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RELAY COORDINATION IN THE PROTECTION OF RADIALLY-CONNECTED POWER SYSTEM NETWORK

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Abstract

Protective relays detect intolerable or unwanted conditions within an assigned area, and then trip or open one or more circuit breakers to isolate the problem area before it can damage or otherwise interfere with the effective operation of the rest of the power system. It often happens that a substation feeder relay and supply-side relay both trip for the same feeder fault. This occurrence, known as over-trip is undesirable, and is usually blamed on poor relay coordination. The relay and breaker nearest to the point of fault must be able to see the fault and operate before other relays in the system so that healthy parts of the system will not be interrupted. How to achieve this is the subject of this paper.

Keywords: relay, fault, trip, coordinating time interval, feeder

1. Introduction

When a feeder fault causes the supply-side relay to trip, not only are the customers on the faulted feeder inconvenienced with an outage, but all the customers that are being served by the other feeders from the same supply-side relay and breaker also experience an outage. Therefore necessary discrimination must be enabled during fault conditions. This can be achieved in the following ways [1]:

(a) by monitoring only current level – current grading

(b) by monitoring time delayed operation – time grading

2. Application

2.1. Current grading

With reference to figure 1, correct discrimination can be achieved with instantaneous overcurrent relays by setting R_2 at lower current than R_1. Thus, the current setting of a relay nearer the source must always be higher than the setting of the preceding relay. The current in the feeder between B and C is 500A and the current between A and B is 200 + 500 = 700A. The relays must have current settings which are higher than any current which can flow through the relays under normal conditions i.e. 110% of the rated current. Electronic and microprocessor-based relays have current setting steps of 5% [2], [3].

The current setting of the relay, $R_2 = \frac{550}{800} = 0.69$;

The setting of R_1 should be at least $\frac{I}{I_N} = \frac{770}{800} = 0.96$;

If relay R_2 were given a higher setting than R_1 mal-operation would occur in the protection. In any case, in the event of short circuit beyond R_2 downstream, large currents much greater than 800A would flow, and the two relays would trip at the same time. Current grading will therefore not be suitable.

2.2. Time grading

Selectivity during fault conditions would be achieved by using relays set to operate after different time delays. The difference in operating

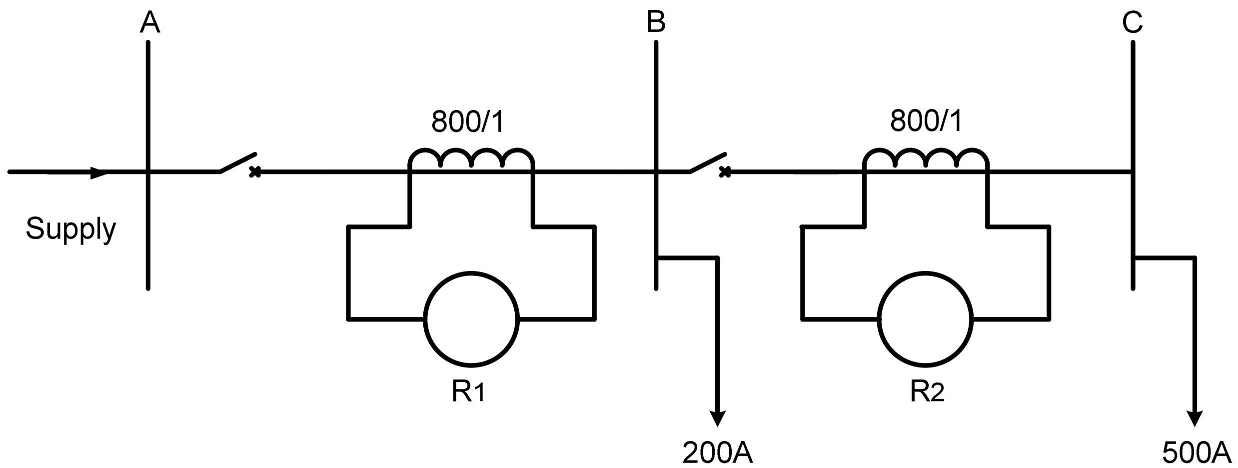


Figure 1: Current discrimination in a radially-connected network.

times between upstream and downstream relays for discrimination or coordination purposes is called coordinating time interval (CTI). As stated earlier, the goal is to allow enough time for the relay and breaker closest to the fault to clear the fault from the system before the relay associated with the adjacent section nearer to the source could initiate the opening of its circuit breaker. For example, the feeder relay and breaker, which are downstream, should clear a feeder fault before the supply-side relay and breaker (upstream) could trip. Generally, CTI of about 0.4 seconds is allowed. This CTI takes the following into consideration [4]:

- Breaker fault-interruption time is taken as 0.15s.
- Over travel of the induction disk or solid-state relay after the fault current has been interrupted is provided for by 0.1s.
- A safety margin of 0.15s to compensate for possible deviations in calculated fault currents, relay tap selection, relay operating time, and current transformer ratio errors.

