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HYBRID PSO WITH GA RECOMBINATION OPERATOR FOR EFFICENT TRANSMISSION SYSTEM PLANNING

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ABSTRACT

Transmission system planning is relevant problem and crucial part of power system planning which determines the number, time, and location of new lines for adding to transmission network. In this paper, PSO-GA hybrid which combines PSO with genetic operators was proposed to solve the planning problem. The proposed hybrid technique combines the strengths of PSO and utilize crossover operator of GA to realize the balance between natural selection and good knowledge sharing to provide robust and efficient search of the solution space. In this hybrid model, two driving parameters are utilized to optimize the performance by giving preference to either PSO or GA. Simulation results show that the proposed hybrid algorithm can overcome the disadvantages of particle swarm optimization and genetic algorithm, and achieve better performance. Results show that with the correct combination of GA and PSO, the hybrid does outperform both the standard PSO and GA models

Keywords – Hybrid, Operator, Planning, TSP, TNEP

I. INTRODUCTION

Transmission system Planning (TSP) is a critical concept in modern interconnected electric energy systems because lines which carries transmission allow energy flows from nodes starting from generating station to demand point. Demands must be continuously fulfilled even in the worst situations, like peak load or the failure of a generating unit. Thus, transmission expansion plans should be planned such that even if one of these situations occurs, demands are efficiently supplied. Transmission network expansion planning problem (TNEP) is a complex decision-making problem since it involves a multiattribute objectives, nonlinear constraints, and a non convex feasible region. As a result, different approaches have been proposed to deal with this complexity.

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TNEP is solved previously by conventional approaches such as linear programming [1], Mixed Integer programming [2-3], Bender decomposition [4] and branch & bound methods [5-6]. Numerous Authors adapted Intelligent Metaheuristic algorithms like simulated annealing [7], Tabu search [8], Genetic Algorithms (GA) [9-10] and Harmony search Algorithm [11] to solve TNEP. The applicability of PSO Algorithm to TSP is mentioned in [12-13]. A comparative study on non convex optimization methods for TNEP is quoted in [14]. Genetic Algorithms evaluates simultaneously many points in the search space, so it is more likely to find the global solution of a given problem. Additionally, it uses only a simple scalar performance measure that does not require or use derivative information, so methods classified as GA are easy to use and implement. Compared with GA, PSO also has some attractive characteristics like memory, so knowledge of good solutions is retained by all the particles; whereas in GA, previous knowledge of the problem is discarded once the population changes. It has constructive cooperation between particles; that is, particles in the swarm share information among themselves. To date, PSO has been successfully applied to optimizing various continuous nonlinear functions in practice. Hybridization of evolutionary algorithms with local search has been investigated in many studies. Such a hybrid is often referred to as a mimetic algorithm. In the case at hand, we will combine two global optimization algorithms, i.e., GA and PSO, as PSO and GA. Both work with an initial population of solutions and combining the searching abilities of both methods seems to be a reasonable approach. Originally, PSO functions according to knowledge of social interaction, and all individuals are taken into account in each generation. On the contrary, GA simulates evolution and some individuals are selected while some others are eliminated from generation to generation. Taking advantage of the compensatory property of GA and PSO, we propose a new algorithm that combines the evolutionary natures of both (denoted as GA-PSO).

Hybrid Neuro and GA approach [15] for TEP have been introduced in past decades. Hybridization of GA and PSO approach are mentioned by different authors in [16-20], which is the motivation behind this paper. The main focus of the paper is to investigate efficiency of proposed algorithm for TNEP with the proficiency of exploring optima in terms of diversity, convergence and computational time. First, the TEP is formulated as a non linear mixed integer programming problem. Secondly, a Hybridization of GA and PSO termed as hybrid PSO-GA based method is developed for TNEP problem and is applied to three IEEE test systems. The practicability and effectiveness of the suggested Algorithm is shown by test results for three systems.

