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An accurate method for overcurrent–distance relays coordination in the presence of transient states of fault currents

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ABSTRACT

Regarding to dynamic nature of power system, short-circuit current also includes transient currents in addition to steady current. Transient components of fault currents may disturb the coordination between overcurrent (OC) and distance (Dis) relays because of the dependence of the operating time of inverse time overcurrent (OC) relays to the value of the short-circuit current. In this paper, a method for OC–OC and OC–Dis relay coordination, considering transient states of short-circuit currents, is presented. The dynamic model of the inverse time OC relay is used. A new formulation based on the dynamic model is presented to incorporate the pickup current (Ip) into the coordination algorithm, in addition to the time setting multiplier (TSM). To improve OC–OC and OC–Dis relay coordination, the selection of various curves types for OC relays is considered. Adapted particle swarm optimization (PSO) algorithm is used to obtain optimal results for the coordination of relays. The proposed OC–OC coordination and OC–Dis coordination methods are implemented on a radial and a meshed network, and the results are compared with the conventional method of coordination.

1. Introduction

The electrical power system is the largest dynamic system created by mankind. Therefore, it is expected that, in the event of any change (i.e., fault) in the system, its dynamic nature will likely cause transient states in the fault current.

OC relays are widely used for the protection of sub-transmission and distribution power networks. In previous studies, several methods for the optimal coordination of OC relays have been introduced. These methods include mathematical and heuristic optimization methods. Linear programming [1], quadratic programming [2], binary integer programming [3] and the interior point algorithm [4] are among the mathematical optimization methods proposed. Intelligent optimization coordination methods are also presented for obtaining the optimal TSM and Ip for inverse time OC relays, including the: genetic algorithm [5]; evolutionary algorithm [6]; differential evolution algorithm [7]; firefly algorithm [8]; and non-dominated sorting genetic algorithm [9]. References [10,11] have a brief comparison between various optimization algorithms.

Since the OC relay coordination algorithm may have no answer in interconnected networks, methods for finding the break point [12–14] and considering the priority of constraints [15] are proposed. To achieve better results for optimal coordination, standard and non-standard characteristic curves of OC relays are considered in the optimization problem in References [16,17] and [18], respectively. Authors in Reference [19] used six pairs of short-circuit currents for relay coordination.

Protection of sub-transmission networks is usually offered by both OC and Dis relays. Previous studies [20,21] attempt to set Dis relays in coordination with the OC relays. In Reference [22], OC–Dis and Dis–OC relay coordination as well as OC–OC coordination were investigated. In Reference [23], by presenting a non-standard characteristic for Dis relays, coordination between OC and Dis relays was established. This coordination is investigated in a series-compensated system in Reference [24].

Previous studies in the field of relay coordination optimize the operating time of relays using fixed short-circuit currents and ignore the transient states of current. Therefore, relays are apparently coordinated, but in practice, the coordination constraints may not be satisfied because of transient currents. Reference [25] investigates the effect of transient states of fault current limiters (FCLs) and distributed generations (DGs) upon relay coordination in distribution systems, and introduces a method to coordinate relays in the

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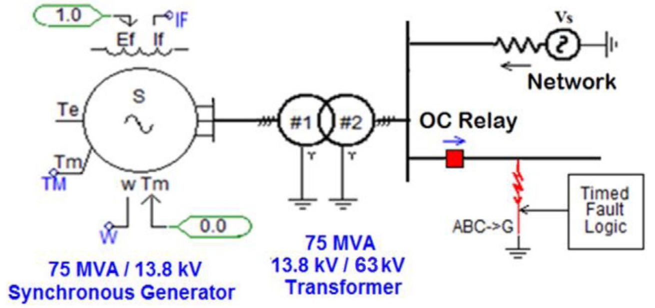

Fig. 1. Part of a sample network with a synchronous generator.

presence of transient states of FCLs and DGs. The proposed method calculates time settings of relays using the genetic algorithm.

In this study, the effect of generator transient currents on the performance of the relays, including OC and Dis relays, is assessed. Then, a practical method is proposed using a dynamic model of the OC relay to coordinate OC–OC and OC–Dis relays in the presence of transient fault current. To improve relay coordination, it is essential to incorporate the selection of the Ip and the curve type of OC relays using the optimization algorithm. A new formulation based on dynamic model of OC relay is proposed to achieve this goal. The proposed method can be used in the computing software to obtain accurate setting of OC and Dis relays in the presence of various transient fault currents of network. Finally, the new method is applied on two sample network, and the results are compared with the conventional method.

2. Problem statement

There are different sources in the power system that may produce transient fault currents, including; generators, large motors, fault current limiters, and inverters. In this paper, the transient fault currents of synchronous and asynchronous generators are studied. Since the proposed method is based on dynamic model of OC relay, it can be extended to other sources of transient fault current.