2.2.1. Time grading using relays with definite operating times

Let us illustrate this phenomenon with figure 2 shown below.

Network parameters: G: 2MVA, 10%; T_1: 2MVA, 11/3.3KV, 7%; T_2: 500KVA, 3.3/0.415KV, 6%; Lines 1, 2, 3: 0.02 Ω/ph; Line 5: 0.2Ω/ph; Line 8: 0.2Ω/ph; System MVA base = 20MVA; Positive and negative sequence impedances are assumed equal. [1]

In this network, for a fault at the point F_1, relays R_1, R_2 and R_3 must not operate in less than 0.5s.

Reactance of $G = 1p.u$; Reactance of $T_1 = 0.7p.u$; Reactance of Line $8 = 0.367p.u$; Reactance of Line $5 = 0.367p.u$; Reactance of $T_2 = 2.4p.u$; Reactance of Line $1 = 2.323p.u$;

A three-phase fault gives the highest short-circuit current. This current is applied in the settings for the protection to be used [5]. The fault current, I for three-phase fault at the points are:

$$F_1 : I = \frac{1}{7.157} \times \frac{20000}{\sqrt{3} \times 0.415} = 3888A$$

Similarly, $F_2 : \ I = 5756$A, $F_3 : I = 1437$A, $F_4 : I = 1693$A, $F_5 : I = 2058$A.

According to the maximum ratings of the lines, and allowing 100% setting, the current settings of the relays should be as follows: $R_1 = 200$A; $R_5 = 105$A; $R_8 = 280$A; $R_{10} = 105$A. It can be seen that with instantaneous over-current relays, if current of 400A, for example, due to overload flows in line1, relay R_1 only will trip, giving correct discrimination. But for fault current of 3888A at point F_1, R_{10} would operate instantly since this is about 1.5 times its setting. This is undesirable. So it is necessary to add time discrimination with time settings increasing towards the source, as shown in figure 3.

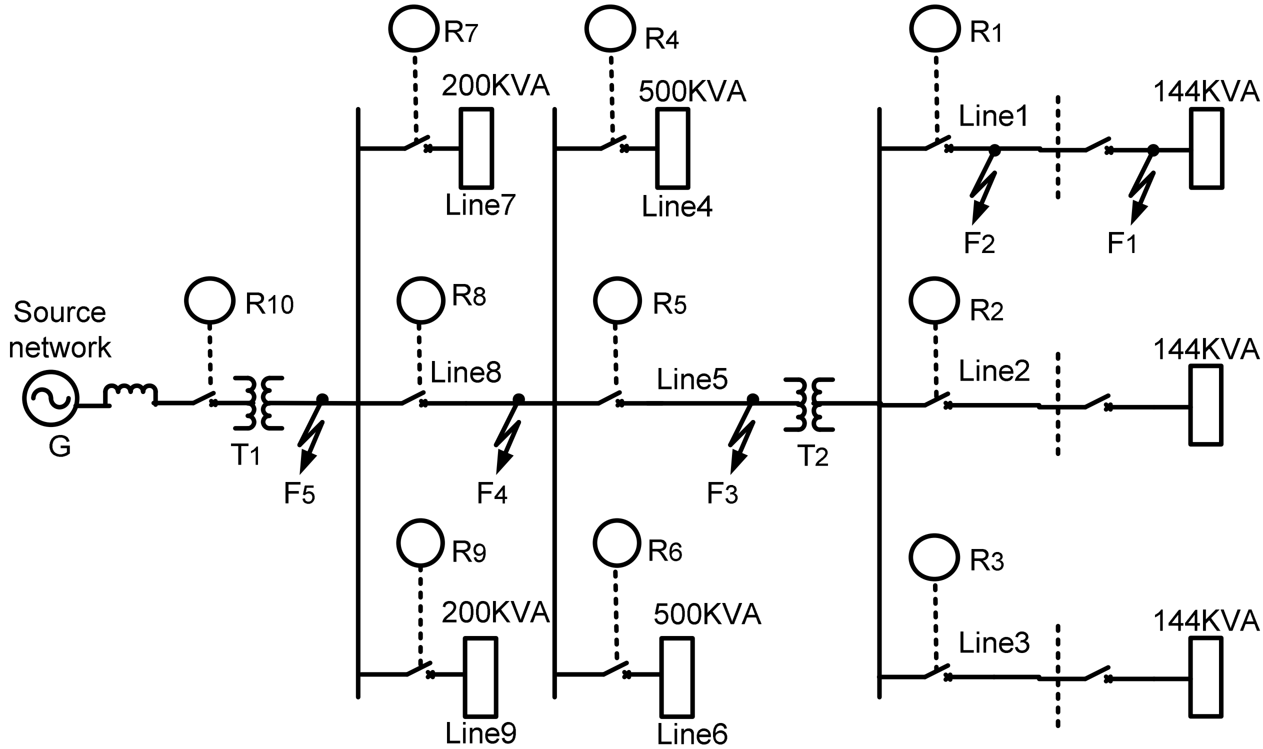


Figure 2: Protection of radially-connected network.

