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WIPSO Based Combined Emission Economic Dispatch

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ABSTRACT

Particle Swarm Optimization technique is used to solve an Emission Economic Dispatch Problem. This problem has been getting more attention recently due to the deregulation of the electric power industry and also strict environmental regulations. To schedule the committed generating units to meet the required load demand with minimum operating cost and minimum emission simultaneously. The objective of Economic load dispatch is to minimize the overall production cost and the objective of emission dispatch is to minimize the emission level. This paper, concentrate on both total production cost and emission level simultaneously. This combined Emission Economic Dispatch problem is a Multi objective optimization problem. Price penalty factor converts this into single objective problem. WIPSO technique is also used to solve this problem.

KEYWORDS: PSO (Particle Swarm Optimization), CEED (combined Emission Economic Dispatch), WIPSO (Weight Improved Particle Swarm Optimization).

INTRODUCTION

Economic dispatch is one of the main functions of electric power system operation, management and planning. The economic dispatch problem in a power system is to determine the optimal combination of power outputs for all generating units which will minimize the total production cost while satisfying the required equality and inequality constraints [1]. Burning of fossil fuels causes a vast amount of carbon-di-oxide, sulphur–di-oxide and nitrogen oxide emissions into atmosphere .Increase of these contaminants in large amount can result in some deadly environment effects such as global warming [2]. Generation allocation should take into account the pollution control also. The operation based on minimum environmental impact will results in higher production cost. The operation with minimum total production cost will not meet the emission requirement. So, combined Emission Economic Dispatch strategy is applied to satisfy the above mentioned conflicting objectives. This multi objective Combined Economic Emission Dispatch problem is changed into a single objective function with the help of price penalty factor. In [3] Fuzzy logic controlled genetic algorithm is used to solve CEED problem. Evolutionary programming (EP) based algorithm can be used for Environmental constrained economic dispatch problem has been proposed in [4]. A direct Newton-Raphson method based on an alternative Jacobian matrix to solve combined economic emission problem has been suggested in [5]. Hybrid algorithm developed by combining GA and SA have been proposed and developed for evaluating the trade off between fuel cost and pollutant emissions in power dispatch is described in [6]. An elitist multi objective evolutionary algorithm based on NSGA-II is applied to the environmental economic power dispatch optimization problem in [7]. In [8] Immune Genetic algorithm is used to solve the economic emission load dispatch problem. Multi–objective differential evolution has been presented in [9] for solving economic

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environmental dispatch problem. Results obtained from the proposed approach have been compared with those obtained from pareto differential evolution, strength pareto evolutionary algorithm 2 and non dominated sorting genetic algorithm-II.A novel binary successive approximation-based evolutionary search strategy has been proposed to solve the economic-emission load dispatch problem by searching the generation pattern of committed units in[10]. A reliable differential evolution (DE) based algorithm for solving environmentally constrained economic dispatch (ECED) problem with equality as well as non-equality constraints is presented in [11]. A hybrid differential evolutionary algorithm with Incremental cost as the decision variable to solve CEED problem with valve point effects has been developed in [12]. An Artificial Neural Network approach for solving the Combined Economic and Emission Dispatch (CEED) problem using Radial Basis Function (RBF) based neural network has been suggested in [13]. A new non dominated sorting genetic algorithm (NSGA) based approach is presented in [14] for solving the environmental/economic power dispatch Optimization problem. The problem is formulated as a nonlinear constrained multi objective optimization problem where fuel cost and environmental issues are treated as competing objectives. A modified non-dominated Genetic Algorithm has been applied to solve the CEED problem with conflicting objective such as fuel cost and emission. The results show that MNSGA-II is an effective tool for handling multi-objective optimization problem is discussed in [15]. All these techniques are powerful with origins in nature. Particle Swarm Optimization is one of the intelligent search techniques that can be used for solving the CEED problem. This algorithm was first proposed by Kennedy and Eberhart. PSO was developed through simulation of simplified social systems and has been found to be robust in solving non linear optimization problem. A novel Meta heuristic, fuzzy clustering- based particle swarm optimization (FCPSO), approach has been successfully employed in [16] to solve the multi objective EED problem. The problem has been formulated with conflicting fuel cost and emission objectives are the two main constraints. In [17] summarized the review for economic dispatch using PSO. A Particle Swarm Optimization algorithm has been suggested in [18] to solve the economic power dispatch of power system with pollution control. The fuel cost and emission are combined in a single function with a difference weighting factor. An application of a new evolutionary Technique, Harvest Season Artificial Bee Colony Algorithm, for solving CEED problem has been proposed in [19]. A new approach based on Harmony search Algorithm (HSA) has been proposed in [20] and the approach was tested on 6 unit system with renewable energy and results are compared with recent optimization techniques. It shows that the proposed technique is superior. The differential evolution algorithm has been successfully implemented to solve ED problems with the generator constraints as linear equality and inequality constraints in [21] Artificial Bee Colony (ABC) algorithm has been proposed in [22] for solving Emission and Economic Load dispatch problem

