PSO And GSA Based Over Current Relay With DG Penetration

[1] CHHEUY BONA [2] Mr. CHENG HORCHHONG (Professor)[3] NEMALI SANTOSH GANESH M.TECH

National Polytechnic Institute of Cambodia,Cambodia

ABSTRACT

Modern distribution systems consist of various Distributed Generators (DG) to make reliable power system. In this DG integrated distribution systems, coordination of overcurrent relays is a big challenge for protection engineers. With the addition of DG, distribution system experiences change in the short circuit level of the system and thus earlier relay settings causes mal operation of relays. Nowadays, various programming optimization techniques are frequently used to find optimal relay settings of overcurrent (OC) relays. This paper presents a comparative study of Particle Swarm Optimization (PSO) and Gravitational Search Algorithm for the coordination of overcurrent relay for a system containing DG. A proper combination of primary and backup relay is selected to avoid mal operation of relays and unwanted outages when DG is penetrated

Keywords—*Distributed Generation, GSA, Overcurrent relay, PSO, Relay coordination.*

1. Introduction

Reliable operations of the power grid are becoming importance nowadays more than ever, due to the embedding of electric powered technology in all human activities. Protection of the electric grid against interruptions caused by different faults occupies the priority of power system researchers concerns [1]. Planning of protection schemes accurately is required to guarantee reliability, speed and selectivity of protective relays to insulate the parts under faulted conditions from the rest of the network. Protection issues have become more complex with evolving of the distribution networks (DNs) toward the vision of distributed generations (DGs). Additionally, the growing of the DGs connections introduced extra challenges with the concept of micro-grids (MGs). To obtain the maximum advantages from these upcoming power generation technologies with maintaining the existing power system infrastructure, there are main protection issues required to be taken into considerations which are false tripping, binding tripping recloser malfunctions, binding, nuisance (sympathetic) and undesired islanding

Traditional distribution system is radial in nature. The protection of these networks is relatively simple protective devices such as overcurrent (OC) relays, fuses and reclosers [3]. An OC relay is a device that determines whether sending signal or not to open a circuit breaker by measuring the current which pass through it [4]. There are other relays kinds such as directional relays, definite time OC relays and distance relays. Yet, inverse time OC relay is extensively used and it is considered the most preferable type in protection system of DNs because of their fine selectivity, economic advantages, simplicity and efficiency in installation and implementation [5]& [6] In decades, for the distribution systems, obtaining costly effective and reliable performance adopt the OC scheme coordination amongst the inherited requirements. The OC relays utilized as a primary (p) as well as backup (b) protection respectively in the transmission and sub-transmission systems [7]. They work at a coordinated structure with a composed predesigned. As a rule, firstly, the primary OC relay isolates the fault in coordinated scheme, if this primary OC relay being unsuccessful to trip in the pre-designed time after a specific pre-calculated time known as Coordination Time Interval (CTI), the backup OC relay isolates the fault automatically. Fig.1 illustrates the coordination constraint between primary and backup relays. It considers a constraints problem beside both of the Plug Setting (PS) range and Time Dial Setting (TDS) range of relay. This problem is extremely complicated both in constraints set and in objective function (OF)

In the optimal methods, operating time of the relays are optimized against the coordination constraints, relay characteristic curves. In optimization of relays operating time, the limits of the relay settings should also considered as constraint. Particle swarm optimization is a meta heuristic method that follows social behavior of animals like bird flocking and is very efficient [9], [10]. It is based on movement and intelligence of swarm. It is a population-based search algorithm where each individual is referred to as a particle and represents the optimal solution. PSO strives to improve itself by imbibing the attributes of its successful peers.

