

Analysis of Overcurrent Relay for Transmission Line Protection

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Abstract—Overcurrent relays are used for protection of lines, transformer, generators, and motors. Generators and load are connected together through transmission lines, which transport electric power from the place where it is generated to the place where it is used. By doing the analysis and testing, overcurrent relay may protect the power system and deal with any abnormality of a system which involves the electrical failure of the equipment. The role of protective relays in a power system is to detect systems abnormalities and to execute appropriate commands to isolate swiftly at the faulty component from healthy system. The analyze overcurrent relay protection was carried out at PencawangMasukUtama (PMU) SEGARI (SGRI) and SUNGAI SIPUT (SSPT).

Keywords— Electrical Protective Relay, Overcurrent Relay Protection, Sverker 608E, Omicron CMC 256, SPAJ 140C, GEC MEASUREMENT

I. INTRODUCTION

The earliest protective schemes evolved around the excessive current resulting from a fault, which is the basis of overcurrent protection schemes. For transmission line protection in interconnected systems, it is necessary to provide the desired selectivity such that relay operation results in the least service interruption while isolating the fault [1].

These relays operate based on the measure expected current from the monitored Time Multiplier Setting (TMS) and current setting. The setting of overcurrent relays operating is based on the current flow through the system. Basically, during the fault, the current flow more than the current setting and at certain time, the trip alarm will be activated by the relay. The overcurrent relay is necessary when power system fault not cleared by main protection means that failure of main protection fault clearing system. Overcurrent protection was applied in two parts. The first one is non-directional and the second one is directional. Overcurrent protection, on the other hand,

is directed entirely to the clearance of faults, although with the settings usually adopted some measure of overload protection may be obtained [2].

This project is to make sure the electrical protective devices is healthy and good condition. The purpose of testing this electrical protective device is to protect the transmission line from faults. So from the testing relay, the results will show whether the protective devices is passed or failed to protect the system. Each result must be record and keep as a result must be recorded and kept as a reference for future use. It also can be as evidence when the system has been trip. The testing protective devices were using secondary test equipment known as Omicron CMC256 and another test set is Sverker 608E. Testing relay has been done at PMU SGRI and PMU SSPT.

There are 2 types of relay such as SPAJ 140C and GEC MEASUREMENT have been tested and recorded. The main advantage of using overcurrent relay is that each relay can, by an appropriate choice of setting, acts as the backup relay to a relay nearer the fault position and operate after a suitable time delay to clear the fault in the event of protection or circuit breaker elsewhere in the system

II. OVERCURRENT RELAY PROTECTION

Protective relays generally operate in response to one or more electrical quantities to open or close contacts. The earliest forms of relays were electromechanical devices, a type that gained general acceptance because of its simplicity [3]. Relays are constructed using either electromechanical or static. For electromechanical, these relays were the earliest forms of relay used for the protection of power systems. The mechanical force is generated through current flow in one or more windings on a magnetic core, hence the term electromechanical relay. For static relay, the term 'static' refers to the absence of moving parts to create the relay characteristic [3]. It is designed based on the use of analogue electronic

devices instead of coils and magnets to create the relay characteristic.

A relay is an electrically operated switch. Relays with calibrated operating characteristics and sometimes multiple operating coils are used to protect electrical circuits from overload or faults. In a typical application the overcurrent relay is connected to a current transformer and calibrated to operate at or above a specific current level. Overcurrent relay is very important because overcurrent relay is dependable protection based on simple independent current measurements.

A. Relay Characteristics

Relay characteristic have two types which is independent or definite time and dependent time or Inverse Definite Minimum Time (IDMT). It is important that in any case of the system abnormalities or faults, the IDMT overcurrent must be capable to isolate only the faulty component from the healthy system [4]. Independent time means that overcurrent relays are normally also provided with elements having independent or definite time characteristics [2].

