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Improved Sine Cosine Algorithm for Solving Dynamic Economic Dispatch Problem

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Abstract: This paper presents an Improved Sine Cosine Algorithm (ISCA) for solving economic dispatch problem (EPD) and dynamic economic dispatch (DED) problem. The DED problem exhibits non-convex nature due to the inclusion of valve-point loading effects and ramp rate limits. In Sine Cosine algorithm (SCA), the searcher agents which interact with each other based on the trigonometric function. This paper proposes a novel ISCA that track the best solution to improve the convergence and solution quality of SCA. The results obtained by the ISCA are tabulated, graphed and compared with that obtained by the SCA and other algorithm available in the literature. The outcomes show that the implementation of ISCA provides a feasible solution with significant savings.

Key words: Economic Dispatch Problem, Dynamic Economic Dispatch Problem, Sine Cosine algorithm and Improved Sine Cosine Algorithm.

I. INTRODUCTION

Dynamic economic dispatch (DED) is a power system problem to identify the generation dispatch of generating units which is kept ON in the unit commitment problem based on the system forecasted demands over a specified time period. There by to operate a system more economically. In DED problem, it is the responsibilities of the system operators to balance the generation capacity that meets the load demand as well as the transmission losses in the system. Initially, the valve-point loading effects of generating units are neglected in the problem formulation of DED problem. However, practical generating unit model will take into account the valve-point effects in DED problem. The problem takes care that the generation dispatch of each generator is within the limits, ramp constraints and value point effect, failing to which a penalty factor is added to the total cost. This approach ensures that the optimal result that would come up shall satisfy all the realistic constraints. Inclusion of valve point effect in generating cost coefficient makes the DED problem as more complex problem. In addition, the solution space of the DED problem is asymmetrical due to the inclusion of above constraints. Therefore, finding the optimal solution to the DED problem by considering valve point effect is a difficult task. The existing algorithm and techniques for solving DED problem are classified as conventional optimization method and meta-heuristic methods. The conventional optimization-based methods consist of linear programming (LP), Lagrangian relaxation (LR) and dynamic programming (DP). Since, inclusion of valve point effect in generating cost coefficient makes the DED problem as non-convex with many local minima. Hence, DED problem cannot be solved by traditional conventional techniques. Recently, stochastic search algorithms such as Genetic Algorithm (GA), Particle Swarm Optimization (PSO) [1], Simulated Annealing (SA) [2],Differential Evolution(DE)[3], Adaptive Particle Swarm Optimization [4],Harmony Search [5],Bacterial foraging PSO-DE [6],Evolutionary programming (EP) [7], Modified hybrid EP-SQP (MHEP-SQP) [8], Deterministically Guided PSO(DGPSO) [9], Chaotic Self-adaptive PSO(CSAPSO)[10], Artificial Immune system[11], Improved Enhanced Cross-Entropy (ECE)[12], artificial bee colony (ABC)[13], Time-varying Acceleration Coefficients IPSO (TVACIPSO) [14], Self-adaptive Modified Firefly Algorithm (SAMFA) [15], Enhanced Bee Swarm Optimization (EBSO) [16], Modified Teaching-Learning Algorithm (MTLA) [17], Mixed Integer Quadratic Programming (MIQP) [18] and Enhanced GA(E-GA) and DE (E-DE) [19] have been successfully used to solve power system optimization problems due to their ability to find the near global solution of a non convex optimization problem. From the above cited literatures, it is inferred that, there is great inducement for research in this area with emphasize on reducing cost and execution time. In this paper a new conceptual model is proposed to improve the convergence speed and solution quality of Sine Cosine algorithm (SCA),.

II. PROBLEM FORMULATION

The objective is to minimize the fuel cost of generating units. The objective function can be written as:

Minimize

$$F = \sum_{t=1}^{T}\sum_{i=1}^{N} F_{it}(P_{it}) + \sum_{t=1}^{T}\sum_{i=1}^{N}(a_i + b_i P_{it} + C_i P_{it}^2 \; e_i \sin(f_i(P_{i\min} - P_{it})) \qquad (1)$$

Subject to the list of constraints given below.

