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A Comparative Review on Minimizing Transmission Losses Using Genetic Algorithm, Particle Swarm Optimization and Coordinate Aggregation Particle Swarm Optimization

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ABSTRACT: Today every developed and underdeveloped country is facing same problem i.e. transmission losses, so the basic challenge is to optimize this losses by various techniques. In order to minimize the losses in the power industry researchers are introducing several techniques and algorithms in the field of transmission losses. This paper will present a new approach to minimize the losses through three different techniques i.e. genetic algorithm, particle swarm and coordinate aggregation particle swarm. It will highlight the features of these techniques, furthermost it will also explore the development and future application regarding with these techniques.

Keyword: Transmission losses, Optimization Technique, Genetic Algorithm, Particle Swarm, Coordinate Aggregation Particle Swarm.

I. INTRODUCTION

Today at present day scenario electric power transmission is growing very vastly in worldwide. Due to this bulk transfer of electric energy a huge transmission losses create in the transmission system which causes from generating plant to electric substations. It is therefore becoming essential to optimize these losses with optimization techniques [1]. To use these mathematical methods in optimization problems it is necessary to select a suitable initial starting point for their algorithms [2]. It has been found that Newton based algorithms will face problem in having large number of inequality constraints.

It have been approved short coming of Linear programming methods is associated with the piecewise linear cost approximation. Non linear programming methods have also been applied to solve the convergence problem. Evolutionary Programming (EP) technique, evolutionary computation technique such as Genetic Algorithm (GA), Artificial Neural Network (ANN), Particle Swarm Optimization (PSO), etc, are some of the proposed methods to solve to minimize the transmission losses in power system. These techniques have been successfully used to solve a number of important power system problems.

The proposed methods discussed here are GA, PSO and CAPSO. While Genetic algorithm offers a new and powerful approach to this optimization problem .It made possible by increasing the availability of high performance computers. These algorithms have recently found extensive application in solving global optimization searching problems. It updates the conventional load flow programs. This will help to optimize the transmission losses.

II. GENETIC ALGORITHM

Genetic algorithm (GA) is a search heuristic that mimics the process of natural evolution. This heuristic is routinely used to generate useful solutions to optimization and search problems.

Genetic Algorithms [8] are a family of computational models inspired by evolution. These algorithms encode a potential solution to a specific problem on a simple chromosome-like data structure and apply recombination operators to these structures as to preserve critical information. Genetic algorithms are often viewed as function optimizer, although the ranges of problems to which genetic algorithms have been applied are quite broad.

An implementation of genetic algorithm begins with a population of (typically random) chromosomes [3]. One then evaluates these structures and allocated reproductive opportunities in such a way that these chromosomes which represent a better solution to the target problem are given more chances to reproduce' than those chromosomes which are poorer solutions. Various components of the proposed algorithm used to solve the basic problem, the details of which are presented in the following sections [14].

A. Coding

The variables are first coded in some strings structures. While in some GA it is directly used on the variables themselves. Binary-coded strings having 1's and 0's are mostly used. The length of the string is usually determined according to the desired solution accuracy. While the strings are represents as $(y_1^{(l)}, y_2^{(l)})^T \& (y_1^{(u)}, y_2^{(u)})^T$.

Usually the variable x_i is coded in a substring s_i of length l_i as shown here

$$y_i = y_i^{(l)} + \frac{y_i^{(U)} - y_i^{(l)}}{2^{li} - 1} \text{ decode value } (s_i) \qquad ...(1)$$

The decoded value of a binary substring s_i is calculated as

$$\sum_{i=0}^{i-1} 2^i s_i \qquad …(2)$$

where s_i ∈ (0, 1) and the string s is represent as $(s_{i-1}, s_{i-2} \cdots\cdots s_2, s_1, s_0)$. Generalizing this concept, we may say that with a l_i bit coding for a variable, the obtainable accuracy in that variable is shown previously in the above decoded values. Once the coding of the variables has been done, the corresponding points as given $y = (y_1, y_2, y_3 \ldots\ldots, y_N)$.

B. Fitness Function

GA means the survival-of-the-fittest principle of nature to make a search process. So they are naturally suitable for solving the problems. A fitness function *F(x)* is first derived from the objective function and used in successive genetic operations. For maximization problem the fitness problem is same as the objective function as *F(y) = f(y)*. While in case of minimization the fitness function is same as maximization. The following fitness function is often used as given

$$F(y) = 1/(1+f(y)). \qquad …(3)$$

This fitness function value of a string is known as the string's fitness.

