*International Journal of Recent Research and Review, Vol. XII, Issue 3, August 2019*
ISSN 2277 – 8322

# OPTIMAL COORDINATION OF OVERCURRENT RELAY BY PARTICLE SWARM OPTIMIZATION

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***Abstract-* Power system protection is designed to continuously monitor the system to ensure maximum continuity of supply without damaging the system equipment's. Since developments in power system changes its structure, power system protection becomes vital. If any abnormality (fault) occurs in system, there must be such devices which can identify that fault in order to isolate the faulty section from remaining healthy section. This very much essential function is carried out by "Protective Relays". Relay coordination is to select the suitable relay settings such that their fundamental protective function is met under the requirements of sensitivity, selectivity, reliability and speed. The main objective of optimization of relay coordination in an extensively large power system network is to enhance the selectivity and at the same time reducing the fault clearing time to improve reliability of the system. The relays provided are set to function properly in normal as well as abnormal condition. In this work; the main focus is to find out optimal Time Dial Setting (TDS) for the relays connected in whatever configuration using artificial intelligence based algorithms. The innovative feature of this work is the application of nature inspired algorithms to one of the major problem of optimization in the field of power system protection.**

**Keywords: Relay Coordination, Linear Programming (LP), Particle Swarm Optimization (PSO).**

## I. INTRODUCTION

Representation of power system network including all three phases becomes too complicated therefore it is simpler to present the network as symbolic representation of each element of the network. This presentation is known as single line diagram of power system. Consider the single line diagram of power system. Power is generated in generating station then it stepped up by step up transformer (T1) at Transmission level to reduce line losses. This power is then transmitted by long transmission lines. The voltage is stepped down to a level with the help of step down transformer (T2).Due to faulty condition the current is diverted from its normal path. Because of the faulty conditions the fault impedance is low and fault current is relatively high. During the faulty conditions the power is diverted to fault during faults, power is diverted towards the fault .This faulty part must be isolated from remaining healthy system. In order to isolate the faulty section from the healthy part and to maintain continuity of supply, circuit breakers are employed in power system Modern power system consists of more generation, transformers and huge network. To protect the power system, the protective scheme must have a high degree of reliability. To protect the power system from hazards, due to fault currents and/or abnormal voltages produced by faults, there is need of reliable protective scheme arises. Short circuit is the most common abnormality against which protective scheme is required. There are other abnormal conditions like overloads, over-voltage, under- voltage, open-phase, power swings, under and over-frequency, instability etc. against which there must be suitable protective scheme.

The protection system in power system plays vital role in power system. Its main purpose is to detect and clear the faults in shortest time and isolate only the faulted part of the system. Due to the complicated structure topology of the modern interconnected power systems and the operation close to its limits, the setting and coordination of protective relays have become [1] very complex and tedious operation. For coordination of over current relay Trial And Error method is traditionally used, the trial and error approach was used to solve the relays coordination problem. But this method requires a large number of iterations in order to achieve the optimal relay setting and having slow rate of convergence Due to increase in complexity of the modern interconnected system, trial and error approach is time consuming and not optimal [2]. In paper [3], an algorithm for relay coordination is proposed. It uses the Simplex two- phase method, this algorithm consist of two phases. I check whether all the selected operating conditions between the primary and backup relays are valid, then Phase II gives the optimum relay settings. The operating conditions which are detected in Phase I to be "not valid are excluded at the beginning of the Phase II. The algorithm, based on a linear programming technique using the Simplex two-phase approach, which optimizes the operating time of the relays. The developed technique has the ability to identify the infeasible conditions and to isolate them. Optimal coordination of over-current relays is carried out by a method in which it remove requirement of include additional auxiliary variables and an objective function. It is a very simple technique and the number of iterations for the program to converge is comparatively low. It also considers both relays of the characteristics of which are linearly proportional to TDS (L.P) and nonlinearly proportional to TDS (N.L.P) [4].