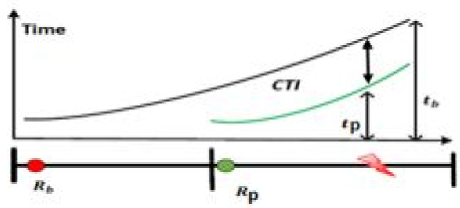


Fig.1: The of coordination constraint among primary (p) and backup (b) relay

Over Current Relay Coordination Methods

In the past four decades, there are a considerable number of methods have been proposed for the overcurrent relays coordination. According to this review, these methods can be illustrated and divided into optimization techniques, new constraints for optimal coordination, non- standard characteristics (NSCs) and dual setting protection schemes. This classification is illustrated in fig.2 as following

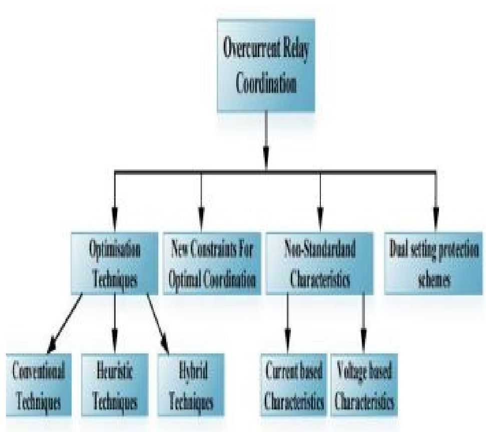


Fig.2: Over Current Relay Coordination Methods

2. PROBLEM FORMULATION

2.2.1 Objective Function

The OC relays coordination problem relays in interconnected power systems, it is usually stated as a constrained optimization problem, where the objective function (OF) is used to minimize the total operating time of the primary and backup relays

$$OF = \sum_{t=1}^{m} t_{i,j}$$

Where $t_{i,j}$indicates the operation time of the primary relay at i for near end fault and m is the primary relays numbers. The following constraints have achieved this objective

2.2.2 Coordination criteria

$$t_b - t_b \geq CTI$$

Where t_p is the primary relay operating time for near end fault, while, t_b is the backup relay operating time, similarly for near end fault. Usually CTI selected as ($0.2s \leq CTI \leq 0.5s$)

2.2.3 Bounds on relay operating time

The of bounds expression on TMS and PS are shown as following

$$TMS_{min} \leq TMS_i \leq TMS_{max}$$

$$PS_{min} \leq PS_i \leq PS_{max}$$

Where $TMSmin$ and $TMSmax$ are the minimum and maximum TMS value, whereas $PSmin$ and $PSmax$ are in order of the minimum and maximum PS value of relay

2.2.4 Bounds on Pickup current

The minimum value of pickup current is determined by maximum load current seen by each relay. The maximum pickup current is determined by minimum fault current seen by each relay. This will impose bound on relay plug setting (PS) also which is given below as:

$$I_{P\,min} \leq I_p \leq I_{p\,max}$$

$$PS_{min} \leq PS \leq PS_{max}$$

2.2.5 Relay characteristics

All relays are identical and assumed to have IDMT characteristic as

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

$$t_{op} = \frac{\lambda(TMS)}{(I_{relay}/PS \times CT_{\sec rated})^{\gamma} - 1}$$

Where, t_{op} is relay operating time, PS is plug setting. TMS is time multiplier setting, PSM is plug multiplier setting, I_{relay} is fault current seen by relay and $CT_{sec\ rated}$is rated current of CT secondary. For normal IDMT characteristic relay, γ is 0.02 and λ is 0.14. Hence we have two parameters, TMS and PS to be determined using GSA.

3. Heuristic Techniques

Currently, evolutionary and heuristic formulation depending on methods like genetic algorithm (GA) was successfully implemented for optimal coordination overcurrent relay to reduce the operation time of relays and reduce miscoordination problem. For particle swarm optimization (PSO) in the formulation of the optimal relay settings, confirmed that PSO is more suitable for dealing with discoordination issues for both discrete and continuous PSM and TSM instead of GA though. In relation to the enhanced convergence properties, some GA improvements like progressive GA. They have adopted Evolutionary programming and various types of DE techniques like the adaptive (ADE) algorithm and opposition-based chaotic DE algorithm in order to obtain the optimum setting of relays by the improvements of discrete values of decision variables. Conducted an evaluation on the five varied versions of modified differential evolution (MDE) in order to comparatively judge their performance in offering a solution to the relay coordination problem. In these techniques, the local optima influence the solution because of the constant scaling components. made an attempt to attain the OC relays coordination through the improved PSO methods.

