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OPTIMAL POWER FLOW SOLUTION USING CUCKOO SEARCH ALGORITHM

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ABSTRACT

The optimal power flow (OPF) problem in power system is a very large problem, which can be solved using soft computing techniques. The problem has many equality and inequality constraints. A new population based search algorithm called cuckoo search algorithm (CSA) solves the problem fast and accurate. The cuckoo search algorithm is based on the behavior of cuckoo birds in its breeding, is formed as the mathematical formulation to solve a real world non-linear problems. In this paper CSA algorithm is used to solve the OPF problem. The performance of the algorithm is compared with the particle swarm optimization (PSO) algorithm and genetic algorithm (GA). MATLAB programing is used to program the concept of the solution. IEEE-62 bus Indian utility system is used to test the performance.

Keywords: optimal power flow, cuckoo search algorithm, particle swarm optimization.

INTRODUCTION

The optimal power flow problem of power system is a large and complicated problem, which has been solved by many algorithms using computers [1]. The optimal power flow problem has many equality and in equality constraints. The solution of OPF is worked out by many computation techniques like GA, PSO etc. [2]. Even though it can be solved still accurate and fast manner. The genetic algorithm is used to solve the OPF problem [4] with power security enhancement and taking remedial action for network over loading due to the contingencies [3]. Particle swarm optimization techniques also used to solve the optimal power flow, which makes the solution derivative free [5].

Cuckoo search algorithm is used for solving the non-convex economic load dispatch considering generator characteristics including valve point effects, multiple fuels, prohibited zones, spinning reserve and power loss and the literature survey of nearly 16 papers has made [6] for proving the accurate and better solution. The convex and concave economic load dispatch with fossil fuel fired generators considering transmission loss, multiple fuels, value point loading, prohibited operating zones and for micro grid power dispatch problems [7].

The cuckoo search algorithm is tested with ten different test functions and it is compared with genetic algorithm and particle swarm optimization for 10,000 numbers of run. The 100% success rate for all the problems is obtained [8]. Here the CSA is applied to solve OPF problem.

PROBLEM FORMULATION

The problem of optimal power flow is formulated as below [1].

Objective function

The minimization of fuel cost function, which is derived from the incremental cost curve is the objective function and also called as total generation cost.

$$F_i(P_i) = \sum_{i=1}^{Ng} (aP_i^2 + bP_i + c) \qquad (1)$$

P_i = Generated power at generator bus i.
a, b, c = Cost co-efficient.
Ng = Number of generators.

Constraints

Here both equality and in-equality constraints considered.

In-equality constraint

$$V_{i\,min} < V_i < V_{i\,max} \qquad (2)$$

$V_{i\,min}$ = Minimum voltage, which should be maintained at each bus (0.9 p.u)
$V_{i\,max}$ = Maximum voltage, which should be maintained at each bus (1.1 p.u)

Equality constraint

$$P_L + P_{loss} - \sum_{i=1}^{Ng} P_i = 0 \qquad (3)$$

P_L = Total Demand in entire power system (summation of total demand)
P_{loss} = Total line loss in entire power system

GENETIC ALGORITHM [9]

The nonlinear programing method fails to produce the global optimum solution. So the genetic algorithm is used to get the global optimum solution. The GA is based on Darwin's theory of survival of the fittest. The basic elements of natural genetics are reproduction, crossover and mutation.

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Reproduction is the first operation applied to the population for selecting good strings to form a matting pool. It selects good strings from the population.

Crossover is used to produce the new strings by exchanging the strings in it. And mutation uses the binary digit 1 to 0 or 0 to 1. Several operators are available.
The solution procedure is shown below [9].

Step-1: Choose the string length and assume the population size (m), crossover probability (Pc), mutation probability (Pm) and convergence criteria.

Step-2: Generate a random population of size *m*, each has string length of *l*. Evaluate the fitness values F_i where i= 1, 2,..m

Step-3: Do the reproduction process

Step-4: Do the crossover

Step-5: Do the mutation operation

Step-6: Evaluate the fitness for the new population and find him standard deviation.

