

Testing of Circuit Breaker and over Current Relay Implementation by Using MATLAB / SIMULINK

Dinesh Kumar Singh

dsdineshsingh012@gmail.com

Abstract

Circuit breaker and relays are being utilized for secure, reliable and convenient operation of power system. The over current protection relay is widely used in the power system for protection of short circuit or wrong setting of system to the pre-specified value. Erroneous setting of over current relay in the power system it is difficult to send the trip signal. So it is connected carefully in the power system. Therefore it is important to accredit the setting of power protection equipment. The paper represents the modeling of over current relay in MATLAB/SIMULINK. The over current relay has the types of instantaneous, definite time, inverse time and inverse definite minimum time (IDMT) according to the time characteristics. This paper most important feature is the comparison of times between ideal & calculated results of over current relay. To make the protection system of transmission line by the circuit breaker and over current relay in MATLAB/SIMULINK. To proper transmit the electric power from sending end to receiving end without suffering from any difficulty and dangerous condition. Implementation of over current relay and testing of circuit breaker & over current relay are using in MATLAB software. And show the result of operating & fault current and also trip signal time of the over current relay.

Keywords

Current transformer, potential transformer, circuit breaker, over current relay.

Introduction

With the growing demand of electric power, the distribution is increasing year by year and therefore maintenance of power system / power system equipment is very important for decreasing of cost and maintenance of power distribution for most reliable of the power system or power system equipment. Protection of power system is very important for different fault of over current, over voltage, and over load. We are used protection scheme for the protection of the short circuit and failure of equipment. It may be very dangerous condition for the operation of any power system equipment, electronic devices or circuits, generation, distribution and power transmission. So we are used the two main component or devices in power system protection, i.e. Circuit breaker and relays. These devices give safe operation or handling of any mechanical equipment like generator, motor, and

transformer etc. for the short circuits. When the short circuit event occurs in a distribution feeder then the light loads such as computers and electronic equipment will be affected in few seconds. So power system protection of fault is very important [1-3].

All electrical machines, operation and other forms of electrical equipments must satisfy two main requirements i.e. they must be able to operate continuously under normal condition and must be able to resist short- time over currents and over voltages. For operation of electrical machines and other apparatus with full reliability in normal operating condition, the two requirements should be fulfilled and they are [4]-

- (1). Rated current \geq Actual load current
- (2). Rated voltage \geq operating voltage of the equipment.

Circuit breaker is a mechanical device which consists of two functions according to the normal and abnormal condition they are open contacts for the faulty or abnormal condition and closed contacts for the normal or healthy condition. Circuit breaker is automatically operating device by the relays, when the relay coil will energized then a trip signal send to the circuit breaker. And circuit breaker contacts are open and safe the operating equipments such as motor, generator and transformer and also light loads electronics equipment or devices.

Circuit breaker carries the full load current continuously without overheating or damage, it opens and closes the circuit on no load, it makes and breaks the normal operating current and circuit breaker makes and breaks the short circuit currents of magnitude to the specified value [5].

Relay is a sensing device which sense of short circuit and faulty condition. When fault occurs in system then the high current flowing in the circuit and relay coil get energized and one trip signal is send to the circuit breaker which opens the circuit breaker contacts and protect the circuit by isolating the faulty section. Relay input current and voltage takes to the current transformer (CTs) and potential transformer (PTs) respectively. The amplitude and phase relation depends on the conditions of the system for a predefined value gives by the manufacturer or designer [6].

In this paper, testing of circuit breaker is done by using unit step input control signals of circuit breaker with the parallel RL load, supply voltage is 100V 50Hz And current through the resistance is 5M Ω in the MATLAB. And also modeling of over current relay implementation with inverse characteristics is standard inverse, very inverse, extremely inverse and long inverse by using instantaneous over current relay, definite time over current relay and inverse definite minimum time (IDMT) over current relay and also testing of over current relay with π -Transmission line.

Testing of circuit breaker and parameter in the MATLAB

A circuit breaker is a switching and current interrupting device. It is used in electrical power systems to protect an electrical circuit from damage caused by over current, over voltage and over load or short circuit events. And also circuit breaker detects the fault conditions [4]. When the circuit breaker detect the high voltage and current in the circuit then the circuit breaker contacts will open otherwise at the normal operating condition circuit breaker will closed and system is operate normally.