In this paper, Weight Improved Particle Swarm Optimization [WIPSO] algorithm is used for solving CEED problem in power system network. In order to show the effectiveness of the proposed method it has been compared with PSO techniques. This proposed algorithm is tested on standard IEEE 14-bus, 30-bus and 57 - bus test systems.

II. Problem Formulation:

1. Economic Dispatch:

The Economic dispatch problem finds the optimal combination of power generation for each generating unit in such a way that the total generation cost of the system is minimized while satisfying the equality and inequality constraints.

The problem can be formulated as

$$F_T = \sum_{i=1}^{N_G} (a_i P_{Gi}^2 + b_i P_{Gi} + c_i) \quad (1)$$

Where,

F_T is the total production cost in $/hr

N_G is the total no. of generating units

P_{Gi} is the power output of i^{th} generating unit in MW

a_i ,b_i and c_i are the fuel cost coefficients of the i^{th} generating unit

i represents the corresponding generator (1,2,…n)

The equation (1) is subjected to the following constraints

1.1. Generating capacity constraint

$P_{Gi}^{min} \leq P_{Gi} \leq P_{Gi}^{max}$, i=1,2,3…….NG

where,

P_{Gi}^{min} is the minimum output of i^{th} generating unit

P_{Gi}^{max} is the maximum output of i^{th} generating unit

1.2. The power balance constraints

$$P_D + P_L - \sum_{i=1}^{N_G} P_{Gi} = 0$$

where,

P_{Gi} is the real power output of i^{th} generating unit

P_L is the total line loss in MW

P_D is the total demand of the system in MW

2. Emission Dispatch:

The total amount of pollutant emission is not included in the classical economic dispatch problem. The total amount of pollutant emission from a fossil fired thermal generating unit depends upon the amount of power generated by each unit.

The problem is formulated as

$$E_T = \sum_{i=1}^{N_G} (\alpha_i P_{Gi}^2 + \beta_i P_{Gi} + \gamma_i) \quad (2)$$

Where,

E_T is the total amount of emission in (lb/hr)

α_I, β_i, and γ_i are the emission coefficients of i^{th} generating unit

3. Combined Economic Emission dispatch Problem:

The multi objective optimization function is converted into a single objective optimization problem by introducing price penalty factor (h_i).

h_i blends the fuel cost with emission cost and it is the ratio between the maximum fuel cost and the maximum emission of the corresponding generator.

$$h_I = \frac{a_i P_{Gi}^2 \max + bi P_{Gi} \max + C_i}{\alpha_i P_{Gi}^2 \max + \beta_i P_{Gi} \max + \gamma_i}$$

The combined objective of economic and emission dispatch is given by the following expression.