Particle swarm optimization (PSO) algorithm is a method having ability to determine optimal current setting multiplier and time setting multiplier of Over current relay. Additionally this technique, the objective function is introduced. This technique is cable to solve the problems as discontinuous and continuous time setting and plug setting and also it can solve the problem of mis-coordination problem among the relays. This method improves coordination and the operational speed of relays. This technique Gives the absolute optimal point, which is not being trapped in a local optimal point, its ability to be applied on large network [5-6]. For Computation of minimum relay break point set (BPS) an Integer linear programming (ILP) method can be used. In this paper present an alternate maximum independent relay Break point set formulation to minimizing dependency within the Break point set. For optimal coordination of over current relay paper [7] presents new Hybrid method. This technique takes both time setting multiplier as continues parameter and pick up current setting as a discontinues parameter in optimization procedure. The new thing of this paper is that quantizing pick up current setting parameter is considered as a part of optimization producer in particle swarm optimization iterations. Then, calculate the optimum time multiplier setting with linear programming technique at the end of each iteration of Particle Swarm optimization algorithm. In order to increase the accuracy of particle swarm optimization algorithm, first of all particle positions of swarms are calculated with linear technique. In this technique far end faults and near end faults are both are consider in the constraints in optimal coordination of over current relay [8]. Particle swarm optimization algorithm which is in standard format is not able to deal the coordination of directional over current relay which is a constrained optimization problem. If this standard format of particle swarm optimization is modified, it can be used to deal with constrained optimization problem. In this literature two modifications are introduced. For searching an optimal setting of relays, another method for initializing Particle swarm optimization, rather than the random initialization is proposed [9].

With considering different network topologies for coordination of relay technique based on interval analysis for directional over current relay is present in this article. Formulation of relay coordination problem as a linear programming problem having large inequality constraints and different network configuration is considered. This paper present an algorithm, in which the set of inequality constraints related to each relay pair is converted to an interval constraint. By using this method, the coordination problem is formulated as an integer linear programming problem with interval inequality constraints. The obtained integer linear programming problem, having no equality constraints, is converted to a standard Linear programming [10].

## II. PROBLEM FORMULATION

### *A. Problem objectives*

In the protective system, to maintain reliability the accurate or suitable setting and coordination of protective relays require that the relays which is closes to the fault location must operate faster than the remaining relays ,to remove only, the faulted portion of the power system. Every main relay has a backup relay operate after a certain time delay which is known as coordination time interval (CTI), for giving the time to the main relay to operate.

*Objective function*

In coordination problem of over current relays the objective is to determine the time setting multiplier (TSM) and plug setting multiplier(PSM) of each relay so that overall operating time of relays is minimized [23].

$$S = min\sum_{i=1}^{n} t_i \quad (1)$$

Where,ti is the operating time of ith relay. The number of relay is n.The operating time of overcurrent relay is given by (IDMT relay)[24]

$$T = Ki*TDS \quad (2)$$

Where,

$$K_i = \frac{0.14}{(PSM)^{0.02}-1} \quad (3)$$

### B. System Constraints

In this paper following equality and inequality constraints are considered [25]:

$$t_{2,k}-t_{1,k} \geq MCT \quad (4)$$

$$t_{1,k,min} \geq t_{1,k} \geq t_{1,k,max} \quad (5)$$

## III. SWARM INTELLIGENCE BASED ALGORITHMS

### A. Linear Programming Method

#### 1) Overview

A mathematical technique to help for planning and make decisions relative to the trade-offs Necessary to allocation of resources will find the minimum or maximum value of the objective which guarantees the best or optimal solution to the model formulated. Linear programming is a very well-known and popular method used in mathematical modelling technique which can determine the optimum allocation of scarce resources among the competing demands. Resources typically include raw materials, manpower, machinery, time, money and space. As from its name implies, the linear programming technique uses linear objectives and linear constraints, which means that the variables in the problem have a proportionate or linear relationship.

#### 2) Formulation of Linear Programming Problem

1) Define the objective function of a problem will be to maximize or to minimize some numerical value.
2) Define the variables in a linear program are a set of quantities that need to be determined in order to solve the problem known as decision variables.
3) Define Constraints the possible values that the variables of a linear programming problem may take, including the Non-negativity Constraints.

### B. Particle Swarm Optimization

#### 1) Overview

Particle Swarm Optimization (PSO) algorithm is an efficient evolutionary algorithm (EA) which is inspired by the social flocking behaviour of birds and the schooling behaviour of fish. All the particles in the PSO fly through problem space. Thus, working behaviour of swarm intelligent techniques is based on three important factors [26]:

1. Cohesion—Stick together.
2. Separation—doesn't come too close.
3. Alignment—Follow the general heading of the flock.

#### 2) Initialization

As like other evolutionary algorithms, PSO is also initialized with some random solutions. In PSO, each individual "i", called particle, represents a solution to the optimization problem i.e. a vector of decision variables, $X_i$ [27].