To acquire the OC relays optimum coordination in the ring-based power systems,utilized the Teaching learning-based optimization (TLBO) algorithm. Then, recommended an advanced group search optimization algorithm in the DO relays' coordination. In addition, in order to deal with the DO relay coordination influenced by the dynamic alteration in the network topology and Ant colony optimization (ACO) have been applied in solving the coordination problem in OC relays suggested a new seeker optimization method for the DO relays coordination. But, most of the past techniques have a major deficiency that is the convergence threat in the local optima. Firefly algorithm (FA) was selected to obtain an optimized OC relay function. In the optimization, the FA performance is related to a random value of Gaussian distribution that results to moderate trapping and convergence during the local optimizing point. Thus, an advanced adaptive modified FA (AMFA) is suggested to determine the OC relays optimal coordination. AMFA amends the FA through the manner of investigation in the search of the OC relays' optimum coordination and growing the speed in the convergence. An ant lion optimizer (ALO) is applied to solve coordination problem as a constrained optimization problem. In the distribution system, the (OF) was targeting a minimum OT of OC relays. A new optimization technique called Water cycle algorithm (WCA) is presented to deal with the problem of overcurrent relays coordination. To define the best OC relay setting, the adapted problem is mathematically formulated

3.1particle swarm optimization

In PSO, each single solution is a "bird" in the search space. We call it "particle". All of particles have fitness values, which are evaluated by the fitness function to be optimized, and have velocities, which direct the flying of the particles. The particles fly through the problem space by following the current optimum particles. When a particle takes part of the population as its topological neighbors, the best value is a local best and is called p-best. Figure 6 shows the flowchart of Particle Swarm Optimization. In the particle swarm optimization algorithm, particle swarm consists of “n” particles, and the position of each particle stands for the potential solution in D-dimensional space. The particles change its condition according to the following three principles:

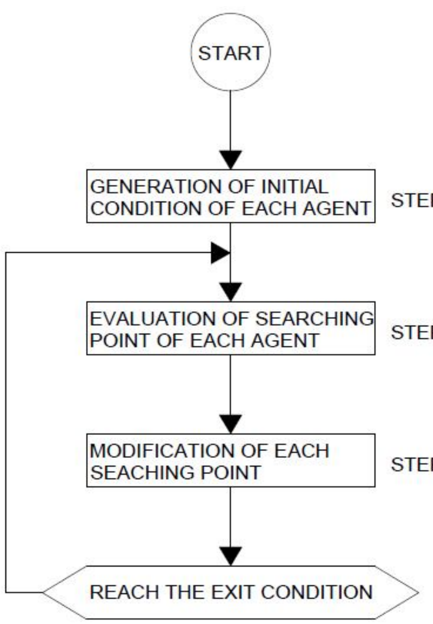
(1)To keep its inertia

(2) To change the condition according to its most optimist position

(3) To change the condition according to the swarm’s most optimist positionthe general flow chart of PSO can be described as follows:

PSO is a computational intelligence method that optimizes a problem by emulating a flock searching over candidate solutions (information carried by the particles) through search space. This algorithm allows all the random particles to search for the optimum solution in the search space through iterative process. Each particle will earn their best experience while interacting with each other to share their knowledge. PSO is afaster convergence and less parameters to tune and easier searching in very large problem spaces.

Flow Chart of PSO



Step 1: Generation of initial condition of each agent Initial searching points and velocities of each agent are usually generated randomly within the allowable range. The current searching point is set to *p*best for each agent. The best evaluated value of *p*best is set to *g*best and the agent number with the best value is stored.

Step 2: Evaluation of searching point of each agent. The objective function value is calculated for each agent. If the value is better than the current *p*best of the agent, the *p*best value is replaced by the current value. If the best value of *p*best is better than the current *g*best, *g*best is replaced by the best value and the agent number with the best value is stored.

