Overcurrent Relays Coordination Using MATLAB Model

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Abstract*: *Substation protective relay coordination setting plays a vital role in the safe operation of power system. The objective of protective relay coordination in an interconnected power system is to achieve selectivity without sacrificing sensitivity and fast fault clearance time. Proper coordination of relays is essential to minimize unnecessary outages. In recent years, power demand has increase substantially while the expansion of the system has been severely limited due to abnormalities of Isolation of faulty areas by the protection system as a result of lack of effective coordination of the relay operation. This paper presents a study on protection coordination of over-current relays (OCRs) in a 132/33kV transmission substation by considering its different operating modes using a MATLAB model. Over-current (OC) relays are the major protection devices in a distribution system. The operating time of the OC relays are to be coordinated properly to avoid the mal-operation of the backup relays. The purpose is to find optimum values of Time Multiplier Setting (TMS) and Plug Setting (PS) which is used to find optimum coordination of Over-current Relays.

***Keywords*: Over-Current Relays, Time Multiplier Setting, Plug Setting, Relay Coordination, MATLAB**

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I. Introduction

According to Zoran and Milenko [1], overcurrent protection represents one of the basic protections in every power system. Overcurrent and directional overcurrent relays are widely used for the protection of radial and ring subtransmission systems and distribution systems. They are also used as backup protection in transmission systems. The input signal for this protection is the rms current of the protected element according to which tripping time of the relay is determined.

The problem of coordinating protective relays in power system networks consists of selecting their suitable settings such that their fundamental protective function is met under the requirements of sensitivity, selectivity, reliability and speed. In modern power system, abnormal condition can frequently occurring cause interruption in the supply, and may damage the equipments connected to the power system, which allows us to think the importance of designing a reliable protective system [2]. The modern society has come to depend heavily upon continuous and reliable availability of electricity and a high quality of electricity too. Since power system developments change its structure, the power system protection becomes very vital. The continuous of power systems expansion with inconsistent increase of transmission loadability leads to protection systems which are required to perform with reliability and security in the network [3].

Protection of transmission substations is one of the most important issues in power systems. Over-current relay is one of the most commonly used protective relays in these

systems. There are two types of settings for these kinds of relays: current and time settings. A proper relay setting plays a crucial role in reducing undesired effects of faults on the power systems. Over-current relays commonly have plug setting (PS) ranging from 50 to 200% in steps of 25%. The PS shows the current setting of the over-current relays. For a relay installed on a line, PS is defined by two parameters: the minimum fault current and the maximum load current. However, the most important variable in the optimal coordination of over-current relays is the time multiplier setting (TMS) [4]. For designing the protective relaying, understanding the fault characteristics is required. Related to this, protection engineer should be conversant about tripping characteristics of various protective relays. The design of protective relaying has to ensure that relays will be able to detect abnormal or undesirable conditions and then trip the circuit breaker to disconnect the affected area without affecting other undesired areas. According to statistical evidence, large numbers of relay tripping are due to improper or inadequate settings rather than to genuine faults [5].

This paper presents a study on protection coordination of over-current relays (OCRs) that will facilitate the calculation of the time multiplier setting and current setting of all relays so that the overall operating time of the primary relays are minimized properly. For optimal relay coordination, these parameters should fulfill all constraints under the operating time and lead to optimal coordination of over-current relay.

II. CHARACTERISTICS OF OVERCURRENT RELAYS

The overcurrent relay is the simplest type of protective relay. As the name implies, the relay is designed to operate when more than a predetermined amount of current flows into a particular portion of the power system. There are two basic forms of overcurrent relays: the instantaneous type and the time-delay type.

Gupta [6] pointed out that an instantaneous over current relay is one in which no intentional time delay is provided for operation. In such a relay, the relay contacts close immediately after the current in the relay coil exceeds that for which it is set. Although there will be a short time interval between the instant of pick-up and the closing of the relay contacts, no intentional time delay is provided.