In the MATLAB power system block set in simpowersystem circuit breaker is R and L series circuit and two contacts. They are one is open and other is closed contact, when circuit breaker is open it consist in the MATLAB is '0' otherwise circuit breaker is closed it consist in the MATLAB is '1' (Initial state '0' for 'open' and '1' for closed). Circuit breakers

resistance and inductance are $10\text{m}\Omega$ and $10\mu\text{H}$ respectively and snubber resistance is $1\text{M}\Omega$.

Testing of circuit breaker in 22KV distribution feeder by using control signal of unit step input with the parallel RL load and 100V, 50Hz source voltage is done using control signal of unit step input figure.1 shows the model of testing of circuit breaker in 22KV distribution feeder with parallel RL load. Figure.2 represents the control signal applied to the circuit breaker, while figure.3 shows the operating current flowing through the feeder and CB when fault occurs.

Circuit breaker consist the two metal contacts, one is fixed and another is moving. These are touching to each other and carry the current under the faulty condition. Circuit breaker is operate by the relay, when the relay provide the signal to circuit breaker will trip when fault occur in the power system.

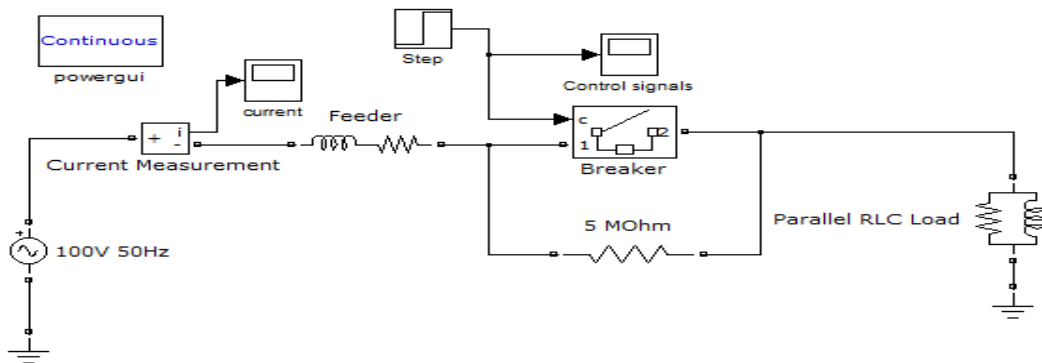


Figure.1 Testing of circuit breaker in MATLAB/SIMULINK.

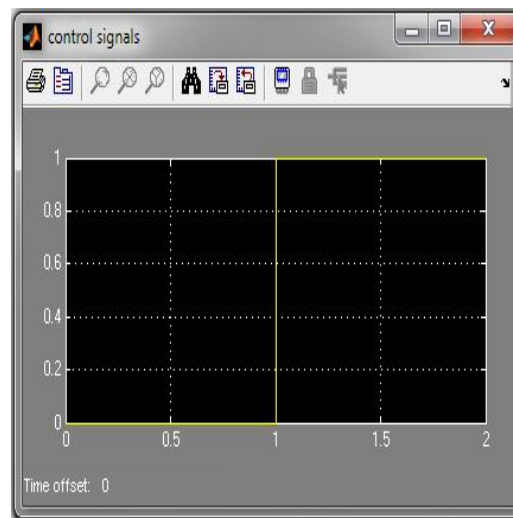


Figure.2 Control signal.

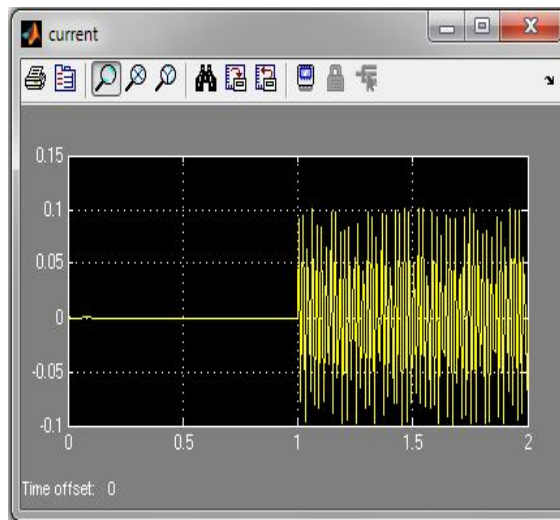


Figure.3 Operating current flowing through the circuit breaker and feeder when fault occur.

