2011 International Conference on Signal, Image Processing and Applications
With workshop of ICEEA 2011
IPCSIT vol.21 (2011) © (2011) IACSIT Press, Singapore

Optimal Coordination of Overcurrent Relays By Mixed Genetic and Particle Swarm Optimization Algorithm and Comparison of Both

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Abstract. Nowadays coordination of overcurrent relays is important subject in different networks. On the contrary to other kinds of relays, fuses and reclosers, Overcurrent relays coordination has been suggested in many methods in different papers. As of Such techniques are optimal coordination methods that have advantages as compared to common coordination techniques. The operation of relays in network is considered linear and symmetrical attribute of time setting multiply (TSM).whereas that isn't like this and the attributes of time setting multiply and relay current setting are unknown quantities. Thus object function converts this problem into a nonlinear problem. Some of network elements are nonlinear and discontinuous; therefore this is a complicated problem. Hence, mathematic optimization techniques have many problems in solving it. In this paper to solve the problem, both Genetic Algorithm (GA) and Particle Swarm Optimization (PSO) Algorithm have been deployed with combination of linear programming. And the results are compared with each other, and then the more perfect algorithm is introduced.

Keywords: Overcurrent relay, Optimal coordination, Genetic algorithm, PSO algorithm, Linear programming

1. Introduction

Overcurrent relays commonly applied for primary protection of distribution lines and secondary protection of transmission lines. The main function of the protective devices in the power system is to detect and remove the selected faulty parts as fast as possible. It is essential backup protection in power system equipments protection that can result in system reliability improvement.In the overcurrent coordination program, two types of setting, i.e. current and time setting must be calculated in a way that the relays operation times become to the minimum value and each part of system is protected by a main and backup relay and no interference could occur in main and backup relays operation. Thus, relays coordination is an optimization problem with many constraints.

Researchers have described various optimization methods to solve relays coordination problem. At first as [1], overcurrent relays coordination has been considered as an optimization problem and has been solved by Non Linear (NL) programming method. But I_{set} is a discontinuous variable in performance and it must be approximated to the closest number. This approximation can cause the problem solution to be impossible. References [2]-[3] show I_{set} is supposed fixed and the obtained LP problem is solved in various methods.

As LP problem may be huge, they used a first analyze to decrease optimization constraints [4] and speed up to solve LP problem. References [5]-[6] show that GA method is performed to coordination problem and both TDS and I_{set} have been seemed discontinuous.

In this paper, initially, LP has been used and the more perfect solutions have been send to evolutional algorithms and the results of two algorithms are compared with each other , then the more perfect algorithm is introduced.

2. Over current Relays Coordination Problem

The purpose of relays coordination is to detect costs of relays I_{set} and TDS in a way that relays operation time become minimum. Object function is presented as follows:

$$object\ function = \min \sum_{i} w_i t_i^k \tag{1}$$

Where t_i indicates the operation time of relays R_i for a fault in zone k and w_i is a coefficient which indicates the probability of the occurrence of the fault on a line and is usually set to 1, thus assuming equal probability of fault occurrence on each line.

The constraints can be stated as follows.

3. Main and Backup Relays Constraints

In order to coordinate two overcurrent relays, one as main relay (i) and the other as backup relay (j), the difference between the operation time of backup relay and main relay should be more than CTI. So the constraints for coordination of overcurrent relays i and j will be in the form of inequality (2):

$$t_j^k - t_i^k \geq CTI \tag{2}$$

t_j and t_i are respectively the operation time of backup and main relay for a short circuit in k.

CTI is the time interval for coordination of main and backup relay and it can take a value between 0.2 and 0.5 seconds.

m is the number of backup relays and n is the number of main relays.

Current setting and time dialing setting have a maximum and minimum value.

Bounds on relays settings and operation time is follows :

$$TDS_i^{min} \leq TDS_i \leq TDS_i^{max} \tag{3}$$

$$I_{set_i}^{min} \leq I_{set_i} \leq I_{set_i}^{max} \tag{4}$$

Where TDS, I_{set} are the time dialing and the pickup current settings of relays R_i .

TDS can take a value between 0.1 and 1.0 as a continuous variable but I_{set} is a discontinuous variable.

4. Ralay Characteristics

Various equals have been applied for overcurrent relays characteristics simulation. Several typical of these simulations are presented as follows:

$$t_i^k = \frac{3 \times TDS_i}{\log 10\left(\frac{I_i^k}{I_{set_i}}\right)} \tag{5}$$

$$t_i^k = \frac{k_1 \times TDS_i}{\left(\frac{I_i^k}{I_{set_i}}\right)^{k_2} - 1} \tag{6}$$

where I_i is the short circuit current passing through the relay.