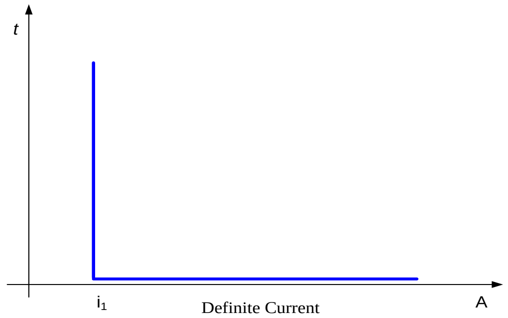

Fig. 1. Instantaneous Relay

Jignesh [7] explained that a definite time over current relay can be adjusted to issue a trip output after specified delay when the relay picks up (PSM>1). This delay is fixed and it is independent of PSM value. Thus, it has an adjustable time setting as well as a pick up adjustment. It is used for short length feeders where the fault current does not change significantly with the location of the fault across the feeder.

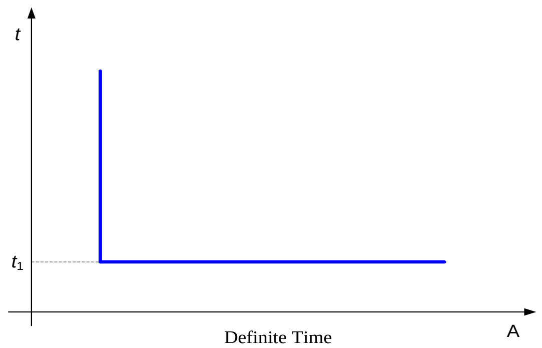

Fig. 2. Defining Time Over-Current Relay

In this type, two conditions must be satisfied for operation (tripping), current must exceed the setting value and the fault must be continuous at least a time equal to time setting of the relay. Modern relays may contain more than one stage of protection each stage includes each own current and time setting.

Definite time over current relay is applied as:

- Back up protection of distance relay of transmission line with time delay
- Back up protection to differential relay of power transformer with time delay.

Main protection to outgoing feeders and bus couplers with adjustable time delay setting

Li-aung, Y [8] stated that inverse time over current relays (IDMT Relays) is slow to trip at low currents and faster to trip at high fault currents. It is used to coordinate over load protection, which may have a high starting current. Generally, it is the most sensitive (lowest amps pickup), and slowest to operate.

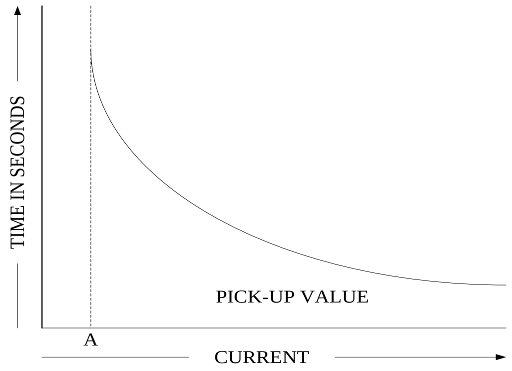

Fig. 3. Inverse Characteristics

The operating time of all over current relays tend to become asymptotic to a definite minimum value of actuating quantity. This is inherent in electromagnetic relays due to saturation of the magnetic circuit. So, by varying the point of saturation different characteristics are obtained. These are (I) definite time (II) inverse definite minimum time (III) very inverse and (IV) extremely inverse, as shown in figure 4.

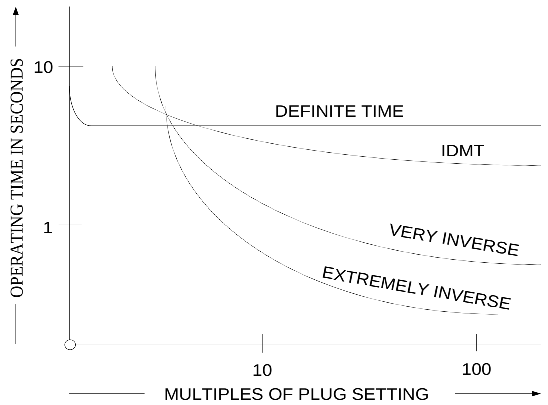

Fig. 4. Characteristics of Various Over-Current Relays

Steven [9] pointed out that the IEC 60255 standard defines four standard current/time characteristics - standard inverse (SI), very inverse (VI), extremely inverse (EI) and long-time inverse.

