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Protection Relay Setting based on Overcurrent Phenomena in Commercial Building

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ABSTRACT

Nowadays, every single distribution system needs to install an appropriate relay to keep the system safe. The operational and commonly recommended relay for distribution systems is the overcurrent (OC) relay. Throughout the distribution system, the protective relay is one of the methods that can detect and protect the location according to its observation from any fault from abnormal activity. Note that time coordination between the protective equipment relay needs to be a minimum of time interruption to prevent faults occurs. The ideal setting for all coordination protection relays is necessary to protect the device against electrical failure and interference. This paper analyzes the real results data collected for the selected commercial building of an OC relay implemented in a distribution board for high voltage and low voltage downward at a commercial building. All the parameters need to be clarified first before testing has been made and measurement is carried out using the MICROTEST 860 set. Based on the analysis, it proves that according to the IEC Standard of 0.10-time multiplier Setting (TMS) is practical to be used to obtain the operation time in seconds for the current curve set. Other than that, the results show that the normal inverse curve from manual calculation results is more accurate compared to the service setting (SS) made based on the incoming setting in a real commercial building. The case study for OC relay setting is related between current injection and time-tripping, which complies with the IEC 60255-3 standard using its formula. This method was applied to determine the characteristics of the curve. Hence, this research successfully determined the proper methods for the OC relay setting for the power distribution system. Besides, the feasibility and efficiency of OC relay data transmission are tested and checked successfully to implement the measurement method in the relay coordination study.

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1. Introduction

Overcurrent (OC) protection relays are commonly used for the main protection provided sub-transmission and distribution system [1-5]. The protection relay will react when the load current exceeds the setting value limit. Apart from that, the present current setting multiplier based on injection current towards OC protection relays can be generally classified from a minimum percentage of 130% to a maximum of 250% increase within 100% for on-site measurement. The rising use of load in distribution systems bare a risk for protection relays due to increasing levels of short circuits and load structure [3]. Note that the service setting (SS) for every single relay can be measured through two specifications for the OC protection relay. First is the low (minimum) set current, and second is the high (maximum) set injection current [6]. The protection OC relay will be applied at high- and low-voltage systems with current transformer (CT) saturation to reduce the signal level given to the protection relay [7,8]. Saturation of the CT prevents correct distinction between the internal fault current and a transformer's magnetizing inrush current and endangers the proper operation of a relay. Therefore, in Figure 1 CT saturation compensation may significantly improve efficiency and healthy relays [9]. A protection relay is an electrical device that can provide a trigger signal for the circuit breaker to cut off or tripping at the system when in an unsafe load area [10]. To ensure and preserve where the protection device will operate at the proper location in the protective orders. Thus, the equipment is affected by various fault potentials and should be selective to make sure the system stability in safe operation. One of the essential requirements for the system is proper coordination for OC relays in power systems. The complexity of the system can probably cause an unhealthy condition. In order to fix this issue, interconnected systems must be used complicated methods to achieve the best result in a minimum outage of the power system while completing this analysis with output results from the actual data of commercial buildings [11]. Besides that, a better result can be simulated using a heuristics algorithm technique and intelligent relay characteristics [12,13].

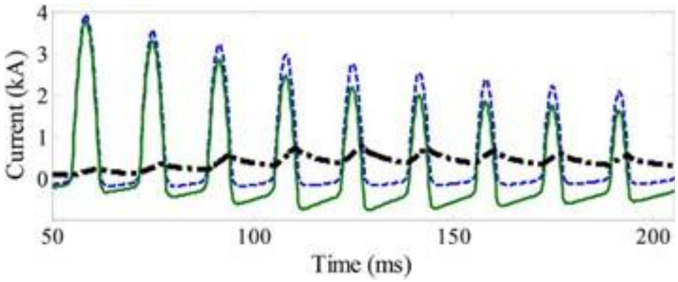


Fig. 1. Typical primary (dash line) and scaled secondary (solid line) of a saturated CT due to fault current [9]

For any fault location, the relay must trip to the nearest fault that occurs, in which an engineer is required to troubleshoot the problem with arrangement and continuity of relay operation. TMS functions as a high set instantaneous feature to lessen the tripping time and improve the system when surge faults currents happen and become much more effective compared to the protected circuit impedance [14]. The TMS based on predetermined pick-up and SS can be optimized to maximize efficiency while testing to ensure the system trips according to the measured parameter. Furthermore, to ensure continuity in the operation of the protection system, the backup relay does not operate first until the primary relay refuses to perform or fails to take steps to identify the faults. This paper presents the selected commercial building approach to the OC protection relay of the 11 kV main incoming supply [15]. The main agenda based on the result obtained conventional technique of over current protection relay with curve fitting and graph theory according to the over current relay characteristics in the contribution in this paper. For effective protection of the radial power system, the protection relay must coordinate effectively to have standard inverse curve characteristics for the whole electrical installation system.