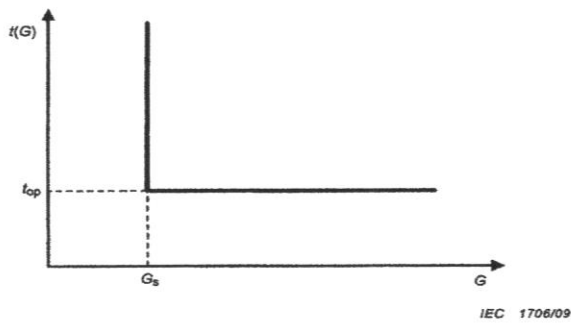


Figure 1: Independent Time Characteristics

Figure 1 shows that independent time characteristics means of coordinating several relays in series in situations in which the system fault current varies very widely due to changes in source impedance, as there is no change in time with the variation of fault current.

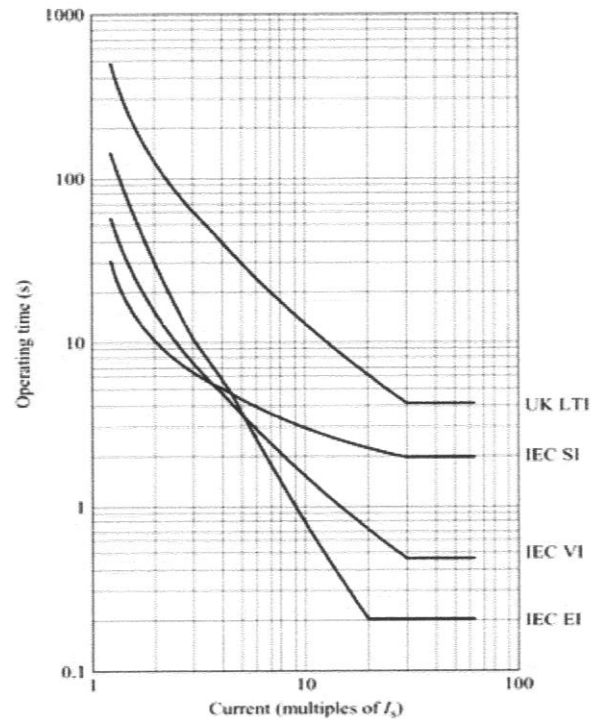


Figure 2: Dependent Time Characteristics or IDMT

The Figure 2 shows relay characteristics is dependent time or IDMT means that the current/time tripping characteristics of IDMT relays may need to be varied according to the tripping time required and the characteristics of other protection devices used in the network [2]. The inverse-time characteristics of overcurrent relays are defined in this standard. The purpose of this standard is to provide an analytic (formula) representation of typical relay operating characteristic curve shapes of various inverse-times relays [5].

Table 1: Relay Characteristics for I.D.M.T

TYPE OF CHARACTERISTICS	FORMULAE
Standard Inverse SI	$t = \frac{0.14}{I^2 - 1}$
Very Inverse VI	$t = \frac{13.5}{I^2 - 1}$
Extra Inverse EI	$t = \frac{80}{I^2 - 1}$
Long Time Inverse LTI	$t = \frac{120}{I - 1}$

Table 1 shows the type of relay characteristic and formulae. For these purposes, IEC 60255 define a number of standard characteristics as follows as Standard Inverse (SI), Very Inverse (VI), Extremely Inverse (EI) and Definite Time (DT).

B. Overcurrent Protection Setting

The time of operation of overcurrent relays (OCR) can be reduced, and at the same time, coordination can be maintained, by selecting the optimum values of time multiplier setting (TMS) and plug setting (PS) of OCR [6]. The TM (time multiplier) setting of the relay adjusts the “backstop” of the rotating disc. The time operation is proportional to the distance through which the disc must rotate in order to operate the contacts. With the multiplier set to one, the backstop is as far back as it can go (180 degree), and the disc has to move through its maximum travel in order to operate the contacts. If the time multiplier is set to zero then the backstop is positioned so that the contacts are permanently closed.

The standard characteristic is graph of time versus the plug multiplier setting (PSM); this avoids one graph with many curves and can be used to calculate the actual time of operation for the relay. PSM can be calculated where:

$$P.S.M = \frac{I_s}{p.s \times I_r}$$

Where:

I_s = secondary current in amps

p.s = plug setting

I_r = rated current (either 1A or 5A)

As the standard curve is for TM=1, then the actual time of operation (T_a) is given by:

$$\text{Time of operation, } T_a = T.M \times T_1$$

Where:

T_1 = time obtained from standard characteristic graph for given fault condition.