A. Power Balance Constraints

$$\sum_{t=1}^{N} P_{it} = P_{dt} + P_{Lt} \qquad t = 1,2.....T \qquad (2)$$

The system losses can be calculated using equation (3).

$$P_{Lt} = \sum_{i=1}^{N}\sum_{j=1}^{N} P_{it} B_{ij} P_{jt} + \sum_{i=1}^{N} B_{oi} P_{it} B_{oo} \qquad (3)$$

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B. Operation Constraint

$$P_{i\min} \le P_{it} \le P_{i\max}$$
(4)

C. Generating Unit Ramp Rate Limit

$$P_{it} - P_{i(t-1)} \le UR_i \qquad i \in N, t \in T \tag{5}$$

$$P_{i(t-1)} - P_{it} \le DR_i \qquad i \in N, t \in T$$
(6)

D. Prohibited Operation Zones

$$P_{i\min} \le P_i \le P_i^1$$
$$P_i^{k-1} \le P_i \le P_i^k$$
$$P_i^{nz} \le P_i \le P_{i\max}$$
(7)

E. System Spinning Reserve Constraints

$$\sum_{t=1}^{N} (P_{i\max} \times I_{it}) \ge SR_t \qquad t = 1,2.....T$$
(8)

Where

a_i, b_i, c_i	Fuel cost coefficient of i^{th} unit
ei, fi	Valve point coefficient of i^{th} unit
N	Number of generating units
P_{min}	Minimum generating limits of i^{th} unit (MW)
P_{it}	Power output of i^{th} unit at time t (MW)
F_{it}	Fuel cost function of i^{th} unit in \$ /h at time (t)
F	Total Fuel Cost (\$ /h)
T	Number of intervals in the entire dispatch period
PD_t and P_{Lt}	Total load demand and transmission loss in MW at time (t)
$P_{i\,max}$	Maximum generation limit of i^{th} unit (MW)
$P_{i\,(t-1)}$	Power output of ith unit at time (t-1) (MW)
URi and DRi	Up and down ramp rate limits of i^{th} unit (MW/h)
SRt	System spinning reserve requirements the t^{th} time intervals
B_{ij}, Bo_i, Boo	Transmission loss coefficients
I_{it}	Indicate ON/OFF Status (1 or 0) of Generating Unit.

III. SINE COSINE ALGORITHM (SCA)

Sine Cosine Algorithm (SCA) [20] has been developed by simulating the trigonometric waves as searching behavior in the optimization techniques. It is a population-based search technique and is used as an optimization tool in solving non-linear optimization and complex problems. The position of each population is updated by the following equation.

$$P_i^{k+1} = P_i^k + r_1 * \sin(r_2) * | r_3 P_{best} - P_i^k | \tag{9}$$

$$P_i^{k+1} = P_i^k + r_1 * \cos(r_2) * | r_3 P_{best} - P_i^k |$$
(10)

Where, P_i^{k+1} is the position of i^{th} population in the next iteration P_i^k is the position of i^{th} population in present iteration. r_1, r_2 and r_3 are random numbers, P_{best} is the location of the target point in i^{th} dimension, and || specifies the absolute cost.

The above two equations are combined to be used as follows:

$$P_i^{k+1} = \begin{cases} P_i^k + r_1 * \sin(r_2) * | r_3 P_{best} - P_i^k |; r_4 < 0.5 \\ P_i^k + r_1 * \cos(r_2) * | r_3 P_{best} - P_i^k |; r_4 \ge 0.5 \end{cases} \tag{11}$$

Where *r4* is a random number between [0, 1]. As the above Eqs. (9)– (11) show, there are four key parameters in SCA: r_1; r_2; r_3 and r_4. Parameter *r1* decides the direction of movement. r_2 parameter decides the step level. r_3 parameter provides the random load for the destination in order to stochastically deemphasize (r_3<1) or emphasize (r_3>1) the influence of destination in describing the distance. r_4 parameter decides to choose sine or cosine for the position update.

A. Suitability of the SCA for ED and DED Problem

In the conventional SCA, the parameter r_1 decides the direction of movement and r_2/r_3 decides the step level of movement, raising a potential problem for the algorithm as applied to the power system optimization problem. To demonstrate the above problem, let as considered 10 populations in the search space. The populations P1, to P10 are initially distributed randomly in the solution space as shown in Fig. 1. Each population will modify its position based on a best population. In the ED and DED problem, the output power of the generator (population) with respect minimum cost is the best solution (best population).