Step-7: Test for the convergence if converged stop the iteration or go to next step

Step-8: Test for the generation number if is equal stop the iteration or go to step-3.

PARTICLE SWARM OPTIMIZATION

PSO is based on the behavior of the food search in a group of fish or bees or birds. The procedure of the algorithm is given as follows [9].

Step-1: Assume the size of the swarm or particle (N). usually size of 20 to 30 particles are used.

Step-2: Generate the initial population of X in the range $X^{(l)}$ and $X^{(u)}$ randomly as $X_1, X_2, \ldots X_N$.

Step-3: Evaluate the objective function value.

Step-4: Find the velocities of particles. All velocities are initially assumed as zero. All particles move towards the optimal point.

Step-5: Find the historical best value of the particles, which is known as local best, or particle best (P_{best}) and find the best particles of all the previous iterations called as global best or G_{best}. Find the velocities of the particles j in ith iteration as follows,

$$V_j(i) = V_j(i-1) + c_1 r_1 [P_{best} - X_j(i-1)] + c_2 r_2 [G_{best} - X_j(i-1)] \quad (4)$$

Where j = 1,2,…N.
c_1, c_2 = learning factor assumed as 2
r_1, r_2 = uniformly distributed random numbers range 0 and 1.

Now find the position or coordination of the jth particle in the ith iteration

$$X_j(i) = X_j(i-1) + V_j(i) \quad (5)$$

Now evaluate the objective values of the above X_j.

Step-6: Check the convergence of the current solution, if the positions of all particles converge to the same set of values the method is assumed to have converged else increment the iteration number and evaluate step-5.

CUCKOO SEARCH ALGORITHM

Cuckoo bird lays eggs in communal nests. If the host bird finds the different eggs in its nest it may push down the eggs or it may abandon the nest and build new nest. The cuckoo bird selects the nest of host to lay eggs with similarity in shape and color of eggs to that of host eggs. This increases the probability of hatching cuckoo eggs. And also cuckoo birds eggs hatches faster compared to host bird eggs. And also chicks can mimic the host bird sound for getting food from it. This concept is made as mathematical equation and the concept of search of levy flights which make 90 degrees turn leading to scale free search makes this algorithm more reliable. The procedure of Cuckoo search algorithm is shown as below [6].

Step-1: Assume the n host nests X_i (i= 1, 2,..n) and maximum number of iteration.

Step-2: Check for maximum number of iterations and select a cuckoo randomly by levy flights evaluate the fitness or cost function (F_i).

Step-3: Choose a nest among n randomly say (j).

Step-4: Check if F_i is less than F_j replace j by new solution.

Step-5: A fraction of (Pa) worst nest is abandoned and new ones are built. Keep the best nest or solutions

Step-6: Rank the solutions and find the current best.

Step-7: Do it for all the iterations and end when the maximum iterations are reached.

Step-8: Display the results.

RESULTS AND DISCUSSIONS

The GA, PSO and CSA algorithms are applied to solve OPF problem of power system with one equality and one inequality constraint. The IEEE 62 Indian utility system is used as the test system the results of the above said problem are tabulated below. The CSA algorithm performs better compared to PSO and GA.

The PSO algorithm produces lesser cost compared to GA and CSA but the time taken for solving the solution is more. The Genetic algorithm requires more iteration number and more time to converge the result. But cuckoo search algorithm produces better results compared to other algorithms. It takes lesser number of population compared to other algorithms and the three times running the algorithm for convergence also makes large difference in PSO and GA but CSA produces better results.

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Table-1. Results of converged cost function for indian utility 62-bus sytem.

	Cost ($/hr)	**Total loss** (MW)	**Execution time** (s)
GA			
1st run	9493.6	1362.2	7196.69
2nd run	8366.2	1158.7	7521.31
3rd run	9493.6	1362.2	7059.75
PSO			
1st run	7200.908	939.24	3923.666
2nd run	8057.42	836.077	4015.819
3rd run	6548.75	864.041	4201.48
CSA			
1st run	7100.5	896.64	2412.14
2nd run	6844.7	866.735	2412.68
3rd run	6860.5	786.0055	2565.07

Table-2. Power generation in each generator for three runs with GA.

