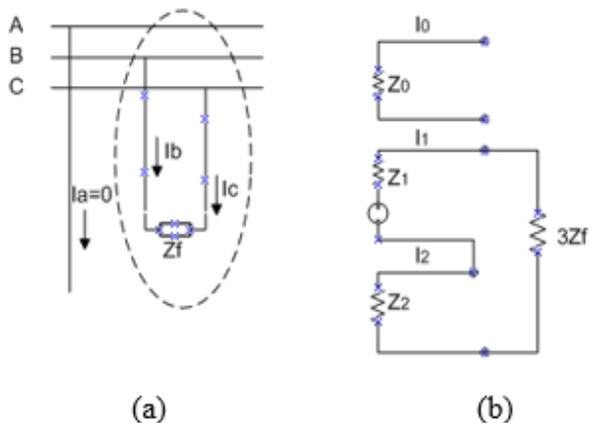


Figure 4 Line to line fault (a) Phase connections (b) Sequence connections

Figure 4 shows the line to line fault, zero sequence current is zero.

$$I_1 = -I_2 = V_f / (Z_1 + Z_2 + Z_f) \quad (5)$$

For the line to line fault three components in sequence space which are related to each other according to equation (6) as follows:

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} 0 \\ I_1 \\ -I_2 \end{bmatrix} \quad (6)$$

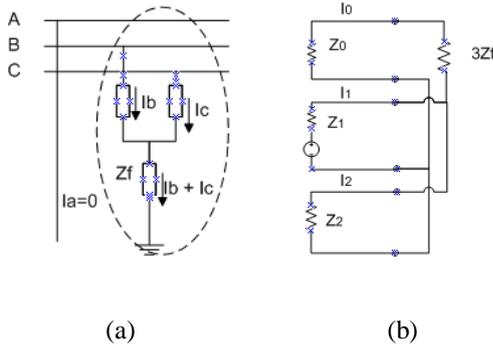


Figure 5 Double line to ground fault (a) Phase connections (b) Sequence connections

Fig. 5 shows the double line to ground fault.

$$I_1 = V_f / (Z_1 + Z_2 \cdot Z_0 / (Z_2 + Z_0)) \quad (7)$$

$$I_2 = V_2 / Z_2 = -I_1 (Z_0 / (Z_2 + Z_0)) \quad (8)$$

$$I_0 = V_0 / Z_0 = -I_1 (Z_2 / (Z_2 + Z_0)) \quad (9)$$

space which is related to each other according to equation (10) as follows:

$$\begin{bmatrix} I_a \\ I_b \\ I_c \end{bmatrix} = \begin{bmatrix} 1 & 1 & 1 \\ 1 & a^2 & a \\ 1 & a & a^2 \end{bmatrix} \begin{bmatrix} I_0 \\ I_1 \\ -I_2 \end{bmatrix} \quad (10)$$

2.4. The Protection Relay Threshold

An overcurrent relay has a minimum operating current, known as the current setting of the relay. This paper simulation that full load ampere is 1.0 ampere, and relay current setting is 1.5 ampere, and ground fault relay setting current is 0.75 ampere. Although by using a current set that is only just above the maximum load current in the circuit a certain degree of protection against overloads as well as faults may be provided, the main function of this overcurrent protection is to isolate primary system faults and not to provide overload protection. The relay settings are first determined to give the shortest operating times at maximum fault levels and then checked to see if the operation will also be satisfactory at the minimum fault current expected. A high-set instantaneous element can be used where the source impedance is small in comparison with the protected circuit

impedance. The rapid fault clearance time achieved helps to minimize damage at the fault location.

Calculation of phase fault overcurrent relay settings. The resultant settings are then traditionally plotted in a suitable log/log format to show pictorially that a suitable grading margin exists between the relays at adjacent substations. The calculation of the maximum of phase and earth fault currents for the three fault point zones, the 0% fault location point as a representation of the point of a disturbance at the substation, 50%, and the 100% farthest point location representation.

In testing used 1.5 times the network current. The TMS setting for the current threshold is used phase short circuit current, or two phases at the farthest point of disturbance (100%), taking into account the current delay setting time with 0.4 seconds.

Determine the threshold setting of the instantaneous (50). In this study, the cable uses 2.5 mm², the highest safety limit is 10 Ampere. Determining the minimum delay time threshold setting for Ioset > fault current ground (51N) is the value between 0.3 to 0.5 minimum trip in phase fault current. The mechanism of the protection system against one phase to ground short circuit, phase to phase, two-phase to ground, and three-phase short circuit.