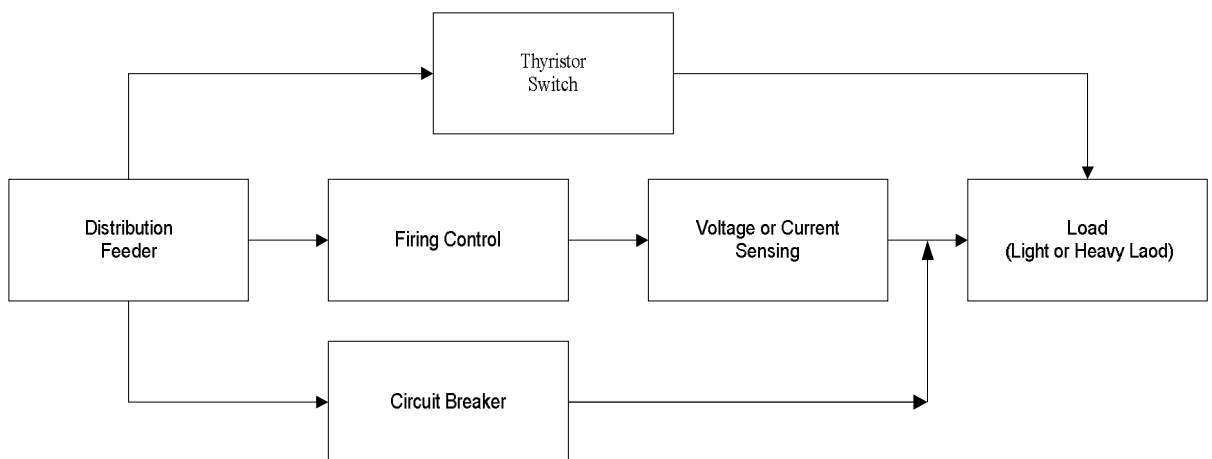


Figure 4: Block diagram of power system to the distribution test feeder.

The test distribution feeder block diagram of power system is shown in figure.4. In this test feeder distribution feeder is connected to SCR (thyristor) switch, firing control and circuit breaker. These three units are operating as a switch in the test feeder and depend on each other. The voltage or current sensing unit is connected to the firing control and finally connected to the load in the power system.

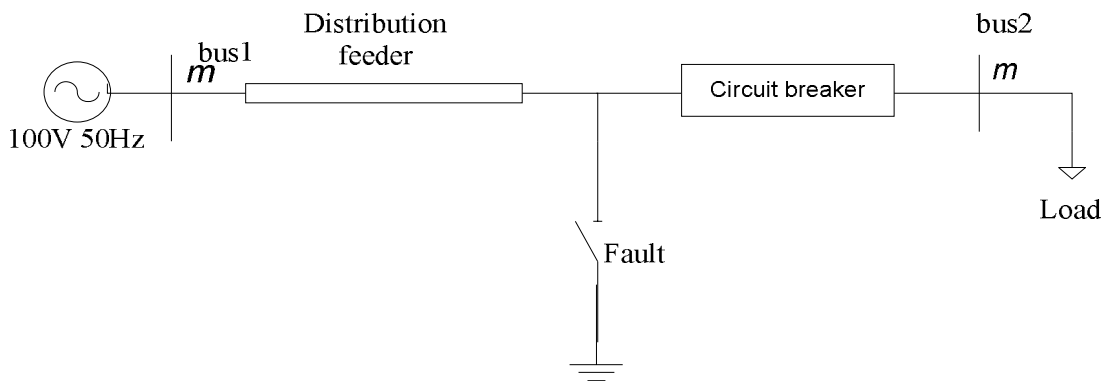


Figure 5: Test feeder system

As high current flows due to short circuit, so it is connected to the ground and safely operated when the fault occurs in the power system. The power system block set model of distribution test feeder or testing of circuit breaker in the distribution feeder is shown in figure.5.