The time settings of the relays are: R_1: 0.5s, R_5: 0.9s and R_8: 1.3s; R_{10} = 1.7s.

Thus for the protection of a network containing several sections in series as shown in figure 2, the relay nearest to the source may have unacceptably high operating times for faults in the sections they protect. In other words, the tripping time for a fault near the power source may be dangerously high [6]. This is because the current level associated with such faults is large and destructive, and must be removed very quickly. Therefore relays with definite time lags are suitable for the protection of networks with relatively few series-connected sections only.

2.2.2. Time grading using relays with inverse time/current characteristics

In these relays tripping time is inversely proportional to the current magnitude. We apply inverse definite minimum-time (IDMT)' relay with normal inverse characteristic given as [7]

$$t = \frac{0.14}{\left(\frac{I}{I_S}\right)^{0.02} - 1} T_P \quad (1)$$

Where t = tripping time of relay, T_p = time

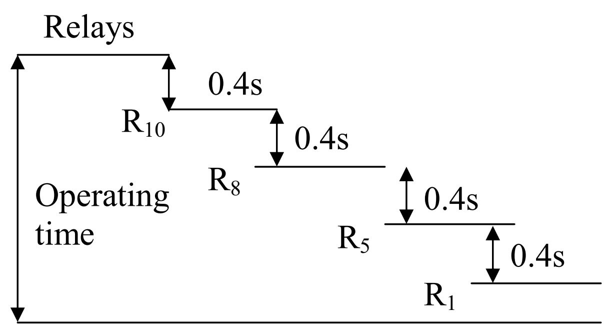


Figure 3: Discrimination achieved with definite-time over-current relay.

Table 1: Summary of settings.

Relay	$\mathbf{I_S}$ (A)	$\mathbf{T_P}$
R_1	200	0.22
R_5	105	0.24
R_8	280	0.24
R_{10}	105	0.3

multiplier setting (TMS), I = fault current, I_S = set pick-up current.

So for relay R_1 in figure 2, $I = 3886$A (fault at point F_1), $I_S = 200$A, $t = 0.5$s.

Note that it is assumed that R_1 operated in 0.5s to discriminate from the relay which operates in 0.1s [2]. Therefore, from equation (1), $t = 2.29T_P$. So if the relay R_1 is set at 1.0 (TMS), it would operate in 2.29s. However, as R_1 is required to operate in 0.5s, T_p is equal to 0.22, which is now the relay setting. For three-phase fault at point F_2, $I = 5756$A. This is the maximum possible short circuit current that can flow in line 1, i.e., the fault level. Therefore the time, t which relay R_1 takes to interrupt this current is computed as:

$$t = \frac{0.14}{\left(\frac{5756}{200}\right)^{0.02} - 1} \times 0.22 = 0.44\text{s}$$

So the tripping time of R_1 has now been reduced to 0.44s

For R_5:

$I_S = 105$A, $t = 0.44 + 0.4 = 0.84$s, $T_p = 0.24$.

The maximum fault current which relay R_5 would have to deal with is 1437A.The operating time of R_5 for this current is $2.6 \times 0.24 = 0.62$s.

For R_8:

I_S =280A, $t = 0.62 + 0.4 = 1.02$s, $T_p = 0.24$.

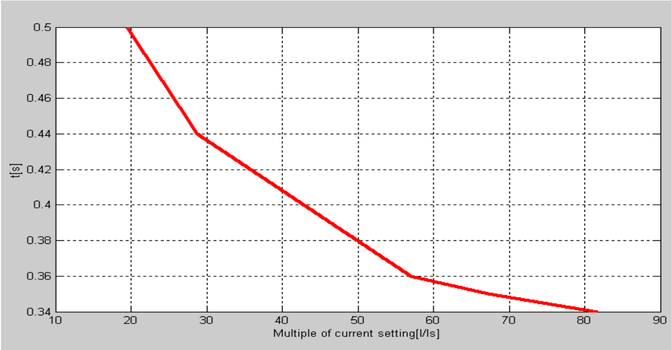
The fault current level of line 8 is 1693.The operating time of R_8 for this current is $3.82 \times 0.24 = 0.92$s.

