Solving Combined Economic Emission Dispatch Solution Using Jaya Optimization Algorithm Approach

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Abstract:- For large power system operation Economic Load Dispatch is one of the most important problem. Its objective how to schedule generation at various inter connected generating plants , to meet required load demand, considering system constraints to keep operating cost at minimum level. In combined economic emission dispatch (ceed) not only minimize the operating but simultaneously keep emission level low also. There are various technique, proposed by several researchers to solve ceed problem. In this paper Jaya, Particle Swarm Optimization and Bare-Born Particle Swarm Optimization and Differential Evolutionary algorithms are applied to minimize operating cost with minimization of emission too. Generation for various units and Power loss is calculated using Newton-Raphson power flow method on IEEE-6 and IEEE-14 bus test data.

Key Words:- Combined Economic Emission Dispatch, Particle Swarm Optimization , Bare-Bone PSO, Jaya Optimization Algorithm

I. Nomenclature:-

Fi(Pi)	Fuel cost function of i^{th} generator
P_i	Real power generation of i^{th} generator
P_i^{min}	Minimum limit of real power generation
P_i^{max}	Maximum limit of real power generation
P_D	Total real power demand
P_L, Q_L	Real and reactive power losses of the system
NG	Number of generator
E_i	Total Emission from generators
a_i , b_i ,c_i	Cost coefficient of i^{th} generator
d_i , e_i , f_i	NO_x emission coefficients of i^{th} generator
h	Price penalty factor
Pbest	Particle best position

Gbest	Globle best position of particle
$\mu^k_{i,j}$	mean of pbest and gbest in j^{th} decision variable of i^{th} particle at k^{th} iteration
$\sigma^k_{i,j}$	absolute difference pbest and gbest in j^{th} decision variable of i^{th} particle at k^{th} iteration
N	represents gaussian distribution

2. Introduction :- Generating stations are interconnected to achieve benefits of better operating conditions, flexibility with better reliability of system. By economic load dispatch minimum production cost can be achieve. As per government regulations on environment protection , the conventional operation at absolute minimum fuel cost, cannot be the only basis of dispatching electric power. There is expectation from society for adequate and secure electricity at minimum possible price with minimum levels of pollution, produced by fossil-fuelled electric power plants. The clean Air Act Amendments instruct to reduce NO_x and SO_2 emission also be minimum from such power plants. The single objective can no longer be considered alone. So Environmental Economic dispatch is a multi-objective problem. Well known long established techniques such as integer programming, dynamic programming and legarangian relaxation method[1-2] have been used to solve economic load dispatch problem. Nanda et al. solved economic-emission problem using goal programming technique for a system having six generator[3]. Nanda et al. also applied classical technique based on coordinated equation to obtain economic emission load dispatch for IEEE14 and 30 bus system[4].Dhillon et al.[5] applied weighted minimax technique and fuzzy set theory to find out solution. Recently other optimization method such as Genetic algorithm[7],Artificial Bee Colony Optimization[8], Modified Ant Colony Optimization[9] are applied for ceed solution,. Swarm intelligence algorithms [12 -16] is also applied by researchers. Niched parato genetic algorithm is also reported for optimum solution for ceed problem.

In this paper NO_x contains are minimized by applying Particle Swarm Optimization (PSO) and Bare-Bones Particle Swarm Optimization (BBPSO), Differential Evolutionary (DE), Jaya Algorithm and their results are compared for various load demand. A price penalty factor (h) [8,11], is used in the objective function to combine the fuel cost and emission function.

3. Problem Formulation :-

The mathematical formulation of the total fuel cost function as follows

$$\text{Min j} = \sum_{i=1}^{NG} \text{Fi(Pi)} \qquad (1)$$

Where F_i is the total fuel cost for the generator (in Rs/Hr). Generally the fuel cost of thermal generating unit is represented by polynomial function

a_i , b_i, c_i are cost coefficient of generator i

The combined economic and emission dispatch problem can be formulated as to minimize

$$\text{Min f} = \sum_{i=1}^{NG} \text{Fi(Pi)} + h \sum_{i=1}^{NG} \text{Ei(Pi)} \quad (2)$$

where

$F_i(P_i) = a_i p_i^2 + b_i\, p_i + c_i$ (3)

and a_i, b_i, c_i are cost coefficient of generator i

$E_i(P_i) = d_i\, p_i^2 + e_i p_i + f_{ii}$ (4)

Where d_i, e_i, f_i are NO_x emission coefficient and h is price penalty factor.

