Implementation of Genetic Algorithm to find the optimal timing of Overcurrent relays

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Abstract-**This paper discusses a new approach to optimize overcurrent relay coordination in power distribution system by using a genetic algorithm. A modified objective function with constraints is taken to solve the relay coordination problem considering time setting and current setting multiplier. The result shows that the proposed method is fast, accurate and applicable compared to previous work proposed. In this study IEEE-8 bus system is tested to demonstrate the coordination and confirm that proposed approach method is practical.**

Keywords-Overcurrent relays; Optimization; Simplex method; Genetic Algorithm (GA); Relay Setting Coordination; Network Topology.

I. INTRODUCTION

A typical power system may consist of hundreds of equipment and even more protection relays to protect the system. Each relay in the system needs to be coordinated with the relay protecting the adjacent equipment. If backup protections are not well coordinated, mal-operation can occur and, therefore, OC relay coordination is a major concern of power system protection [10,4,11]. Proper coordination of overcurrent relays requires the selection of time multiplier setting (TMS) and plug setting multiplier (PSM) such that they satisfy all the constraints and operate within the shortest time[12,6]. In a system where with sources at both ends of the line, fault and load current can flow in either direction. Relays protecting the lines are, therefore, subject to fault currents flowing in both the directions. If non directional overcurrent relays (OC) were used in such system, they would have to be coordinated with, not only the relays at the remote end of the line, but also with relays behind them. Since directional relays operate only when the fault current flows in the specified tripping direction, they avoid coordination with the relays behind them. The directional OC relay coordination problem in distribution system can be defined as constrained optimization problem and can be solved using GA technique [9,2].

II. PROBLEM DEFINITION

The coordination problem of directional OC relays in interconnected power systems, can be stated as an optimization problem, where the sum of the operating times of the relays of the system, for near end fault is to be minimized

$$\min z = \sum_{i=1}^{n} t_{i,i} \tag{1}$$

Subjected to the following inequality constraints

$$t_{`j,i} - t_{i,i} \geq \Delta t \tag{2}$$

$$t_{i,i,\min} \leq t_{i,i} \leq t_{i,i,\max} \tag{3}$$

$$(t_{op})_i = \frac{\lambda (TMS)_i}{(PSM)_i^{\gamma} - 1} \tag{4}$$

For normal Inverse definite minimum time (IDMT) relay γ is 0.02 and λ is 0.14., equation (4) becomes

$$t_{op} = a_i (TMS)_{\text{i}} \tag{5}$$

$$a_i = \frac{\lambda}{(PSM)_i^{\gamma} - 1} \tag{6}$$

and PSM $= I/I_S$

Making substitution from equation (6) in equation (4), the objective function becomes

$$\min z = \sum_{i=1}^{n} a_i (TMS)_i \tag{7}$$

This is a non-linear optimization problem.

Where

$t_{i,i}$ is the operating time of the primary relay at i, for near end fault.

$t_{j,i}$ is the operating time for the backup relay, for the same near end fault.

Δt is the coordination time interval(CTI).

$t_{i,i,\min}$ is the minimum operating time of relay at i for near end fault (fault at i).

$t_{i,i,\max}$ is the maximum operating time of relay at i for near end fault (fault at i).

t_{op} is the relay operating time .

I is the input current.

I_s is the setting current.

TMS is time multiplier setting, and

PSM is plug setting multiplier.

Coordination of over current relay can be easily understood by this simple radial system and the same concept can be applied for larger system also using algorithm:

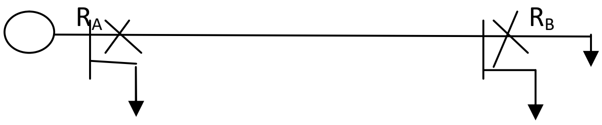

Fig. 1. A radial feeder both relays are non directional

The maximum fault current just beyond bus A= 4kA

Maximum fault current just beyond bus B= 3kA

Plug setting of both the relays= 100%

CT ratio of R_A =300:1

CT ratio of R_B = 100:1

Minimum operating time of each relay = 0.25 sec

CTI = 0.57 sec

For this system Coordination problem is

Min Z =$2.63X_1 + 2 X_2$

Where X_1 and X_2 is TMS of relay R_A and R_B

Subject to:

$2.97X_1 - 2X_2 \geq 0.57$

$2.63 X_1 \geq 0.2$

$2X_2 \geq 0.2$

Using GA

$(TMS)_A$ =0.682 sec and $(TMS)_B$ =0.2 sec

III. GA ALGORITHM

Relays coordination is an optimization problem with lots of constraints and many local optimal points. In usual methods, such as LP, NLP (Non Linear Programming), IP (Integer Programming), because optimization is beginning from first point, final solution intensely is depending on that point and it may achieve a local optimal solution. Optimization technique generally advantageous over conventional approach as it eliminates the need to find the minimum set of break points. the coordination process as a linear-programming (LP) problem to reduce the operating time of the relays based on coordination constraints, the relay characteristics and the limits of the relay settings [5][13]. In optimization method, GA algorithm starts searching solution from a population of primary points. Thus trapping probability of these algorithms in local optimal points is very rare. Main difficulty of GA algorithm is achieving the time of solutions. In massive problems with many constraints maybe that necessary time to accept optimal solution becomes so much [11,13,1]. A network is assumed with 8 relays and it is supposed that each relay has 10 setting points for TMS and 5 setting points for Iset.

