Optimum Coordination of Overcurrent Relays: GA Approach

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***Abstract*—Overcurrent (OC) relays are the major protection devices in a distribution system. The operating time of the OC relays are to be coordinated properly to avoid the mal-operation of the backup relays. The purpose is to find an optimum relay setting to minimize the time of operation of relays and at the same time, to keep the relays properly coordinated to avoid the mal-operation of relays. This paper presents Genetic Algorithm for optimum time coordination of OC relays. The method is used to find optimum values of Time Multiplier Setting(TMS) and Plug setting(PS)which is used to find optimum coordination of Overcurrent Relays. The method minimizes the original objective function and gives the optimum time coordination of OC relays.**

I. INTRODUCTION

Over current relays are usually employed as backup protection. In distribution feeders, they play a more important role and there it may be the only protection provided [1,2]. The problem of coordinating protective relays consists of selecting their suitable settings such that their fundamental protective function is met under the requirements of sensitivity, selectivity, reliability, and speed [3,4]. If backup protections are not well coordinated, mal-operation can occur and, therefore, OC relay coordination is a major concern of power system protection [5]. Each protection relay in the power system needs to be coordinated with the relays protecting the adjacent equipment. The overall protection coordination is thus very complicated. The OC relay coordination problem in distribution system can be defined as constrained optimization problem. The objective is to minimize the operating time of relay for fault at any point. A protective relay should trip for a fault in its zone and should not, for a fault outside its zone, except to backup a failed relay or circuit breaker traditionally; a trial and error procedure is employed for setting relays in multi loop networks. In the past few years, several mathematical techniques have been reported. warakanath and Nowitz [2] suggested a systematic approach for determining the relative sequence setting of the relays in a multiloop network. They used a linear graph theory approach which provided a directional loop matrix. A minimal set of break points spanning all loops of the system graph were obtained from this matrix.Damborg et al. [3] extended the graph theoretic concepts and proposed a systematic algorithm for determining a relative sequence matrix corresponding to a set of sequential pairs which reduced the number of iterations. Jenkins et al. [4] proposed a functional dependency concept for topological analysis of the protection scheme. They expressed the constraints on the relay settings through a set of functional dependencies. **A** arametric optimization approach was reported by Urdeanneta et al. *[5]* that optimized the time multiplier settings (TMS) using the Simplex method. Optimal values of the pick-up currents for selected **TMS** were then determined by using a generalized reduced gradient technique. The objective of this paper is to present some of the optimization concepts and their use in the project.

A. Justification for Using Genetic Algorithms

This paper describes a systematic overcurrent (OC) protection grading method based on genetic algorithm (GA).Genetic algorithms are computerized search and optimization algorithms based on the mechanics of natural genetics and natural selection. Professor Holland of University of Michigan envisaged the concept of these algorithms in the mid 60's. Thereafter a number of students and other researchers have contributed to the development of this field. Genetic algorithm is good at taking larger, potentially huge, search space and navigating them looking for optimal combinations of things and solutions which we might not find in a life time.

B. Solution Approach

For linear programming, the values of time dial setting (TDS) have been found for given values of pickup currents (Ip) [3] and for non-linear programming, the values of pickup currents (Ip) have been found for given values of TDS [4]. Using GA subject to the constraints and hence the operating times of the relays is minimized.

II. OPTIMAL COORDINATION PROBLEM

Directional overcurrent (DOCR) coordination problem is a parametric optimization problem, where different constraints have to be considered in solving the objective function [1]. Here the objective function to be minimized is the sum of the operating times of the relays connected to the system, subject to the following constraints.

A. Relay Characteristics

A typical inverse time directional over current relay consists of two elements, an instantaneous unit and a time overcurrent unit. The overcurrent unit has two values to be set: Pick up current value (Ip) and the time dial setting (TDS). The pickup current value (Ip) is the minimum current value for which the relay operates [5]. The time dial setting defines the operation time (T) of the device for each current value, and is normally given as a curve T vs M, where M is the ratio of relay fault current I, to the pickup current value i.e.