II. PROBLEM FORMULATION

DC modeling having non linear and mixed-integer type is used for formulating the static TEP problem. The objective function can be formulated as follows:

$$\text{Minimize IC} = \sum_{ij\in\beta} l_{ij} B_{ij} . \qquad (1)$$

s.t.

$$RP = Q + M\theta . \qquad (2)$$

$$l_{ij} \leq \left(n_{ij}^{0} + n_{ij}\right) l_{ij}^{max} \qquad (3)$$

$$G_{imin} \leq G_i \leq G_{imax} . \qquad (4)$$

$$0 \leq x_{ij} \leq x_{ijmax} . \qquad (5)$$

$$\theta_{ijcal} \leq \theta_{ijmax} . \qquad (6)$$

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(1) represents the equation for objective function which indicates equipped transmission lines capital cost with certain limitations. IC represents transmission investment cost, I_{ij} is the cost of additional branch circuits, and B_{ij} is additional branch ij. Here β indicate set for all branches considered as candidates for expansion of branches. (2) - (7) are the formulation of equations for the constraints which are necessary for satisfactory planning requirement.

The linear inequality constraint for node power conservation is indicated by (2) where, RP is the vector representing existing real power in the power plants, Q is the vector for node load demand for all networks and M is the matrix indicating susceptance of the current and extra network lines. Here θ is the vector of phase angle for bus voltage. Again inequality constraint (3) is required to check the maximum power flow for each path with limit. Each element in constraint (3) for the formulated DC power can be calculated by using (7):

$$l_{ij} = \frac{\left(n_{ij}^{0}+nij\right)}{r_{ij}} * \left(\theta_i - \theta_j\right). \qquad (7)$$

Where l_{ij}, l_{ij}^{max} ,n_{ij}, and n_{ij}^{0}, r_{ij} are overall power flow in the branch ij, power flow which is maximum in the branch ij, Additional circuits of the ij branch, the original base system circuit number and reactance in the ij branch. Here θ_i and θ_j indicates the phase angle of voltage at ith and jth bus respectively.

Generated power constraint is taken as (4) where G_i is the real generated power at node i, G_{imin} and G_{imax} are the minimum and maximum limit of real power generation at node i respectively. For satisfactory planning, it is required that know the specified location of the additional circuit. Mathematically, this is expressed by (5) where x_{ij} and x_{ijmax} represent the total circuits required to add to the branch ij and maximum circuits required to add to branch ij respectively. Equation (6) indicates the voltage bus angle constraint.

2.2 Mathematical formulation of fitness function:

The fitness function calculation for proposed hybrid algorithm is stated below:

$$F = \frac{1}{IC+pf*C}. \qquad (8)$$

$$C = \sum_{i=1}^{k} V_i. \qquad (9)$$

Where, k is number of constraints taken in the formulated objective function. V_i is violation of ith constraint in percentage and pf is the penalty factor.

III. METHODOLOGY ADOPTED

3.1 Particle swarm optimization

In PSO, a number of “particles” which represent the candidate solution form the “swarm”. These particles flutter in the problem region and strive to discover the optimal solution in the region. Thus each particle could be representing by its “position” (variable vector) and “velocity” (in which direction to move in that instant). At each iteration particle moves towards an most favorable solution during its nearby velocity and their personal best solution attained by themselves and global best result conquered by all particles.

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Mathematically velocity and position of the particles have been updated by (10) and (11) as given below:

$$V_{t+1}^{i} = w \times V_t^i + c1 \times rand() \times (P_t^i - X_t^i) + c2 \times rand() \times (P_t^g - X_t^i) \quad (10)$$

$$X_{t+1}^{i} = X_t^i + V_{t+1}^{i}, \forall i = 1,2 \ldots .. N \quad (11)$$

The weighting factor e is modified using (12) to facilitate quick convergence:

$$e = e_{max} - \frac{e_{max} - e_{min}}{iter_{max}} \times iter . \quad (12)$$

e_{max} is the initial weight, e_{min} is the final weight, $iter$ is the current iteration number and $iter_{max}$ is the maximum iteration number.