Constraints of the system:-.

Inequality constraint:- Generation of power of each generator should be within limit of their maximum and minimum limits. The inequality constraint for each generator

$$P_i^{min} \le P_i \le P_i^{max} \quad (5)$$

Cost coefficients and emission coefficients are given for generators units are in use while penalty factor ‘h’ is to be evaluate. A practical way of evaluating h is discussed in [9] The procedure to calculate’ h is as follow.

For given load in the system P_d MW

(1) Calculate the maximum cost of each generator at its maximum output, i.e. $F_i(P_{imax}) = (a_i P^2_{i\,max} + b_i P_{i\,max} + c_i)$ Rs/hr

(2) Calculate the maximum NO_x emission of each generator at its maximum output $E_i(P_{i\,max}) = (d_i P^2_{i\,max} + e_i P_{i\,max} + f_i)$ kg/hr

(3) Divide the maximum cost of each generator by its maximum NO_x emission.i.e.,

$$\frac{F_i(P_{imax})}{E_i(P_{imax})} = \frac{a_i P_{imax}^2 + b_i P_{imax} + c_i}{d_i P_{imax}^2 + e_i P_{imax} + c_i} \quad (6)$$

$$\frac{F_i(P_{imax})}{E_i(P_{imax})} = h_i \text{ Rs / Kg} \quad (7)$$

After calculation of h_i

(4) Arrange h_i for (i = 1,2,3 …….n) in ascending order.

(5) Add the maximum capacity of each unit, ($P_{i\ max}$) one at a time starting from the smallest h_i unit total demand is met to satisfy

$\sum_{i=1}^{NG} P_{imax}$ >= P_D

(6) At this stage, h_i associated with the last unit in the process is the price penalty factor h in Rs/kg for the given load

Arrange h_i in ascending order . h = [h_1,h_2,-------------,h_n] for a load of P_D starting from the lowest h_i of maximum capacity of unit is added one by one and when this total equals or exceeds the load, h_i associated with the last unit in the process is the price penalty factor for the given P_D, then substituting the value of ' h', equation can be solved.

4. Jaya Algorithm: an overview

The word Jaya is taken from sanskrit its meaning is victory. Jaya algorithm is developed by R.Venkata Rao in 2015 [23]. It is algorithmic specific parameter-less optimization algorithm. It requires only common controlling parameters like population size and number of generations for its working. It can be applied for solving constrained and unconstrained optimization problems. Among the population best candidate f(x)best and worst candidate f(x)worst are obtained from entire candidate solution. Its implementation moves solution towards best solution and avoid solution moves towards worst solution. The steps of implementation of jaya algorithm is as follows

Step(a) : Initialization population of size n, with m design variables

$P = [X_1, X_2, X_3 \text{------------} X_n]$

$X_i = [X_{i1}, X_{i2} , X_{i3}, \text{--------} X_{im}]$

Step(b) : Evaluate fitness for each population

Step(c) : Obtain best value (i.e.f(x) best) and worst value (i.e.f(x) worst) among the population

Step(d): Update each population as per following eqution

$X_{j\ worst,i} = X_{j,k,i} + r1_{j,i} (X_{j,best,i} - | X_{j,k,i} |) – r2_{j,i} (X_{j\ worst,i} - |X_{j,k,i}|)$

Where $X_{j,best,i}$ is the value of variable j for the best candidate

$X_{j\ worst,i}$ is the of the variable j for the worst candidate

$X_{j\ worst,i}$ is the updated value of $X_{j,k,i}$

$r1_{j,i}$, $r2_{j,k}$ are random numbers for the j^{th} variable during i^{th} iteration the term “$r1_{,j,i}$ ($X_{j,best,i}$ - | $X_{j,k,i}$ |) “ has tendency to bring solution closer to solution while the term “$r2_{j,i}$ ($X_{j\ worst,i}$ - |$X_{j,k,i}$|) “ has tendency to avoied the worst solution. $X'_{j,k,i}$ is accepted if it gives better function value. All better function values become the input for next iteration.