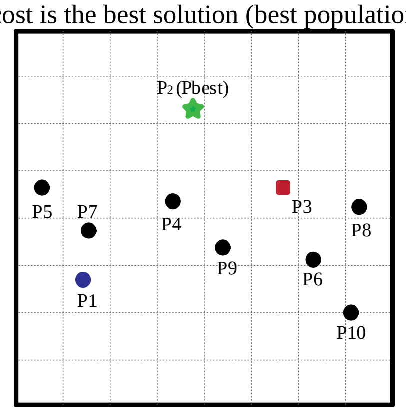

Fig. 1 Sine cosine Algorithm – Initial population

From the Fig. 2, let as assume the population P_2 is the best solution among ten populations. Hence, the other population will update their position based on the position of the best population (i.e. P_2). Let us consider a population P_1, the updation of P_1 with respect to the best population P_2 is illustrated in Fig. 2 (a). The search space for P_1 in both directions is shown in Fig. 2(a). The direction of movement is defined by the parameter r_1. For the ED and DED problem, if the random number r_1 is negative then the population P_1 is moved on left hand side (direction shown in red arrow). The movement on left side is restricted since it is update away from the best solution. Similarly, the updation of P_3 with respect to the best population P_2 is illustrated in Fig. 2 (b). Here, if the random number r_1 is positive then the population P_3 is moved on right hand side (direction shown in red arrow).

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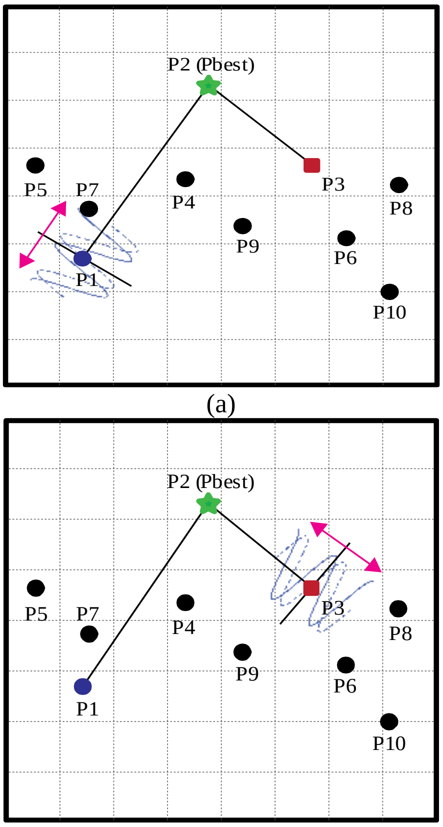
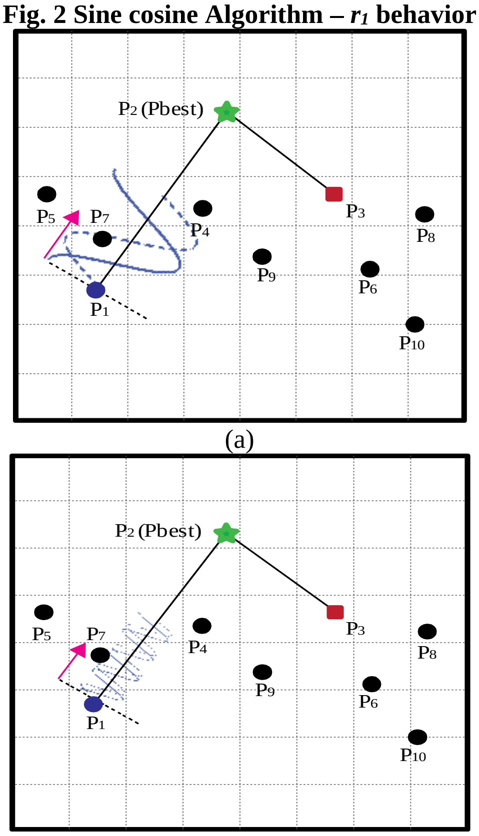
The movement on right hand side is restricted since it is update away from the best solution. In the conventional SCA, the direction of movement is defined by r_1, due to this characteristic of the Sine cosine algorithm the population leads to escape from the vicinity of the global point and takes more time to converge.



(a)

(b)

Fig. 2 Sine cosine Algorithm – r_1 behavior



(a)

(b)

Fig. 3 Sine cosine Algorithm – r_2 & r_3 behavior

The randomization factor r_2 and r_3 in Equation (9) presents a further problem which is illustrated in the Fig. 3. Here, the step level is decided by the parameter r_2 and r_3. Fig. 3 (a) discuss about the problem due to large step. The step changes that are too large may lead the population to escape from the vicinity of the global point. Similarly, if the step level is small, then it takes more number of iterations to converge to the best solution which is shown in Fig. 3 (b).