2. Control System Scheme for Protective Relay Coordination

A current transformer (CT), typically mounted in a standardized building called a CT unit, often shield the massive power grid lines. The overcurrent (OC) relay is a type of protection relay (switch) that triggers a circuit breaker when a high voltage current reaches a particular fixed setting value. Other than that, OC relays use CT to measure the current flow because the current of the high-voltage line may not be tested directly [16-18]. OC protection is the most used protective relay towards the primary or secondary system to prevent defective equipment in broad short circuit current. Usually, OC protection is synchronized with the time when it is used. Hence, the devices nearest to the fault operate and isolate only the equipment section until devices perform further away from the fault and isolate larger sections of the system [6]. These OC time systems often need to be synchronized with equipment exposure curves, such as buses and cables, to clear the fault before the OC can cause damage to the equipment. The scheme consists of a CT unit that senses the current and provides the same voltage level for control. On the other hand, the unit and curve measurement show the CT used for metering and protection purposes generating a second alternating current that will be equivalent to the primary alternating current (AC) current. During fault conditions, it provides the signal to the relay. CT saturation causes unnecessary distortion of the current waveform computed, which can cause serious problems in the optimal performance of protective relays. This principle of OC time synchronization is well understood, and general guidelines are implemented to compensate for measurement errors and other technical inaccuracies. Due to the CT saturation, reduced signal levels given to relays are usually not considered during coordination studies. This reduced signal level would result in protection relays running slower than needed. Correspondingly, relays could trip slower than upstream systems, isolating more of the electrical system than expected, or can trigger disruption to primary devices before tripping [9]. Figure 1 and Figure 2 represent the principal characteristics of CT In primary and secondary current output. Chosen current transformers with saturation characteristics suitable for the expected fault current levels in the system. Review the CT's datasheet, which provides details on saturation behavior such as the rated primary current and corresponding saturation current. Verify that the CT's saturation current exceeds the anticipated fault current levels and to analyze the optimal settings for the overcurrent protection relays. This result involves examining the time-current characteristics of protective devices in the system. By considering the saturation characteristics of the CTs, you can make adjustments to the relay settings to accommodate potential saturation effects.

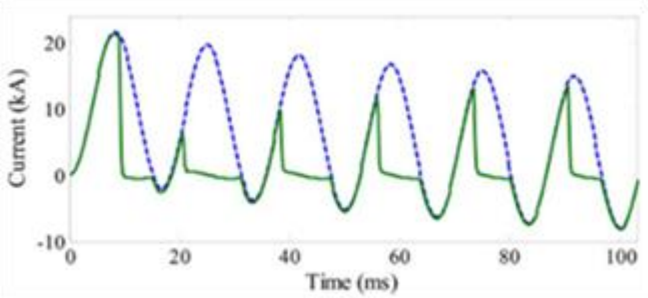


Fig. 2. Typical primary (dash line), scaled secondary (solid line), and CT magnetizing current (dash-dot line) of a saturated CT due to inrush current [9]

3. Type of Noise

According to the relay current-time characteristics curve from the traditional and conventional method which task of determining the TMS and Plug Setting Multiplier (PSM) for each relay is still considerable for a simple network. Figure 3 demonstrates a simplified single-line diagram (SLD) layout for the model under study. Firstly, load flow analysis is conducted in one complete radial network on the system to verify the load in balance condition. The SLD is the fundamental schematic diagram used to track the electrical operation of the substation [19]. Note that it focuses on the coordination of the roles of the electrical equipment and the related protection in the radial control system shown in Figure 3.

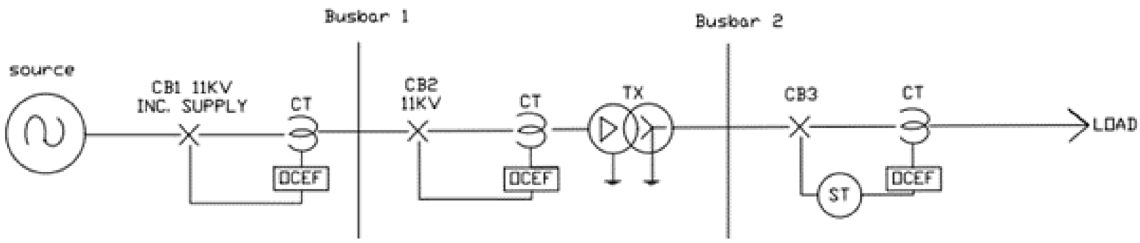


Fig. 3. Basic three-phase connection in a single-line diagram

where,
CB = Circuit Breaker
CT = Current Transformer
TX = Transformer
OCEF = IDMT Overcurrent Earth Fault Relay
3P = 3-Pole
ST = Shunt Trip

3.1 Gaussian Noise

Basically, protection relay coordination consists of the case study, especially for on-site measurement, according to the protection structure shown in Figure 4. First, the basic mathematical equation for relays will be defined and relevant to all types of characteristics of relays, as described in Eq. (1). Other than that, the schematic approach to displaying the performance of each relay at pick-up is addressed. In this case, for commercial buildings, it was found that the curve characteristics based on the implemented system setting for protection over overcurrent relay are a Standard Inverse (SI) curve. Besides, the operating time of Inverse Definite Minimum Time (IDMT) over overcurrent (OC) relays is conversely proportional to the current. Thus, such relays operate fast when sensing a high current. IDMT characteristics are categorized into different types of characteristics such as SI, Definite Time (DT), Very Inverse (VI), Extremely Inverse (EI), and Long Time Inverse (LTI). Otherwise, Definite time (DT) not include in the Table 1 because Definite Time is a characteristic of overcurrent relays, representing a fixed time delay before the relay responds to an overcurrent event. Unlike inverse time or time-delayed relays, which have variable operating times based on fault current magnitude and duration, definite time relays offer a constant operating time. Definite Time overcurrent relays are commonly used in scenarios where a consistent and specific operating time is desired, regardless of the magnitude of the fault current. These relays deliver a dependable and predictable response to faults and are often coordinated with other protective devices for selective fault clearing. The operating time of a definite time overcurrent relay is pre-determined and set based on the intended protection scheme and coordination requirements. Once the fixed time delay has passed after detecting an overcurrent condition, the relay trips or activates its output circuit, irrespective of the fault current level.