Where N is particle number in the swarm, $c1\&c2$ are acceleration constants,w is Inertia weight, rand ( ) is uniform random value between 0 to 1, P_t^g is global best at generation t,P_t^i is best position that particle i possibly will find up to now. The first part of equation represents the previous velocity inertia, another part is cognition element and tells about the ones information of particle and last or third element is social component as it represents information among particles.

3.2 Genetic Algorithm

GA is a hunt practice, which is used in computing to discover exact or estimated (close together) outcome to optimization of search difficulties. Genetic algorithms are classified as global examine heuristics. Genetic algorithms are an accurate group of Evolutionary Algorithm that use procedures inspired by evolutionary biology such as inheritance, mutation, assortment methods. The development for the most part begins from a populace of calmly produced people in eras. In each generation the robustness function of all individual in the population is determined, numerous cases are stochastically chosen from the at hand population, and customized or rearranged to forman original inhabitants. Generally, the algorithm end when any a greatest number of iteration has been produced, or a acceptable fitness stage has been arrive at for the population. If the genetic algorithm has finished due to a maximum number of iteration, a acceptable come back may or may not have been reaching. Once we have the genetic demonstration and the fitness function distinct in the Algorithm, It proceeds to plan a population of results randomly, and then get better it through insistent application of GA operators.

3.3 Hybrid PSO-GA Algorithm

In this Hybridization of PSO and GA Algorithm, both PSO and GA are run in parallel. The concept behind this type of hybridization is that the gbest particle position does not change its position over some designated time steps. The crossover operation is performed on gbest particle with chromosome of GA.

To overcome the limitations of PSO, hybrid algorithms with GA are proposed. Crossover and mutation rates can subtly affect the convergence of GA, but these cannot be analogous to the level of control achieved through manipulating of the inertia weight. In fact, the decrease of inertia weight dramatically increases the swarm's convergence. By applying crossover operation, information can be swapped between two particles to have the ability to fly to the new search area.

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IV. IMPLEMENTATION OF HYBRID PSO-GA TO TNEP PROBLEM:

The implementation steps to solve formulated TNEP problem is given below:

1. Specify input parameters of GA and PSO.
2. Random Initialization of particles position and velocity consisting of set of lines to be added satisfying all constraints.
3. Evaluate fitness value to the entire population corresponding to the objective function using (8) and (9).
4. Update P_{best} and G_{best} of a particle if its fitness is greater than its current P_{best} and G_{best}
5. Using (12),calculate inertia weight 'w'.
6. Calculate the velocity of each particle using (10).
7. Change particle position using (11) with the velocity calculated in step 9.
8. Check iteration counter, if it reaches its maximum value then switch to step 7, else move to step 9.
9. Swarm generating final G_{best} by PSO gives the optimal solution.
10. Tournament Selection between final G_{best} and GA chromosomes for breeding process.
11. Perform crossover process between final G_{best} and GA chromosomes.
12. Evaluate final population with mutation process.
13. Check iteration counter, if it reaches its maximum value then switch to step 4, else move to step 14.
14. Final population consisting of chromosomes is the optimal solution.

Table I and II shows the parameter details of GA and PSO for two bus system.