Over Current Relay

The protective relay is an electrical device, it is mediator between the main circuit and the circuit breaker in such a manner that for any abnormality in the circuit relay will operate. Relay input take from the CT's and PT's connected in the circuit and relay takes the CT secondary current and sense the fault and short circuit in the power system. And one trip signal sends to the circuit breaker, than circuit breaker opens protect the power system from damage. Relay operates when the fault occur in the power system, the relay coil will energized [6]. Relay consist of two contacts one is fixed contact and another is moving contact, when the relay coil will energized then the moving contact attract to fixed contact then the circuit will complete of the relay and relay will operate and safe the circuit or power system.

All the relays are consisted of most important three fundamental units as shown in block diagram given below.

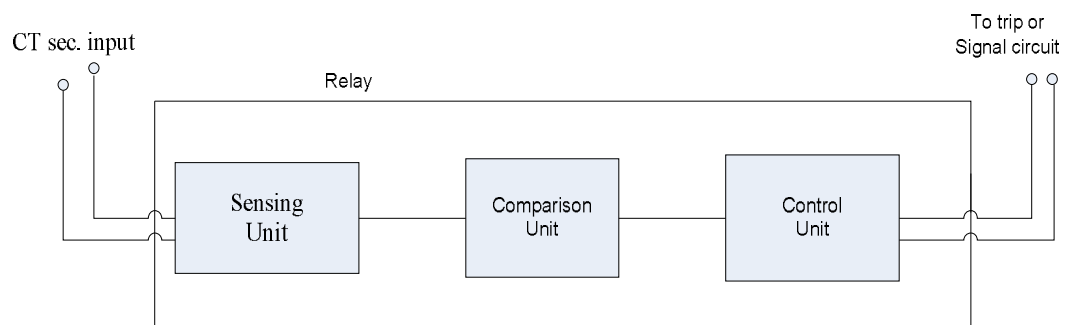


Figure 6: Basic units for operation of relay.

- 1.Sensing unit: When any abnormality in the system or up and down the value of operating quantity to the pre-specified values [7]. Then the relay sense the abnormality and some time also called the measuring unit.
- 2.Comparing unit: Operate to compare the working of the actuating quantity on the relay with the predetermined setting of relay given to the manufacturer.

3. Control unit: Control element on a pickup of the relay, accomplishes a sudden change in the control quantity such a closing of the operative current circuit.

According to timing characteristics relay can be classified to given below.

- I. Instantaneous over current relay: This type of over current relay complete operation takes place after very short time duration from the event of the current resulting in operation. This type of relay operation time is lesser than 0.2 second [8].
- II. Definite time over current relay: This type of relay, operation time is independent of the magnitude of the current or other quantity causing operation.
- III. Inverse time over current relay: This type of relay operation time is approximately inversely proportional to the magnitude of the current or other quantity causing operation.
- IV. Inverse-Definite minimum time (IDMT) over current relay: This type of relay time of operation is nearly inversely proportional to the lesser value of current or other quantity causing operation and tends to be a definite minimum time as the value increases without limit [9].

According to the time characteristics of over current relay they are represented with the following equations as given below.

Relay current (I_r):

$$I_r = \frac{I_f}{CT.ratio} \quad (1)$$

I_f = Fault current

Pick up value of relay = Current setting \times Rated secondary current of CT

Plug setting of multiplier (PSM):

$$PSM = \frac{I_r}{\text{Pickofvalueofrelay}}$$

Time setting multiplier (TMS):

$$TMS = \frac{T}{\text{TimeofoperationcorrespondingtoPSM}}$$

Actual relay operating time (T):

$$T = \frac{K}{\left(\frac{I}{I_{sp}}\right)^\alpha} \times TMS \quad (2)$$

K: Constant for relay characteristic.

α : Constant representing inverse time type, [$\alpha > 0$]

I: Relay input current.

I_{sp} : Current set point.

Above equations use the calculation of operating time, time setting multiplier, relay current, pick up value of relay and plug setting multiplier. Table I given below show the value 'K' and 'α' corresponding to each curve [6].