C. GA Operators

The operation of GAs begins with a population of random strings, it represent the decision variables or representing the design. The three main GA operators are reproduction, crossover and mutation to create a new population of points.

D. Reproduction

Reproduction is an operator that makes more copies of better strings in a new population. Reproduction is usually the first operator applied on a population. Reproduction selects good strings in a population and forms a mating pool. The reproduction operation is said to be sometimes as the selection operator. It encodes successful structures to produce copies more frequently. For better individuals, these should be from the fittest individuals of the previous population.

E. Crossover

A crossover operator is used to recombine two strings to get a better string. In crossover operation, recombination process creates different individuals in the successive generations by combining material from two individuals of the previous generation. It is important to note that no new strings are formed in the reproduction phase. In the crossover operator, new strings are created by exchanging information among strings of the mating pool. When crossover probability of p_c is used, only 100 p_c per cent strings in the population are used in the crossover operation and 100(1- p_c) percent of the population remain as they are in the current population.

F. Mutation

Mutation adds new information in a random way to the genetic search process and ultimately helps to avoid getting trapped at local optima. It is an operator that introduces diversity in the population whenever the population tends to become homogeneous due to repeated use of reproduction and crossover operators. Mutation may cause the chromosomes of individuals to be different from those of their parent individuals. Mutation in a way is the process of randomly disturbing genetic information. The mutation operator changes 1 to 0 and vice versa with a small mutation probabilityp_m. This new population is used to generate the further population and yield the solution which is closer to the optimum solution. These values express the fitness of the solutions of the new generations. However this complete one cycle of genetic algorithm known as generation. In each generation if the solution is best then it is stored as the best solution. This process is repeated till convergence.

III. PROPOSED METHODOLOGY FOR MINIMIZING THE LOSSES

Step 1: Using load flow program referring any IEEE bus system, determine the transmission losses through it. Determine the bus system data analysis.
Step 2: Forming Y-bus and also perform the load flow.
Step 3: Now this transmission losses will represent the problem parameter.
Step 4: Set the range of the tapping and shunt compensation for any bus IEEE bus system.
Step 5: Specify the parameter for Genetic Algorithm
Step 6: Generate initial population and apply to genetic algorithm in order to optimize the objective function.
Step 7: If Gen > Gen_{max} or other termination criteria are satisfied then the process will end.
Step 8: Perform reproduction on the population.
Step 9: Perform crossover on random pairs of strings.
Step 10: Perform mutation on every string.

Step 11: Evaluate strings in the new population. Set Gen=Gen+1 and go the Step 2.

Step 12: After the iteration are completed we will able to see that transmission losses before using GA are more.

In general GA flowchart is shown below:

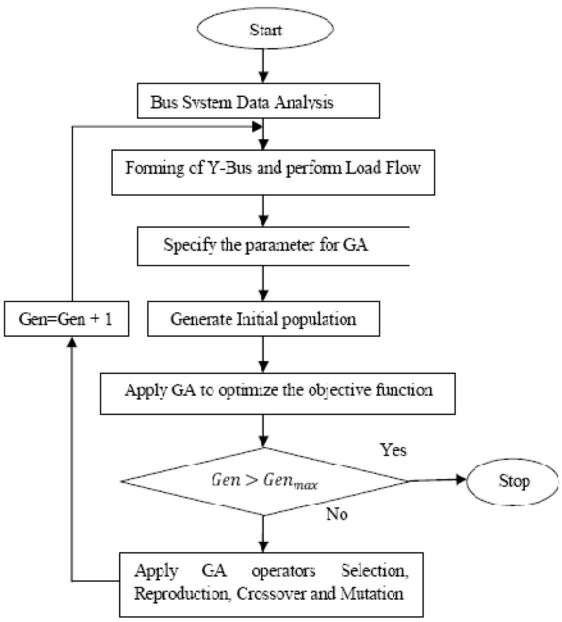

Fig. 1. Flowchart of the GA procedure.

IV. PARTICLE SWARM OPTIMIZATION (PSO)

In 1995, Kennedy and Eberhart first introduced the PSO method, motivated by social behavior of organization such as fish schooling and bird flocking. PSO, as an optimization tool, provides a population-based search procedure in which individuals called particles change their positions (states) with time. In a PSO system, particles fly around in a multidimensional search space. During flight, each particle adjusts its position according to its own experience, and the experience of the neighboring particles, making use of the best position according encountered by itself and its neighbors. The swarm direction of a particle is defined by the set of particle neighboring the particle and its history experience [14].