$\varphi_T = w_1 F_T + W_2 h E_T$

where,

φ_T is the combined objective function

W_1 and W_2 are weighting factors

and

(i) $w_1 = 1$ and $W_2 = 0$ for pure economic dispatch

(ii) $w_1 = 0$ and $W_2 = 1$ for pure emission dispatch

(iii) $w_1 = 1$ and $W_2 = 1$ for combined emission economic dispatch

III. Introduction Of Particle Swarm Optimization:

The Particle Swarm Optimization technique was first introduced by Kennedy and Eberhart in 1995. The technique is motivated by social behaviour of organisms such as fish schooling and bird flocking. In the PSO, a swarm consists of a set of particles represent a solution to the optimization problem. Each particle adjusts its position according to its own experience and the experience of its neighbouring particles. The position and velocity of the i^{th} particle in the N-dimensional search space is represented as

$X_i = (x_{i1}, x_{i2}, ... x_{in})$

$v_i = (v_{i1}, v_{i2}, ... v_{in})$

The best position achieved by a particle is recorded and is denoted by

$P_{best\ i} = (x_{i1}^{Pbest}, ... x_{in}^{Pbest})$

The best particle among all the particles in the population is represented by

$G_{best\ i} = (x_{i1}^{Gbest}, ... x_{in}^{Gbest})$

The updated velocity and position of each particle in $(K + 1)^{th}$ step are calculated as follows

$X_i^{k+1} = X_i^k + V_i^{k+1}$

where,

$V_i^{k+1} = wV_i^k + C_1 rand_1 (x_i P_{best\ i}^k - x_i^k) + C_2 rand_2 (GP_{best\ i}^k - x_i^k)$

x_i^k = Position of individual i at iteration k

X_i^{k+1} = Position of individual i at iteration k + 1

v_i^k = Velocity of individual i at iteration k
w = weight parameter
C_1 = Cognitive factor
C_2 = Social factor
$P_{best\ i}^k$ = best position of individual i until iteration k
$G_{best\ i}^k$ = best position of group until iteration k
$rand_1$, $rand_2$ = random numbers between 0 and 1.

In this velocity updating process, the acceleration coefficients C_1,$C_2$and weight parameter 'w' are predefined and $rand_1$and$rand_2$are uniformly generated random numbers in the range of [0, 1].

IV. Weight Improved Particle Swarm Optimization:

To get a better global solution, the algorithm is improved by adjusting the weight parameter, cognitive and social factors. The velocity of the individual using WIPSO is rewritten as

$$V_i^{k+1} = W_{new}\, V_i^k + C_1\, rand_1 (p_{best\ i}^k - x_i^k) + C_2\, rand_2 (G_{best\ i}^k - x_i^k)$$

Where,

$$w = w_{\max} - \left\{ \frac{w_{\max} - w_{\min}}{Iter_{\max}} \right\} x Iter$$

$$w_{new} = (w_{\min}) + (W \times rand_3)$$

$$C1 = C_1 \max - \left\{ \frac{C_{1\max} - C_{1\min}}{Iter_{\max}} \right\} x\ Iter$$

$$C2 = C_2 \max - \left\{ \frac{C_{2\max} - C_{2\min}}{Iter_{\max}} \right\} x\ Iter$$

w_{min} ,w_{max} = initial and final weights
C_{1min}, C_{1max} =initial and final cognitive factors
C_{2min}, C_{2max} = initial and final social factors
$Iter_{max}$ = maximum iteration number
Iter = current iteration number
$rand_3$ = random numbers between 0 and 1

V.Algorithm:

1. Choose the population size, the number of generations, w_{min}, w_{max}, C_{1min}, C_{1max}, C_{2min}, C_{2max}, pbest, gbest.

(Population size 20, no. of generations 200)

2. Initialize the velocity and position of all particles randomly, ensuring that they are within limits. Here the individuals represent the real power generation of generator buses in the system.
3. Set the generation counter t=1.
4. Evaluate the fitness for each particle according to the objective function.
5. Compare the particle's fitness function with its$P_{best\ i}$. If the current value is better than $P_{best\ i}$, then set $P_{best\ i}$ is equal to the current value. Identify the particle in the neighborhood with the best success so far and assign it to G_{best}.
6. Update velocity by using the global best and individual best of the particle.
7. Update position by using the updated velocities. Each particle will change its position.
8. If the stopping criteria is not satisfied set t=t+1 and go to step 4.Otherwise stop.