Then the overcurrent protection setting also discuss about how to get the value current pickup setting for overcurrent and earth fault.

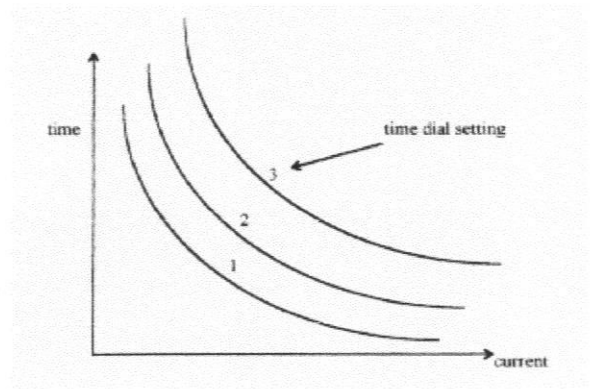


Figure 3: Time Delay Characteristic

Figure 3 shows about time delay characteristics in overcurrent relay protection and it operate with a time delay. The time delay is adjustable. For a given setting, the actual time delay depends on the current through the relay coil. In general, higher current will cause a faster operation of the relay. The minimum current at which the relay operates (pick-up current) is also adjustable. It will be used in definite time overcurrent.

$$\text{Pickup current} = \text{Rated Secondary Current of CT} \times \text{Current Setting}$$

III. METHODOLOGY

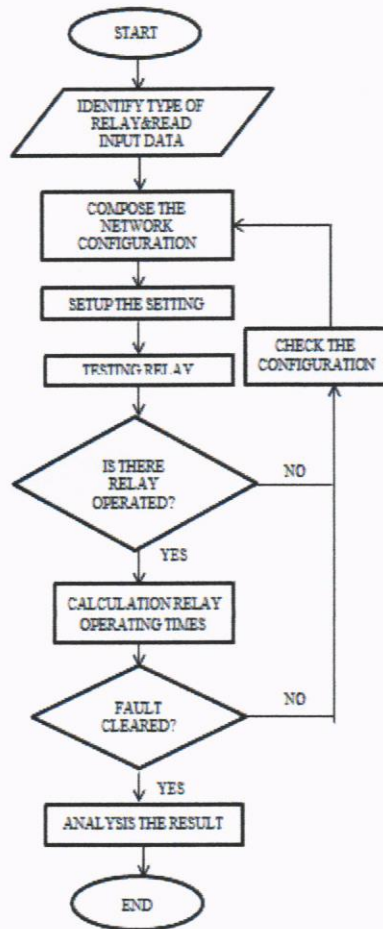


Figure 4: Flow Chart of Methodology

Figure 4 shows that the method how the testing begin and end with the result. Testing relay must follow the procedure to avoid faults to the system.

A. TYPE OF RELAY AND READ INPUT DATA

1) PMU SGRI

Firstly the type of relay is identified. There are types of overcurrent relay and must know how to read the data from the relay. After know the type of overcurrent relay, the input data from the relay must be read.



Figure 5: Overcurrent Relay Type SPAJ 140C

The type of SPAJ 140C used as overcurrent relay protection at PMU SGRI to protect the system as shown in Figure 5.

2) PMU SSPT

Based on relay type GEC MEASUREMENT, the relay show that the results using test set SVERKER 608 E, TM200 and Multimeter to test the relay whether the relay is good condition or not. The testing will be at PMU SSPT



Figure 6: Overcurrent Relay Protection for Non-Directional

This relay is known as non-directional type GEC Measurement as shown in Figure 6. When the relay operates; one or more contacts will operate and energize to trip (open) a circuit breaker. The magnetic system in induction disc overcurrent relays is designed to detect overcurrent in a power system and operate with a pre-determined time delay when certain overcurrent limits have been reached.

A. COMPOSE NETWORK CONFIGURATION

The input data in the relay must be checked and compared with configuration Engineering. The data must be same with the input relay so that the relays operate follow what the company want.

