INVERSE DEFINITE OVERCURRENT RELAY DISCRIMINATION ALGORITHM AND ITS APPLICATION IN INDUSTRIAL POWER SYSTEMS

Noor Zaihah Jamal[1], Omar Aliman[2] and Mohd Herwan Sulaiman[2]
[1]Fakulti Teknologi Kejuruteraan, Universiti Malaysia Pahang, Malaysia
[2] Fakulti Kejuruteraan Elektrik & Elektronik, Universiti Malaysia Pahang, Malaysia
E-Mail: zaihah@ump.edu.my

ABSTRACT

In a normal electrical network, it is crucial to design a system complete with protection to prevent any abnormalities or fault occurrence to disturb the whole source of electrical to be shut down. Only a portion of effected area should be closed and fault duration at high current value should be closely monitored. Overcurrent protection device discrimination play vital roles to ensure protective relay will react accordingly. This paper introduces a systematic overcurrent discrimination algorithm which is based on standard formulation and constant value by IEC 60255-4 and IEEE Std C37.112-1996. The proposed algorithm has been tested to an 11kV industrial power system. Two bus data have been tested and the tests result of the network was studied, analyzed and discussed. The algorithm has proven successfully fulfilled the discrimination requirement.

Keywords: Inverse definite minimum time, overcurrent relay, discrimination time interval, setting current and time multiplier setting.

INTRODUCTION

The overcurrent relay is an important protection device. The purpose of an overcurrent relay is to limit any excessive current of the rated current of equipment without any severer losses or damage to the equipment itself and to the system. A reliable protective system is vital for stable operation of the system and the assurance of customers' supply security [1]. Inverse definite minimum time (IDMT) overcurrent relay is widely used and implemented as an overcurrent relay device in many distribution networks. These IDMT overcurrent relays are suitable for the application of any electrical distribution network since the setting of the relay operating time is closely related with current transformer ratio, plug setting and time multiplier setting. The setting of relay operating time can be calculated by referring to IEC 60255-4[2] and IEEE Std C37.112-1996 [3].

In a distribution network, there are several protection devices installed to isolate the affected faulty area as quickly as possible to avoid any un-affected area to continuously service for the system. This is where the coordination study plays a vital role to discriminate which relays to operate first and next within their zone of protection. On the other hand, the coordination study of protective devices was developed to determine the setting of the devices [4, 5]. Backup relay also designed to be a secondary protector if any of the primary protective devices is not functioning accordingly. Zoning system used to protect devices within coverage which means a group of protection devices will react to any fault occurrences within their zone. The discrimination time interval (DTI) between primary protective device and back-up devices must be carefully discriminated moreover for the complicated network system so that the devices will react according to their sequences within a safe time frame and up to safe current level in order to ensure the faulty areas are isolated and controlled to protect the equipment, users and the devices itself.

Although optimization techniques have becoming popular amongst researchers nowadays, conventional coordination method is still practical to be used and had proven reliable for industrial electrical network. For industrial distribution network, determination of protection discrimination setting shall be prepared and reviewed by an experienced engineer. Critical consideration should be made in determined the time multiplier setting (TMS) and setting current (Is) for each relay in order to satisfy the DTI value to get the best protection and discrimination setting in certifying the reliabilities during the occurrence of any faulty conditions [6]. Failed to provide a good discrimination setting value which met the constraint of discrimination time interval (DTI) value will resulted to the sympathy trips to the system. This sympathy trips will be dragged the healthy portion of the network which would be costly numbers to the owner. The coordination of time overcurrent relays can best be performed numerically using tables or spread sheets [7].

This paper described a systematic overcurrent discrimination algorithm based on standard formulation and constant value. The proposed algorithm is applicable for electromechanical and digital based relays. The proposed algorithm has been tested for an industrial 11kV electrical network.

PROBLEM FORMULATION

The inverse definite minimum time current is formulated in accordance to IEC 60255-4 [2] and IEEE Std C37.112-1996 [3]:

$$T(n) = \frac{K}{M(n)^{\alpha} - 1} * TMS \qquad (1)$$

Where
T(n) = relay operating time in second for n relay
TMS = time multiplier setting
M(n) = I/Is (I is input current,Is is setting current)

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k and α = constant value for selected curved type

STUDY CASE

An 11kV electrical network has been used to test the proposed algorithm. The system is consisting of electromechanical relay and digital relay. The system was conducted with three-phase short circuit analysis to find out the near-end fault level at each busbar.

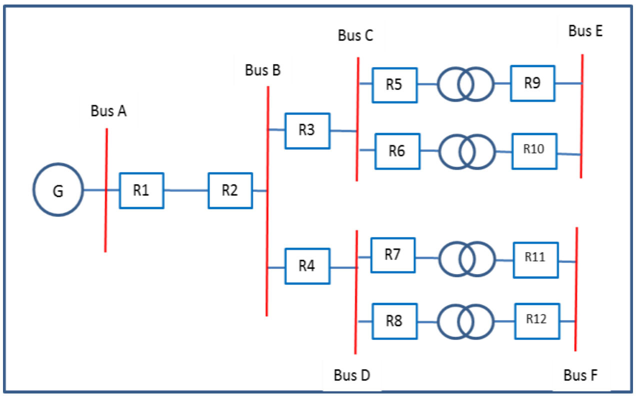

Figure-1. System diagram.