GA		
1st run	**2nd run**	**3rd run**
50	50	50
50	50	50
150	0	150
50	50	50
50	50	50
200	50	200
50	50	50
0	0	0
100	100	100
50	150	50
0	100	0
269.19	50	269.19
0	0	0
0	0	0
76.3843	50	76.3843
100	0.0026	100
50	292.0531	50
100	100	100

Table-3. Power generation in each generator for three runs in PSO.

PSO		
1st run	**2nd run**	**3rd run**
50	50	50
50	50	50
0	0	0
74.97	50	50
120.99	50	71.24815708
50	141.57	50
50	50	50
0	0	0
0	0	0
150	149.67	50
0	0	79.51456602
50	50	50
0	28.21	60.04769668
0	0	0
50	50	50
100	0	86.63072355
50	50	50
126.66	100	100

Table-4. Power generation in each generator for three runs in CSA.

GA		
1st run	**2nd run**	**3rd run**
78.3924	55.8436	57.2185
55.8829	58.7983	50.1156
0.4707	6.1518	71.2509
60.6107	50	52.3517
50.0731	50.0005	50
62.7049	50	120.4444
58.1419	50	50.0758
22.277	0	3.3525
3.7365	32.7871	0.3326
50.324	99.6292	50.1403
21.4408	9.5601	2.3512
54.8424	76.6669	50.0003
21.6279	3.3081	0.128
6.5134	1.0816	0.0021
101.3525	62.2573	54.1329
63.9222	55.4137	7.3967
67.7078	88.6369	50.0712
100.0253	100	100.0406

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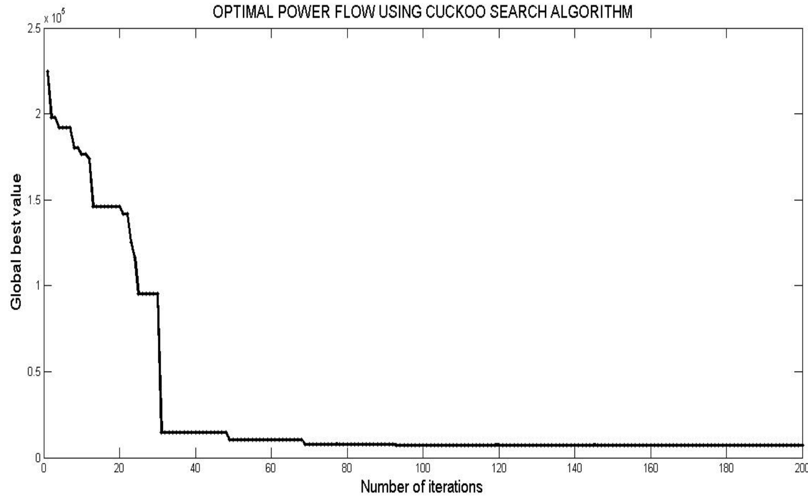

Figure-1. Convergence graph of CSA: Global best value VS Number of iterations.

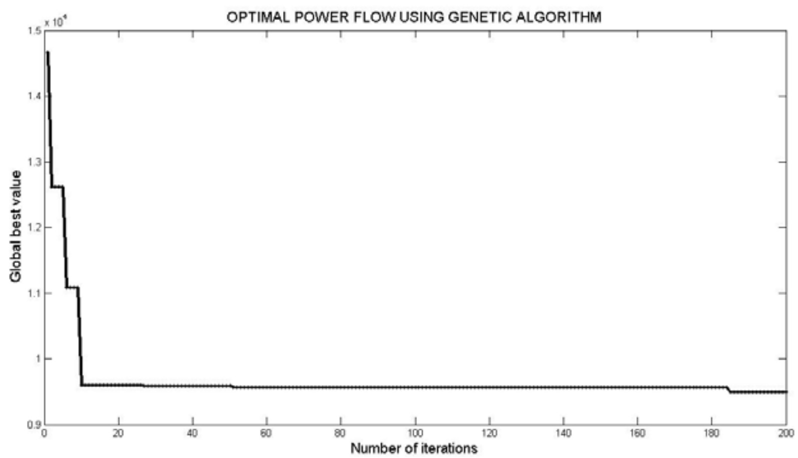

Figure-2. Convergence graph of GA: Global best value Vs Number of iterations.

