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Coordination of directional overcurrent relays using opposition based chaotic differential evolution algorithm

Thanga Raj Chelliah [a], Radha Thangaraj [a], Srikanth Allamsetty [a,*], Millie Pant [b]

[a] Department of Water Resources Development and Management, Indian Institute of Technology Roorkee, Roorkee 247667, India
[b] Department of Applied Science and Engineering, Indian Institute of Technology Roorkee, Roorkee 247667, India

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ABSTRACT

Coordination of directional over current relays (DOCR) has been considered as an optimization problem and has been solved using different types of optimization techniques by the developers. A wide variety of algorithms have been proposed over the past few decades for dealing with such problem. However considering its practical significance, there is always a scope for improvement in this area to get better results. In the present study, a set of two algorithms named opposition based chaotic differential evolution (OCDE1 and OCDE2) has been developed and applied to solve this problem. Both variants use the concept of opposition based learning and chaotic scale factor for obtaining an optimum solution. The proposed method is implemented in four test cases. The results are compared with previously proposed algorithms available in the literature and it was observed that the proposed schemes are quite competent for dealing with such problems.

1. Introduction

Most of the power systems are interconnected in nature and were introduced to improve the system performance, reliability and economics of power delivery. As peak loads may not occur at the same time in all the areas, exchanging of peak loads is possible with these inter connected systems i.e. local load can be mitigated. Thus reliability of the supply increases. Present day power systems consist of several generating stations, running in parallel and feeding a high voltage network which further supplies consuming centers at different voltage levels. Several such systems belonging to different licenses are again interconnected to form a multi area system or a power pool which serves as an economic and reliable reservoir of power [1]. However this process of development has added complexity in power protection schemes, presenting a new set of conditions on the coordination of protective devices, since the fault current may flow to the fault point from both ends of any meshed line element [2].

1.1. Problem description

Over current (OC) relays which were quite adequate protective devices for radial circuits, are not generally capable of being properly coordinated for meshed transmission systems. It has been improved by the addition of a directional element. This relay is called directional over current relay (DOCR), which is the simplest and least expensive, but is most difficult to apply. They also have the disadvantage in changing their coordination characteristics as the network and generation sources change. Thus these relays may require periodic readjustment [2].

A relay should trip for a fault in its own zone of operation only. It should not trip for a fault outside its zone, except to back up a failed relay or circuit breaker. Coordination of protective relays is nothing but obtaining selective tripping. The determination of the time delays of all backup relays is known as coordination of the protection system. While coordinating the backup protection with the primary relay characteristic, we have to ensure that the backup relay has sufficient time delay to allow the primary relay and its breaker to clear the fault. Main objective is to achieve the minimum possible summation of operating times of all primary relays while maintaining coordination among all relays.

1.2. Solution approach

In time and current graded OC protection systems, the relay has two settings, i.e. time dial setting (TDS) and Plug setting (PS). These are called decision variables as the TDS decides the operating time of the relay and PS decides the current required for the relay to pick up. The optimal values for these variables have been found using opposition based chaotic differential evolution (OCDE) algorithm to avail proper tripping of the relays. This paper explains the improvement in minimization of objective function with this proposed algorithm. The OCDE algorithm utilizes the advantages of

* Corresponding author.
E-mail address: askanth31@gmail.com (S. Allamsetty).

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Nomenclature

TDS	time dial setting
PS	plug setting
I_f	fault current in kA
I_f^i	fault current corresponding to relay i
I_f^j	fault current corresponding to relay j
I_{relay}	current seen by the relay
$CT_{pr\text{-}rating}$	CT primary rating
$CT^i_{pr\text{-}rating}$	CT primary rating corresponding to relay i
$CT^j_{pr\text{-}rating}$	CT primary rating corresponding to relay j
N_{cl}	number of relays responding for close-in fault
N_{far}	number of relays responding for far-bus fault
$T_{pri\_cl\_in}$	primary relay operating-time for close-in fault
$T_{pri\_far\_bus}$	primary relay operating-time for far-bus fault
T_{backup}	operating time of backup relay
$T_{primary}$	operating time of primary relay

opposition based learning to initialize the population of individuals and uses a dynamic scale factor, which is generated by using the chaotic sequence.

1.3. Previous works on DOCR coordination problem

Optimization theory was applied for dealing with coordination of DOCR for the first time in 1988 [3]. The practical significance of the problem prompted the researchers to apply efficient techniques for solving such problems.