TABLE I

GA Parameters	Parameter Values	
	Garver's six- bus system	IEEE 14 -bus system
Population size	50	100
Problem dimension	8	20
Crossover rate	0.8	0.8
Mutation rate	0.1	0.1
Tournament size	2	2

TABLE II

Bus system	Parameter Values						
	Number of particles	Problem dimension	Number of iterations	B_1	B_2	e_{max}	e_{min}
Garver's six-bus system	50	8	20	2	2	0.4	0.9
IEEE 14 - bus system	100	20	20	2	2	0.4	0.9

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3.4 Flowchart of Proposed Hybrid PSO-GA

Detailed implementation of the proposed Algorithm in terms of flowchart is stated below as "Fig .1"

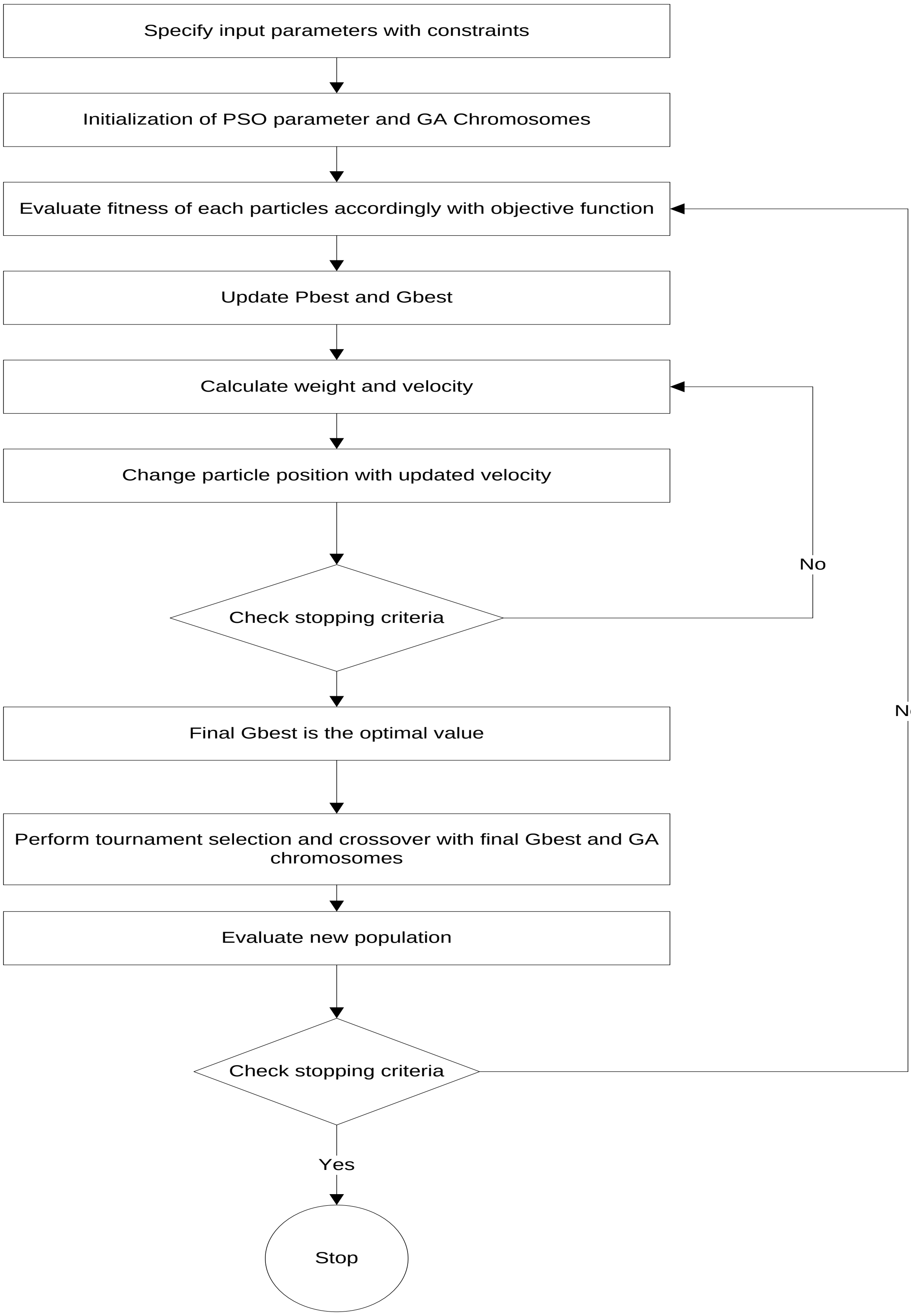

Fig.1

V. RESULT AND DISCUSSION

TNEP problem is tested on two electric systems 1. Garver's 6-bus test system, 2. IEEE 14-bus test system. The programming is developed in environment of Matlab software version 7.9. All the necessary data of the test systems can be found in [21]. For validation of the proposed hybrid method, the comparison of the results found