IV. METHODOLOGY

The IEEE 8-bus network is used as the basis for this study. The network topology may be studied using methods described in [9]. For simplicity, the network is modeled with SIMULINK® MATLAB with the desired electrical parameters. Once the network was modeled, a Graphical User Interface (GUI) from MATLAB is used to provide the user with tools to analyze the expected load current (I_L), minimum fault current ($I_{F, MIN}$), and maximum fault current ($I_{F, MAX}$) of all elements in the network which shall be used as inputs during relay setting with GA.

The GUI then performs relay setting to suit the curve profile selected by the user. The GUI shall create one set of settings based on GA and another based on conventional algorithm. The GUI then provides a plotter for comparing relay operating time vs. fault current for both algorithms. The two sets of relay settings may also be tested by simulating faults in the network through the GUI and the relay operation times are displayed. Fig. 2 below describes the flowchart of the optimization algorithm

FLOW CHART:

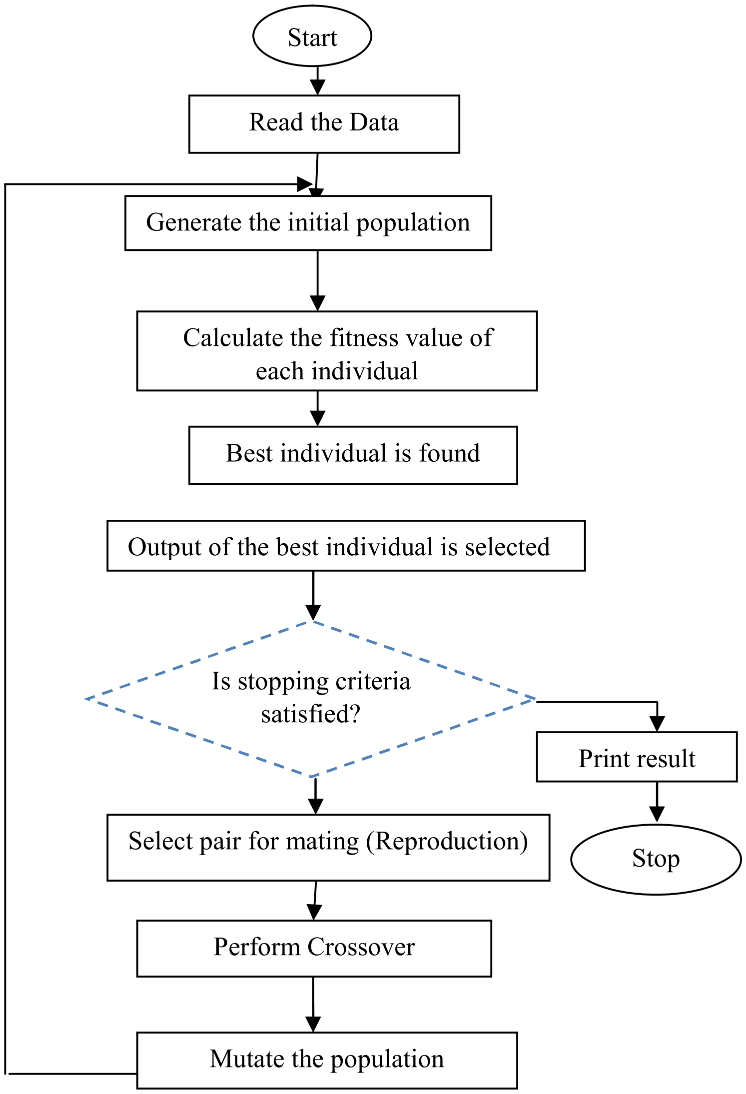

Fig. 2. Flow chart of GA Algorithm

Algorithm for solving the problem:

1. Start.
2. Define fitness function.
3. Enter number of variables in the function.
4. Set stopping criteria.
5. Define GA parameters.
6. Create initial population.
7. Set iteration count = 1.
8. Evaluate the fitness of each chromosome in the population.
9. Sort the fitness and associated parameters.
10. If stopping criteria is satisfied then go to step 16. Else go to step 11.
11. Select pairs for mating (i.e. perform reproduction).
12. Perform crossover.
13. Mutate the population.
14. Increment iteration count.
15. Go to step 08.
16. Display result

V. RESULTS AND DISCUSSION

MATLAB Codes for GA were developed for the simulation purposes. To investigate the validation of the proposed techniques, GA algorithms have been tested on the following IEEE 8-bus system .The data for the above mentioned systems are taken from [4]. The proposed GA method is applied to an IEEE 8-bus, 9-branch network shown in Fig.3. The system data is given in the Appendix Table B.1, Table B.2, Table B.3, Table B.4 and Table B.5. At bus 4, there is a link to another network, modeled by a short circuit capacity of 400 MVA. The transmission network consists of 14 relays which their location are indicated in Fig. 3. The same inverse time characteristic is considered for all of these relays. The TMS values can range continuously from 0.1 to 1.1, while seven available discrete pickup tap settings (0.5, 0.6, 0.8, 1.0, 1.5, 2.0 and 2.5) are considered [3]. The ratios of the current transformers (CTs) are indicated in Table B.4 and CTI is assumed to be 0.3 seconds.