Step 3: Modification of each searching point. The current searching point of each agent is changed.
Step 4: Checking the exit condition such as maximum number of iteration

The PSO Algorithm having following advantages such as,

(i) PSO is based on the intelligence. It can be applied into both scientific research and engineering use.

(ii) PSO have no overlapping and mutation calculation. The search can be carried out by the speed of the particle. During the development of several generations, only the most optimist particle can transmit information onto the other particles, and the speed of the researching is very fast.

(iii) The calculation in PSO is very simple. Compared with the other developing calculations, it occupies the bigger optimization ability and it can be completed easily.

(iv) PSO adopts the real number code, and it is decided directly by the solution. The number of the dimension is equal to the constant of the solution

Basic description of PSO

PSO is a swarm intelligence meta-heuristic inspired by the group behavior of animals, for example bird flocks or fish schools. Similarly to genetic algorithms (GAs), it is a population-based method, that is, it represents the state of the algorithm by a population, which is iteratively modified until a termination criterion is satisfied. In PSO algorithms, the population P={p1,…,pn} of the feasible solutions is often called a swarm. The feasible solutions p1,…,pn are called particles. The PSO method views the set R d of feasible solutions as a "space" where the particles "move". For solving practical problems, the number of particles is usually chosen between 10 and 50

Swarm topology

Each particle i has its neighborhood Ni (a subset of P). The structure of the neighborhoods is called the swarm topology, which can be represented by a graph. Usual topologies are: fully connected topology and circle topology.

Characteristics of particle i at iteration t:

x_i (t) … the position (a d-dimensional vector)

p_i (t) … the "historically" best position

l_i (t) … the historically best position of the neighboring particles; for the fully connected topology it is the historically best known position of the entire swarm

v_i (t) … the speed; it is the step size between x_i (t) and x_i (t+1) At the beginning of the algorithm, the particle positions are randomly initialized, and the velocities are set to 0, or to small random values.

Parameters of the algorithm:

w (t) … inertia weight; a damping factor, usually decreasing from around 0.9 to around 0.4 during the computation

φ1, φ2 … acceleration coefficients; usually between 0 and 4.

Update of the speed and the positions of the particles

Many versions of the particle speed update exist, for example:

v_i (t+1) =w (t) v_i (t)+ φ1u1(pi (t) -x_i (t))+ φ2u2(li (t) -x_i (t)).

The symbols u1 and u2 represent random variables with the U(0,1) distribution. The first part of the velocity formula is called "inertia", the second one "the cognitive (personal) component", the third one is "the social (neighborhood) component". Position of particle i changes according to *xi (t+1) = xi (t) +vi (t+1).*

Stopping rulethe algorithm is terminated after a given number of iterations, or once the fitness values of the particles (or the particles themselves) are close enough in some sense.

PSO variants There is a plethora of different versions of PSOs, which usually modify the formula for the change of velocity (e.g., instead of u1 and u2 they use diagonal matrices U1 and U2, in other variants they use no inertia, but enforce an upper limit on the particle speed, there is the so-called "fully informed" PSO, and there is also a popular modification using a "constriction coefficient"). There exist versions of the PSO for constrained optimization, for discrete optimization, and for multi-objective optimization.

The PSO calculation process is as follows

(1) Set the number of particles, the maximum number of iterations, the weight, and the learning factors.
(2) Initialize the particle swarm and randomly assign positions and velocities for each particle.
(3) Substitute the initial positions into the objective function to assess the fitness values for each particle.
(4) Compare the fitness values and the individual best memory positions *p*best of each particle to select better positions and update *p*best.

(5) Compare*p*bestand the swarm best memory value *g*best if *p*best is superior to *g*best update *g*best.