IV.PROPOSED ISCA FOR SOLVING ED AND DED PROBLEM

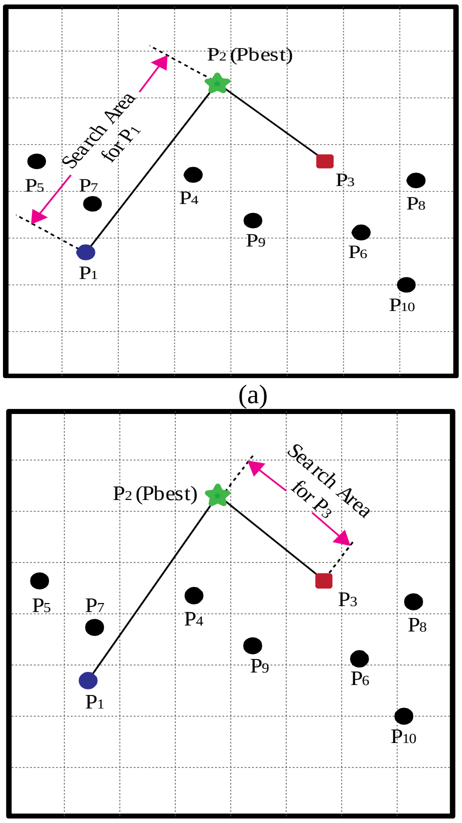
Both problems can be resolved in the proposed Improved SCA by carefully observing the trends in P–V curves under partial shading, taking advantages of trigonometric waves search method. Removing the randomization factor r_2 and r_3, the first random term r_1 may be modified for the MPPT application by taking advantage of trigonometric characteristics. The modified sine and cosine equation is given in Equation (12-14) as follows:

$$P_i^{k+1} = P_i^k + [r_1 * |\sin(P_{best} - P_i^k)|] \quad (12)$$

$$P_i^{k+1} = P_i^k + [r_1 * |\cos(P_{best} - P_i^k)|]$$

(13)

Where D_i^{k+1} is the position of i^{th} population in the next iteration, D_i^k is the position of i^{th} population in present iteration, *Dbest* is position of best population.r_1 is the random factor between [0,1] and || specifies the absolute value.



(a)

(b)

Fig. 4 Improved SCA behavior

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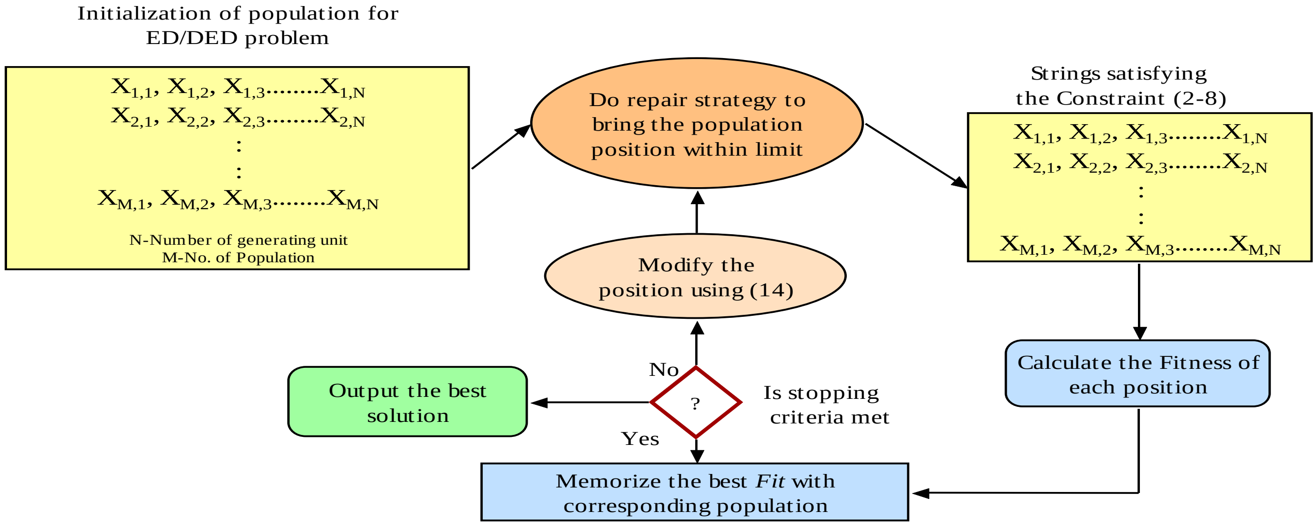