Each characteristic can be calculated from the equation below:

$$t = \frac{K}{\left(\frac{I}{I_S}\right)^{\alpha} - 1} \text{ x TMS}$$

Where,

t	=	Tripping time in (s)
I	=	Fault (actual) secondary CT current (A)
I_s	=	Relay pick-up current setting
TMS	=	Time Multiplier Setting

TABLE I. THE IEC 60255 IDMT RELAY CHARACTERISTICS (ALSTOM, 2011) [10]

Characteristics	Standard Inverse	Very Inverse	Extremely Inverse	Long-time Inverse
α	0.02	1.0	2.0	1.0
K	0.14	13.5	80	120

TABLE II. IEC INVERSE CHARACTERISTIC EQUATION (ALSTOM, 2011) [10]

IEC SI (Standard Inverse)	IEC VI (Very Inverse)	IEC EI (Extremely Inverse)
$t = \frac{0.14}{\left(\frac{I}{I_S}\right)^{0.02} - 1}$ x TMS	$t = \frac{13.5}{\left(\frac{I}{I_S}\right) - 1}$ x TMS	$t = \frac{80}{\left(\frac{I}{I_S}\right)^{2.0} - 1}$ x TMS

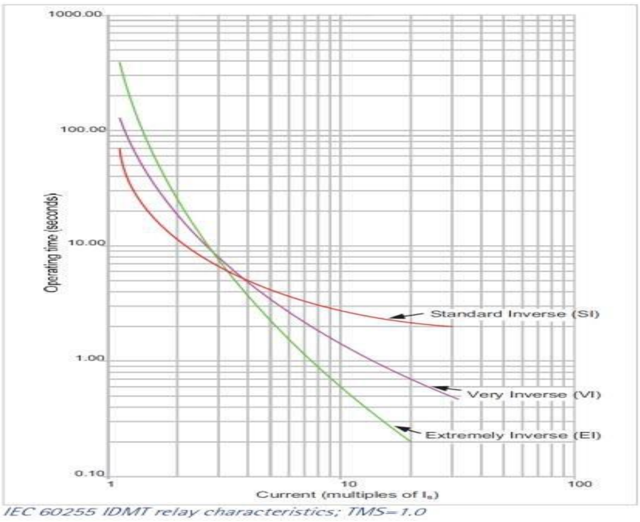

Fig. 5. Typical IEC 60255 IDMT Relay Tripping Curves (Jignesh, 2013)

Relay characteristics are sometimes classified according to the tripping time at 10 times the setting current (i.e. [3s/10] - standard inverse curve which will trip in 3 seconds at 10 times the current setting). Tripping times for the various relays are:

Standard Inverse (SI)	[3s/10] or [1.3s/10]
Very Inverse (VI)	[1.5s/10]
Extremely Inverse (EI)	[0.8s/10]
Long Time Standard Earth Fault	[13.3s/10]

III. RELAY CO-ORDINATION

The objective of relay co-ordination is to determine the characteristics, ratings, and settings of over current protective devices which will ensure that minimum faulted load is interrupted when protective devices isolate a fault or overload anywhere in the system. When relays meant to protect specific equipments, transmission/distribution lines/feeders or primary zone protective relays, do not operate and clear the fault in their primary protection zone, backup relays located in the backup zone, must operate to isolate the fault, after providing sufficient time discrimination for the operation of the primary zone relays.

The correct overcurrent relay application requires knowledge of the fault current that can flow in each part of the network. Since large-scale tests are normally impracticable, system analysis must be used. The data required for a relay setting study are:

- A one-line diagram of the power system
- The impedances in ohms, per cent or per unit, of all power transformers, rotating machine and feeder circuits
- The maximum and minimum values of short circuit currents that are expected to flow through each protection device
- The maximum load current through protection devices

The relay settings are first determined to give the shortest operating times at maximum fault levels. The time interval of operation between two adjacent relays depends upon a number of factors:

- The fault current interrupting time of the circuit breaker.
- The overshoot time of the relay
- Variation in measuring devices errors.
- Factors of safety

IV. APPLICATION STUDY

The overcurrent relay coordination study of 132/33kV transmission substation located in Eket, Akwa Ibom state of Nigeria was evaluated in order to develop a MATLAB model that will facilitate the calculation of the time multiplier setting and current setting so that the overall operating time of the primary relays are minimized properly.