Furthermore, the operating time (t) of an IDMT-type OC relay is inversely related to the fault current depending on the pick-up current (Ip). Therefore, when the IDMT characteristic has been selected, the t of the stage will be a function of the current, meaning that the higher the present current, the shorter the operating time to trip the system [20-23]. The relationship between current and time complies with the BS 142.1966 and IEC 60255-3 standards and can be expressed as follows Eq. (1)

$$t[s] = kx\beta/(I/I >)\alpha - 1) \tag{1}$$

where,
t = operate time in seconds
k = time multiplier
I = measured current value
I>= set start current value

The unit consolidates four specified qualities with a distinctive degree of the inverse. The degree of the sideways is regulated by the estimates of the constants α and β. Apart from that, the relay includes four-times/current curve sets according to BS 142.1966 and IEC 60255-3. The constant α and β determine the slope of the time/current curve sets as in Table 1, and the alpha and beta values are fixed according to four different relay characteristics.

Table 1
Relay characteristics values of constant α and β according to IEC 60255 standard

Relay characteristic (Inversity)	*α*	*β*	Equation (IEC 60255)
IEC-Standard Inverse (SI)	0.02	0.14	$t[s] = k \times 0.14/(1/I>)^{\wedge 0.02} - 1$
IEC-Very Inverse (VI)	1.00	13.50	$t[s] = k \times 13.5/(I/I>)^{\wedge 1.00} - 1$
IEC-Extremely Inverse (EI)	2.00	80.00	$t[s] = k \times 80.00/(I/I>)^{\wedge 2.00} - 1$
IEC-Long-Time Inverse (LTI)	1.00	120.0	$t[s] = k \times 120.00/(I/I>)^{\wedge 1.00} - 1$

Experiments or observations have been analyzed in the proper method to be used for manual calculation of OC relay settings when coming out with the result for the OC relay setting. Note that setting up OC relay parameters must confirm the relay characteristics of IEC 60255 standards for PSM and TMS, as shown in Figure 4. On the other hand, Figure 5 shows the flowchart of a process and the proper step to calibrate the relay from data compilation. It started with computing injected relay current (Iinj) in percentage, the pick-up value of the relay, the PSM, and the actual operation time tripping. Subsequently, we need to determine the characteristics relay type of the IEC 60255 standard and adjust PSM timing if we cannot follow the IEC standard.