B. SETUP THE SETTING

The device setting relay must be setup in table to be more detail and get the specific result when testing were done.

Figure 7: Device Setting Relay

Figure 7 shows that the setting data about relay, nominal value for voltage and current and others. This setting so important to key in so that the finally report after test more detail and it also be a guide for reference. The setting relay only is set by using test set Omicron CMC256. At PMU SSPT, the setting device cannot be set because using test set Sverker 608E.

C. OPERATING TIME CALCULATION

Operating Time, $t_{\text{operating}} = t_{\text{curve}} \times \text{TMS}$

$$t_{\text{curve}} = \frac{0.14}{t^2 - 1}$$

Usually most of cases use of the standard inverse, SI curve proves satisfactory.

Time Multiplier Setting (TMS) were be setup in the relay depend on the configuration

Engineering. So the TMS were being a guide to calculate the operating time.

1. PMU SEGARI

At PMU SGRI, current setting is 1.5A and TMS is 0.25. Current Transformer (CT) ratio is 600/1.

Operating Time, $\text{top} = t_{\text{curve}} \times \text{TMS}$

For 2 times current setting, t_{nominal} will be:

$$T_{\text{nominal}} = \frac{0.14}{2^{0.02} - 1} \times 0.25 = 2.51$$

For 3 times current setting, t_{nominal} will be:

$$T_{\text{nominal}} = \frac{0.14}{3^{0.02} - 1} \times 0.25 = 1.58$$

2. PMU SUNGAI SIPUT

At PMU SSPT, current setting is 1.0A and TMS is 0.35. Current Transformer (CT) ratio is 200/1.

For 2 times current setting, t_{nominal} will be:

$$T_{\text{nominal}} = \frac{0.14}{2^{0.02} - 1} \times 0.35 = 3.51$$

For 3 times current setting, t_{nominal} will be:

$$T_{\text{nominal}} = \frac{0.14}{3^{0.02} - 1} \times 0.35 = 2.206$$

IV. RESULTS AND DISCUSSION

A. TESTING at PMU SEGARI

Table 2: The Timing Test for Red, Yellow, Blue Phase

Type	Relative To	Factor	Magnitude	Angle	Tnom	tmin	tmax
L1	(---)	n/a	3.00 A	n/a	2.51 s	2.22 s	2.84 s
L1	(---)	n/a	4.50 A	n/a	1.58 s	1.43 s	1.74 s
L2	(---)	n/a	3.00 A	n/a	2.51 s	2.22 s	2.84 s
L2	(---)	n/a	4.50 A	n/a	1.58 s	1.43 s	1.74 s
L3	(---)	n/a	3.00 A	n/a	2.51 s	2.22 s	2.84 s
L3	(---)	n/a	4.50 A	n/a	1.58 s	1.43 s	1.74 s

Table 2 shows the result for timing test in red, yellow and blue phase at PMU SGRI. The magnitude current will be doubled and tripled to show the different timing test. Current setting is 1.5A. When testing start, the result will show that timing for minimum time and maximum time. At minimum time it will be

display 1 and show the LED and at maximum time it will display 2 at LED trip will be turn on and relay will trip.

Table 3: The Pickup Timing for Red, Yellow, Blue Phase

Type	Relative To	Factor	Magnitude	Angle	t _{nom}	t _{act}	Overload	Result
L1	(---	n/a	3.00 A	n/a	2.51 s	2.59 s	No	Passed
L1	(---	n/a	4.50 A	n/a	1.58 s	1.63 s	No	Passed
L2	(---	n/a	3.00 A	n/a	2.51 s	2.57 s	No	Passed
L2	(---	n/a	4.50 A	n/a	1.58 s	1.63 s	No	Passed
L3	(---	n/a	3.00 A	n/a	2.51 s	2.61 s	No	Passed
L3	(---	n/a	4.50 A	n/a	1.58 s	1.64 s	No	Passed

Table 3 shows that the pickup timing will be tested using secondary test set Omicron CMC256. The magnitudes current were being double and triple for red, yellow and blue. This testing shows that the pickup timing for pickup current. Then the pickup timing will be come out to show that timing for drop off current. For the example, the pickup current to be trip the alarm is 3.32A for double magnitude. Then the relay will show the trip alarm. So the current will be drop off to see that what time come out to turn off the trip alarm at the relay. That what the test set have be done for this Table 3.