For R_{10}:

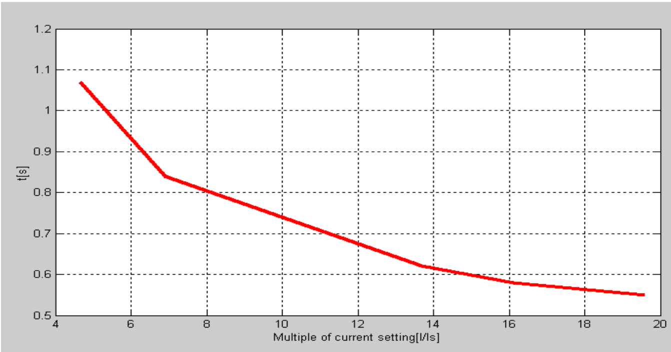
I_S =105A, $t = 0.92 + 0.4 = 1.31$s, $T_p = 0.3$.

The maximum fault current that would go through relay R_{10} is 616A.The operating time of R_{10} for this current is 3.9 s $\times$ 0.3 = 1.17s

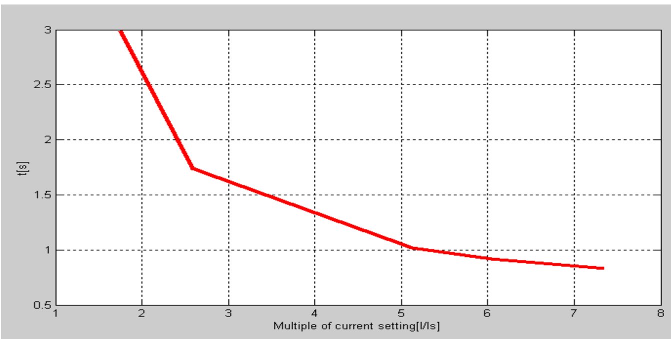
The tripping times of the relays for the various fault currents are shown in table 2, and the trip time/current curves follow in figures 4a, 4b, 4c and 4d.



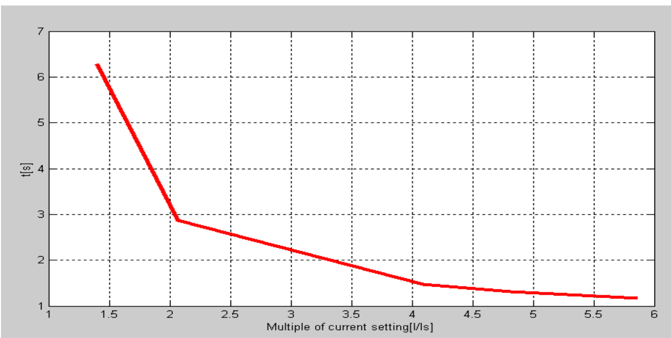
(a) Trip time characteristic of inverse time over-current protection relay R_1



(b) Trip time characteristic of inverse time over-current protection relay R_5



(c) Trip time characteristic of inverse time over-current protection relay R_8



(d) Trip time characteristic of inverse time over-current protection relay R_{10}

Figure 4:

Table 2: Fault currents and trip times of relays.

Fault location	**Fault current, I (A)**	**Trip time, t(s)**			
		$\mathbf{R_1}$	$\mathbf{R_5}$	$\mathbf{R_8}$	$\mathbf{R_{10}}$
F_1	3888	0.5	1.07	2.99	6.28
F_2	5756	0.44	0.84	1.74	2.87
F_3	1437	0.36	0.62	1.02	1.47
F_4	1693	0.35	0.58	0.92	1.31
F_5	2058	0.34	0.55	0.83	1.17

From the graphs, it is clear that tripping time is inversely proportional to the magnitude of fault current. As fault current increases, trip time decreases.

3. Conclusion

Obviously, to obtain correct discrimination, relays with inverse time/current characteristics are preferred. They give rapid clearance for large faults and sustained over-loads. Current grading using instantaneous over-current relays have very limited use. They can only be applied where there is abrupt difference in magnitude between fault current within the protected section and fault current outside it. In radial circuits with many sections in series, application of relays with definite operating time results in the tripping time for a fault near the power source being dangerously high.

References

1. C. Christopoulos, A. Wright. *Electrical Power System Protection*, Kluwer Academic Publishers, the Netherlands, 1999.
2. T. Davies. *Protection of Industrial Power Systems*, Newnes, 2001.
3. Sachdev, M.S. *Microprocessor Relays and Protection Systems*, IEEE Tutorial Course, 88EH0269-1-PWR, 1988.
4. Michael Ray Russell, Russ Poteet. *Transmission and Distribution World*, October, 1998.
5. B.M. Weedy, *Electric Power Systems*, John Wiley and Sons, 1975.
6. A.R. van C. Warrington, *Protective Relays: Their Theory and Practice*, Chapman and Hall, 1971.
7. 7SJ600 V2 - *Siemens Relay Manual*.