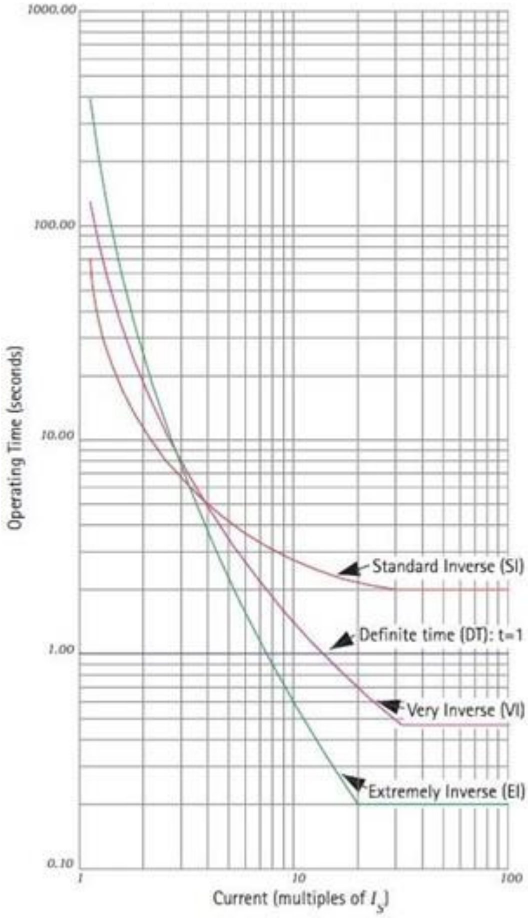


Fig. 4. IDMT relay characteristics of the overcurrent coordination

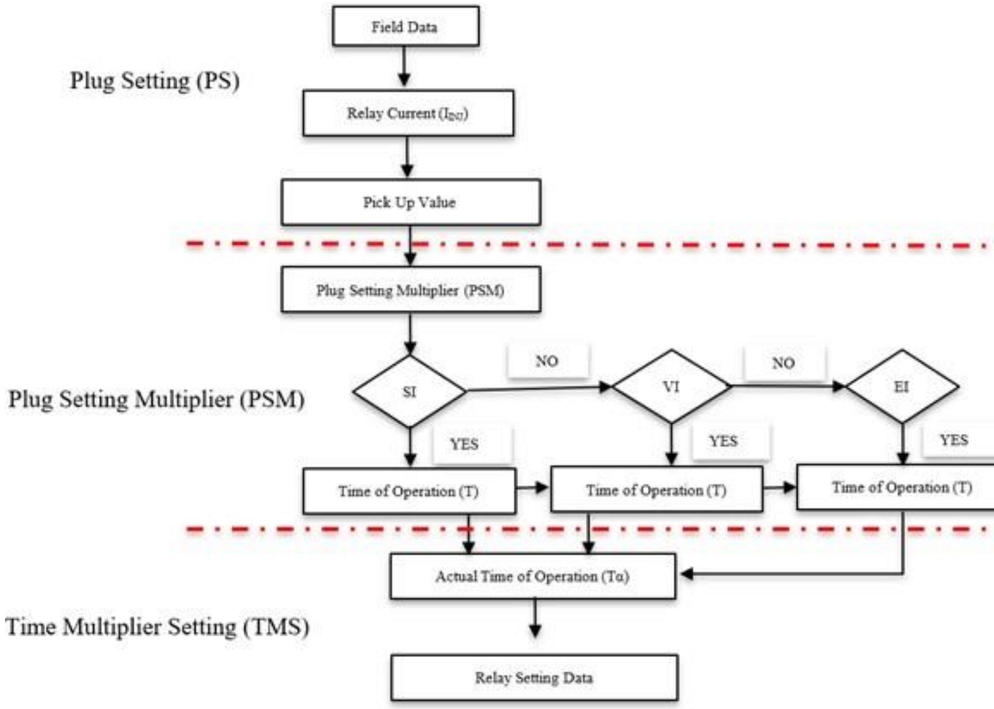


Fig. 5. Flow chart of the algorithm implemented in the overcurrent relay model [17]

The main idea for the flowchart of Figure 5 shows the flowing how to test and calibrate the overcurrent protection relay to have measurement data and result.

(i) Start: Begin the testing and calibration process.
(ii) Select Test Current: Choose a test current level that represents the desired operating conditions for calibration.
(iii) Apply Test Current: Apply the selected test current to the input terminals of the overcurrent protection relay.
(iv) Measure Operating Time: Use a precise timing mechanism to measure the operating time of the relay for the applied test current.
(v) Record Measured Time: Document the measured operating time along with the corresponding test current level.
(vi) Adjust Settings: If necessary, make adjustments to the relay's settings, such as time delay or pickup current, to achieve desired calibration performance.
(vii) Repeat Steps 2-6: Iterate the process by selecting different test current levels and measuring the operating time for each level.
(viii) Validation: Validate the calibration results by comparing the measured operating times with the expected performance based on relay specifications or industry standards.
(ix) Document Calibration Data: Record all the calibration data, including the test current levels, measured operating times, and any adjustments made.
(x) End: Complete the testing and calibration process.

3.2 Layout Commercial Building with Three-Phase System from Incoming High Voltage

The design electrical power system for a selected commercial building in Malaysia, as shown in Figure 6, starting from an incoming source of 11 kV, has a short current rating of 286MVASC of three-phases. Consequently, the system will step down 11 kV/415 V transformer is 1500 kVA (6%), and

1000 kVA (6%) of transformer impedance is installed to supply for low voltage system of main switchboard (MSB) feeders. Here, the SLD in Figure 6 is the real summarized diagram from a commercial building. All the parameter and rating of electrical equipment needed has been tested at the substation. From the data collected, the manual calculation referred to the real diagram from the substation.