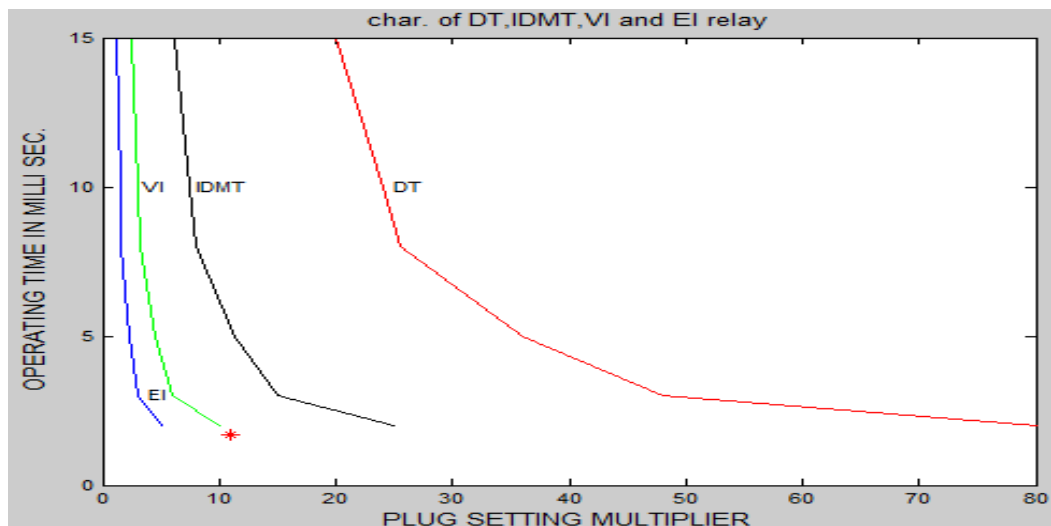


Figure 7: Characteristics of Various over current relays

TABLE I
VALUE OF 'K' AND 'α' FOR DIFFERENT TYPE OF INVERSE CHARACTERISTICS CURVE

Relay Characteristic Type	α	K
Standard Inverse	0.02	0.14
Very Inverse	1	13.5
Extremely Inverse	2	80
Long Inverse	1	120

Over current relay in MATLAB/Simulink

The implementation of over current relay in the MATLAB/SIMULINK is the maximum fault current is 5500A (single phase to ground) and minimum fault current (single phase to ground) is 1698A. A low pass filter is connected in the model to reduce the harmonics of current. This value of current is converted to the root mean square (RMS) value and compared with the given constant value, pick up value of current is increased to the pre-specified value and relay coil is energized & one signal is send to the circuit breaker to protect the circuit. The operating time and trip signal time of the relay is calculated and also relay current with the fault current is calculated. Over current relay Implementation is shown in figure.8 and parameters in table II. That is given below.

TABLE II
RELAY SETTING PARAMETERS AND TESTING ANALYSIS

Measurements	Full load current	330 A
	Minimum fault current (Single phase to ground)	1698 A
	Maximum fault current (three phase to ground)	5500 A
Relay Settings	Current transformer ratio	500:1
	Pickup value	1 A
	Time multiplier setting	0.5