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using GA, PSO and proposed hybrid algorithm, are made. For each algorithm, the best results are found after 20 iterations for two test systems. Penalty factor for the two test systems is taken as 2. “Fig.” 2 and 3 shows characteristics of cost convergence of proposed hybrid Algorithm For both test system. Maximum number of iterations in each case are 20. “Fig.” 4 and 5 shows the cost comparison convergence characteristics of proposed method with GA and PSO for both the test systems. Result shows that Proposed Hybrid Algorithms gives good convergence characteristic than GA and PSO. Table 3 gives the comparison of GA, PSO and Hybrid PSO-GA for the two test systems in terms of optimal investment cost (in US $)and additional lines requirement.

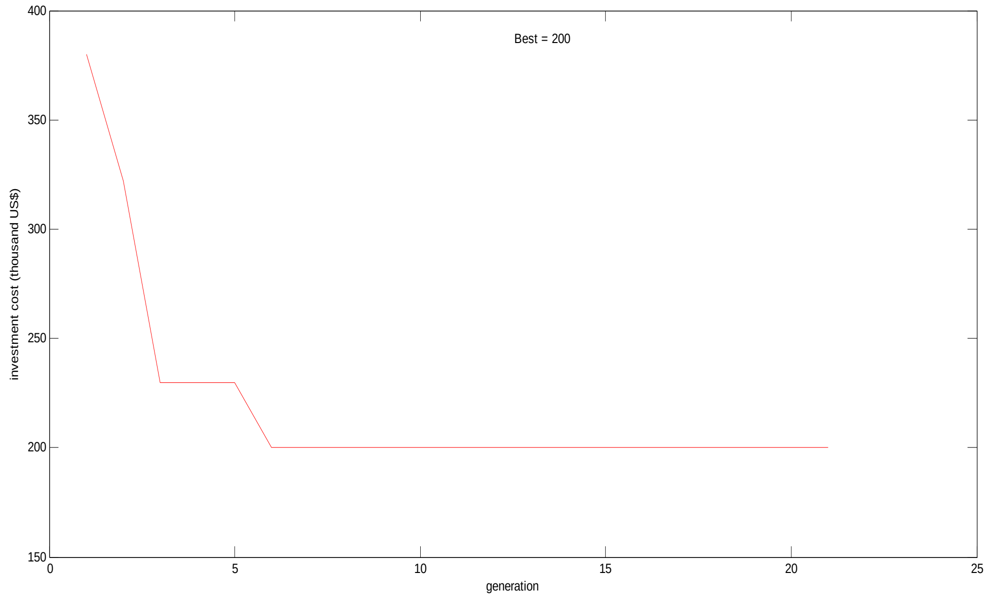

Fig. 2

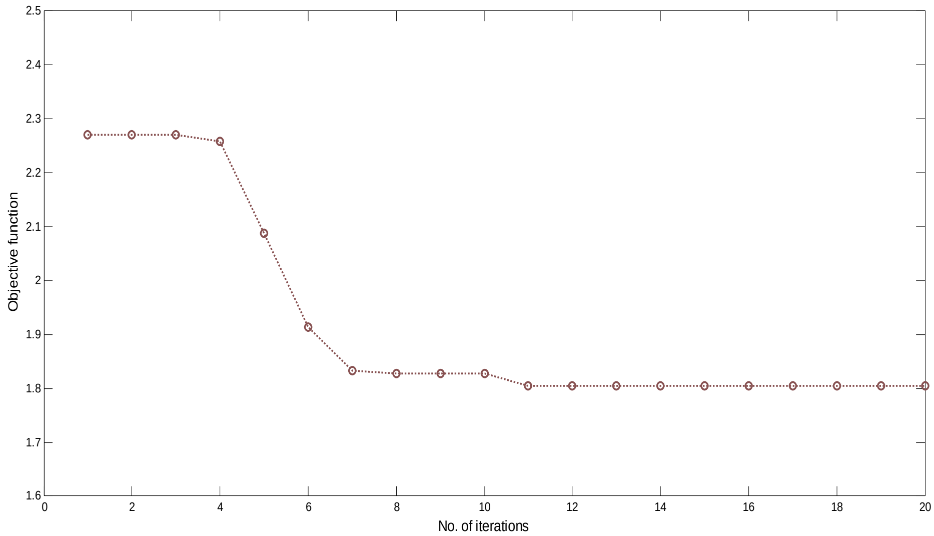

Fig. 3

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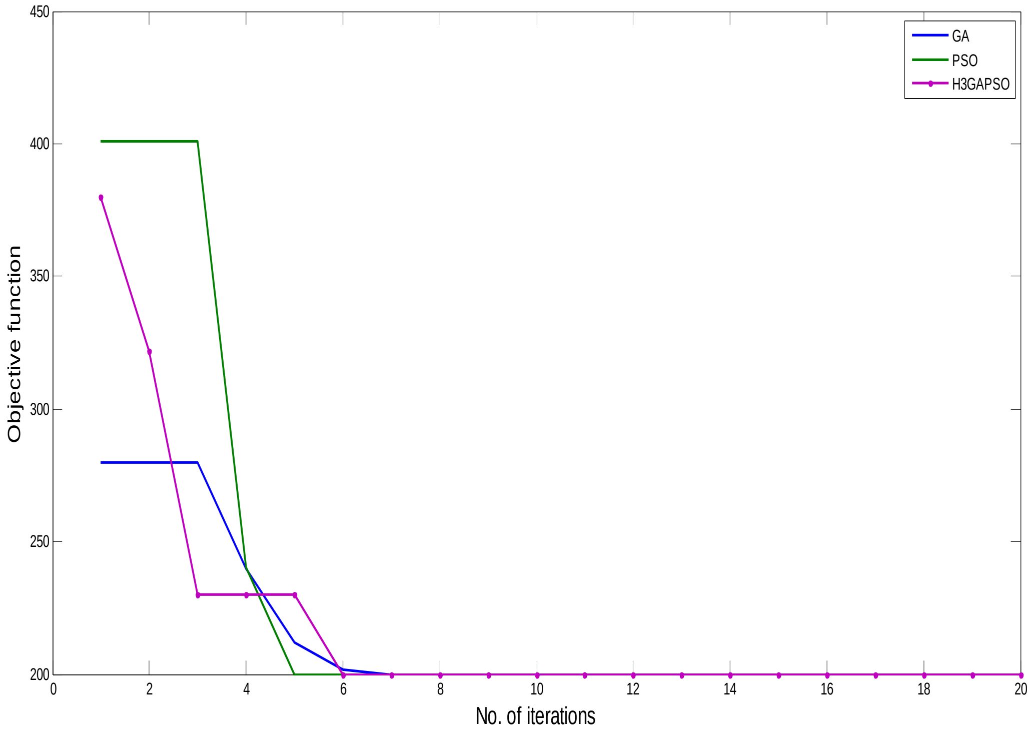