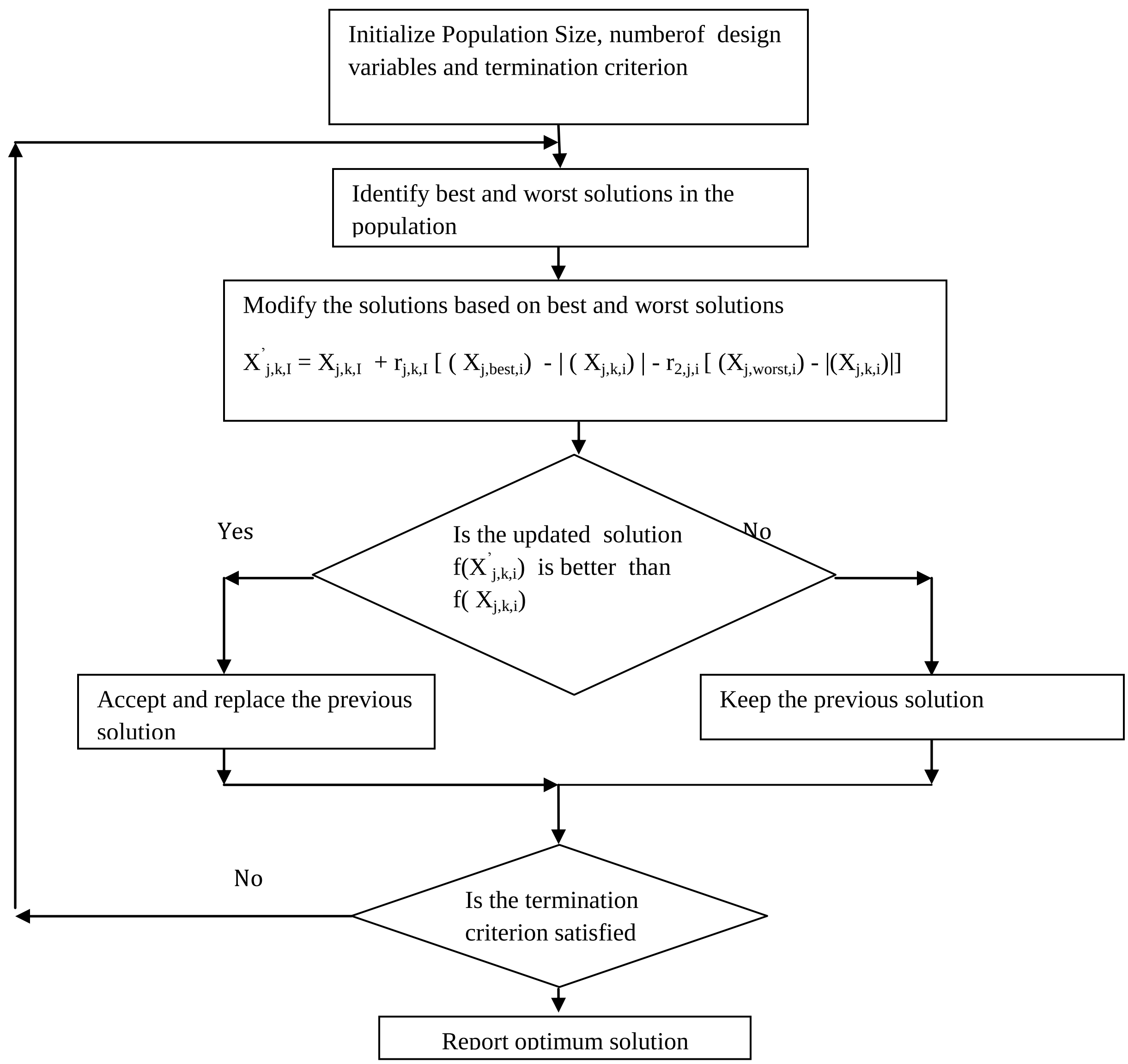

Fig 1 Flow Chart for Jaya Algorithm

5. **Results and Discussion** :- The applicability and validity of PSO and BBPSO,DE, Jaya algorithm, tested on IEEE 6 Test system and IEEE 14 Test system by taking various load demands. Table No. 1. Are applied to 6- bus system consist of three generator buses and three load buses while 14 – bus system consist of five generator bus and 11 load buses .