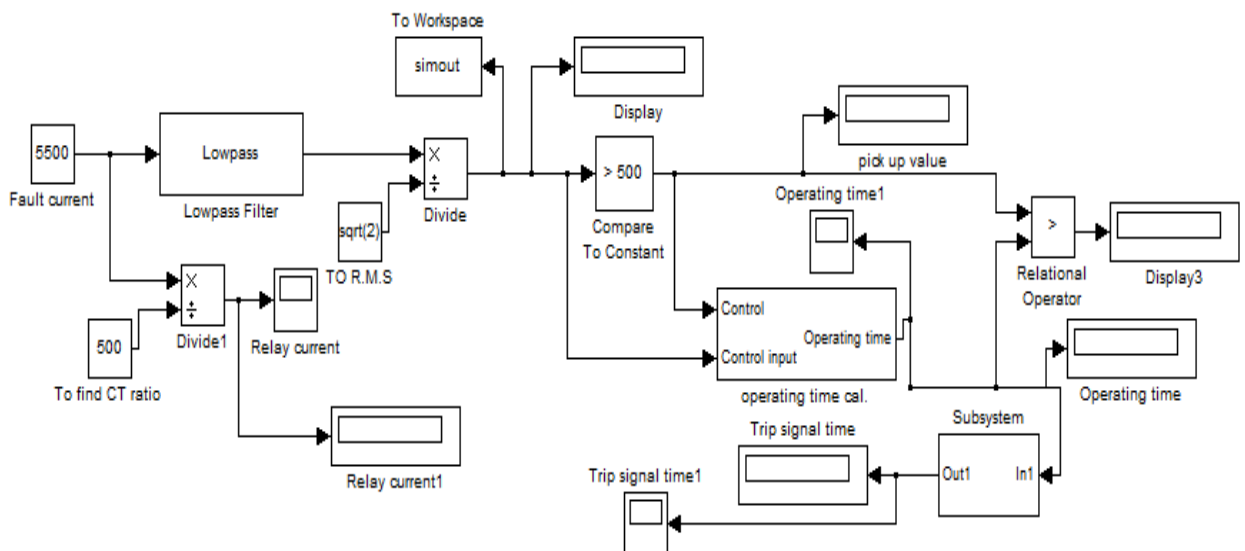


Figure 8: Implementation of over current relay in MATLAB

TABLE III
COMPERISION OF THE RESULTS OVER CURRENT RELAY AND IDEAL
CALCULATION

Summary of result from proposed relay model (Fault applied at t=2sec)				
Curve	Standard Inverse	Very Inverse	Extremely Inverse	Long inverse
Time (sec.)				
Operating Time	1.686	1.015	0.6957	9.025
Ideal Operating Time	1.6777	1.0040	0.6826	8.525
Trip Signal Time				
Trip Signal Time	3.686	3.017	2.6910	11.030
Ideal Trip Signal Time	3.6780	3.0040	2.6826	10.520

Table III shows the comparison of the results of over current relay and ideal calculation of the relay. All the four time characteristics over current relay are operating and trip signal time of relay shown in table III. Standard inverse operating time and trip signal time shown in figure.9 and figure.10 respectively.

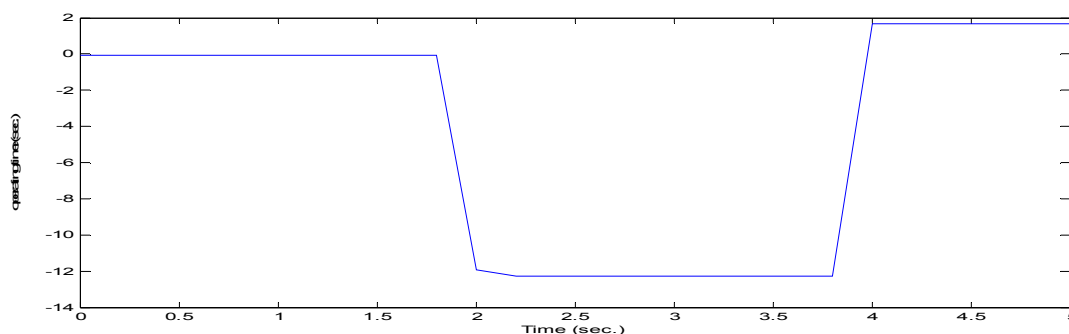


Figure.9 Wave form of operating time (sec.)

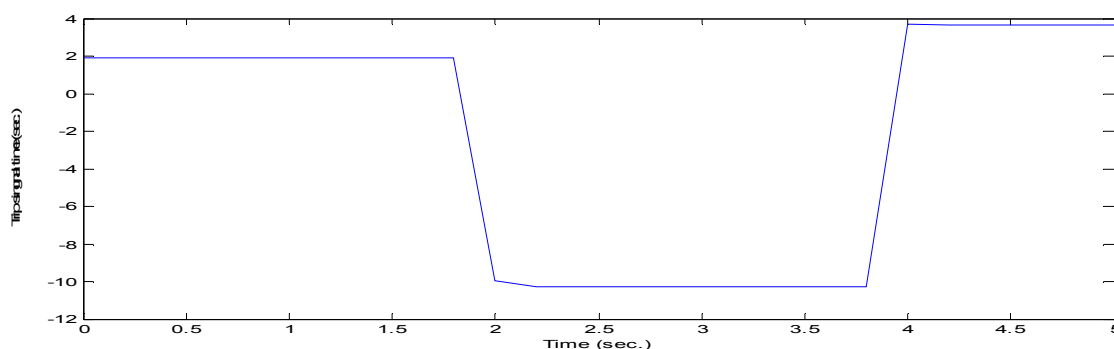


Figure.10 Wave form of trip signal time (sec.)