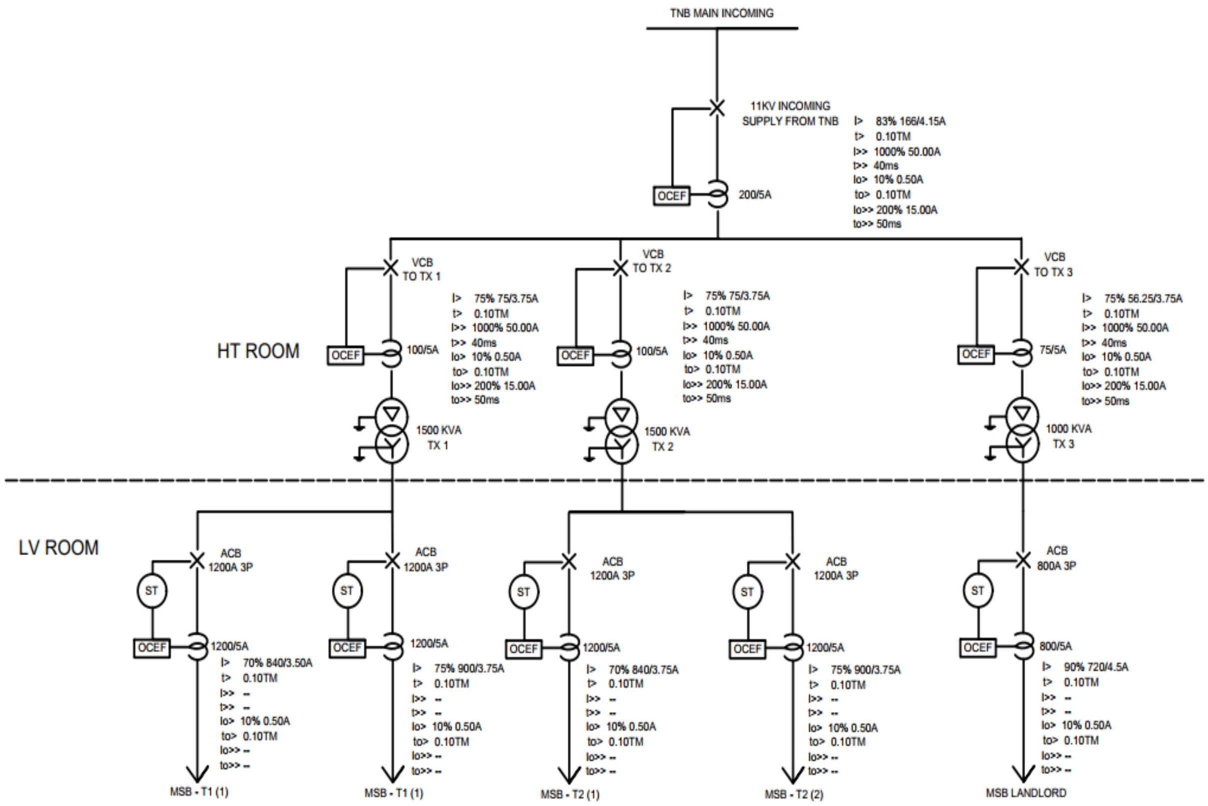


Fig. 6. Single-line diagram of 11kV commercial building in Malaysia

3.3 Layout Commercial Building with Three-Phase System from Incoming High Voltage

Data compilation from on-site measurements in Table 2 to Table 5 shows the OC relay and earth fault (EF) setting made for MSB from Tenaga Nasional Berhad (TNB), which supplies energy in Malaysia between feeder to MSB and MSB landlord. Note that the type of relay implemented for all switchboards is the same. Tripping volts for high voltage systems measure the capability of the battery charger compared to low voltage tripping volts will depend on the voltage for a single phase. Table 2 shows main incoming relay setting given by TNB should not exceed 83%, which means the secondary current was set into 4.15 A and the primary current (carry amps) will be 166 A. The high setting for OC protection was set at 1000% with a second injection of 50 A, while EF protection normally will set at 200% with the second injection of 10 A appropriate relay type.

Table 2
OC and EF setting for incoming TNB (Based on the setting letter given by TNB)

Relay details					
Make:	MIKRO	Rated amp:	5A	Trip test:	-
Type:	MK 1000A	Trip volt:	32.1Vdc	Curve	Normal inverse
Serial No:	-	CT ratio:	200/5A	ELI:	-
O/C PMS:	0.50-10.00A	O/C TMS:	0.05-1.00 TM		
E/F PMS:	0.10-5.00A	E/F TMS:	0.05-1.00 TM		
Relay setting					
Type of protection	Setting symbol	Service setting	Test setting		
O/C IDMT R Y B Ø	I>	83% 4.15A	83% 4.15A		
Curve: NI	TMS	0.10TM	0.10TM		
O/C-HS	I>>	1000% 50.00A	1000% 50.00A		
	t>>	40ms	40ms		
E/F IDMT	Io>>	10% 0.50A	10% 0.50A		
Curve: NI	TMS	0.10TM	0.10TM		
E/F-HS	Io>>	200% 15.00A	200% 15.00A		
	To>>	50ms	50ms		

The incoming supply was separated into three outgoing feeders depending on the division of the total connected load for each MSB feeder. Table 3 shows that the relay setting for MSB T1 has been calculated with all specifications provided, such as implementing a CT ratio that should not exceed 75%. This means that the secondary current was set into 3.75 A, and the primary current (carry amps) will be 75 A. Other than that, a high setting will be set according to the request for OC protection was set at 1000% with a second injection of 50 A, while EF protection normally will set at 200% with the second injection of 10 A appropriate relay type.

Table 3
OC and EF Setting for MSB T

Relay details					
Make:	MIKRO	Rated amp:	5A	Trip test:	-
Type:	MK 1000A	Trip volt:	32.1Vdc	Curve	Normal inverse
Serial no:	-	CT ratio:	100/5A	ELI:	-
O/C PMS:	0.50-10.00A	O/C TMS:	0.05-1.00 TM		
E/F PMS:	0.10-5.00A	E/F TMS:	0.05-1.00 TM		
Relay Setting					
Type of protection	Setting symbol	Service setting	Test setting		
O/C IDMT R Y B Ø	I>	75% 3.75A	75% 3.75A		
Curve: NI	TMS	0.10TM	0.10TM		
O/C-HS	I>>	1000% 50.00A	1000% 50.00A		
	t>>	40ms	40ms		
E/F IDMT	Io>>	10% 0.50A	10% 0.50A		
Curve: NI	TMS	0.10TM	0.10TM		
E/F-HS	Io>>	200% 15.00A	200% 15.00A		
	To>>	50ms	50ms		

Table 4 shows the second feeder from the incoming supply feeder depending on the total connected load for MSB T2. Relay settings have been calculated according to the system and should not exceed 75%, which means the secondary current was set into 3.75 A, and the primary current (carry amps) will be 75 A. The high setting for OC protection was set at 1000% with a second injection of 50 A, while EF protection normally will set at 200% with a second injection of 10 A appropriate relay type.