Fig. 5 Graphical representation of proposed algorithm

In equation (12)-(13), if $(D_{best} > D_i^k)$ then the generated random value r_1 is positive; otherwise generated random value r_1 is negative. The two equations (12)-(13), are combined to be used as follows:

$$P_i^{k+1} = \begin{cases} P_i^k + [r_1 * |\sin(P_{best} - P_i^k)|], & if \quad r_2 > 0.5 \\ P_i^k + [r_1 * |\cos(P_{best} - P_i^k)|], & if \quad r_2 \le 0.5 \end{cases} \quad (14)$$

Where, r_2 is a random number in [0,1]. In the proposed Improved SCA, there are two random factor r_1 and r_2. To illustrate the importance of random factor, consider the same pattern as before, with the initial positions of the populations. Among the 10 populations, P2 is the best population, P_{best}. With the proposed modification, the movement of P_1 and P_3 is illustrated in Fig. 4 (a-b). In Fig.4 (a) shows the direction of movement of population P_1 and search limit available for the population P_1. Here, the random factor r_1 and sine/cosine term define the direction of movement of population and the $(P_{best} - P_i^k)$ defines the search limit of population P_1. Similarly, Fig. 4 (b) shows the direction of movement of population P_3 and search limit available for the population P_3. Since P_2 is the best population, the P_2 is unchanged, and P_2 does not contribute to the exploratory process. To avoid this, a small perturbation is introduced to ensure changes in power towards global maxima reducing the chance of missing the global solution.

If a solution representing a position is not improved by a predetermined number of trials, then that position is abandoned and the harmonics waves will be employed. The number of trials for releasing a harmonic is equal to the value of "count", which is an important control parameter of ISCA algorithm. The count value reaches specified count then harmonics will be introduced.

A. Implementation of proposed SCA for PSD and MPPT Problem

The implementation of proposed methodology to solve ED and DED problem is shown in Fig. 5.

V. RESULTS AND DISCUSSION

The MATLAB code is developed for ED and DED problem using ISCA in i5 3.6 GHz, 4 GB RAM processor. To validate the proposed algorithm, two different problems are considered for analysis.

A. Economic Dispatch (ED) Problem

Three different test systems are taken to validate proposed ISCA. Test systems are 6-unit, 10 unit and 40-unit systems. Algorithm parameter settings***:*** In the population-based algorithm, if the number of populations in more than we will get more accurate solution. However, a more number of populations also lead to longer computation time. Therefore, a trade-off should be made to obtain quality solution with good computational time.

(i) Test System 1: 6 Unit System

The six-unit system data is taken from ref. [1]. The economic dispatch problem with losses is solved using MFFA by considering generation limit constraints, ramp constraints and Prohibited Operation Zones. Here loss of the system is calculated using B loss coefficient taken from [1]. ED problem is solved for 6-unit system using MFFA for the load of 1263 MW and the results are presented. The best solution obtained using ISCA is 15345.85 $. The comparison of result is given in Table 1.

Table 1 Comparison of result –6-unit system

Unit No.	GA [1]	PSO [1]	ISCA
1	474.8066	447.4970	445.86
2	178.6363	173.3221	164.24
3	262.2089	263.4745	256.99
4	134.2826	139.0594	149.60
5	151.9039	165.4761	200.00
6	74.1812	87.1280	50.00
System loss, MW	13.0217	12.9584	3.694
Fuel cost, $	15459.00	15450.00	15345.85

(ii) Test System 2: 10 Unit System

The ten-unit system data and transmission loss coefficient are adapted from ref. [21] and ED problem is solved for the load of 2000 MW. The best solution obtained using MFFA is 111495.62 $. The comparison of result is given in Table 2.

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Table 2 Comparison of result –10-unit system

Unit	BSA [21]	QOTLBO [22]	TLBO [22]	DE [22]	ISCA
1	55.0000	55.0000	55.0000	55.0000	55.0000
2	80.0000	79.9991	80.0000	79.8063	80.0000
3	106.9295	107.9231	105.9616	106.8253	106.9499
4	100.6028	98.6479	99.9321	102.8307	100.5763
5	81.4990	82.0180	80.6424	82.2418	81.5010
6	83.0074	83.4878	85.7878	80.4352	83.0116
7	300.0000	300.0000	300.0000	300.0000	300.0000
8	340.0000	340.0000	340.0000	340.0000	340.0000
9	470.0000	469.9706	469.6979	470.0000	470.0000
10	470.0000	469.9988	469.9943	469.8975	470.0000
Tot.al Cost $	111497	111498	111500	111500	111495