VI. Simulations and Results:

The proposed optimization problem using PSO and WIPSO techniques has been tested on a standard IEEE 14, 30 and 57 bus test systems. The generation limit, fuel cost and emission coefficients for each unit of the system are shown in Table1 to Table 3 for all three test systems.

Table 1: Cost, emission coefficients and MW limits of IEEE 14 bus system

Gen. No.	Max MW	Min. MW	γ	β	α	a	b	c
1	250	10	0.0126	-0.90	22.983	0.00375	2.0	0
2	140	20	0.0200	-0.10	25.313	0.01750	1.75	0
3	100	15	0.0270	-0.01	25.505	0.06250	1.0	0
5	120	10	0.0291	-0.005	24.900	0.00834	3.25	0
5	45	10	0.0290	-0.004	24.700	0.02500	3.0	0

Table 2: Cost, emission coefficients and MW limits of IEEE 30 bus system

Gen. No	Max MW	Min. MW	γ	β	α	a	b	c
1	200	50	0.0125	-0.90	22.983	0.00375	2.0	0
2	80	20	0.0200	-0.10	25.313	0.01750	1.75	0
3	50	15	0.0270	-0.01	25.505	0.06250	1.0	0
4	35	10	00291	-0.005	24.900	0.00834	3.25	0
5	30	10	0.0290	-0.004	24.700	0.02500	3.0	0
6	40	12	0.0271	-0.0055	25.300	0.02500	3.0	0

Table 3: Cost, emission coefficients and MW limits of IEEE 57 bus system

Gen. No	Max MW	Min. MW	γ	β	α	a	b	c
1	576	50	0.0126	-0.90	22.983	0.0017	1.7365	0
2	100	10	0.0210	-0.10	26.313	0.0100	10.0	0
3	140	20	0.0194	-0.20	25.888	0.0071	7.1429	0
4	100	10	0.0210	-0.10	26.313	0.0100	10.0	0
5	550	40	0.0134	-0.82	23.104	0.0018	1.81	0
6	100	10	0.0210	-0.10	26.313	0.0100	10.0	0
7	410	30	0.0152	-0.76	23.736	0.0024	2.4390	0

The test results for CEED problem are given in Tables 4, 5 and 6 for IEEE14, 30 and 57 bus test systems. It represents the generation output of all the generating units and results of fuel cost and emission level are tabulated. The load demands are assumed to increase gradually at load bus. The performance on increased load demand is also listed in the tables 4, 5 and6 for all the three test systems. The equivalent bar chart are also represent for all the three system for various load conditions are represented in Fig.1,2 and 3.

Table 4: Test Results from PSO AND WIPSO ON CEED for the IEEE 14 bus test System

Output	Base Load(MW)		Increment Load demand (MW)							
			5%		10%		15%		20%	
	PSO	WIPSO	PSO	WIPSO	PSO	WIPSO	PSO	WIPSO	PSO	WIPSO
PG1 (MW)	134.98	134.98	140.31	140.89	146.82	146.82	152.78	152.79	158.68	158.78
PG2 (MW)	50.53	50.53	53.43	53.04	55.55	55.55	58.06	58.06	60.88	60.57
PG3 (MW)	26.33	26.33	27.57	27.49	28.65	28.65	29.81	29.81	30.94	30.97
PG4 (MW)	30.40	30.40	32.77	32.69	34.97	34.97	39.26	37.26	39.57	39.55
PG5 (MW)	24.92	24.92	26.65	26.66	28.40	28.40	30.14	30.14	31.69	31.88
Total PG (MW)	267.16	267.16	280.73	288.77	294.39	294.39	308.05	308.06	321.76	321.75
Losses (MW)	8.16	8.16	8.73	8.77	9.39	9.39	10.05	10.06	10.76	10.75
Fuel cost ($/hr)	737.85	737.85	786.17	785.88	834.88	834.88	884.88	884.88	935.80	935.87
Emission (lb/hr)	340.61	340.61	368.76	369.23	399.61	399.61	431.77	431.78	465.80	465.74
Total Cost ($/hr)	1254.09	1254.09	1345.07	1345.48	1440.54	1440.54	1539.23	1539.29	1641.78	1641.76