The first model is applied in this paper.

5. Combination of LP and PSO Algorithm and GA

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. GA and PSO algorithm start 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 and PSO algorithm is achieving the time of solutions. In massive problems with many constraints maybe that necessary time to accept optimal solution becomes so much. In the proposed method to remove this quandary, all of constraints are put in LP and just convergence criteria of LP is put in GA and PSO .

Furthermore, to constitute algorithms and LP, input values decrease and search space and achieving time to optimal solution intensely decrease.

6. Input Variables

Evolutional algorithms input variables for relays coordination, consist of current setting and time dialing setting for all relays.(figure 1)

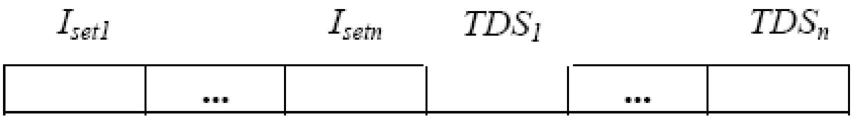

Fig.1: input variables in general algorithms

But in the proposed method, just I_{set} is input value and TDS is obtained by LP.(figure 2)

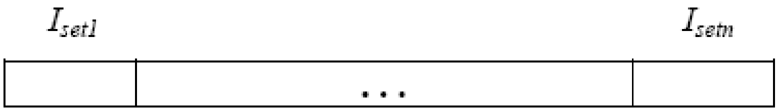

Fig.2: input variables in proposed algorithms

A network is assumed with 14 relays and it is supposed that each relay has 10 setting points for TDS and 5 setting points for I_{set} . In general method, search space equals $5^{14}\times10^{14}$ positions. But in proposed method, search space equals 5^{14} positions. In other words search space in the proposed method decrease 10^{14} positions in regard of general method. However, in the proposed method to execute LP in each GA and PSO iteration, execution time is farther than general method. But in the proposed method, this time increment per iteration, no matter how much it maybe, in comparison with 10^{14} is of less important.

7. Genetic Algorithm

GA like all other optimization methods needs initial values which are chosen randomly. I_{set}s of relays are the unknown quantities in the optimization problem. Therefore, the I_{set}s with respect to the number of relays are considered as the genomes of the chromosomes in GA. In other words, these values are relays I_{set} that put in a chromosome. The number of I_{set}s' sets is referred as the population size. The number of population detects search space. Population size must be detected by chromosome length. After each iteration, the new I_{set}s' sets belong to relays R_1 to R_n are given to the algorithm. To evaluate the worth of each chromosome, it is essential to define an OF. The purpose of optimization is to minimize the OF. The chromosomes are evaluated regarding the OF and the chromosomes which have more effectiveness and will be used for producing new generation of chromosomes. Mutation per iteration will cause the algorithm not to be trapped in local minima. After a fixed number of generations, the process will be terminated. Increasing the number of generations will lead to the better solutions and on the other hand, will increase the run time. The required number of generation varies from system to system depending on the system complexity and the size of population.

8. Particle Swarm Optimization

Particle swarm optimization (PSO) is one of the evolutionary computational approaches developed by Kennedy and Eberhart in 1995. PSO is initialized with a population of random solution. The individual in a population is called a particle. The position of each particle is a potential solution. The velocity of each particle represents the distance to be moved at the next step. The fitness of a particle is calculated by putting its position into a designated objection function. Each particle adjusts its position by considering the record of its previous best position, the information of the previous global best position, as well as its current position and current velocity.

These processes enable a PSO system to combine the local search methods with global search methods. Suppose that the searching space of a problem is a N-dimensional space. Then, the position of nth particle at iteration k is represented by a N-dimensional vector $X^k_n=(x_{n1},\ldots x_{nN})$, in addition, the nth particle's flying velocity is also a N-dimensional vector, denoted by $V=(v_{n1},\ldots v_{nN})$. A velocity is usually updated by the following formula:

$$v_{k+1}^{i} = w_k v_k^{i} + c_1 r_1(p_k^{i} - x_k^{i}) + c_2 r_2(p_k^{g} - x_k^{i}) \quad (7)$$