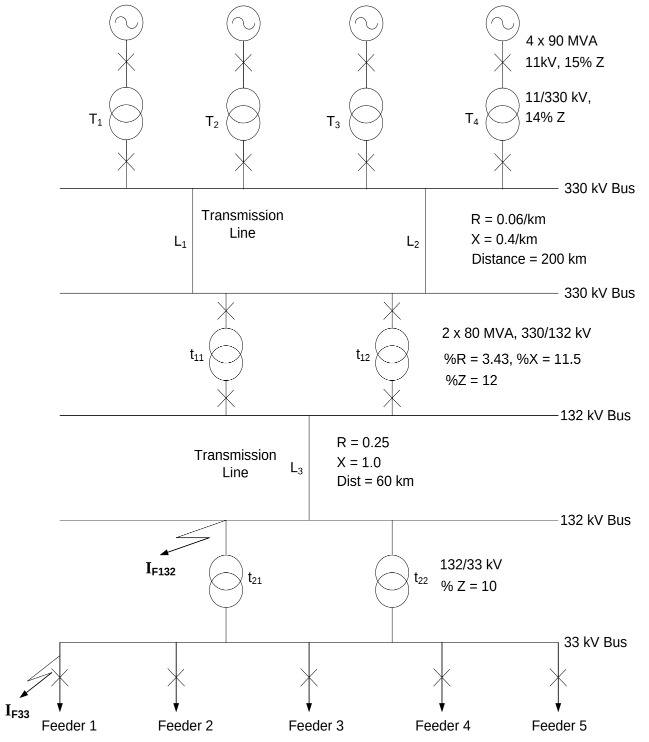

Fig. 6. Short Circuit Analysis of Eket 132/33kV Transmission Substation

The short circuit analysis of Eket 132/33kV transmission substation was carried out using hand calculation in order to obtain the fault current on 132kV and 33kV bus respectively. The results obtained are shown below.

Fault Current at IF33 = 2054.08 A

Fault Current at IF132 = 698.32 A.

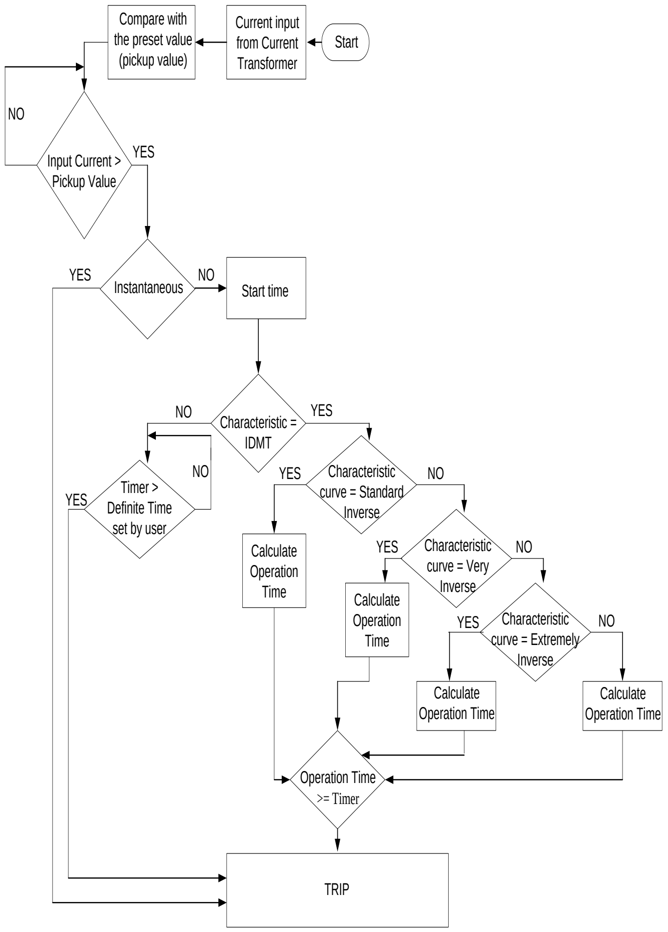

Fig. 7. Protection Algorithm Implemented in the Overcurrent Relay Model

Relay Co-Ordination Settings are generally based on their characteristic curve, which indicates the speed of operation. The characteristics are: (1) Standard Inverse (2) Very Inverse and (3) Extremely Inverse