Table 5: Test Results from PSO AND WIPSO ON CEED for the IEEE 30 bus test system

Output	Base Load (MW)		Increment Load demand (MW)							
			5%		10%		15%		20%	
	PSO	WIPSO	PSO	WIPSO	PSO	WIPSO	PSO	WIPSO	PSO	WIPSO
PG1 (MW)	131.99	131.33	136.77	136.86	142.74	142.41	148.67	149.25	156.96	156.88
PG2 (MW)	50.30	50.47	52.93	52.91	55.44	55.35	58.06	58.35	61.71	61.72
PG3 (MW)	27.18	26.79	27.99	27.98	29.38	29.16	31.53	30.62	32.15	32.23
PG4 (MW)	29.84	30.34	32.50	32.48	33.89	34.63	35.00	35..00	35.00	35.00
PG5 (MW)	25.53	25.53	27.24	27.22	28.96	28.92	30.00	30.00	30.00	30.00
PG6 (MW)	26.74	26.74	28.53	28.51	30.36	30.28	32.35	32.47	34.92	34.90
Total PG (MW)	291.22	291.20	305.96	305.96	320.77	320.75	335.61	335.69	350.74	350.73
Losses (MW)	8.22	8.20	7.96	7.96	8.77	8.75	9.61	9.69	10.74	10.73

Fuel cost ($/hr)	826.30	826.60	880.27	880.19	934.96	934.87	991.25	990.24	1046.29	1046.39
Emission (lb/hr)	377.93	377.48	406.79	406.87	438.17	438.03	471.16	472.15	509.72	509.60
Total Cost ($/hr)	1518.94	1518.41	1625.79	1625.87	1738.00	1737.64	1854.74	1855.54	1980.45	1980.33

Table 6: Test Results from PSO AND WIPSO ON CEED for the IEEE 57 bus test system

Output	Base Load		Increment Load demand (MW)							
			5%		10%		15%		20%	
	PSO	WIPSO	PSO	WIPSO	PSO	WIPSO	PSO	WIPSO	PSO	WIPSO
PG1 (MW)	436.38	437.94	453.34	453.43	472.53	469.49	489.18	485.72	505.04	502.09
PG2 (MW)	35.39	21.44	27.28	27.36	42.84	33.39	547.00	39.42	50.56	45.45
PG3 (MW)	88.09	87.84	95.86	95.11	100.72	102.23	103.72	109.36	106.30	116.48
PG4 (MW)	24.53	21.40	28.88	27.36	35.73	33.39	41.90	39.42	58.13	45.45
PG5 (MW)	373.99	381.31	393.67	394.30	389.39	407.07	394.76	419.83	426.52	432.60
PG6 (MW)	32.54	21.19	26.19	27.36	45.18	33.39	55.32	39.42	47.07	45.45
PG7 (MW)	287.09	305.98	316.76	317.04	321.26	328.03	331.39	339.02	344.22	350.01
Total PG (MW)	1278.01	1277.71	1341.98	1341.96	1407.65	1406.99	1473.27	1472.19	1537.84	1537.53
Losses (MW)	27.01	26.10	28.98	28.96	31.65	30.99	35.27	34.19	36.84	36.53
Fuel cost ($/hr)	4546.28	4345.60	4731.72	4731.72	5289.50	5122.98	5763.27	5519.70	6012.63	5921.94
Emission (lb/hr)	4968.34	5177.66	5599.42	5599.42	5872.32	6044.93	6273.40	6513.27	6914.85	7004.69
Total Cost ($/hr)	8726.01	8701.43	9442.36	9442.36	10229.73	10208.41	11040.91	10999.14	11829.90	11814.79