(6) Use the core PSO formulas to update particle velocities and positions. These formulas are shown as follows:

$$V_i^{j+1} = W \times V_i^j + C_1 \times rand1(\cdot) \times (P_{best} - P_i^j$$

$$+C_2 \times rand(\cdot) \times (G_{best} - P_i^j)$$

$$P_i^j = V_i^{j+1} = P_i^j$$

(7) Stop tracking if the stop conditions are met. Otherwise, rerun Steps 4 through 6. To stop conditions are either locating the global optimum or reaching the maximum number of iterations.

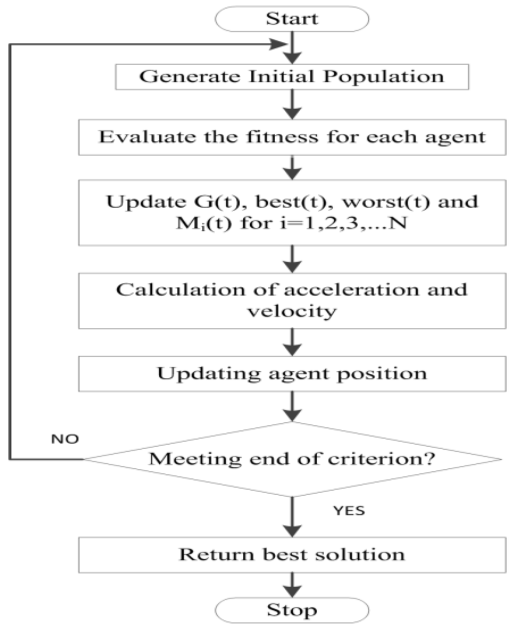
The search efficiency and success rate of PSO are determined primarily by the values assigned for the weights and the learning factors. When the weight is too high, the particle search might lack accuracy because the movement step sizes are too large. However, if the weight is low, particle movement becomes slow, and the local optimum trap might be unavoidable when facing multi-peak values. Thus, weighting is typically based on the objective function.

Conventional PSO is fast and accurate when searching for the output characteristic curves of PV module arrays with single peak values. However, when some modules are shaded, weights in conventional PSO must be readjusted appropriately based on various multipack curve characteristics. If this is not performed, excessively high or low weights result intracking failure. Thus, conventional PSO-based MPPT must be modified when some of the

3.2GRAVITATIONAL SEARCH METHOD

Gravitational Search Algorithm is a population based heuristic algorithm based on gravitational and Newton's law of motion. Agents are regarded to be bodies having variable masses [13]. Gravitational force between masses guides the movement of the agents. Every particle in the universe attracts every other particle with a force that is directly proportional to the product of their masses and inversely proportional to the square of distance between them [14]. Four parameters quantify each body in GSA: Position of the mass in d-th dimension, inertia mass, active gravitational mass, passive gravitational mass. The velocity of a body in a dimension is controlled by the gravitational and inertial masses. Moreover, the fitness value obtained through the application of this algorithm gives the value of these parameters [16]. The basic flowchart of GSA is given in Fig. 1

Flow Chart of GSA



4. SIMULATION RESULTS

A 4 bus radial system is taken, in which the grid is of 25 MVA and standard line data's are taken. Two cases are taken here, utility only mode, grid connected mode with 20 % penetration of DG. In all cases PSO and GSA techniques are applied to find the optimum value of TMS and PS of six relays present in each feeder. This optimization is achieved in MATLAB platform. The complete problem formulation of case I is described here. Similar process is adopted for other cases.

.

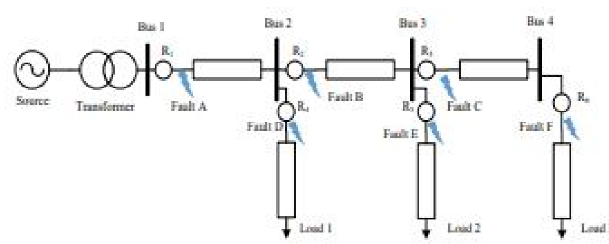


Fig. 2. Single source 4 bus radial system

TABLE I. C.T RATIOS OF EACH RELAYS (CASE I)