Optimum TDS and PS of Overcurrent Relays have been determined Using Linear Programming (LP) Technique in [17]. In this study, the coordination problem was modeled as a nonlinear programming problem (NLPP) then the problem was converted into LP problem by selecting a particular combination of PSs. Four LP techniques, namely, revised simplex, dual simplex, two phase simplex and Big-M methods have been used to solve the nonlinear programming problem (NLP). Coordination problem has also been solved considering the priority of constraints by assigning weights [18]. A selection criterion has been adopted in [19] to get discrete pickup currents, which mitigate the selectivity constraints effect on the minimization of time multiplier settings. Then selectivity constraint equations are classified into individual groups with respect to backup relays. When solving these systems of equations, the initial time multiplier settings are obtained then increased gradually to find the final solution for all of the constraint equations. This problem is formulated as a mixed-integer nonlinear programming problem in [20] and is then solved by seeker optimization technique.

A new approach based on the interval analysis has been introduced in [11] to solve this problem by considering uncertainty in the network topology. Here, the problem is formulated as an interval linear programming (ILP) problem and has been converted to standard linear programming (LP). As a result, the number of coordination constraints is significantly reduced in the proposed methods.

Optimal DOCR Coordination has been obtained in [4]-[5] Genetic Algorithms (GA). Here the objective was to minimize the operating times of the relays. Ref. [34], an approach has been introduced to optimize overcurrent relay coordination in power distribution systems using a genetic algorithm, involving transformer protection. An objective function is adopted considering not only the time setting but also the current setting multiplier Sparse dual

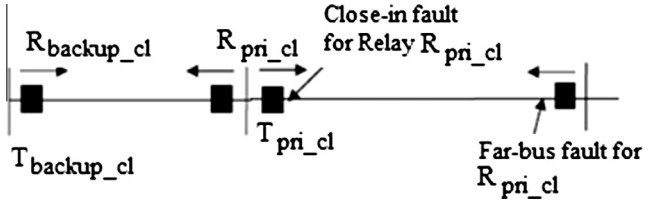

Fig. 1. Diagram showing close-in and far-bus faults for relay R_{Pri_Near}.

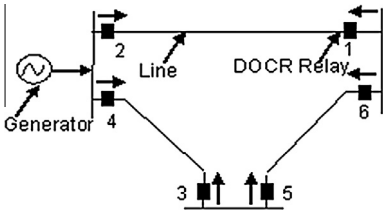

Fig. 2. IEEE 3-bus model.

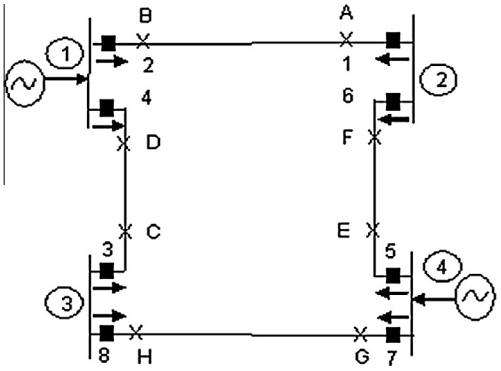

Fig. 3. IEEE 4-bus model.

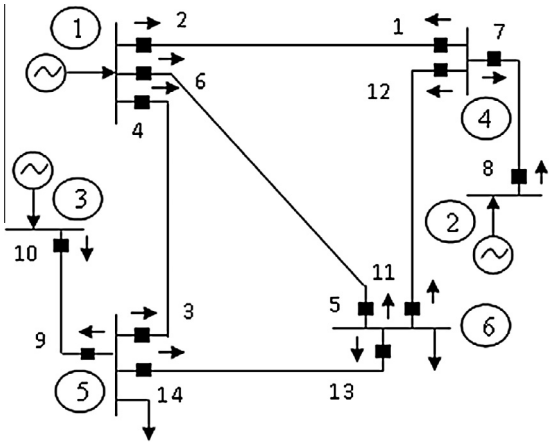

Fig. 4. IEEE 6-bus model.

revised simplex method of linear programming has been used in [6] which is a parallel processing algorithm to optimize the TDS settings for assumed non-linear PS settings. Linear programming techniques are also applied in [7]. In [8] the non-linear Random