$$X_i = X_i^{min} + rand()*(X_i^{max} - X_i^{min}) \quad (6)$$

Here, NP shows the number of particles,(i=1, 2.....NP)

*3) Update the solution vector*

In PSO algorithm particles follow the fittest member of the swarm and move toward historically good areas of the provided space. Each particle tries to modify its position using. In order to modify the solutions vector, each individual is associated with some velocity, v. Starting from some random value, velocity is updated in each iteration by the following equation [28].

$$v_{ij}^{t+1} = wv_{ij}^{t} + c_1R_1(Pbest^t - X^t) + c_2R_2(Gbest^t - X^t) \quad (7)$$

$V^t_{ij}$ is velocity of jth member of ith particle at iteration number t which is bounded in its min-max limits [29]

$$v_j^{\min} \le v_{ij} \le v_j^{\max}$$

Here, Gbest is the global best position in the problem space. Pbest is the best known individual position of a particle.$R_1$& $R_2$ are the random numbers generated between 0 and 1.

On the other hand, $C_1$& $C_2$ can vary in range of 0-4 but these are adjusted such as sum of $C_1$ and $C_2$ should be 4. w is inertia-weight which is given as below [30].

$$w = w^{\max} - \frac{(w^{\max} - w^{\min}) * iteration}{\max iteration} \quad (8)$$

The position vector of swarms is updated by adding the velocity 'v' in the current solution vector as given below [31].

$$X^{t+1} = X^t + v^{t+1} \quad (9)$$

## IV. SIMULATION STUDY & RESULTS

*a) System under study*

There are two systems under study, system-1 and system-2 as given below in fig.1 and fig.2. System data for both the systems is also given in Table I, II, III and IV as below.

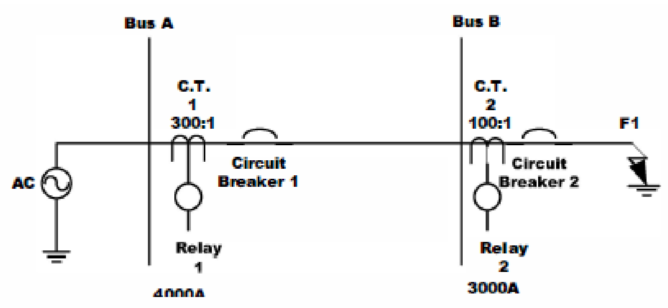


Fig. 1 System-1 under study

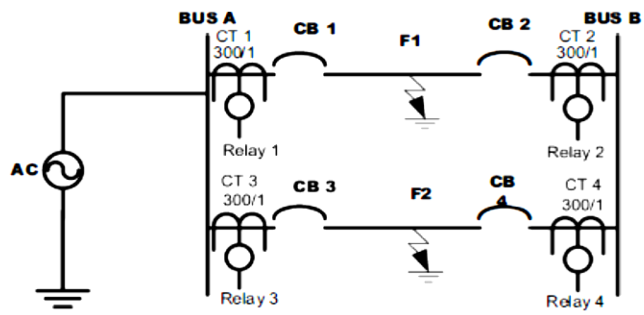


Fig. 2 System-2 under study

Table I

System 1 Data

| | Bus A | Bus B |
|---|---|---|
| Maximum fault current | 4000 A | 3000A |
| CT ratio | 300/1 | 100/1 |
| Plug setting | 100% | 100% |

Table II

Constraints for System -1

| | |
|---|---|
| Minimum and maximum operating time | 0.2 s and 1.2 s |
| Minimum coordination time | 0.25 sec |
| TDS | 0 to 1.1 |

Table III

System-2 Data

| | Bus-A | Bus-B |
|---|---|---|
| Maximum fault current | 4000 A | 4000A |
| CT ratio | 300/1 (for all relays) | 300/1 (for all relays) |
| Plug setting | 100% | 100% |
| Primary and back-up relay | R3 and R2 | R4 and R1 |

Table IV

Constraints for System -2

| | |
|---|---|
| Minimum and maximum operating time | 0.2 s and 1.2 s |
| Minimum coordination time | 0.5 sec |
| TDS | 1 to 1.1 |

*b) Optimal solution obtained*

Comparative study for optimal coordination of over current relay in system-1 and system-2 is given in table V. Parameters setting obtained by PSO algorithm is compared with the solutions of linear programming.