Fig. 4

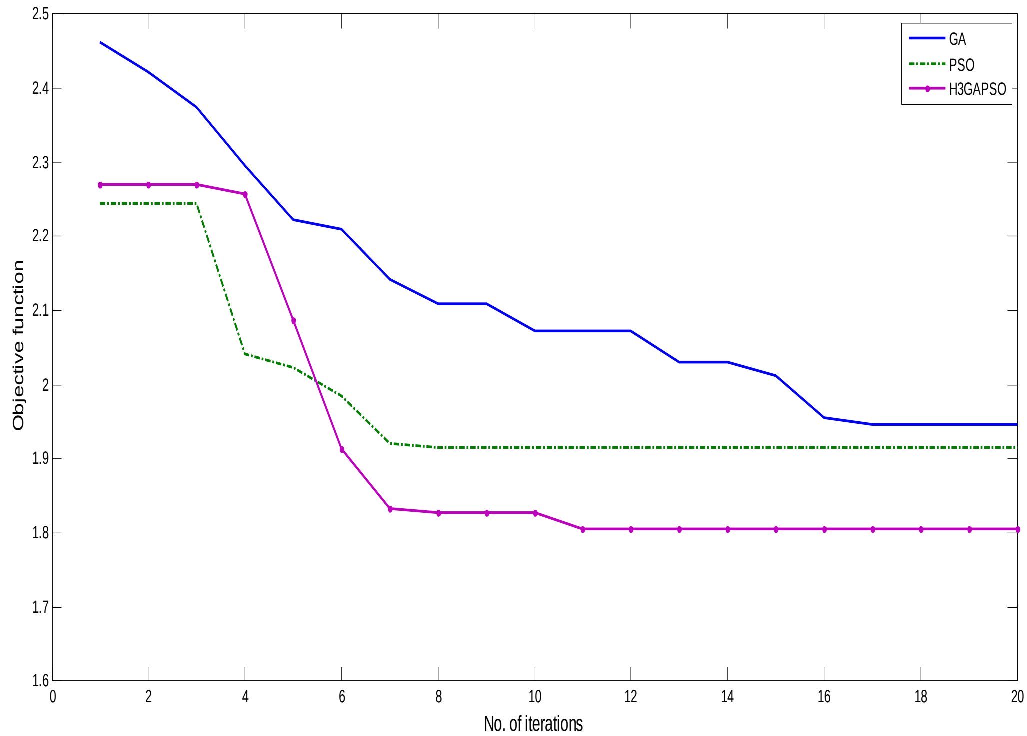

Fig. 5

TABLE 3: Comparison of hybrid algorithms with GA and PSO for Garver's 6-Bus system

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Garver's 6-bus system	Best cost (in US Dollar)	Optimal investment cost (in US dollar)	Line Requirement
GA	200	200	7
PSO	200	200	7
HYBRID PSO-GA	200	200	7

TABLE 4: Comparison of Hybrid algorithms with GA and PSO for IEEE 14-Bus system

IEEE 14- Bus system	Best cost (in US Dollar)	Optimal investment cost (in US dollar)	Line Requirement
GA	1.9369e+003	780	24
PSO	1.9156e+003	700	23
HYBRID PSO-GA	1.8051e+003	690	23

IX. CONCLUSION

Above results shows that Hybrid PSO-GA Method is efficient in obtaining Optimal Investment cost for both test systems as compared to GA and PSO both. Similarly best cost obtained is also less for proposed hybrid Algorithm for Both tested systems taken. An important advantage of the PSO is its ability to cope with local optima by maintaining, recombining and comparing several candidate solutions simultaneously. In contrast, local search heuristics algorithm only refines a single candidate solution and is notoriously weak in cope with local optima. Conventional PSO conducts a globalized searching for the optimal clustering, but it may be trapped in a local optimal area. The Hybrid PSO-GA algorithm combines the ability of fast convergence of the PSO algorithm with the competence of ease to exploit previous solution of GA for avoiding the premature convergence. Its success lays in their abilities to extent a large subset of search space. Due to their simplicity and efficiency in navigating large search spaces for optimal solutions, PSO and GA are used in this research to develop efficient, robust and flexible algorithms toTSP.

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