System summary
Number of busbar = 6
Number of branch = 7
Number of OC relay = 12

Data of current transformer ratio and relay rating have been shown in Table-1.

Table-1. Current transformer ratio and relay ratings.

Relay	Current transformer ratio (A/A)	Relay rating (A)
1	300/5	5
2	200/5	5
3	200/5	5
4	200/5	5
5	150/5	5
6	150/5	5
7	150/5	5
8	150/5	5
9	1000/5	5
10	1000/5	5
11	1600/5	5
12	1600/5	5

APPLICATION OF TIME-CURRENT TO OVERCURRENT RELAY DISCRIMINATION

Inverse definite minimum time overcurrent relay operates inversely between time and current. The tripping condition will be faster when the fault current value is higher and lower fault current value will be resulted to longer time of tripping condition. In this section, step by step of preparing the time coordination curve for each relay will be explained.

The proposed time-current curve plotting technique is briefly explained below.

Step 1: Determined maximum fault level

Each level/ busbar fault value shall be determined by performing the short circuit study using per-unit system.

Step 2: Determined the voltage level

The voltage (132kV/33kV/11kV/0.415kV) used for each relay must be at same value to ensure that the relay grading is possible to be performed. For this test system, voltage of 0.415kV has been used.

Step 3: Calculate the starting relay trip time.

The starting point for relay trip time can be computed using equation (1)

1) Range of time multiplier setting (TMS) of each IDMT relay

   $TMS_{min} \leq TMS \leq TMS_{max}$

   Minimum value of time multiplier setting as stated in [8] is 0.01 and maximum value of time multiplier setting is 1.

2) Setting current (I_s) value of each IDMT relay

   $I_{s\ min} \leq I_s \leq I_{s\ max}$

   Where, $I_{s\ min}$ is not lower than the maximum load demand (MD) for that particular busbar and $I_{s\ max}$ is maximum current setting.

3) Selected characteristic curve constant, k & α used for that particular relay as tabulated in Table-1.

Table-2. Constant value for characteristic curve type.

Relay type	k	α
Type A	0.14	0.02
Type B	13.5	1.0
Type C	80.0	2.0

For this case study, we have selected type A curve.

Step 4: Repeat step 3 for several current points by considering the below constraint.

1) Range of multiples of I

   $N_{min} \leq N \leq N_{max}$

The normal range recommended by [3] is 1.5-20 multiples of the I. Which means N_{min} is 1.5 and N_{max} is 20. However, N_{max} should be at current fault level at that particular relay busbar.

Step 5: Plot the time-current characteristic curve for each relays inside the system from the output value from step 1 – 4.

OVERCURRENT RELAY DISCRIMINATION

In this section, discrimination algorithm has been tested to an 11kV electrical network is presented. Microsoft excel software has been used to generate the discrimination curve for each relay and trip time value for each relay in the system by implementing the formulation in (1).

Relay discrimination is to satisfy the discrimination time interval (DTI) between primary relay and the back-up relay while considering the circuit breaker opening time, over-travel and safety factor to ensure no cascading between devices curve for relay to react in sequence.

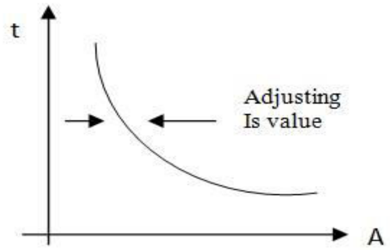

Figure-2. Adjusting the setting current value.

The implementation of each type of curve will be according to discrimination time interval (DTI) value to be achieved which indicates the time margin between the primary and the backup relay. The DTI is considering the circuit breaker opening time, over-travel & safety factor and can range between 0.3s – 0.4s [9].

Selectivity constraint

$T(n+1) \geq DTI + T(n)$

Where Tn is trip time of the primary relay and Tn+1 is trip time of the back-up relay with DTI between 0.3s - 0.4s.

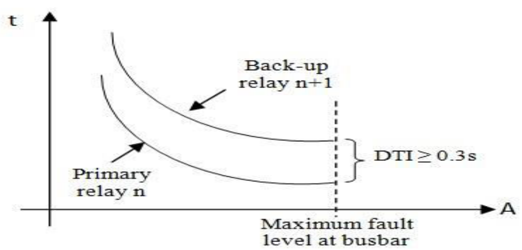

Figure-3. Discrimination time interval between primary relay & back-up relay.

Selectivity constraint shall be repeated if DTI value is < 0.3s until it meet the required DTI value by adjusting the time multiplier and setting current value. From Figure-2, adjusting the setting current value will move curve left and right. Adjusting the time multiplier value will move curve up and down as shown on Figure-4.