Table V

Optimal Solution for System-1 and System-2

| | Linear programming | | | | PSO algorithm | | | |
|---|---|---|---|---|---|---|---|---|
| System-1 | R1 | | R2 | | R1 | | R2 | |
| Time dial setting | 0.1539 | | 0.1 | | 0.1515 | | 0.1 | |
| Total operating time(s) | 0.6041 | | | | 0.5985 | | | |
| Number of decision variables | 02 | | | | 02 | | | |
| Max. iterations | 100 | | | | 200 | | | |
| System-2 | R1 | R2 | R3 | R4 | R1 | R2 | R3 | R4 |
| Time dial setting | 0.125 | 0.125 | 0.035 | 0.035 | 0.122 | 0.122 | 0.035 | 0.035 |
| Total operating time(s) | 0.14 | | | | 0.12 | | | |
| Number of decision variables | 04 | | | | 04 | | | |
| Max. iteration | 100 | | | | 200 | | | |

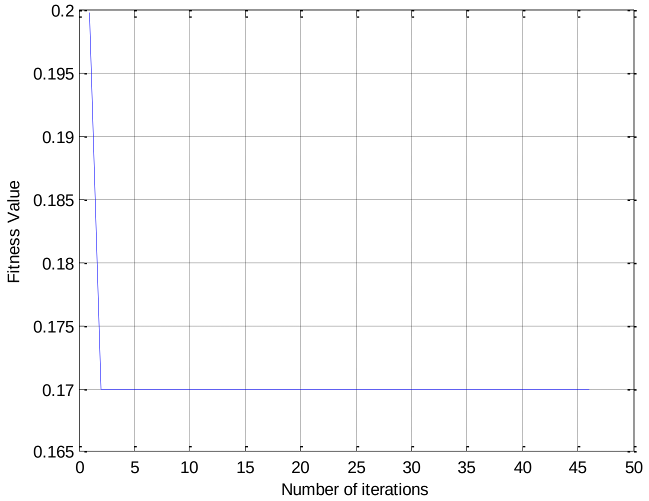


Fig.3 Fitness curve for relay coordination of system-1obtained by PSO technique

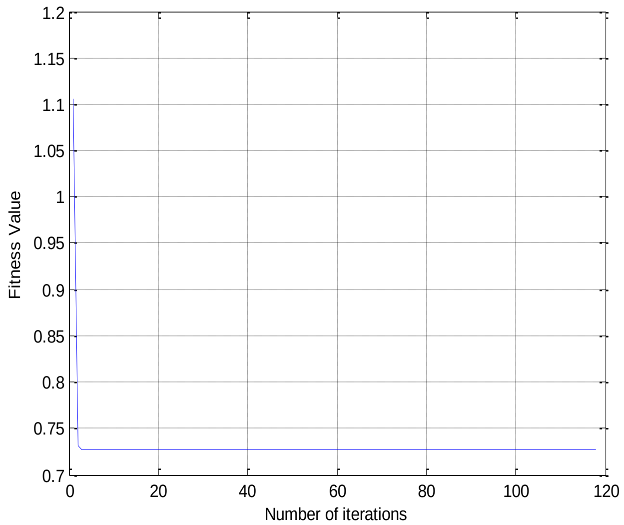


Fig.4Fitness curve for relay coordination of system-2 obtained by PSO technique

Fig. 3 shown above gives the fitness curve obtained for optimal coordination of system-1. Maximum number of iterations kept is 100 but the algorithm converged in only 42 iterations and minimized the operating time up to 0.17 sec. Fig. 4 shown above gives the fitness curve obtained for optimal coordination of system-2. Maximum number of iterations kept is 150 but the algorithm converged in only 118 iterations and minimized the operating time up to 0.726 sec.

## V. CONCLUSION

The main objective of optimization of relay coordination in an extensively large power system network is to enhance the selectivity and at the same time reducing the fault clearing time to improve reliability of the system. The innovative feature of this work is the application of nature inspired algorithms to one of the major problem of optimization in the field of power system protection. The operating time of the relays for coordination is obtained for two systems using two techniques i.e. linear programming method and particle swarm optimization. System-1 and system-2 understudy carries two and four relays respectively. Parameters setting obtained by PSO algorithm for system-1 and system-2 minimized the operating time by 70% and 35% respectively, in comparison of results obtained by linear programming technique. Maximum number of iterations kept in PSO while study of system-1 is 100 but the algorithm converged in only 42 iterations on the other hand LPP taken 100 iterations. The comparative study of the results obtained using both the techniques for relay coordination shows that the particle swarm optimization performs better than linear programming technique in terms of minimized operating time as well as less time taken in convergence.

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