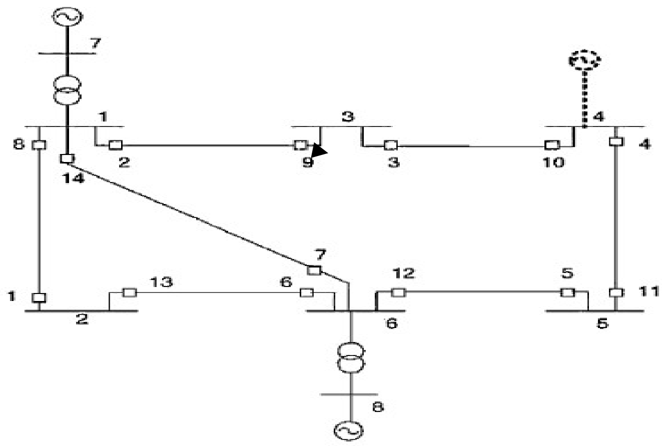

Fig. 3. IEEE 8-bus test system

The optimization problem is formed with the help of data given in appendix and equation (1) to (7). In IEEE 8 bus system there are twenty eight variables (14 for *TMS* and 14 for pickup tap), twenty eight constraints due to bounds on relay operating time and twenty constraints due to coordination criteria. The parameter selected for GA is given the following table

Table 1: Parameters of GA

Parameters of GA	
Population size (np) of individuals	256
Number of bits per parameter	100,50
Mutation rate	15%
Crossover rate	50%

Table 2: Optimal settings of the relay

Relay no	Result obtained		Standard result	
	I_S	TMS	I_S	TMS
1	1.00	0.28	1.00	0.30
2	2.50	0.30	2.50	0.29
3	2.50	0.25	2.50	0.25
4	2.50	0.19	2.50	0.18
5	1.50	0.18	1.5	0.17
6	2.5	0.25	2.5	0.27
7	0.50	0.54	0.50	0.53
8	2.50	0.24	2.50	0.23
9	2.00	0.17	2.00	0.185
10	2.50	0.18	2.50	0.189
11	2.50	0.20	2.50	0.20
12	2.50	0.30	2.50	0.28
13	1.50	0.22	1.50	0.22
14	0.50	0.51	0.50	0.52

The optimum values of *TMS* and Pickup tap obtained using GA technique (the numbers indicate the relay number) is shown in Table2.

VI. CONCLUSIONS

From the results presented above for the IEEE 8 bus systems we can observe that the proposed method is more accurate compare to result obtained in [13]. It is found that by using modified objective function and genetic algorithm result is more accurate and practical.

VII. REFERENCES

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Appendix

IEEE 8-bus test system
No. of buses: 8
No. of lines: 9
No. of generators: 3
No. of relays: 14

Table B.1: Line Data

Nodes	R(Ω/km)	X(Ω/km)	Y(Ω/km)	Length(km)
1-2	0.004	0.05	0.0	100
1-3	0.0057	0.0714	0.0	70
3-4	0.005	0.0563	0.0	80
4-5	0.005	0.045	0.0	100
5-6	0.0045	0.0409	0.0	110
2-6	0.0044	0.05	0.0	90
1-6	0.005	0.05	0.0	100

Table B.2: Generator data

Node	S_n (MVA)	V_p (KV)	X %
7	150	10	15
8	150	10	15

Table B.3: Transformer data

Nodes	S_n (MVA)	V_p (KV)	V_S (KV)	X %
7-1	150	10	150	4
8-6	150	10	150	4

Table B.4: CT Ratio:

Relay no.	CT ratio	Relay no.	CT ratio
1	240	8	240
2	240	9	160
3	160	10	240
4	240	11	240
5	240	12	240
6	240	13	240
7	160	14	160

Table B.5: P/B Relay Pairs and the fault currents in the main network topology:

P/B pairs		Near end fault currents(KA)	
Primary relay no	Back up relay no	Primary relay	Backup relay
1	6	3.200	3.200
2	1	5.900	0.990
2	7	5.900	1.800
3	2	3.556	3.567
4	3	3.883	2.244
5	4	2.400	2.400

6	5	6.101	1.197
6	14	6.101	1.874
7	5	5.203	1.180
7	13	5.203	0.980
8	7	6.084	1.890
8	9	6.084	1.160
9	10	2.480	2.480

10	11	3.880	2.340
11	12	3.707	3.707
12	13	5.890	0.980
12	14	5.890	1.870
13	8	2.990	2.990
14	1	5.190	0.990
14	9	5.190	1.160