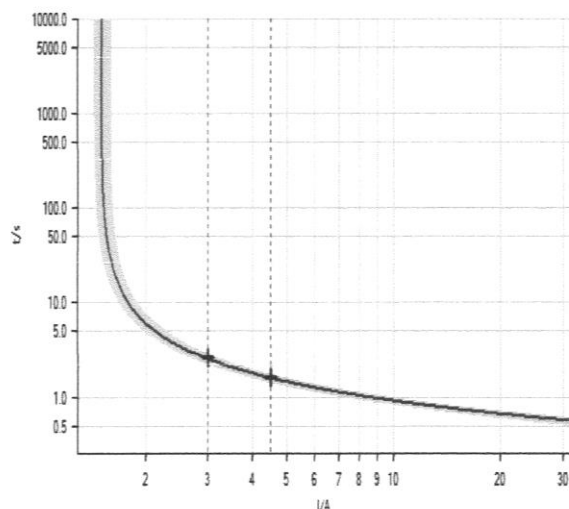


Figure 8: Characteristics for Red, Yellow and Blue Phase

So all the result have a characteristic and show that the result is passed and relay are good condition shown as Figure 8. Operating equations and allowances are provided in the standard. Electromechanical inverse-time overcurrent relay reset characteristics are defined in the event that designers of microprocessor based relays and computer relays want to match the reset

characteristics of the electromechanical relays [9]. Since the standard curves provided cover most cases with adequate tripping times, and most equipment is designed with standard protection curves in mind, the need to utilize this form of protection is relatively rare. Each test must be more detail to avoid tripping in any busbar or system. The test set OMICRON 256 also tell that the result whether is passed or failed. When the result is failed, the relay setting configuration must be check one by one. Make sure the setting relay must be following the configuration from the Engineering Department.