3. RESULTS

3.1. The Result of The Experiment of Short Circuit Test

The calculation to proceed is the maximum of the short circuit current design Section 2.2. is tabulated to that shown in Table 1. The result of the calculation maximum fault current shows in Table 1, and the graph in Fig.6 shows the result of the test at point T1 the disturbance of phase to ground fault can produce more fault current than a three-phase fault. The impedance zero-sequence ZT0 is 85 percent form ZT1 refers to a core-type transformer that has a lower exciting impedance and the zero-sequence impedance can be 85 to 100 percent of the positive-sequence impedance. The magnitude of maximum fault current at T1 is 30.84 ampere, at T2 is 11.75 ampere, at T3 is 7.93 ampere. The Capability of equipment at the substation (Power Transformer is 50 ampere, and Circuit Breaker is 25 ampere), and the cable network is 10 ampere. The experiment for testing the maximum fault current in locations T1 and T2 cannot be done in this simulator, due to cable capability for loading at location T2, and Circuit Breaker at T1.

3.2. Setting The Protection Relay Threshold

The threshold setting of ground fault relay inverse time delay I0 >> is 0.75 ampere, instantaneous I0 >> is 5.5 ampere, phase fault relay inverse time delay I > is

1.5 ampere, and instantaneous $I_{>>}$ is 7.5 ampere. The full load ampere is 1 ampere. Figure 7 shows that the phase of over current fault will be operated in all symmetrical and asymmetrical fault except for open one phase fault disturbance.

Figure 11 shows that the ground of over current fault will be operated only in asymmetrical fault. For safety consideration, the instantaneous phase relay protection threshold setting is 5.5 ampere, and the instantaneous phase relay protection threshold setting is 7.5 ampere.

Table 1 The result calculation the maximum phase and earth fault currents

Fault type	Fault location in T1		Fault location in T2		Fault location in T3	
	Magnitude (Ampere)	Angle (degree)	Magnitude (Ampere)	Angle (degree)	Magnitude (Ampere)	Angle (degree)
Single phase to ground	30.84	-90	9.07	65.6	6.38	-54.58
Line-to-line	25.39	0	10.85	19.98	6.28	24.8
Line-to-line to ground	30.32	32.68	11.7	179.96	7.87	182.91
Three-phase	29.32	150	11.75	182.73	7.93	186.66
Three-phase to ground	29.32	150	11.75	182.73	7.93	186.66