The performance of each particle is evaluated by the value of the objective function and considering the minimization problem, in this case, the particle with lower value has more performance [11]. The best experiences for each particle in iterations is stored in its memory and called personal best (P_{best}).

The best value of P_{best} (less values) in iterations determines the global best (G_{best}).

Each particle in the PSO algorithm moves with an adaptable velocity within the regions of decision space and retains a memory of the best position it ever encountered [10]. The best position ever attained by each particle of the swarm is communicated to all other particles. Specifically, the conventional PSO assumes an *n*-dimensional search space denoted by *S*.

The position of the i*th* particle at time-*t* is an *n*-dimensional vector denoted by

$$s_i^t = (s_{i.1}^t, s_{.i.2}^t \cdots\cdots s_{i.n}^t) \in S \qquad \ldots(4)$$

The velocity of this particle at time-*t* is also an *n*-dimensional vector

$$v_i^t = (v_{i.1}^t, v_{i.2}^t, \ldots\ldots v_{i.n}^t) \in S \qquad \ldots(5)$$

The best previous position of the *i*th particle is a point in *S*, denoted by

$$p_{gbi} = (p_{gbi1}, p_{gbi2} \ldots\ldots p_{gbin}) \in S \qquad \ldots(6)$$

The global best position ever attained among all particles is a point in S denoted by

$$G_{gbi} = (g_{gbi1}, g_{gbi2} \ldots\ldots g_{gbin}) \in S \qquad \ldots(7)$$

Then, the PSO assumes that swarm is manipulated by the equations

$$V_i^{(t+1)} = (w^{(t)} \cdot v_i^{(t)} + c_1 \cdot rand_1 \cdot (p_{gbi} - s_i^{(t)} + c_2 \cdot rand_2 \cdot (G_{gbi} - s_i^{(t)}) \qquad \ldots(8)$$

$$s_i^{(t+1)} = s_i^t + V_i^{(t+1)} \qquad \ldots(9)$$

Where $i = 1, 2, \ldots\ldots N$; C_1 *and* C_2 are the acceleration constant selected in the range from 1 to 2. While $rand_1$ and $rand_2$ are random number uniformly distributed within [0,1].

The inertia weighting factor for the velocity of particle-*i* is defined by the inertia weight approach

$$w^{(t)} = w_{\max} - \frac{w_{\max} - w_{\min}}{t_{\max}}.t \qquad \ldots(10)$$

Where t_{max} the maximum number of iteration and *t* is the current number of the iterations; w_{max} and w_{min} are the upper and lower limit of the inertia weighting factor respectively.

V. ALGORITHIM FOR PSO

The steps of PSO algorithm are listed bellow as

Step 1: *Generation of initial condition of each particle.*

Initial searching point ($s_i^{(0)}$) and velocity $(v_i^{(0)})$ of each particle are usually random within it ranges. The current searching point is set to P_{best} for each particle. The best evaluated value of P_{best} is set to G_{best}, and the best value is stored.

Step 2: *Evaluation of searching point of each particle.*
The objective function is evaluated for each particle. If the value is better than the current P_{best} of the particle, the P_{best} value will replaced by the current value. If the P_{best} value is better than the current G_{best}, then G_{best} will be replace by the best value is stored.

Step 3*: Modification of each search point.*
The current searching point of each particle is updating using $V_i^{(t+1)}$, $w^{(t)}$ and $S_i^{(t+1)}$.

Step 4: *Checking the exit condition.*
The current iteration number reached the pre-determined maximum iteration number as the stopping criterion. Otherwise the process proceeds to step 2.
The procedure of the particle swarm optimization can be further more summarized in the flow chart as in fig. 2.

VI. COORDINATE AGGREGATION PARTICLE SWARM OPTIMIZATION (CAPSO)

Recently it is seen that the effort is continued by the same and other researchers generating more and more effective Evolution Algorithms (EA). However, the main goal of the proposed EAs remains the same; achievement of the global best solution in the possible shortest time. Under this condition a new more effective method is proposed, which is capable of solving nonlinear optimization problems faster with better accuracy in detecting global best solution. The main idea behind the proposed Coordinated Aggregation (CA) algorithm is based on the fact that the objective values achieved by particles (achievements of particles) are distributed in the entire swarm. Specifically, at each iterative cycle of CA, the particles update their velocities taking into account the differences between their own position and the positions of particles with better achievements.