Testing model of over current relay in simpowersystem

Figure.11 show the testing model of over current relay developed in MATLAB simpowersystem. And the power system fault occurs or not. The important parameters of the test case are:

- Single phase AC voltage source, 50Hz, 440V phase voltage.
- Π -section transmission line, 120Km.
- Three phase block to introduce single phase to ground fault.
- Circuit breaker to connected to load with the trip signal from the over current relay.
- Series RLC load of 5MW.

It proved that (at T=2sec.) the power system is protected by the circuit breaker and over current relay to the over current or short circuit. Relay sense the over current or short circuit and trip signal send (signal '0' for normal and '1' for trip) to the circuit breaker. Circuit breaker open or closed by the trip signal and safe power system operation is done and also reliability is improved of power system.

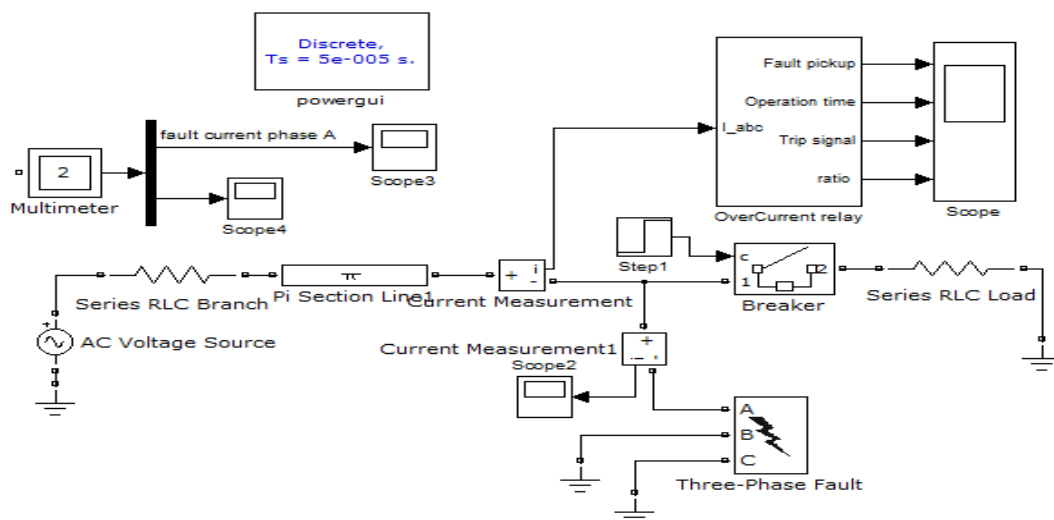


Figure.11 Testing model of both circuit breaker and over current relay in MATLAB.