M = I/IP (1)

In general, overcurrent relays respond to a characteristic function of the type:

T = f(TDS, Ip, I) (2)

B. Relay Settings

The calculation of the two settings, TDS and Ip, is the essence of the directional overcurrent relay coordination study. In general, directional overcurrent relays allow for continuous time dial settings but discrete pickup current settings. Therefore this constraint can be formulated as:

$TDSi\ min \leq TDSi \leq TDSi\ max$ (3)

$IPimin \leq IPi \leq IPimax$ (4)

C. Coordination Problem

In any power system, a primary protection has its own backup one for guaranteeing a dependable power system. The two protective systems (primary and back-up) should be coordinated together. Coordination time interval (CTI) is the criteria to be considered for coordination. It's a predefined coordination time interval and it depends on the type of relays. For electromagnetic relays, CTI is of the order of 0.3 to 0.4 s, while for a icroprocessor based relay, it is of the order of 0.1 to 0.2 s. To ensure reliability of the protective system, the back-up scheme shouldn't come into action unless the primary (main) fails to take the appropriate action. Only when CTI is exceeded, backup relay should come into action. This case is expressed as:

$Tbackup - Tprimary \geq CTI$ (5)

Where, Tbackup is the operating time of the backup relay Tprimary is the operating time of the primary relay
After considering all these criteria, this problem can be formulated mathematically as:

$Min \sum_{i=1}^{n} T_{ii}$ (6)

Where n presents the number of relays

III. GENETIC ALGORITHM

.Genetic algorithm (GA) is a search technique used in computing, to find exact or approximate solutions to optimization and search problems. Genetic algorithms are categorized as global search heuristics [6]-[7]. Genetic algorithms are a particular class of evolutionary algorithms (EA) that use techniques inspired by evolutionary biology such as inheritance, mutation, selection, and crossover [8]-[9].

A. Terminologies Related To Genetic Algorithm

- Fitness function—A fitness function is a particular type of objective function that prescribes the optimality of a solution (that is, a chromosome) in a genetic algorithm so that particular chromosome may be ranked against all the other chromosomes.
- Chromosome—In genetic algorithms, a chromosome is a set of parameters which define a proposed solution to the problem that the genetic algorithm is trying to solve. The chromosome is often represented as a simple string, although a wide variety of other data structures are also used.
- Selection—During each successive generation, a proportion of the existing population is selected to breed a new generation. Individual solutions are selected through a fitness-based process, where fitter solutions are typically more likely to be selected.
- Reproduction—The next step is to generate a second generation population of solutions from those selected through crossover and mutation. For each new solution to be produced, a pair of "parent" solutions is selected for breeding from the pool selected previously. By producing a "child" solution using the above methods of crossover and mutation, a new solution is created which typically shares many of the characteristics of its "parents". New parents are selected for each new child, and the process continues until a new population of solutions of appropriate size is generated.
- Crossover—In genetic algorithms, crossover is genetic operator used to vary the programming of a chromosome or chromosomes from one generation to the next. It is analogous to reproduction and illogical crossover, upon which genetic algorithms are based.
- Mutation—In genetic algorithms of computing, mutation is a genetic operator used to maintain genetic diversity from one generation of a population of algorithm chromosomes to the next. It is analogous to biological mutation. The purpose of mutation in GAs is preserving and introducing diversity. Mutation should allow the algorithm to avoid local minima by preventing the population of hromosomes from becoming too similar to each other, thus slowing or even stopping evolution.

B. Outline Of The Genetic Algorithm

It is very clear from the flow chart given below in Fig. 1

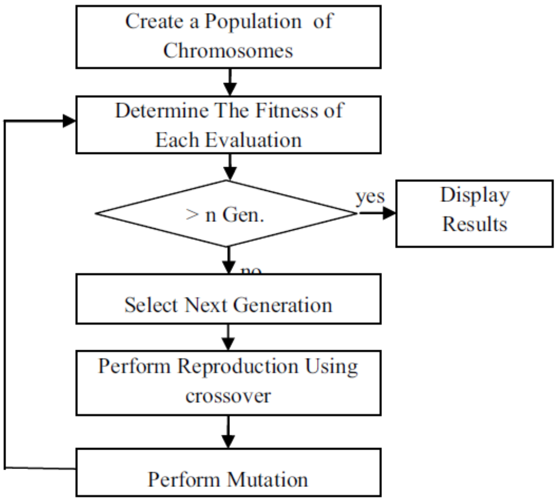


Fig.1 Flowchart of GA method

IV. PROPOSED ALGORITHM

Step 1: Generate P/B relay pairs. The knowledge of primary/backup relay pairs is essential in the formulation of the coordination constraints.