Where Pbest is the best position of the nth particle so far, Gbest is the best position so far by all particles in the population, w is an inertial weight, c1 and c2 are the positive constants, and r1 and r2 are the random numbers between 0 and 1. The position of each particle at the next iteration is updated according to the following equation:

$$x_{k+1}^{i} = x_k^{i} + v_{k+1}^{i} \quad (8)$$

9. Prorosed Algorithm

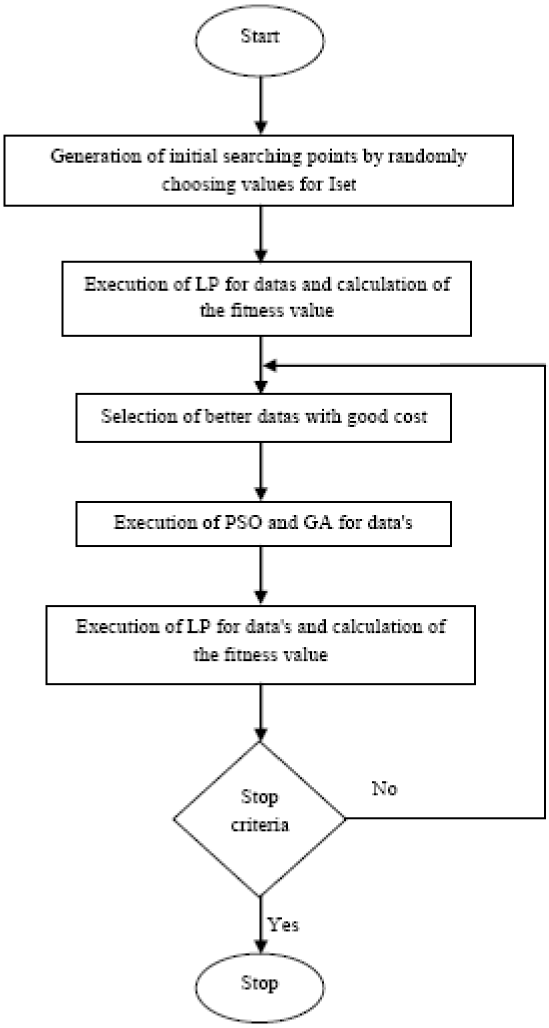

Fig.3 : proposed flowchart of the algorithms

Figure 3 illustrated the general algorithm for the mixed algorithms used to calculate the optimal setting of the relays. Initialize the relays current settings with random values. Now, input variables of LP are current setting (I_{set}) values. (It is obvious when I_{set} is known, relays coordination problem convert to a linear programming problem). By solving LP, the TDS for all relays is calculated and for each relay defined its fitness value using the fitness function.

Then, those strings having more cost are selected and with executing genetic operator such as mutation, commutation operators and in PSO with executing the mention equations, the relays I_{set} are changed and this rotation is repeated to achieve final solution. The stopping criterion of algorithm is not to change solution for much iteration.

With solving LP, TDS of all relays are specified in a way that operation time of each relay becomes minimum value and the constraints are satisfied. But Lp probably doesn't achieve feasible solution and the whole constraints are not satisfied. Thus, such variables must not be selected at next iterations. In those matters by adding, a penalty factor to fitness value of that string in a way the qualifications are prepared so that the string won't be selected at next iterations.

10.Numerical Results

The proposed method for solving the new problem formulated for optimal coordination of protective relays will be illustrated using two different systems. The first is the 8-bus system shown in Fig. 4, which has a link to another network, modeled by a short circuit power of 400MVA.

In this network, 14 overcurrent relays exist. TDS of relays can take a value between 0.1 and 1 and current setting multiply can take a number of 0.6, 0.8, 1.0, 1.5, 2.0, 2.5.

The CT ratio of relays is given in table 5. CTI value has been considered 0.3 seconds too.

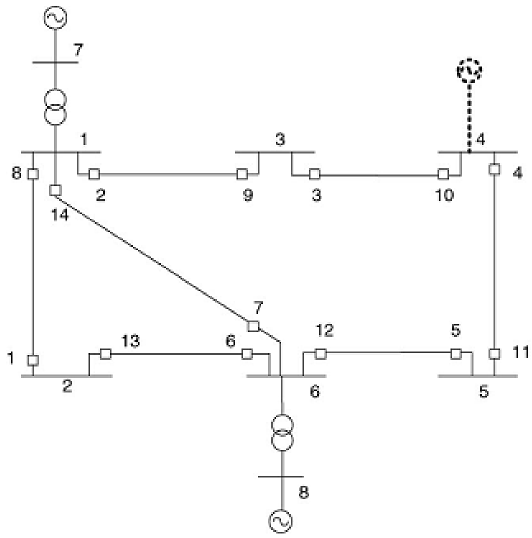

Fig.4 : single line diagram of the 8-bus network

Tables 1–4 present the 8-bus system data. At bus 4, there is also a link to another network modeled by a short circuit power of 400MVA.