Table 3 Comparison of result –40-unit system

Unit no	DE [23]	QO- TLBO [22]	TLBO [22]	NGPSO [24]	ISCA
1	110.9515	111.6943	110.8684	113.9002	111.2043
2	113.2997	111.2043	111.0684	113.9998	111.6943
3	98.6155	97.4031	97.6325	97.54807	97.4031
4	184.1487	179.7438	179.7739	179.752	179.7438
5	86.4013	88.2196	88.2724	95.63781	88.2196
6	140.0000	139.9918	140.0000	140.0000	139.9909
7	300.000	259.6596	259.6298	299.9994	259.6596
8	285.4556	284.5983	284.5909	286.6904	284.5977
9	297.511	284.5977	284.6709	285.1639	284.5983
10	130.0000	130.0000	130.096	130.0002	130.0000
11	168.7482	168.7987	168.8011	94.0000	168.7849
12	95.6950	168.7849	168.3523	168.8099	168.7987
13	125.0000	304.5206	304.425	125.0005	304.5206
14	394.3545	304.5209	214.7863	304.6332	304.5209
15	305.5234	394.2724	484.1771	394.292	394.2715
16	394.7147	304.5265	304.8444	394.2787	304.5265
17	489.7972	489.2933	489.1978	489.4934	489.2933
18	489.362	489.2806	489.4668	489.3192	489.2806
19	520.9024	511.2893	511.4505	511.277	511.2812
20	510.6407	511.2812	511.2885	511.2889	511.2812
21	524.5336	523.3225	523.244	523.4588	523.3225
22	526.6981	523.4356	523.2748	523.4957	523.4356
23	530.7467	523.296	523.3998	523.3027	523.296
24	526.327	523.3315	523.329	523.3203	523.3315
25	525.6537	523.2799	523.3822	523.3953	523.2799
26	522.9497	523.2994	523.2749	523.3058	523.2994
27	10.0000	10.0046	10.0684	10.02291	10.0000
28	11.5522	10.0023	10.0183	10.01614	10.0000
29	10.0000	10.0016	10.1027	10.00005	10.0000
30	89.9076	89.7440	90.5503	97.0000	89.744
31	190.0000	189.9818	190.0000	189.9992	189.9818
32	190.0000	189.9994	190.0000	189.9997	189.9994
33	190.0000	189.9852	190.0000	190.0000	189.9852
34	198.8403	165.3627	164.9021	196.2840	165.3627
35	174.1783	165.0289	164.8606	199.9995	165.0289
36	197.1598	164.9701	164.9206	200.0000	164.9701
37	110.0000	109.9968	110.0000	110.0000	109.9968

(iii) Test System 3: 40 Unit System

The forty-unit system data and transmission loss coefficient are adapted from ref. [21] and ED problem is solved for the load of 10500 MW. The best solution obtained using ISCA is 121427.97$. The comparison of result is given in Table 3.

(iv) Performance Analysis

To compare the computation efficiency of the proposed ISCA, the ED problem is solved using standard PSO and SCA. In this analysis, the initial population of all the three algorithm is kept same. Also, the PSO are tuned to obtain best solution. The PSO parameters are w, c1 and c2. Here, one of the parameter is fixed and the other parameters are varied with the small step interval within minimum and maximum. The best parameter to obtained quality solution is determined for different test system for PSO is given in Table 4. The best cost obtained by PSO, SCA and ISCA is presented in Table 5. The convergence graph of 6, 10- and 40-unit system is shown in Fig. 6-8.

Table 4 Algorithm Parameter – ED Problem

Test Systems	PSO algorithm			Population
	w	C1	C2	
6-unit system	0.5	0.4	0.5	50
10-unit system	0.5	0.4	0.6	100
40-unit system	0.5	0.65	0.5	100

Table 5 Comparison of Result-ED Problem

Solution technique	Minimum cost, $	Mean Computational time (sec)	Converged iteration number	Frequency of achieving minimum cost
6-unit system				
PSO	15380.85	9.45	279	20
SCA	15345.85	9.29	258	23
ISCA	15395.85	8.87	184	25
10-unit system				
PSO	111516.00	14.74	263	19
SCA	111512.00	13.21	231	20
ISCA	111495.00	12.11	173	24
40 unit system				
PSO	121436	34.18	254	15
SCA	121430	23.21	257	16
ISCA	121428	22.33	198	24

