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Power System Protection with Relay Co-Ordination

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Abstract: **Relay co-ordination plays an important role in the protection of power system. For proper protection, proper co-ordination of relays with appropriate relay settings is to be done. Relay settings are done in such a way that proper co-ordination is achieved along various series network. Relay co-ordination can be done by selecting proper plug setting and time multiplication setting of the relay, considering maximum fault current at the relay location. After selecting the plug setting and time multiplier setting, the co-ordination can be checked graphically. When plotting co-ordination curves, certain time intervals must be maintained between the curves of various protective devices in order to ensure the correct sequential operation of the devices when co-coordinating inverse time over current relays. For a given fault current, the operating time of IDMT relay is jointly determined by its plug and time multiplier settings. Thus this type of relay is most suitable for proper coordination. Operating characteristics of this relay are usually given in the form of a curve with operating current of plug setting multiplier along the X axis and operating time along Y axis.**

Keywords: **Optimal coordination of relay, Primary and Back-up relay, Time setting multiplier, Plug setting multiplier, Relay setting, Over current relay, IDMT relay.**

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1. Introduction:

Protection system for power system has been developed to minimize the damage and to make sure supply in safe condition, continuously and economically. Relay is one of the most important components in protection system. There is several kind of relay that each kind has own characteristic. A relay is device that makes a measurement or receives a signal that causes it to operate and to effect the operation of other equipment. It responds abnormal conditions in faulty section of the system with the minimum interruption of supply. The advantages of isolating a system fault as quickly as possible include safety for personnel and public, minimizing damage to Power plant and minimizing effects on system stability.

2. Problem Statement:

Power system for must have a reliable and efficient protection scheme. Once fault occurred on the system, it must be isolated as quickly as possible. This action could minimize the effects on system stability and damage to plant. Referring to figure 1.1, when a fault occurred on the system, one of the relay should be operated. However, sometimes the relay that should be operated due to the fault does not work properly delay in operation or does not function at all. It might be due to the problems from the setting of the relay. Therefore, relay should be set properly to make it will function accordingly. So, related to the problem, the study will be focused to the setting and coordination of the relays that used in distribution system.

3. Primary and Back-up Protection:

For attaining higher reliability, quick action and improvements in operating flexibility of the protection schemes, separate elements of a power system , in addition to main or primary protection , are provided with a back-up and auxiliary protection. First in line of defense is main protection which ensures quick action and selective clearing of faults within the boundary of the circuit section or the element it protects. Main protection is essentially provided as a rule. Back up protection gives back up to the main protection, when the main protection fails to operate or is cut out for repairs etc. Failure of the main protection may be due to any of the following reasons:

A) D.C supply to the tripping circuit fails
B) Current or voltage supply to the relay fails
C) Tripping mechanism of the circuit breaker fails
D) Circuit breaker fails to operate
E) Main protective relay fails

Back up protection may be provided either on the same circuit breakers which will be opened by the main protection or may use different circuit breakers. Usually, more than the faulty section is isolated when the back-up protection operates. Very often the main protection of a circuit acts as back up protection for the adjacent circuit. Back up protection is provided where main protection of the adjacent circuit fails to back up the given circuit. For simplification, back up protection can have a lower sensitivity factor and be operative over a limited back up zone i.e. be operative for only part of the protected circuit.
Methods of back up protection can be classified as follows:

A) Relay Back-up
B) Breaker Back-up
C) Remote Back-up
D) Centrally Co-ordinated Back-up

Back-up protection by Time Grading principle:

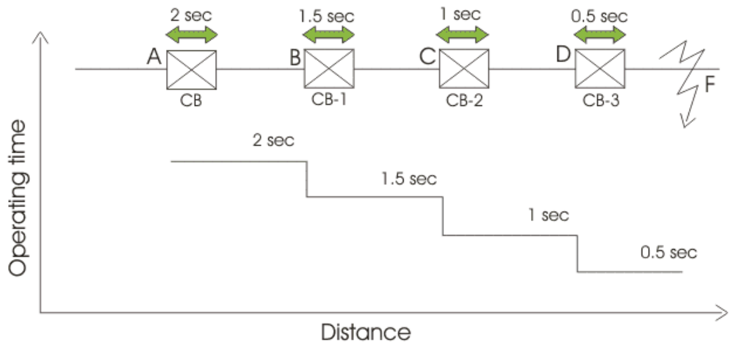

Fig. 1: Primary and Back-up Protection by Time Grading Principle

In this, current is measured at various points along the current path, for e.g., at source, intermediate locations, consumers end. The tripping time at these locations are graded in such a way that the circuit breaker nearest to the faulty section operates first, giving primary protection. The circuit breaker at the previous section operates only as a back-up.