Relay No.	CT Ratio
1	1000/1
2	800/1
3	600/1
4	600/1
5	600/1
6	600/1

5. CONCLUSION

Two optimization techniques are used in this paper in order to find the optimal time multiplier setting (TMS) and Plug setting (PS) of six relays so that their total operating time can be minimized. The objective function is framed for two cases i.e. with and without DG. Further, it is minimized by maintaining the range of TMS of each relay as 0.08 to 1 and coordination time interval as 0.3s.The range of PS, determined for each relay is based on maximum load current and minimum fault current. Coordination is achieved in every case. The mal operation of relays due to presence of DG is thoroughly discussed and a comparative assessment of results is done. A demonstrative result is cited in a tabular form in order to reflect the superiority of GSA over PSO in the context of relay coordination objective.

This represents that GSA is a potential optimization technique which can be applied for relay coordination task. Further two more practical cases, one with divergent DG penetration level and other with varying fault current level are also discussed. From the results it can be inferred that if the relays are adaptive in nature then it can judge the DG penetration level and update the relay settings obtained from the analysis. Once the relays are set as per settings given by GSA it will work for all types of asymmetrical faults that occur frequently in a system. Thus GSA is proved superior in these cases too.

REFERENCES

[1] This article is revised version of PIICON Conference Paper : Jayant Mani Tripathi, Adhishree, Ram Krishan," Optimal Coordinationof Overcurrent Relays using Gravitational Search Algorithm with DG Penetration",6th IEEE Power India International Conference (PIICON), Delhi,5-7 Dec. 2014.

[2] P.P Barker, R.W. de Mello, "Determining the impact of distributed generation on power systems part I- radial distribution systems," IEEE Trans. on Power Delivery,vol. 15, pp. 486-493,Apr.2000.

[3] A.Fazanehrafat, S.A.M. Javadian, S.M.T Batbee, M.R. Haghifam, "Maintaining the recloser-fuse coordination in distribution systems in presence of DG by determining DG size," Proc. IET 9th International Conference on Developments in Power System Protection(DPSP), pp. 132-137, Mar 2008.

[4] A. Urdaneta, et al, "Optimal Coordination of Directional Overcurrent Relays in Interconnected Power Systems," IEEE Trans. on Power Delivery, vol. 3 , no. 3, pp. 903-911, 1988.

[5] P. P. Bedekar, S. R. Bhide, Vijay S Kale, "Coordination of overcurrent relays in distribution system using Linear Programming Problem," International Conference on Control Automation Communication and Energy Conservation -2009, 4th-6th June 2009.

[6] R.E. Albercht, et al, "Digital Computer Protection Device Coordination Program –I General Program Description", IEEE Trans. on Power Apparatus and Systems, vol. 83, no. 4, pp. 402-410, 1964.

[7] M.J. Damborg, et al, "Computer Aided Transmission Protection System Design, Part I – Algorithms," IEEE Trans. on Power Apparatus and Systems, vol. 103, no. 1, pp.51-59, 1984.

[8] L. Jenkines, et al, "An Application of Functional Dependencies to the Topological

Analysis of Protection Schemes," IEEE Trans. on Power Delivery, vol. 7, no. 1, pp. 77-83. 1977.

[9] A. Rathinam, D. Sattianadan, K. Vijayakumar, "Optimal coordination of directional overcurrent relays using particle swarm optimization technique," International Journal of Computer Applications (0975- 8887), vol. 10, pp. 43-47, 2010.

[10] M. R. Asadi, S.M. Kouhsari, "Optimal overcurrent relays coordination using particle-swarm-optimization algorithm," IEEE/PES Power Systems Conference and Exposition (PSCE 2009), 2009.

[11] Adhishree Srivastava, Jayant Mani Tripathi, S.R. Mohanty,"Overcurrent Relay Coordination with Distributed Generation using Hybrid PSOGSA", Electric Power Components and Systems, Taylor and Francis, Vol. 44, pp. 506-517, Feb 2016

[12] P. P. Bedekar, S. R. Bhide, Vijay S Kale, "Optimum coordination of overcurrent relays in distribution system using genetic algorithm,"