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Optimal co-ordination of overcurrent relays in the interconnected power systems using break points

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ABSTRACT

Interconnected power systems are multi-loop structured. In such networks, the determination of settings for all overcurrent relays can be carried out in different forms and may be quite complicated.

Optimal coordination of overcurrent relays is a solution to find optimal time setting of the relays in interconnected networks. However, the optimal coordination method without using correct and efficient starting points i.e. the location of initial relays in the procedure for settings may cause many miscoordinations or the solution may not converge.

In this paper an innovative approach is proposed in which both optimal coordination and break points for initial relays to find the settings of overcurrent relays are utilized. The fault location is in front of main relay and network configuration is so that maximum current flows through backup relay. Therefore, network configuration is taken into consideration and the suggested approach reflects configuration changes. A comparison between optimal coordination of overcurrent relays with or without break points and the conventional procedure of overcurrent relays coordination is presented.

The results show the advantages of the proposed method.

1. Introduction

Directional overcurrent relays are commonly used as an economical protection method for distribution systems as the main protection and for transmission systems as the backup protection. Conventional and computerized methods have been used in past efforts to coordinate overcurrent (OC) relays. Different techniques for both interconnected and industrial networks have been considered by Coordination algorithms [1–4]. The number of loops presented in the system causes increased complexity of the problem. The complication in setting OC relays occurs when the setting of the last relay in a loop, which closes the loop, is done in sequence and it must be coordinated with other OC relay sets in that loop. If this setting is not successful, the procedure must be repeated around the loop again. It is obvious that a given relay is usually shared by more than one loop. Therefore, this procedure needs to be organized. In fact, selecting a minimum set of relays to begin the process using the break points is required for a given network [5].

There are two approaches to coordinate protective devices in power systems: non-optimal and optimal [1,2].

It has been shown that linear optimal programming can be applied to optimize relay settings in interconnected power systems [3]. The optimal coordination of OC relays is a linear-programming problem for minimizing the operating times of OC relays; this is referred to as an objective function subject to the coordination constraints. The constraints define coordination criteria based on the primary and backup (P/B) pair of relays [2,4]. Typical methods of linear programming technique are the simplex [2–4] and dual simplex methods [6].

In [7] a new approach for optimal coordination of directional OC relays is proposed. This approach does not require additional auxiliary variables and an objective function. Simplicity and a lower number of iterations to converge are advantages of this method. Genetic algorithms [8], differential evolution algorithm [9] and particle swarm optimization [10,11] are other methods that have been applied for optimal coordination of OC relays in the power or distribution networks.

In these methods only optimization of relay time setting has been taken into account. The effect of network topology and its changes on the operation of the overcurrent relays have not been considered within the optimal coordination procedure.

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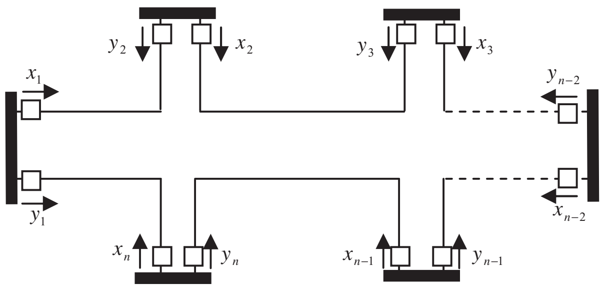

Fig. 1. Single diagram of a sample looped network.

Six pair currents is another technique which can be used for coordination of overcurrent relay settings. An ordinary co-ordination procedure using six pair currents has been used in [6].

In this paper a new coordination method for OC relays is developed in which two important features, an optimal coordination procedure and efficient break points are used in the computer program. Network topology change is also taken into consideration to calculate maximum fault current. Therefore higher accuracy, flexibility, and minimum time settings have been achieved.

2. Problem statement

The existing optimal co-ordination method does not consider the starting point of optimal procedure and most of them only applied on the test networks with a limit number of OC relays. In this paper break point is introduced for optimal coordination. In addition, the condition in which maximum current passes through backup relay is discussed.