Table 4
OC and EF Setting for MSB T2

Relay details					
Make:	MIKRO	Rated amp:	5A	Trip test:	-
Type:	MK 1000A	Trip volt:	32.1Vdc	Curve	Normal inverse
Serial no:	-	CT ratio:	100/5A	ELI:	-
O/C PMS:	0.50-10.00A	O/C TMS:	0.05-1.00 TM		
E/F PMS:	0.10-5.00A	E/F TMS:	0.05-1.00 TM		
Relay Setting					
Type of protection	Setting symbol	Service setting	Test setting		
O/C IDMT R Y B Ø	I>	75% 3.75A	75% 3.75A		
Curve: NI	TMS	0.10TM	0.10TM		
O/C-HS	I>>	1000% 50.00A	1000% 50.00A		
	t>>	40ms	40ms		
E/F IDMT	Io>>	10% 0.50A	10% 0.50A		
Curve: NI	TMS	0.10TM	0.10TM		
E/F-HS	Io>>	200% 15.00A	200% 15.00A		
	To>>	50ms	50ms		

Table 5 shows the third feeder from the incoming supply feeder for the MSB landlord. Relay settings have been calculated according to the system and should not exceed 75%, which means the secondary current was set to 3.75 A, and the primary current (carry amps) will be 56.25 A. The high setting for OC protection was set at 1000% with a second injection of 50 A, while EF protection normally will set at 200% with a second injection of 10 A appropriate relay type. The system was calculated with different sizing of CT ratios for each switchboard.

Table 5
OC and EF setting for MSB Landlord

Relay details					
Make:	MIKRO	Rated amp:	5A	Trip test:	-
Type:	MK 1000A	Trip volt:	32.1Vdc	Curve	Normal inverse
Serial no:	-	CT ratio:	100/5A	ELI:	-
O/C PMS:	0.50-10.00A	O/C TMS:	0.05-1.00 TM		
E/F PMS:	0.10-5.00A	E/F TMS:	0.05-1.00 TM		
Relay setting					
Type of protection	Setting symbol	Service setting	Test setting		
O/C IDMT R Y B Ø	I>	75% 3.75A	75% 3.75A		
Curve: NI	TMS	0.10TM	0.10TM		
O/C-HS	I>>	1000% 50.00A	1000% 50.00A		
	t>>	40ms	40ms		
E/F IDMT	Io>>	10% 0.50A	10% 0.50A		
Curve: NI	TMS	0.10TM	0.10TM		
E/F-HS	Io>>	200% 10.00A	200% 10.00A		
	To>>	50ms	50ms		

3.4 Equipment / Device Setting

The MICROTEST 860 series has been developed especially for secondary protection relay processing. With its check levels up to 200 A a.c., 240 V a.c./d.c., various auxiliary voltages, and an optimized timer resolution of 1 ms. This device is suitable for testing the reliability and time of operation of the safety relays. Figure 7 shows the setup of a secondary current injection test equipment. This portable tool is built to be used in high-voltage substations and manufacturing systems. Basically, this set is very useful to test the OC relay and EF either in good operational condition or instead of that implemented to the board for protection system. This device can only be used by well-qualified individuals who have skilled in the proper use.

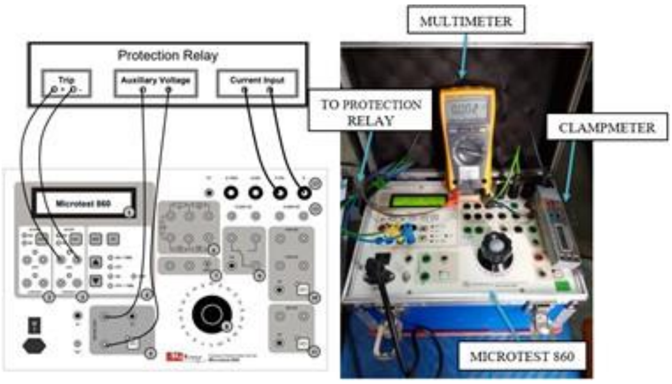


Fig. 7. Set-up the secondary current injection test

4. Results and Discussion

Relay settings are usually based on their characteristics curve, demonstrating the operation time speed. The characteristics basically have four types of time characteristics which are Standard Inverse (SI), Very Inverse (VI), Extremely Inverse (EI), and LTI. The data have been collected based on the commercial building to analyze the characteristics, and most commercial building consists of the same time characteristics of SI. On the other hand, Time Multiplier Setting (TMS) in the relay setting is selected 0.10 TM according to data that had been tested at the substation according to the procedure of IEC 60255 standard. The model relay used for this commercial building is MIKRO type MK1000A, built-in Inverse Definite Minimum Time (IDMT) combination of overcurrent (OC) and earth fault (EF) relay. Apart from that, this relay specification and service setting (SS) are shown in Table 2 to Table 5. The result for the tripping time of low set OC injected among three phases, red phase, yellow phase, and blue phase, can be determined through the curve characteristics.