TABLE I Lines Characteristic

Nodes	R(Ω/km)	X(Ω/km)	Y(S/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 II 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 III Generator Data

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

TABLE IV Load Data

Node	P(MW)	Q(MVar)
2	40.0	20.0
3	60.0	40.0
4	70.0	40.0
5	70.0	50.0

TABLE V CT Ratio Data

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

The short circuit calculations and load propagation is coded in MATLAB. Algorithms presented in fig 3, is coded in MATLAB. Object function is assumed operation time summation of main relays for fault front of them. (eq.1)

In table 6, it's been presented the comparison between proposed and usual algorithms. In the proposed algorithm, it is obvious that the execution time and iteration numbers is lesser than usual algorithm.

TABLE VI Comparison of Proposed Method and General Method

	Execution time	Iteration number
Proposed method	5 minutes	30
General method	4 hours	40000

Simulation results are given in table 7. Table 7 presents the numerical value for the TDS and pickup current settings obtained for both the mixed PSO and GA. As for the mixed PSO, the results obtained are close to optimal as compared with the results of the GA. The results in this section prove that the mixed PSO is working properly and is capable of finding a close optimal solution for this network in comparison with GA.

TABLE VII Optimal Settings of the Relays

	PSO	GA
TDS1	0.151	0.3043
TDS2	0.32	0.2917
TDS3	0.3096	0.2543
TDS4	0.1	0.1851
TDS5	0.123	0.17
TDS6	0.2134	0.2711
TDS7	0.1059	0.5316
TDS8	0.209	0.2387
TDS9	0.1176	0.1856
TDS10	0.21	0.1895
TDS11	0.2345	0.2014
TDS12	0.3497	0.2890
TDS13	0.1412	0.2207
TDS14	0.1576	0.5278
I_{set1}	480	600
I_{set2}	480	640
I_{set3}	500	300
I_{set4}	800	640
I_{set5}	600	600
I_{set6}	400	400
I_{set7}	600	600
I_{set8}	500	400
I_{set9}	480	800
I_{set10}	500	400
I_{set11}	600	300
I_{set12}	500	400
I_{set13}	600	600
I_{set14}	800	800
objective	**17.21**	**19.5**

11. Conclusion

A new problem formulation was presented in this paper for the optimal coordination of overcurrent relays.

In this paper to solve the problem, both GA and PSO algorithm have been deployed with combination of linear programming (LP).Applying this method decrease search space and increase PSO and GA efficient. In the proposed method other number of constraints can be added to coordination problem because of search space decrement. In this paper, both of mixed GA and PSO are compared with each other.

The mixed PSO succeeded in finding a close to optimal solution for the coordination problem as compared with the mixed GA. For a greater problem, the mixed PSO was capable of finding a much better solution than mixed GA.

12. Acknowledgement

This research is supported by the Faculty of Electrical and Computer Engineering in Shahid Rajaee Teacher Training University (SRTTU), Tehran,Iran.

13. References

[1] A.J. Urdaneta, R. Nadira and L.G.Perez , "Optimal coordination of directional overcurrent relays in interconnected power systems," IEEE Trans. Power Deliv. vol.3 pp.903-911, 1988.

[2] A.J. Urdaneta, H. Restrepo, S.Marquez and J. Sanchez, "Coordination of directional overcurrent relay timing using linear Programming," IEEE Trans. Power Deliver. vol.1, pp.122–129, 1996.

[3] B. Chattopadhyay, M.S. Sachdev and T.S. Sidhu, "An online relay coordination algorithm for adaptive protection using linear programming technique," IEEE Trans. Power Deliv. vol.11, pp. 165–173, 1996.

[4] A.J. Urdaneta and L.G. Perez , "Presolve analysis and interior point solution of the linear programming coordination problem of directional overcurrent relays," Electric Power and Energy Systems vol.23, pp. 819-825, 2000.

[5] C.W. So and K.K. Li, "Overcurrent relay coordination by evolutionary programming", Electric Power Systems Research, vol.53, pp.83–90.

[6] C.W. So, K.K. Li, K.T. Lai and K.Y. Fung, "Application of genetic algorithm for overcurrent relay coordination", IEE 6th International Conference on Developments in Power System Protection , Nottingham , UK, pp. 66–69, March 1997.