In Fig.3 the tripping time at sections C, B and A are graded such that for a fault beyond C, breaker at C operates as a primary protection. Relays at A and B also may start operating but they are provided with enough time lags so that breaker at B operates only if breaker at C does not. Thus, for a fault beyond C, breaker at C will operate after 0.1 second. If it fails to operate, the breaker at B will operate after 0.6 second (Back-up for C) and if the breaker at B also fails to operate, breaker a A will operate after 1 second (Back-up for B and C.

4. Test System:

The step by step analysis is described in the subsequent segments.

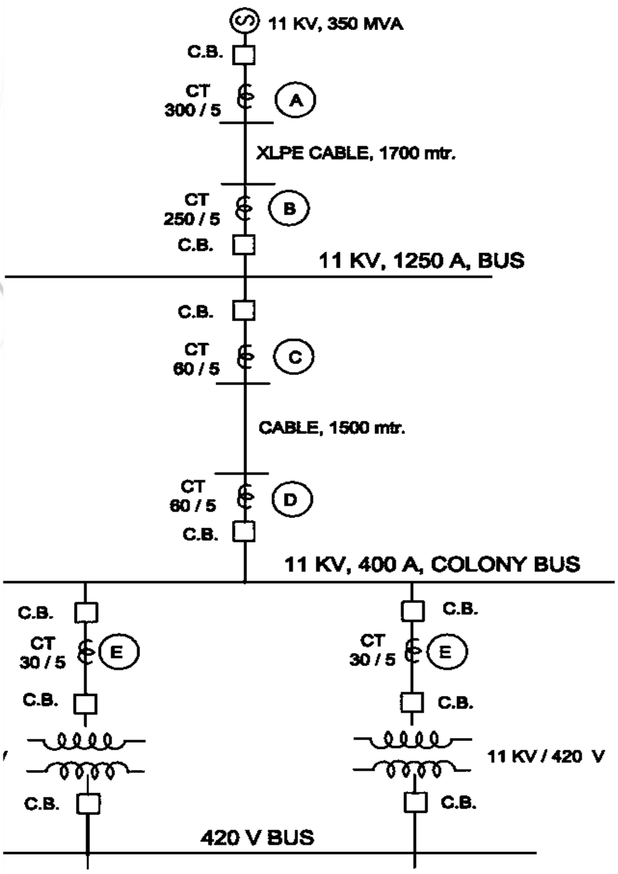

Fig. 2 : Single line diagram

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Relay Characteristics:

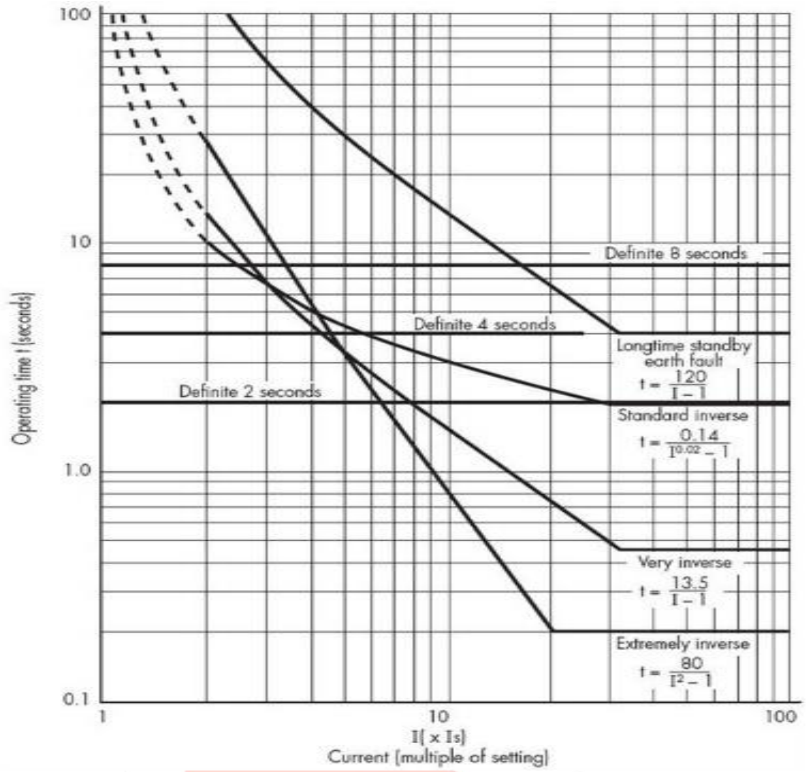

Fig. 3: Various characteristics of IDMT relay

Fig. 3 shows various inverse characteristics of induction disc relays. Characteristics are of four types:

A) Standard or Normal Inverse
B) Very Inverse
C) Extremely Inverse
D) Long Inverse

For Normal inverse over current characteristics, the operation time is inversely proportional to the applied current. Very inverse over current characteristics are particularly suitable if there is a substantial reduction of fault current. The characteristics of this relay are such that its operating time is approximately doubled for a reduction in current from 7 to 4 times the relay current setting. This permits the use of the same time multiplier setting for several relays in series.

5. Calculations :

Calculation of relay operating time:

In order to calculate the actual relay operating

A) Time / PSM Curve
B) Plug Setting
C) Time Setting
D) Fault Current
E) Current Transformer Ratio

The procedure for calculating the actual relay operating time is as follows:-

A) Convert the fault current into the relay coil current by using the current transformer ratio.
B) Express the relay current as a multiple of current setting, i.e. calculate the PSM.
C) From the Time/PSM curve of the relay, with the calculated PSM the corresponding time of operation can be obtained.
D) Determine the actual time of operation by multiplying the above time of the relay by time-setting multiplier in use.

Formulae for calculations:

Relay current at fault condition, $I_R = \dfrac{I_f}{\text{CT Ratio}}$

Plug setting multiplier,

$$PSM = \frac{\text{fault current in relay coil}}{\text{Pick up current}}$$

Pick up current = Rated secondary current of C.T x Current setting

Operating time, $T = \dfrac{0.14}{I_r^{0.02} - 1} \times TMS$ Ir = PSM,

In general,

$$T = \frac{k \times TMS}{(I/I>)^{\alpha} - 1}$$

Where,

T = Operating time in sec

TMS = Time Multiplier Setting

k ,α, β = Curve constants

I = Fault Current,

I > = set current

Type of curve	α	K	β
Normally inverse	0.02	0.14	2.97
Very Inverse	1.0	13.5	1.5
Extremely Inverse	2.0	80.0	0.808
Long-time Inverse	1.0	120.0	13.33

Table : Table of constants for various curves

By using this calculation equation and table, we can calculate PSM, TSM, pick up current, actual operating time as shown in below.

Table of calculation:

C.T. RATIO	P.S. (%)	Fault Current (kA)	TSM
300/5	200	5.870	0.25
250/5	150	5.0	0.20
60/5	125	4.80	0.15
60/5	100	4.75	0.10
30/5	50	4.42	0.05

PSM	PICK UP	IR	ACTUAL OPERATING TIME
0.587	10	0.097	0.146
0.66	7.5	0.1	0.132
0.68	6.25	0.4	0.102
0.95	5	0.39	0.095
1.768	2.5	0.736	0.0884

6. Conclusion:

Main objective of protective relay co-ordination in an interconnected power system is to achieve proper selectivity and speed without sacrificing sensitivity and fast fault clearance time. For optimal relay co-ordination the current setting of relays are known prior and then find the time multiplier setting (TMS) of the relays. Current setting and time multiplier setting of all relays are considered as optimization parameters. By appropriate relay coordination we can achieve proper fault identification and fault clearance sequence. A coordination study provides data useful for selection of instrument transformers, protective relay characteristics and settings, fuse ratings, and other information pertinent to provision of optimum protection and selectivity in coordinating these devices. Coordination is a systematic application of current actuated devices in a power system, which in response to a fault or overload will remove only a minimum amount of equipment from service. The objective of relay co-ordination is to minimize the equipment damage.

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