2.1. Effect of transient currents on OC relays operating time

Fig. 1 shows part of a sample network with a synchronous generator connected via a transformer. The parameters of generator and transformer are given in Appendix A, Table 8. The dynamic parameters of synchronous generator are according to Reference [26]. For a fault occurring close to the circuit breaker of the OC relay, the fault current flowing through the OC relay is obtained as Fig. 2(a). In numerical OC relays, the measured fault current is filtered by applying the discrete Fourier transform (DFT) and DC component elimination. The filtered fault current is given in Fig. 2(b).

In the conventional methods, an approximated fixed fault current is used for relay setting and coordination instead of the real transient fault current. The fixed fault current is calculated using the transient impedance of generator (X′). This is calculated and shown in Fig. 2(b) as a horizontal line for the sample network (1463A).

Using a fixed fault current causes an error in the calculation of the relay operating time. The calculation error for the operating time of OC relays is shown in Fig. 3. In Fig. 3(a) the operating time error is obtained versus the operating time of relay for three curve types. Using the very inverse characteristic curve type (VI), if the real operating time calculated by the transient fault current is 0.1 s, the operating time calculated by the fixed fault current is 0.13 s, with 13% error. These errors cause inaccuracies in the coordination of OC–OC and OC–Dis relays in the real network. Fig. 3(b) shows

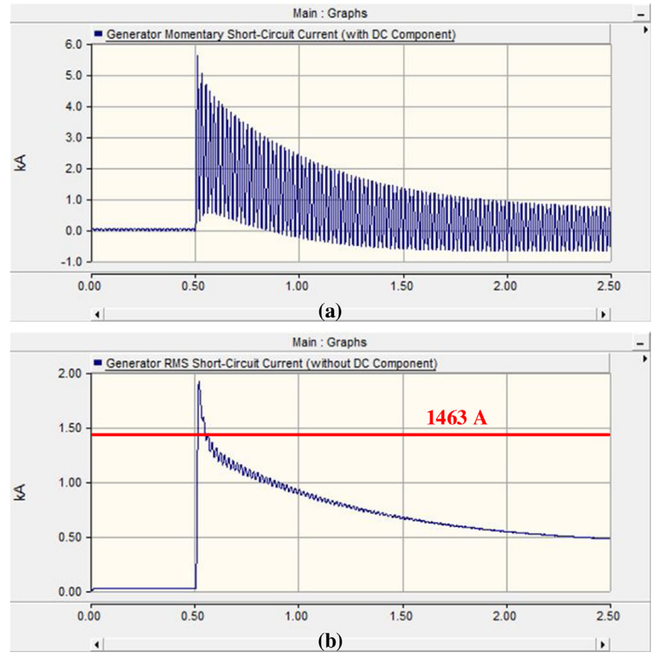

Fig. 2. Transient fault current flowing through OC relay, (a) momentary fault current, (b) fault current after applying DFT and elimination of DC component.

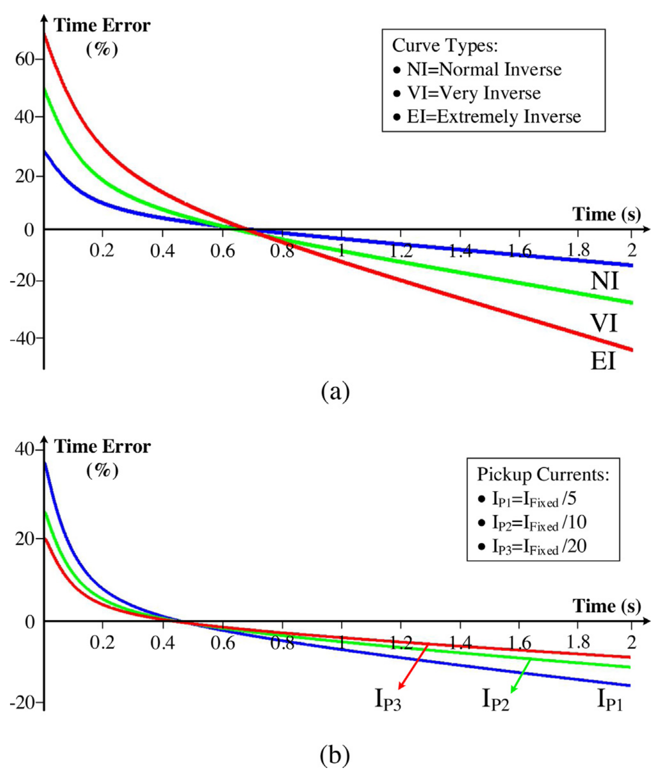

Fig. 3. Error in calculating the operating time of the OC relay: (a) for different relay characteristics curves (current setting: Ip_1); and (b) for different relay current settings (curve type: NI).

that the error of the OC relay operating time depends on the Ip setting of the OC relay.

2.2. Effect of transient currents on OC and Dis relays coordination

To achieve full coordination between backup OC relay and main Dis relay, the time interval should be considered between two