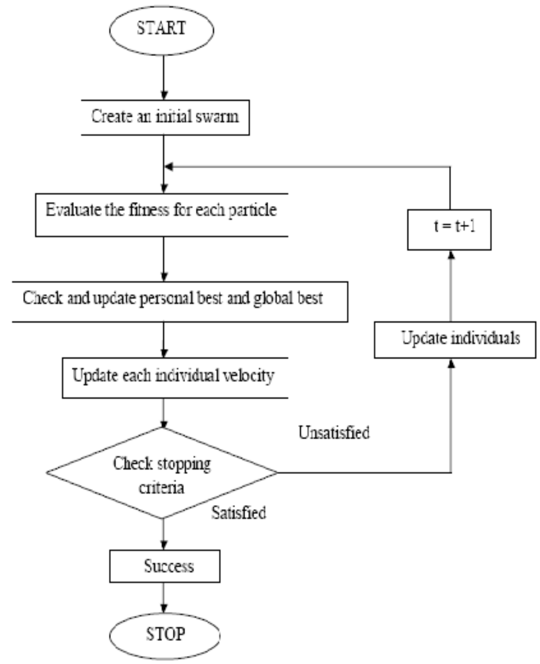

Fig. 2. Flowchart of the PSO procedure.

In CA these differences play the role of regulators and called *coordinators* as they are multiplied by weighting factors. The ratios of differences between the achievement of a specific particle and the better achievements succeeded by other particles to the sum of these differences are the weighting factors of coordinators. The given name of CA (Coordinated Aggregation) inspired from this procedure where particles aggregated using *coordinators*. The best particle in the swarm is excluded from this process, as it regulates its velocity randomly. Specifically, the best particle changes its velocity according to a random coordinator, which takes into account the difference between the position of the best particle and the position of a randomly chosen particle in the swarm. This seems like the *craziness* concept, and helps CA to overcome premature convergence in local minima.
However, in the proposed CAPSO, each particle distributes its achievement in the entire swarm but moves taking into account only the positions of particles with better achievements than its own [12].Specifically, at each iterative cycle-*t* of CA, each particle-*j* with better achievement than particle-*i*, regulates the velocity of the second.This is materialized using regulators of particle-*i* velocity multiplied by weighting factors *(coordinators)*. The differences between the positions of particles-*j* with better achievements and the position of particle-*i* $(S_j^{(t)} - S_i^{(t)})$ are defined as coordinators of particle-*i* velocity [13].

The ratios of differences between the achievement of particle-*i* and the better achievements by particles-*j* to the sum of these differences are the weighting factors of the coordinators, called achievement's weighting factors $w_{ij}^{(t)}$.

VII. ALGORITHM FOR CAPSO

The steps of CAPSO algorithm are listed bellow as

Step 1: Initialization
Generate *N*-particles. For each particle-*i* choose initial position $S_i^{(0)}$ randomly. Calculate its initial achievement $A(S_i^{(0)})$ using the objective function *f* and find the maximum $(A_g^{(0)} = \max A(S_i^{(0)})$ called global best achievement. Then, particles update their positions in accordance with the following steps:

Step 2: Swarm's manipulation
The particles, except the best of them regulate their velocities in accordance with the equation

$$V_i^{(t+1)} = w^{(t)}.V_i^{(t+1)} + \sum_j rand_j.w_{ij}^{(t)}.(S_j^{(t)} - S_i^{(t)}),$$

$$j \in T_i \qquad \ldots(11)$$

where: $i = 1, 2, \ldots, N$; the random parameter $rand_j$ is used to maintain the diversity of the population and is uniformly distributed in the range [0, 1]; $w_{ij}^{(t)}$ are achievement's weighting factors; the inertia weighting factor $w^{(t)}$ is defined in (10).
The role of the inertia weighting factor is considered critical for the CA convergence behavior. It is employed to control the influence of the previous history of velocities on the current one. Accordingly, the inertia weighting function regulates the trade-off between the global and local exploration abilities of the swarms.

Step 3: Best particle's manipulation (Craziness)
The best particle in the swarm updates its velocity using a *random coordinator* calculated between its position and the position of a randomly chosen particle in the swarm.