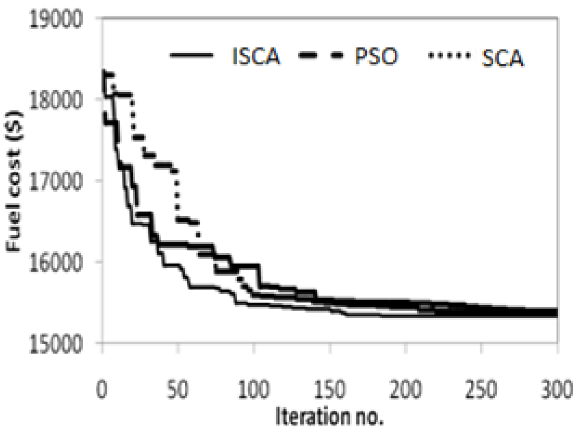

Fig.6 Convergence graph - 6-unit system

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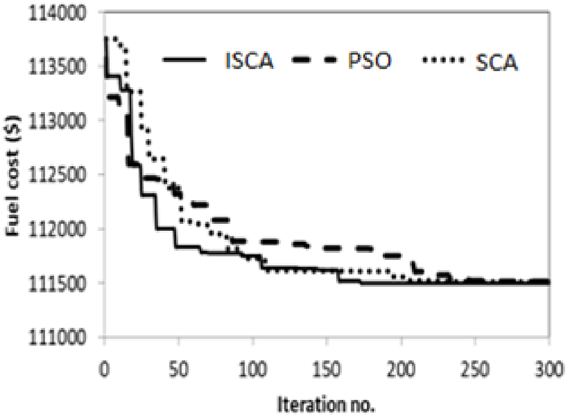

Fig.7 Convergence graph - 10-unit system

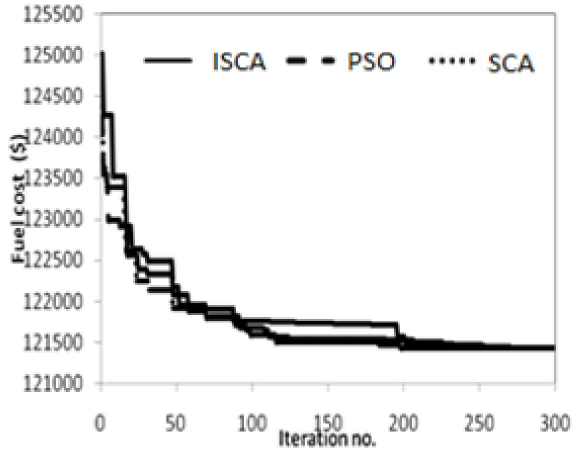

Fig.8 Convergence graph - 40-unit system

Table 6 DED problem solution – 5-unit system

Hour	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5
1	10.00	20.00	30.00	124.47	229.52
2	19.00	20.00	30.00	140.85	229.52
3	10.00	20.00	30.00	190.85	229.52
4	10.00	20.00	67.02	209.81	229.52
5	10.00	23.90	91.55	209.81	229.52
6	10.00	53.90	112.66	209.81	229.53
7	10.00	72.45	112.66	209.81	229.53
8	19.61	91.58	112.67	209.81	229.53
9	49.61	98.53	112.67	209.81	229.53
10	64.01	98.53	112.67	209.81	229.51
11	75.00	104.03	112.67	209.81	229.51
12	75.00	124.71	112.67	209.81	229.51
13	64.01	98.53	112.67	209.81	229.51
14	49.62	98.53	112.67	209.81	229.51
15	47.44	98.53	112.67	174.90	229.51
16	21.56	98.53	112.67	124.90	229.51
17	10.00	87.58	112.67	124.90	229.51
18	10.00	98.53	112.67	165.21	229.51
19	12.70	98.53	112.67	209.81	229.51
20	42.70	119.99	112.63	209.81	229.51
21	39.35	98.53	112.67	209.81	229.51
22	10.00	98.59	112.63	162.13	229.51
23	10.00	96.05	72.63	124.9	229.51
24	10.00	70.87	32.63	124.9	229.51

It is inferred from Fig. 6-8 that the characteristics of ISCA steadily reaches the minimum value after few iterations when compared to other two methods (PSO and SCA). In all the three methods, the maximum number of iterations is fixed as 300 and the population size is 100. The capability of finding the best solution for EDP is higher in the case of ISCA.

B. Dynamic Economic Dispatch Problem

Three different test systems such as 5-unit, 6 unit, and 10-unit systems are considered for solving DED problem for 24 hours. The obtained best solutions are validated and compared with the best solutions published in the existing literatures.