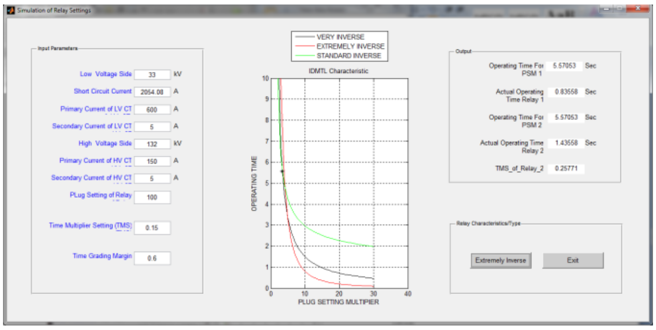

Fig. 8. Extremely Inverse Relay Co-Ordination Setting

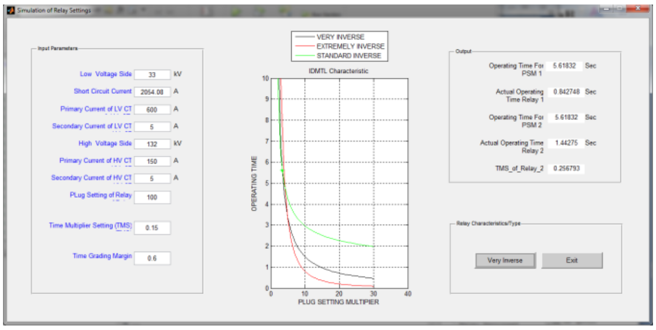

Fig. 9. Very Inverse Relay Co-Ordination Setting

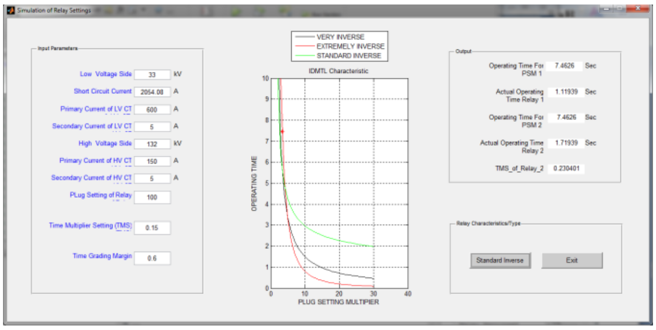

Fig. 10. Standard Inverse Relay Co-Ordination Setting

V. RESULT ANALYSIS

The respective values of actual operating time and time multiplier settings recorded from the simulation of the different overcurrent relay characteristics are shown in Fig. 8 to Fig.10.

TABLE III. OVERCURRENT RELAY CHARACTERISTICS

Characteristics	Standard Inverse	Very Inverse	Extremely Inverse
Actual Operating Time of Relay_1 (sec)	1.11939	0.842748	0.83558
Actual Operating Time of Relay_2 (sec)	1.71939	1.44275	1.43558
TMS (sec)	0.230401	0.256793	0.25771

The time of operation of these relays varies, with the extremely inverse relay the smallest, followed by the very inverse and standard inverse. It would be observed that the three relay characteristics must be considered during the relay setting. The Standard Inverse characteristic takes care of faults within the utility substation. The Very Inverse characteristic takes care of fault at the mid-point of the feeder while the Extremely Inverse characteristic takes care of fault at the far end of the feeder

CONCLUSION

The relays in the power system are to be coordinated properly so as to provide primary as well as back up protection, and at the same time avoid malfunction and hence avoid the unnecessary outage of healthy part of system. In this paper, the operating time of the relays was determined using a MATLAB Graphical User Interface (GUI) model. Thus it can be concluded that the results obtained showed the proper coordination of the different overcurrent relay characteristics.

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