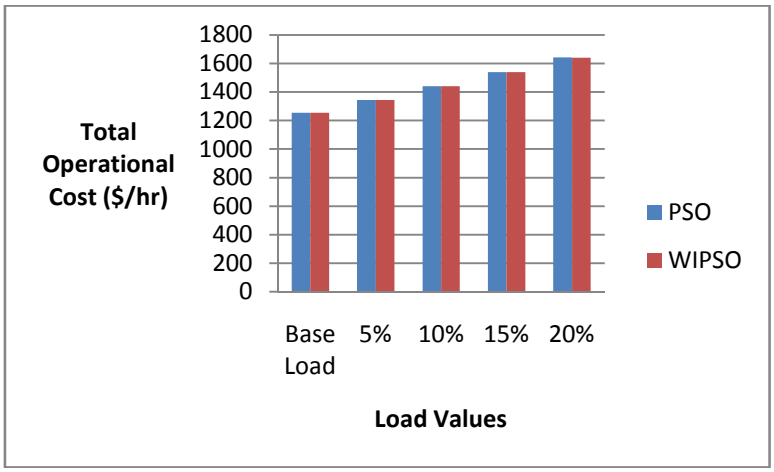

Fig. 1: Bar chart for IEEE 14 bus test system

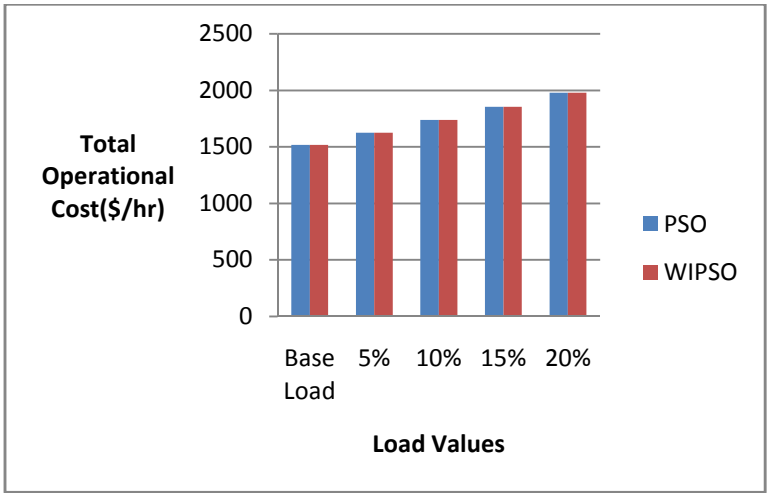

Fig. 2: Bar chart for IEEE 30 bus test system

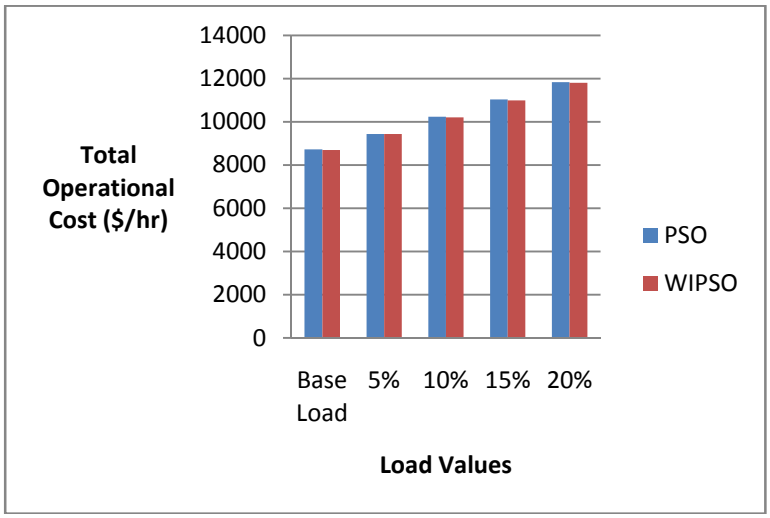

Fig. 3: Bar chart for IEEE 57 bus test system

VII.Conclusion:

In this paper, a new optimization algorithm called WIPSO algorithm, is proposed and applied effectively to solve the CEED problems. The proposed method has been applied in the standard IEEE 14 bus, 30 bus and 57 bus test systems. The performance on increased load demand is also given for all the three test systems. The effectiveness of the WIPSO algorithm has been compared to the standard PSO algorithm and it has been observed that WIPSO algorithm performs better than PSO for most of the cases.

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