2.1. Break points

Selectivity is one of the most important properties of protection systems that should be taken into account especially for relay coordination. Selectivity means that the closest relay to the fault (primary relay) must operate first to isolate the fault. If the relay closest to the fault does not operate, then the backup relay should operate after a time delay. Selectivity guarantees the minimum outage during fault clearance.

Finding the coordination inception points is a very important issue in relay coordination. In radial networks, the coordination procedure starts from the most remote relay with respect to the source. In other words, the most remote relays to the source are the inception points of the coordination problem. Each primary and backup relay can be detected and coordinated easily. However, in interconnected networks containing loops, selection of inception points becomes a challenge. The reason is illustrated in Fig. 1. In this looped network, all x_1 to x_n OC relays are working in the same direction. The x_n relay is assumed the inception point of the coordination procedure and its time setting multiplier (TSM) is set to the minimum value. Then, the time–current characteristics of the relay x_{n-1} can be determined based on the TSM of the relay x_n and the procedure keeps going to the relay x_1. As can be seen from Fig. 1, relay x_n is a backup for the relay x_1 and its TSM should be calculated based upon the relay x_1. This sample network shows how overcurrent relay settings in a loop are dependent on each other sequentially. This is similarly true for settings of the relays $y_1, y_2, \ldots, y_{n-1}, y_n$. In interconnected networks, break points are considered to be suitable tools to determine the inception points of coordination. Therefore, the sequences of relays as well as primary and backup relays are specified, considering break points. For instance, the relay set of x_1 and y_2 in Fig. 1 can be chosen as the break points of the network.

After identifying primary and backup relays, their time coordination condition (such as operation of the primary relay before the

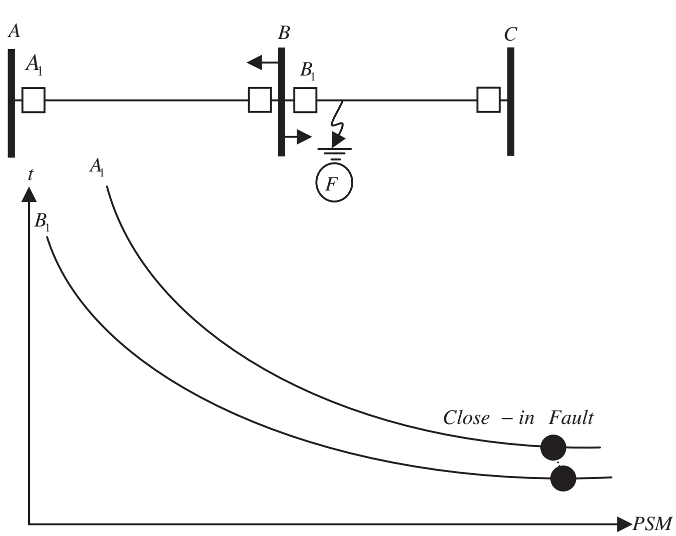

Fig. 2. Location of close-in fault current for each primary and backup relays pair.

Table 1
Constants and exponents for IEC standard characteristics.

Curve type	A	p
Normally inverse (C1)	0.14	0.02
Very inverse (C2)	13.5	1
Extremely inverse (C3)	80	2
Long-time inverse (C4)	120	1

Table 2
Constants and exponents for IEEE standard characteristics.

Curve type	A	B	p
Moderately inverse (U1)	0.0515	0.114	0.02
Very inverse (U2)	19.61	0.491	2
Extremely inverse (U3)	28.2	0.1217	2

Table 3
Three-phase fault current of r_1 (main relay) and r_6 (backup relay) in different network configuration for proposed method.

Condition	Main relay short circuit current (A)	Backup relay short circuit current (A)
Line B_1–B_3 out	5637.38	2916.79
Line B_1–B_3 out and breaker at r_8 open	4667.57	4667.56

Table 4
Three-phase fault current of r_7(main relay) and r_5(backup relay) in different network configuration for proposed method.

Condition	Main relay short circuit current (A)	Backup relay short circuit current (A)
Line B_2–B_6 out	2279.76	599.3
Line B_2–B_6 out and breaker at r_{14} open	5197.98	1903.4
Line B_2–B_6, Trans B_6–B_8 out and breaker at r_{14} open	2105.84	2106.15