(i) Test System 1: 5 Unit System

The five-unit system data is taken from ref. [3]. The dynamic scheduling problem is considered for 24 hours scheduling horizon. Out of 30 trails, the obtained best optimum power generation value for 5-unit system in 24 hours scheduling horizon is given in Table 6. The comparison of results is given in Table 7. From the result it is clear that, the total cost of ISCA is very much lower than SCA and other techniques.

Table 7 Comparison of results – 5-unit system

Solution Techniques	Total cost in $
Simulated annealing [2]	47356.00
Adaptive particle swarm optimization [4]	44678.00
Harmony Search [5]	44367.23
Differential evolution [3]	43213.00
SCA	43184.00
ISCA	43175.00

Table 8 DED solution – 6-unit system

Hr	Unit 1	Unit 2	Unit 3	Unit 4	Unit 5	Unit 6
1	361.22	164.24	256.99	53.767	77.00	50
2	383.06	126.16	210.00	50.00	126.16	50
3	330.58	126.16	255.40	50.00	126.16	50
4	330.58	126.16	250.31	50.00	126.16	50
5	330.58	126.16	255.38	50.00	126.16	50
6	388.22	126.16	256.99	57.09	88.08	50
7	388.22	126.16	251.92	50.00	126.16	50
8	388.22	126.16	256.99	79.023	126.16	50
9	444.00	164.24	256.99	50.00	164.24	50
10	456.55	164.24	256.99	100.00	126.16	50
11	445.86	164.24	256.99	123.12	164.24	50
12	453.34	164.24	256.99	150.00	164.24	50
13	446.21	164.24	256.99	150.00	126.16	50
14	445.86	164.24	300.00	130.08	164.24	50
15	445.86	164.24	256.99	149.60	200.00	50
16	445.86	164.24	300.00	129.85	164.24	50
17	445.86	164.24	256.99	143.50	164.24	50
18	445.86	164.24	256.99	124.38	164.24	50
19	447.18	164.24	256.99	80.00	164.24	50
20	388.22	164.24	256.99	110.00	126.16	50
21	388.22	126.16	256.99	78.579	126.16	50
22	386.81	164.24	210.00	50.00	126.16	50
23	330.58	126.16	256.99	50.527	164.24	50
24	388.22	88.08	256.99	54.355	126.16	50

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(ii) Test System 2: 6 Unit System

DED problem is solved for 6-unit system using ISCA for 24 hours time horizon and results are presented. System load demand for 24 hours time horizon is taken from ref. [13]. The DED solution obtained using ISCA is given in Table 8 and the comparison of result is given in Table 9.

Table 9 Comparison of results – 6-unit system

Solution Techniques	Total cost in $
Bacterial foraging PSO-DE [6]	314025.37
SCA	312450.22
ISCA	312189.00

(iii) Test System 3: 10 Unit System

The ten-unit data is taken from ref. [5]. The DED problem is solved for 24 hours time horizon with considering system losses by considering all the constraints. Here loss of the system is calculated using B loss coefficient taken from ref. [5].The best solution obtained using ISCA is 1020711$. The comparison of result is given in Table 10. It clearly shows the effectiveness of the proposed algorithm with the methods available in the existing literature.

Table 10 Comparison of results –10-unit system

Solution Techniques	Total cost ($)
EP [7]	1054685
EP-SQP [10]	1052668
MHEP-SQP [8]	1050054
DGPSO[9]	1049167
IPSO[10]	1046275
AIS[11]	1045715
ECE[12]	1043989
ABC[13]	1043381
TVACIPSO[14]	1041066
EBSO[16]	1038915
CSAPSO[10]	1038251
SAMFA [15]	1037698
MTLA[17]	1037489
MIQP[18]	1038376
E-GA [19]	1036460
E-DE [19]	1036280
SCA	1021560
ISCA	1020711

VI. CONCLUSION

An Improved SCA is proposed to solve the economic dispatch problem and dynamic dispatch problem. The algorithm has been successfully implemented to ED problem and DED problem for benchmark test systems. From the analysis of ED Problem, it is noted that the ISCA significantly improved the quality of solution and converging fastly compared with SCA and other algorithm available in the literature. Also, the proposed algorithm is validated for DED problem for 24 hours' time horizon and it proves the superiority of the proposed improved algorithm. From the results and discussion, it can be concluded that the proposed method paves the way for the power system operators to take efficient decision in lesser time for effective operation of the system. The proposed algorithm can be implemented to hybrid renewable power system. It can also be used in the smart grid environment with demand side management which is deemed to be essential for future research.

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