Current injection is based on the percentage applied from initiation of 130%, 200%, and 300%. Another view and understanding can be referred to in Table 2 to Table 5, which show the SS from the incoming supply to the outgoing feeder. In this case, the characteristics curve is the same; an SI curve has been proven based on timing checks of a low set of OC and EF tests. Table 6 to Table 12 show secondary injection tests on OC and EF time tripping when applying or injecting current according to IEC 60255 standard test in H(JPE) form given by the energy commission. Note that the time tripping for the current injection of 130% is around 2.661 s, and 200% will be around 1.002 s. In case the existing relay has a high set current injection, the percentage will be 500%. Other than that, this high set setting is according to selective relay and depends on the customer's request whether they want to set the high set setting or not because the injection current of 300% is enough for a commercial building to trip the system. At the same time, faults happen at a high pulse current of around 0.630 s. Subsequently, the bar graph shows more clearly that when a fault occurs with a high surge current in a three-phase system, a faster time operation relay will operate to trip the system. In other words, if there is a fault with a small surge current, the relay will take some time to trip the radial network. As evidence, the dotted green line in Figure 8 is represented as a trendline in order to show the system is based on an SI curve according to IEC 60255 standard with all the manual calculations and analyses that have been made.

It is crucial and critical to ensure the reliability of the distribution network, which can operate smoothly in normal load or peak load, during the study. Therefore, load flow analysis and short-circuit analysis were performed before the relays were coordinated. The process is important for testing the actual system to ensure that all parameters are right and accurate before further analysis. Likewise, the normal load cases are made and analyzed based on load flow analysis and are reliable and able to cater to a variety of conditions. Nevertheless, the result does not reflect any significant voltage drop and power losses in the study. In addition, power factors are maintained within 0.95 pu to 1.0 pu. Finally, the relay coordination is presented in the analysis. The manual calculation is made up clearly, and values are transferred for the relay SS of the system and timing checks of the low set to trip. The results show the formula's capability for deciding the relay setting of the real system. Add in the last paragraph at 3. Results and discussion.

The overcurrent protection relay successfully demonstrates precise and timely operation during testing, it signifies that the relay is functioning as intended. This functionality plays a critical role in safeguarding electrical systems from overcurrent events, thereby ensuring the safety of the building and the individuals within it. Furthermore, functioning of the relay guarantees coordination and selectivity with other protective devices within the electrical system. This ensures that the relay operates in a manner that enables seamless response of upstream or downstream protective devices to faults, thereby maintaining a cascading effect for effective and selective fault clearing. In summary, the positive outcomes and discussions resulting from the overcurrent protection relay testing in a well-maintained commercial building indicate the presence of a reliable electrical system that adheres to safety standards. This not only minimizes downtime but also mitigates overcurrent-related risks. Continual monitoring and maintenance are imperative to sustain the optimal performance of the system over time.

Table 6
OC and EF setting for incoming TNB: Secondary injection tests on O/C and E/F minimum current to check relay low set start function

Inject	RØ	YØ	BØ	Earth fault
Start/Pick-up current (A)	3.75	3.75	3.75	0.50

Table 7
OC and EF setting for incoming TNB: Timing checks of low set O/C and E/F

Inject	RØ	YØ	BØ	Earth fault
Start/Pick-up current (A)	3.76	3.75	3.78	0.50

Table 8
OC and EF setting for MSB T1: Timing checks of low st O/C and E/F

Current injected for low set O/C & E&F	RØ (s)	YØ (s)	BØ (s)	Current injected for E/F(A)	E/F(s)
1.3 × I>= 4.87	2.619	2.620	2.536	1.3 × Io>= 0.53	2.650
2.0 × I>= 7.5	1.066	1.052	1.046	2.0 × Io>= 0.82	1.061
3.0 × I>= 11.25	0.671	0.662	0.664	3.0 × Io>= 1.23	0.634
(I>>) 5.00 × 1>= 50.00	0.031	0.030	0.037	(Io>>) 2.00 × Io>= 15.00	0.056
Reset Time Electromechanical Relay	-	-	-		-

Table 9
OC and EF setting for MSB T2: Secondary injection tests on O/C and E/F minimum current to check relay low set start function

Inject	RØ	YØ	BØ	Earth fault
Start/Pick-up current (A)	3.74	3.75	3.76	0.51

Table 10
OC and EF setting for MSB T2: Timing checks of low set O/C and E/F

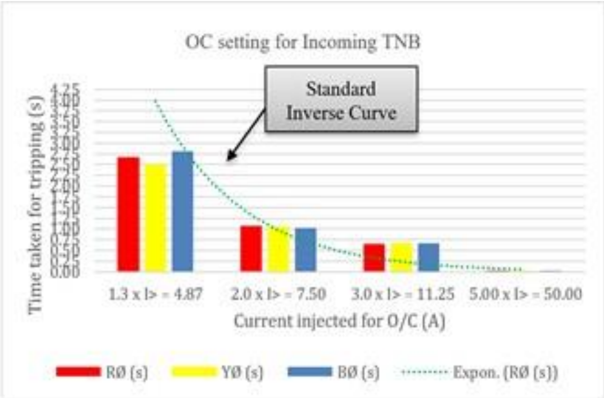
Current injected for low set O/C & E&F	RØ (s)	YØ (s)	BØ (s)	Current injected for E/F(A)	E/F(s)
1.3 × I>= 4.87	2.615	2.690	2.699	1.3 × Io>= 0.65	2.823
2.0 × I>= 7.5	1.019	1.012	1.010	2.0 × Io>= 1.00	1.019
3.0 × I>= 11.25	0.657	0.660	0.671	3.0 × Io>= 1.50	0.656
(I>>) 5.00 × 1>= 50.00	0.042	0.041	0.041	(Io>>) 2.00 × Io>= 15.00	0.059
Reset Time Electromechanical Relay	-	-	-		-