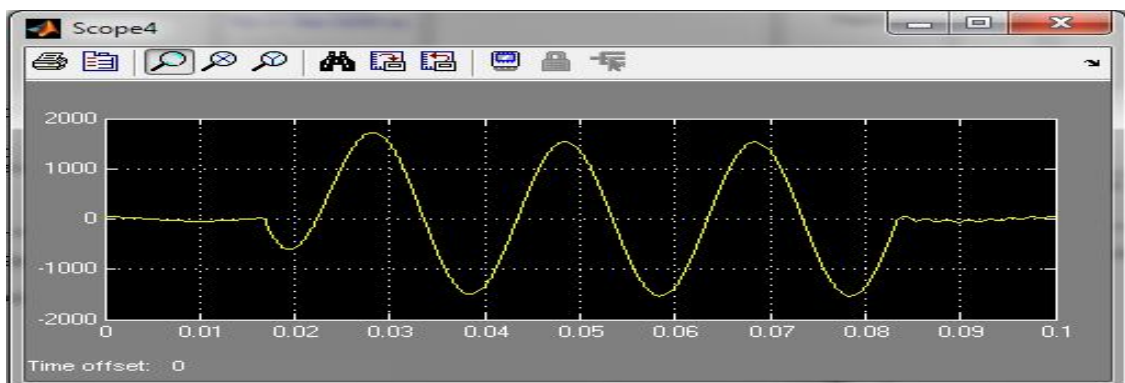


Figure.12 Operating current (A) when fault occur

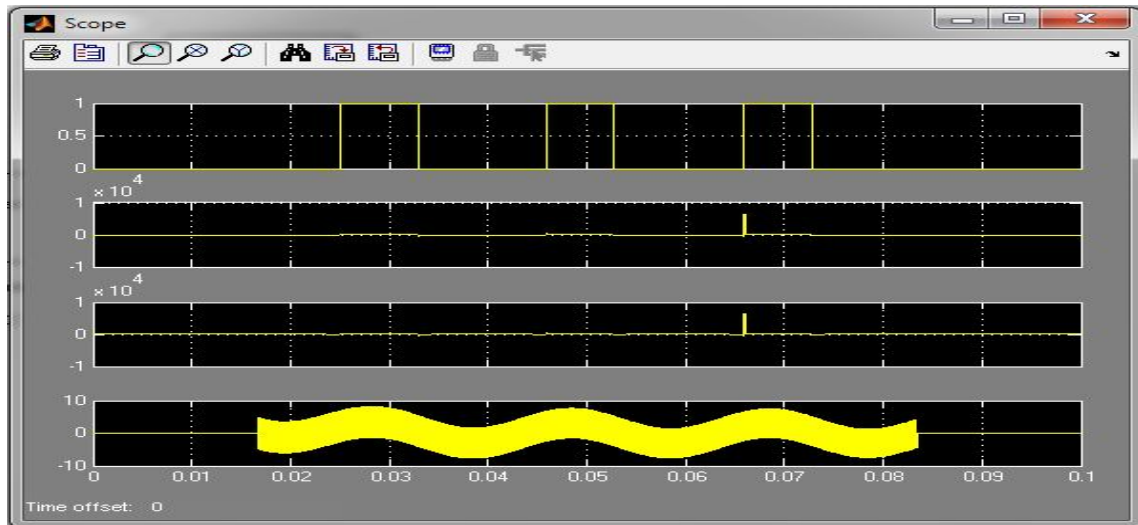


Figure.13 Relay pickup, operating time, trip signal and CT ratio

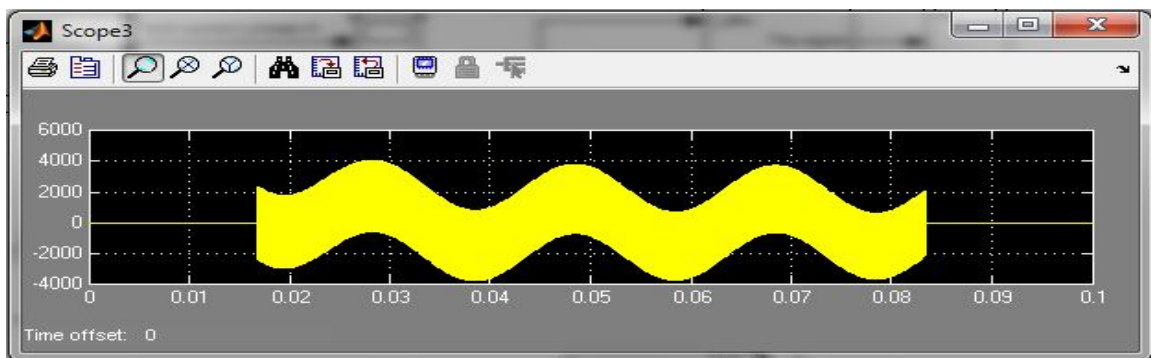


Figure.14 Single phase fault current (A)

Conclusion

This paper presents the study of circuit breaker and over current relay and how to protect the power system. Circuit breaker and over current relay is interconnection relation between the power system. Testing of circuit breaker and over current relay in the 120km π -section transmission line is done by using MATLAB/SIMULINK and comparison between calculated operating & trip signal time and ideal operating & trip signal time of standard inverse, very inverse, extremely inverse and long inverse. And also shows the fault current and relay signals when the fault occurs to give the protection [11]. So complete the testing of circuit breaker and over current relay implementation by using MATLAB/SIMULINK for the protection of power system.

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Author



Dinesh Kumar Singh was born in Mathura, U.P, on March 10, 1990. He received his B. Tech. [Electrical and Electronics Engg.] from GLA institute of technology & management Mathura U.P, India in 2012 and his M. Tech [Power System] pursuing from GBU Greater Noida U.P, India in [2013-2015].

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