Step 2: Load flow analysis is done using Newton-Raphson method to determine line currents. This analysis can be done using any simulation software's and here we have used ETAP simulation software.

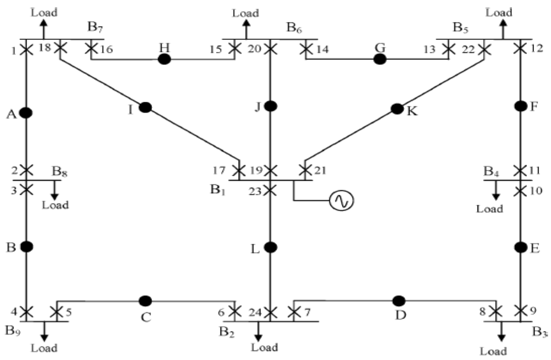
Step 3: Short circuit analysis is done using the same simulation software to find fault currents. Step 4: Pickup current is calculated based on the load current. Here it will be set at 1.5 times the maximum load current, for phase protection

Step 5: Minimization of objective function is carried out and optimum values of TDS are determined using linear programming technique in MATLAB.

Step 6: The values of TDS and minimization of objective function is further optimized using genetic algorithm (GA) using MATLAB toolbox

V. SIMULATION AND RESULTS

The performance of the proposed method is evaluated by, a 9-bus overcurrent relay network shown in Fig. 2. The aim is to find an optimal setting for network relays in order to minimize the final operating time. The coordination time interval (CTI) is assumed to be 0.2 seconds.. In order to solve the relay coordination problem first, it needs to determine the primary and backup relay pairs. Table I shows the primary/backup relays pairs and faults currents. The results of the proposed method are shown in Table III and Table IV for linear and nonlinear function respectively.



A single end fed, ring main system with nine buses and 24 relays, as shown in Fig. 2, was considered. All of the relays were considered as digital (numerical), directional OCR with standard IDMT characteristics, and have their tripping direction away from the bus.

1) System Information: Bus 1 is receiving the power, which has been represented by a source of 100 MVA, 33 kV with a source impedance of p.u. Base MVA is 100 and base kV is 33. Each line has an impedance of p.u. The load currents are shown in Table I. The OCRs are numbered as 1 to 24. The CT ratio for each relay is 500:1. Twelve fault points (one on each line), marked as A to L, were considered. The primary-backup relationship of relays for these fault points is shown in Table II.

Table-I Fault current and Load current

Relay	I_{Lmax} (A)	I_{fmin} (A)
1	105	1300
2	105	8300
3	70	7600
4	70	2200
5	245	18700
6	245	1900
7	141	4100
8	141	13400
9	19	8700
10	19	8600
11	156	13200
12	156	4300
13	45	7400
14	45	6700
15	20	6000
16	20	8500
17	436	12000
18	436	2200
19	416	2100
20	416	9500
21	461	2400
22	461	10400
23	737	3700
24	737	16100

Table-II Primary Backup relationship

Primary Relay	Back up Relay
1	15,17
2	4
3	1
4	6
5	3
6	8,23
7	5,23
8	10
9	7
10	12
11	9
12	14,21
13	11
14	21
15	13,19
16	2,17
17	-
18	2,15
19	-
20	13,16
21	-
22	11,14
23	-
24	5,8

Table-III Results using GA method

Relay	TMS	PS
1	0.025	0.304
2	0.025	0.304
3	0.025	0.054
4	0.025	0.054
5	0.025	0.195
6	0.025	0.195
7	0.624	0.195
8	1.15	0.186
9	0.578	0.054
10	0.705	0.054
11	0.21	0.304
12	0.025	0.304
13	0.025	0.076
14	1.19	0.076
15	1.023	0.076
16	0.942	0.087
17	0.0625	1.103
18	0.0402	1.103
19	0.025	1.027
20	0.025	1.027
21	0.025	1.103
22	0.025	1.103
23	0.025	1.266
24	0.025	1.266
Obj. fun. Value = 54.5078		

VI. CONCLUSION

In this paper, an optimization methodology is presented to solve the problem of coordinating directional overcurrent relays in given power system. The operating time of the relays was determined using genetic algorithm for 9 bus system.. This method increases coordination and the operation speed of relays. Finding the absolute optimal point, the ability to be applied on large networks, the ability to consider both linear and nonlinear characteristics of relays are some of advantages of the proposed method.

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