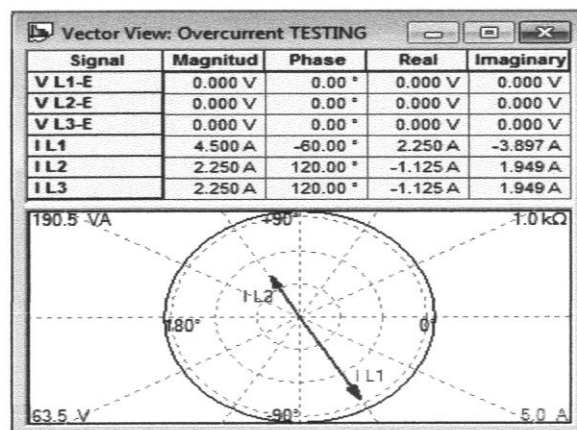


Figure 9: Vector view for Red Phase

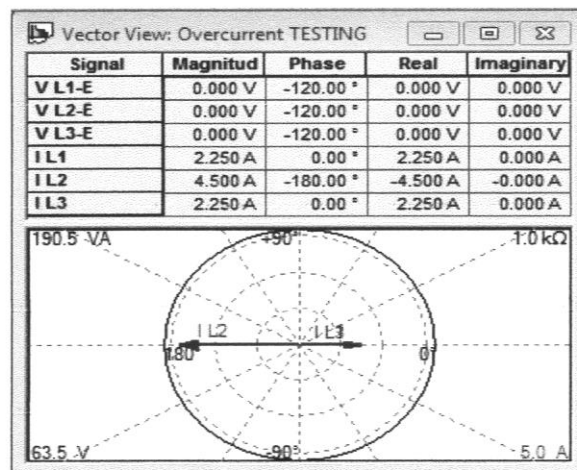


Figure 10: Vector view for Blue Phase

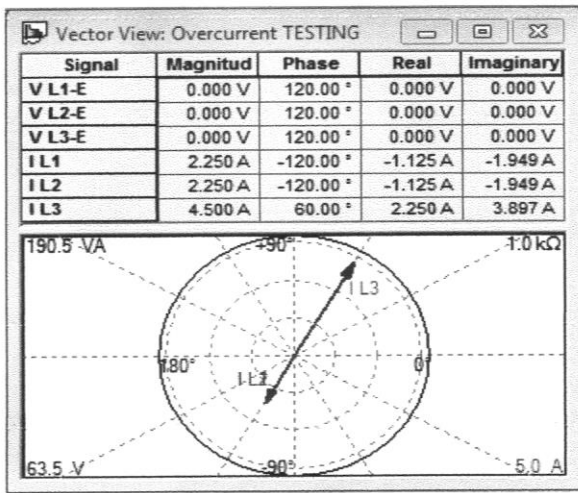


Figure 11: Vector view for Yellow Phase

Figure 9, 10 and 11 show that the point of view for red, yellow and blue phase. So each phase have different phase directional characteristic.

B. TESTING at PMU SUNGAI SIPUT

Table 4: Table Overcurrent Earth Fault Pickup Test

	Phase	Setting I(A)	Actual I(A)	Error (%)
Overcurrent	Red	1.0	1.07	7.0
	Yellow	1.0	1.06	6.0
	Blue	1.0	1.07	7.0

Table 4 shows the result for pickup current test in phase fault. The setting current relay in each phase is $I=1.0$ A. Then the testing electrical devices will begin. The purpose of testing is to see the pickup current where the pickup current will make the relay trip and show the alarm. Then the current pickup will compare with setting current to calculate the percent error. The condition relays accept as true when the percent error is below then 10%. For the example when actual current red phase is 1.07A where the actual currents make relay trip, then the result is passed because the percent error is 7.0% not more than 10%. So the conclusions the value pickup current cannot be too far from the current setting.

Table 5 shows that the results the timing test for the pickup current. The relay will be test $2 \times$ current setting and $3 \times$ current setting to get different timing test. The expected timing test were be calculated by formulae and actual timing will be get from the test set. So the value cannot be too far from the expected.

Table 5: Table Overcurrent Earth Fault Timing Test

	current I(A)		time (S)		
Phase	Test I	I(A)	T nom	T act	Error (%)
Red	$2 \times I_s$	2.0	3.510	3.800	0.88
	$3 \times I_s$	3.0	2.206	2.460	1.04
Yellow	$2 \times I_s$	2.0	3.510	3.772	0.88
	$3 \times I_s$	3.0	2.206	2.300	0.95
Blue	$2 \times I_s$	2.0	3.510	3.900	1.17
	$3 \times I_s$	3.0	2.206	2.400	1.13

When using test set Sverker 608E to testing the relay type GEC MEASUREMENT, the output result cannot be detail compare with another test set such as Omicron CMC256. Sverker 608E is the old one maybe used in early days (80's-90's). This test set using external Timer TM200 and Multimeter to get timing test and pickup current.

C. CONCLUSIONS

Overcurrent relays for transmission line protection testing and analysis has been demonstrated using test set and actual situation. The testing for overall has been successfully demonstrated. This relay is used as the protection because it can extend backup protection coverage and the characteristic the overcurrent to avoid thermal/dynamic consequences of prolonged short-circuit current to protected equipment.

Both type of relay such as SPAJ 140C and GEC MEASUREMENT actually have same goals that is operative by measuring the fault current in the power system and trips instantaneously or delayed according to a specific time characteristic. When testing the relay, determining relay settings, or analyzing event reports, some concept of how the relay determines direction to a fault will be needed. The purpose of protection is to monitor for unwanted conditions and when such conditions arise to remove the fault condition in the shortest time possible whilst leaving unaffected areas operational. The design of the system must have a high level of sensitivity to fault conditions whilst remaining operational during non-fault conditions.

During testing each data and result must be passed so that the electrical devices such as overcurrent relay will operate to protect the system. The testing will ensure the protective device is in good condition or not.

For the future, this project can improve by comparing the testing result from the actual situation and maybe using software PSCAD to simulate the result. This also can be improving to determine the advantage and disadvantage using both ways. The best ways will be used in future to make sure the transmission line system will be protected from the fault.

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