Table 11
OC and EF setting for MSB Landlord: Secondary injection tests on O/C and E/F minimum current to check relay low set start function

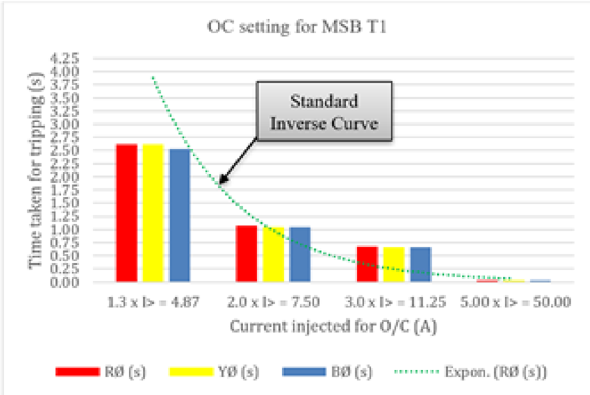
Inject	RØ	YØ	BØ	Earth fault
Start/Pick-up current (A)	3.50	3.50	3.50	0.50

Table 12
OC and EF setting for MSB Landlord: Timing checks of low set O/C and E/F

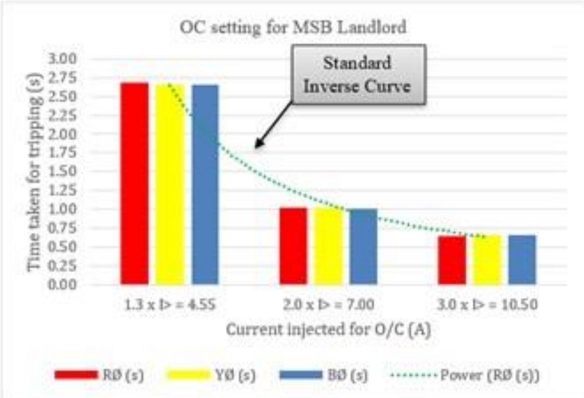
Current injected for low set O/C & E&F	RØ (s)	YØ (s)	BØ (s)	Current injected for E/F(A)	E/F(s)
1.3 × I>= 4.55	2.683	2.656	2.654	1.3 × Io>= 0.65	2.823
2.0 × I>= 7.5	1.028	1.018	1.006	2.0 × Io>= 1.00	1.019
3.0 × I>= 11.25	0.646	0.652	0.654	3.0 × Io>= 1.50	0.656
(I>>) 5.00 × 1>= 50.00	-	-	-	(Io>>) 2.00 × Io>= -	-
Reset Time Electromechanical Relay	-	-	-		-



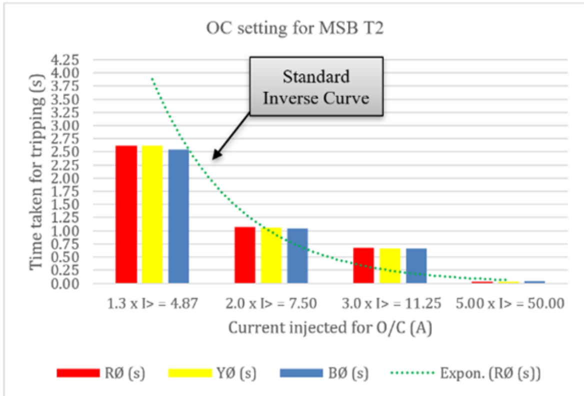
(a)



(b)



(c)



(d)

Fig. 8. The characteristics curve, (a) standard inverse (SI) for incoming TNB, (b) standard inverse (SI) for MSB T1, standard inverse (SI) for MSB T2, and (d) standard inverse (SI) for MSB Landlord

5. Conclusion

All the aims of this project have been successfully accomplished. The appropriate and realistic method for setting up overcurrent (OC) relays in the power distribution network shall be determined. Besides, the performance of the relay coordination is evaluated and verified. The study of the OC relay setting of the chosen commercial building was successfully modelled and tested using tester tools such as a MICROTEST 860 set for secondary current injection made by Megger. Other than that, protection relays are important in the power network to protect the distribution network or feeder line from failure and prevent unwanted interruption of a stable portion of the network. Note that OC relay coordination in the radial network is a very constrained optimization problem. The project involves load flow research, short circuit analysis, Plug Setting Multiplier (PSM), Time Multiplier Setting (TMS) and time of operation (*t*), and relay settings at the substation. While testing and tuning the relay, the PSM and TMS for the OC relays are observed. It was discovered that the normal time of difference for two relays of 0.25 s is used in the study. Apart from that, OC relays need to be carefully configured in such a way that they have accurate differentiation and serve as main as well as protective equipment. While exposed to the substation, this paper illustrates the reliability and potential of the application as a power system device to solve the issue of OC relays in the radial network.

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