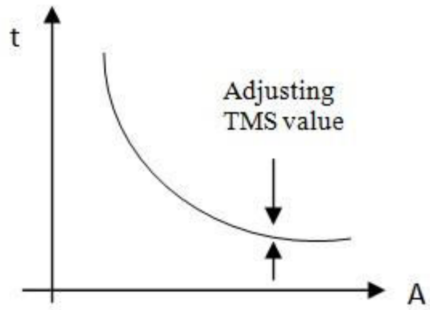

Figure-4. Adjusting the time multiplier value.

RESULTS AND DISCUSSIONS

The results are shown in Figure-5 and Figure-6, where two different busbar E & F has been tested.

Table-3. Value of setting current (A) and time multiplier setting (s) for each relay.

Relay no	Is (A)	Time Multiplier Setting (s)
1	240 @11kV	0.45
2	200 @11kV	0.38
3	150 @11kV	0.3
4	150 @ 11kV	0.3
5	105 @ 11kV	0.2
6	105 @ 11kV	0.2
7	105 @ 11kV	0.2
8	105 @ 11kV	0.2
9	700 @ 0.415kV	0.1
10	700 @ 0.415kV	0.1
11	960 @ 0.415kV	0.1
12	960 @ 0.415kV	0.1

Maximum fault current for bus E is 17.02kA and for bus F is 17.04kA at 0.415kV voltage level. From the Figure-5, when fault occurrence at bus E, the relay R9 will trip first at 0.21s followed by relay R5 at 0.54s, relay R3 at 0.84s, relay R2 at 1.14s and finally relay R1 at 1.44s. The discrimination time interval between relay R9 and relay R5 is not less than 0.3s and the value of discrimination interval for next primary relay and back-up relay is also not less than 0.3s where considering the circuit breaker opening time, over-travel and safety factor. From the Figure-6 for fault occurrence at bus F, relay R11 will be tripped first then followed by relay R7, relay R4, relay R2 and lastly relay R1 which successfully fulfilled the 0.3s discrimination time interval between each relay level. The entire relay coordination curve is investigated in 0.415kV voltage system. From the Table-3, it had shown that discrimination time interval between each relay level will be correlated with the setting current value and time multiplier setting value. The lowest downstream relay should be valued lower than the next upstream level relay in order to satisfy the overcurrent relay discrimination and to ensure that the relay at each level will response trip in correct sequence.

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CONCLUSIONS

The proposed systematic overcurrent discrimination algorithm has successfully discriminated the relays inside a tested 11kV industrial electrical power system. By applying all steps explained in the algorithm, the testing results have proven successfully fulfilled the discrimination time interval for each level.

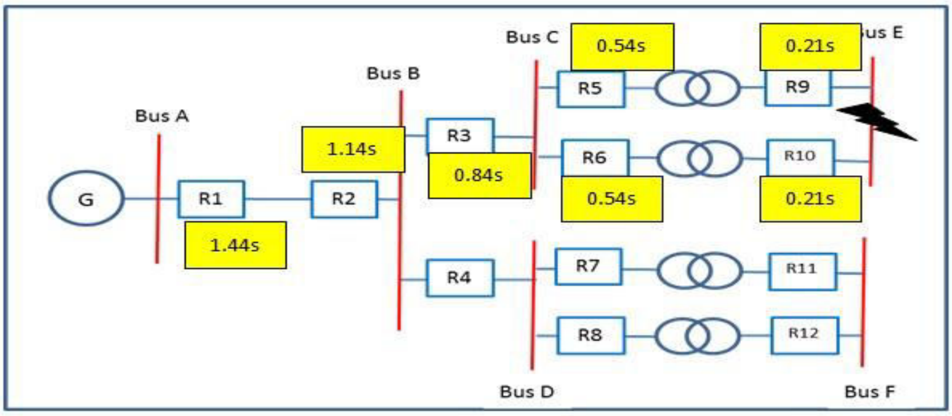

Figure-5. Relay operating time for a 3-phase fault on busbar E.

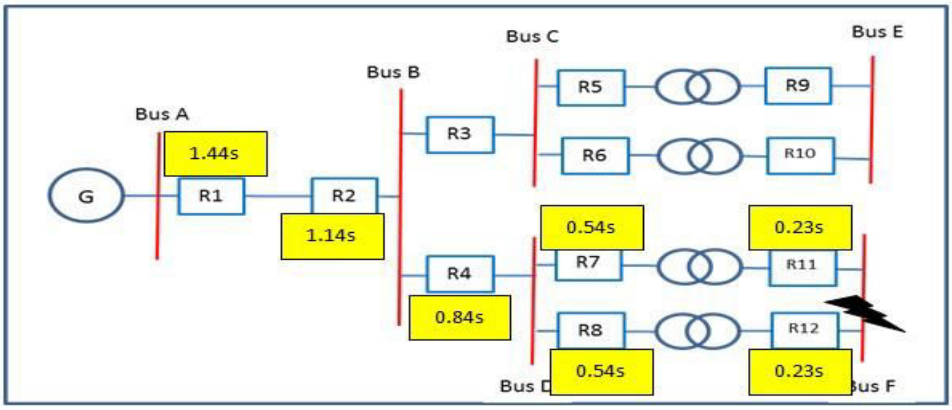

Figure-6. Relay operating time for a 3-phase fault on busbar F.

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