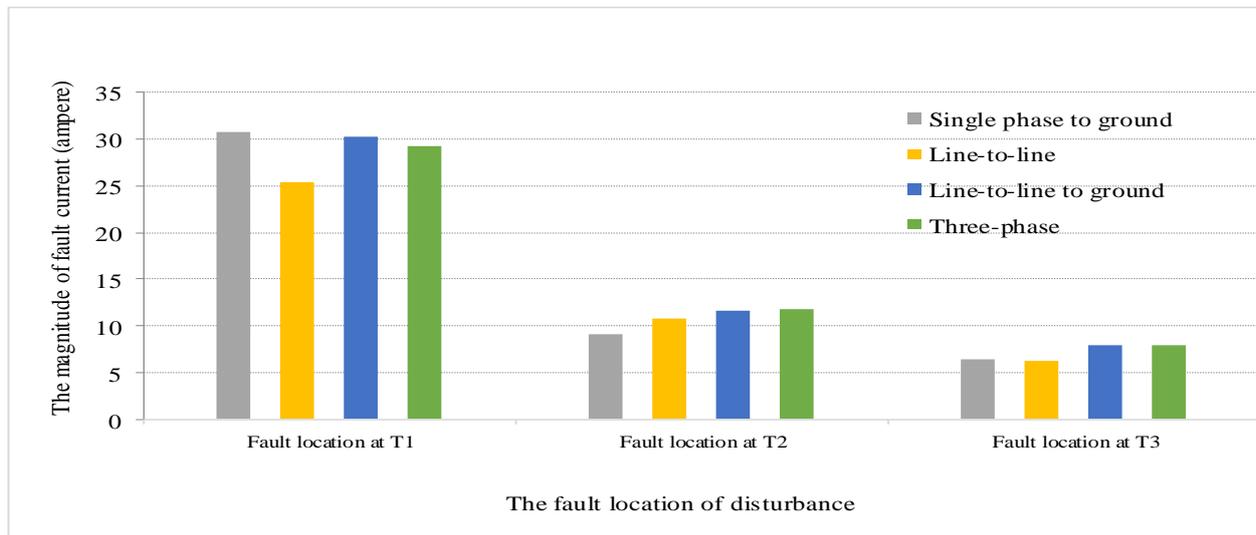


Figure 6 The graph of maximum fault current

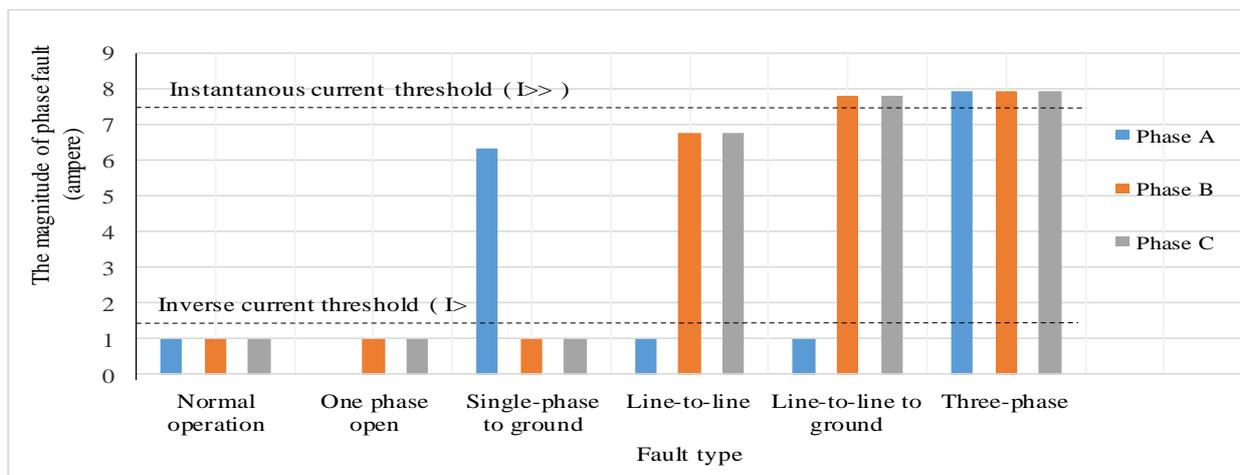


Figure 7 The threshold of the phase relay protection

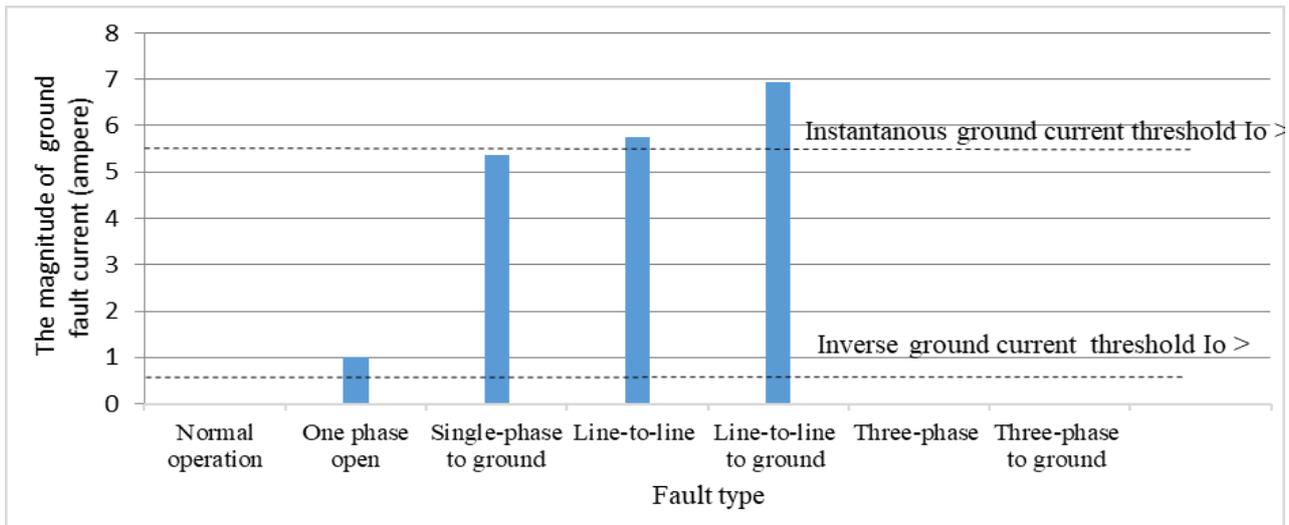


Figure 8 The threshold of the ground relay protection

4. CONCLUSION

The result of the test at point T1 the disturbance of phase to ground fault can produce more fault current than a three-phase fault. The simulator can be used for short circuit testing at point T3. Testing can be done on T1, T2, and T3 safely if the protection relay follows the threshold setting limits. The phase of over current fault will be operated in all symmetrical and asymmetrical faults except for open one phase fault disturbance. The ground of over current fault will be operated only in asymmetrical fault. For safety consideration, the instantaneous phase relay protection threshold setting is 5.5 ampere, and the instantaneous phase relay protection threshold setting is 7.5 ampere.

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