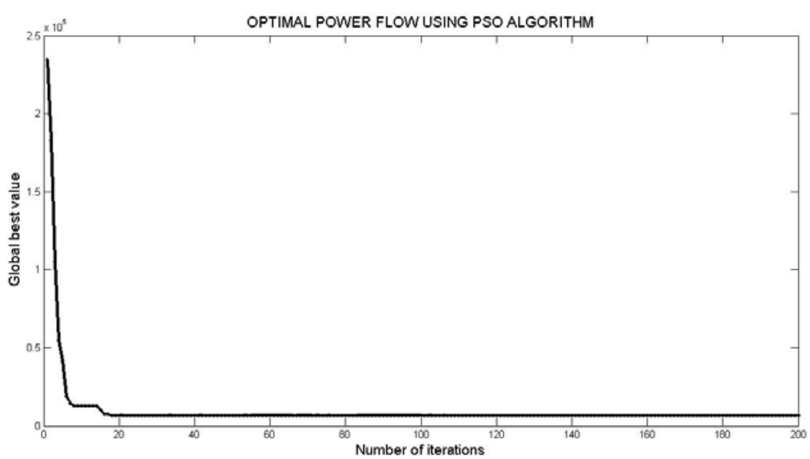

Figure-3. Convergence graph of PSO: Global best value Vs Number of iterations.

The above Figure-1 shows the convergence graph of CSA the graph is plotted between global best fitness value Vs number of iteration. Figures 2 and 3 states that the same as CSA for GA and PSO. The Figure-4 show the voltage Vs bus index graph which shows the satisfaction of inequality constraint.

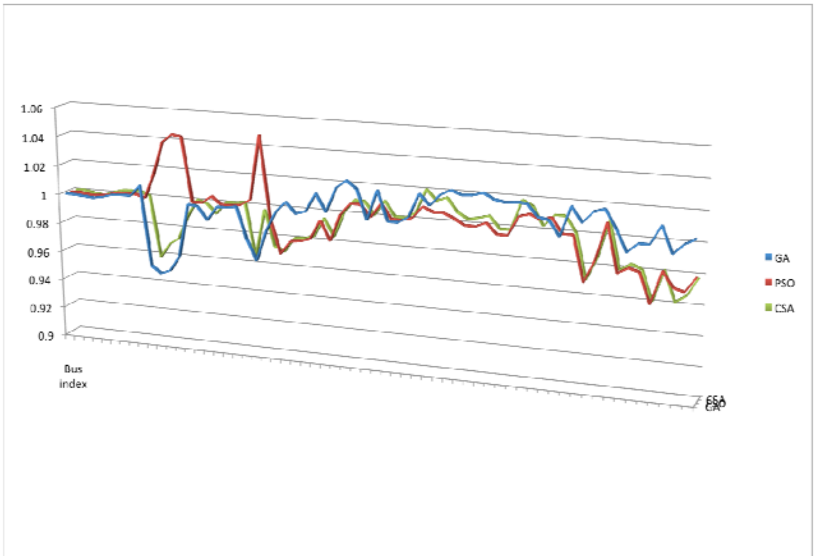

Figure-4. Voltage Vs Bus index (GA, PSO and CSA).

CONCLUSIONS

The Optimal power flow problem is solved using cuckoo search algorithm is compared with the GA and PSO algorithm. The cuckoo search algorithm performs better compared to PSO and GA algorithm. The cuckoo search algorithm provides reliability in solution compared to GA and PSO. The GA requires more number of iteration and convergence time. The PSO needs more time but less reliability. Cuckoo search algorithm performs better in solution time and reliability. The IEEE 62- Indian utility system is used for the analysis and results are graphed and tabulated.

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