Step 4: Check the limits
Check if the limits of velocities are enforced (9). If the limits are violated then they are replaced by the respective limits.

$$[V_i^{\max}, V_i^{\max}], (j = 1,2,3) \qquad \ldots(12)$$

Step 5: Position update
The positions of particles are updated using (9)
Check if the limits of positions are enforced

$$[S_i^{\min}, S_i^{\max}], (j = 1,2,3) \qquad \ldots(13)$$

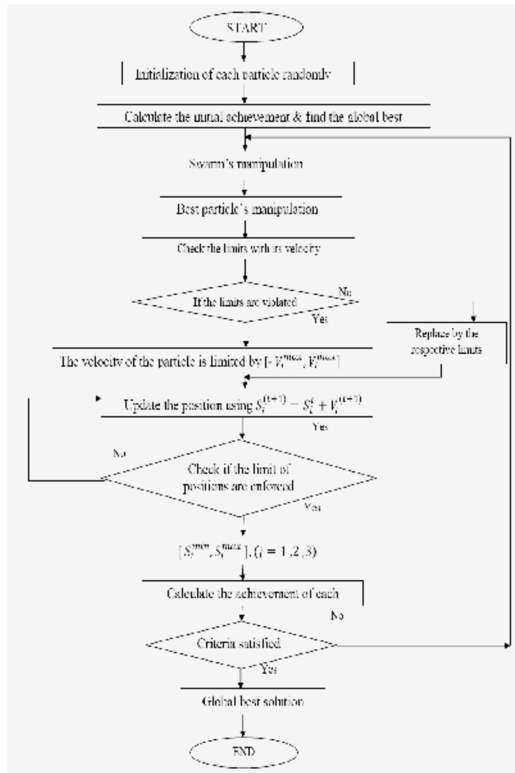

Fig. 3. Flowchart of CAPSO.

Step 6: Evaluation
Calculate the achievement $A(S_i^{(t)})$ of each particle-*i* using the objective function *f*.

Step 7: Check the process
If the stopping criteria are not satisfied go to Step 2. The CA algorithm will be terminated if no more improvement in the global best achievement is observed in the last generations, or the maximum number of allowed iterations is achieved.

Step 8: Global optimal solution
Choose the optimal solution as the global best achievement.

$$S_g = \arg\max A_g(S_g) \quad \ldots(14)$$

The procedure of the particle swarm optimization can be further more summarized in the flow chart as in Fig. 3.

VIII. FEATURES OF THE OPTIMIZATION TECHNIQUE

Comparing GA with conventional techniques it seen that it is more flexible and robust in nature. This method gives more accurate results as compared to other optimization method. It takes lesser processing time as compared with other traditional and conventional method. It is more efficient method which can be applied to reduce the transmission losses and improved power quality. Now some improved genetic algorithm is also used in reducing the losses. Multi-Objective genetic algorithm techniques are also used in order to minimize the losses [4]. It is used to minimize the distance of the solution .While now some more improved genetic algorithm are introduced such as General Quantum genetic algorithm. This GQ-GA technique will help reduce the losses in quick span of time [7]. Switching over other technique i.e. PSO. The PSO technique can be easily adapted to suit various categories of optimization problems with minor modifications. This key attribute makes the PSO a general purpose optimizer that solves a wide range of optimization problems. The PSO technique demonstrated its effectiveness in solving this difficult optimization problem by improving the solution's accuracy and computation time. Now PSO are used in the area of generation expansion planning to solve discrete nonlinear optimization problems. PSO was utilized in solving the expansion planning problem of a transmission line network. Hybrid technique is combining with PSO and other heuristic techniques to improve the performance [9]. While this PSO was more generalized by the technique introduces as CAPSO. It optimally manipulates the swarm regulating the empirical parameters, namely the limits of inertia weighting factor w_{max}, w_{min}, N_1, C_1 & C_2. It takes into account more coordinators for the swarm's manipulation than only one of the best positions a particle ever encountered, in the conventional PSO. it adopts a stochastic coordination for the manipulation of swarm similar to the craziness concept. Now hybridization is also introduced in the CAPSO technique for improvement [13].

IX. CONCLUSION

This paper explains the three different optimization techniques which are used as a effective tool for solving the problem. GA has been used to solve difficult problems with objective function which are multi-modal, discontinuous and non-differential.

It uses the concept of natural evolution where the strongest individuals survive. However, recent literatures show some deficiency of GA-based methods, newly developed heuristic approaches called particle swarm optimization (PSO) has been introduced. It combines social psychology principles and evolutionary computation to motivate the behavior of organisms. PSO has been discovered to have better convergence performances than GA. Another technique explained here completely new PSO algorithm based on the idea of communicating the better achievement succeeded by particles in the swarm manipulation. Coordinated Aggregation (CA) algorithm, each particle updates its position taking into account only the positions of particles with better achievements; with the exception of the particle with the best achievement which moves randomly. This all techniques have a common aim to reduce the transmission losses.

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