Table1,(6- bus system) while Table3,(14 bus system) shows results for fuel cost, emission, total operating cost and computational time for stated optimization algorithms. Table 2 and table 4 shows results using Jaya algorithm for min. power generated by various generating units in 6 and 14 bus system to meet required load demand keeping fuel cost, emission of NOxand total operating cost at minimum level.

Table No. 1 Comparison of Test Results for Three Generating Units, IEEE 6 Bus System

Load in MW	h in RS/kg	Performance Parameter	PSO	BBPSO	DE	JAYA
125	49.4973	Fuel Cost Rs/hr	6991.5	6991.5	6991.55	6991.5
		Emission kg/hr	140.4567	140.457	140.456	140.457
		Total Cost Rs/hr	13943.7268	13943.7	13943.7	13943.7
		Computational Time(sec)	377.25	208.109	594.05	407.02
150	59.4973	Fuel Cost Rs/hr	7763.1962	7763.2	7762.92	7763.2
		Emission kg/hr	145.8932	145.893	145.899	145.893
		Total Cost Rs/hr	14984.5136	14984.5	14984.5	14984.5
		Computational Time(sec)	388.47	183.6894	369.25	406.376
175	86.0448	Fuel Cost Rs/hr	8602.7411	8602.98	8602.85	8602.98
		Emission kg/hr	153.802	153.85	153.807	153.805
		Total Cost Rs/hr	21837.1416	21837.1	21837.1	21837.1
		Computational Time (sec)	553.2954	251.489	386.55	408.554
200	86.0448	Fuel Cost Rs/hr	9398.9336	9398.93	9399.06	9398.93
		Emission kg/hr	163.263	163.263	163.262	163.263
		Total Cost Rs/hr	23446.8033	23446.9	23446.9	23446.9
		Computational Time (sec)	354.4307	210.450	357.274	407.347

Table No. 2 Optimum Power Dispatch Results By Jaya Optimization Algorithm For 3 Units , IEEE Six Bus System

Power Demand	P1(MW)	P2(MW)	P3(MW)
125 MW	58.6394	34.885	35.778
150 MW	66.912	44.1942	43.5112
175 MW	77.6116	52.3504	51.6838
200 MW	86.0307	61.5931	59.4374

Table No. 3 Comparison of Test Result for Five Generating Units, IEEE 14 Bus System

Load in MW	h in RS/kg	Performance Perameter	PSO	BBPSO	DE	JAYA
175	49.4973	Fuel Cost Rs/hr	9439.2639	9430.62	9438.45	9440.64
		Emission kg/hr	224.1429	226.354	222.356	224.191
		Total Cost Rs/hr	20533.32	20634.5	20540.6	20537.5
		Computational Time in Sec.	605.9	291.074	667,921	809.27
225	56.660	Fuel Cost Rs/hr	11028.8068	11013.8	11007.2	11017.4
		Emission kg/hr	244.2414	241.169	234.158	239.642
		Total Cost Rs/hr	24867.8311	24678.7	24585.9	24595.8
		Computational Time in Sec.	577.52	266.42	684.05	711.33
250	56.660	Fuel Cost Rs/hr	11871.1564	12659.5	11846.1	11870.9
		Emission kg/hr	254.5335	304.3	243.393	250.184
		Total Cost Rs/hr	26293.2605	38842.9	26103.2	26046.6
		Computational Time in Sec.	531.42	271.1	869.89	796.53
275	86.0448	Fuel Cost Rs/hr	12657.2009	12716.7	12644.3	12605.9
		Emission kg/hr	306.7821	286.861	266.973	272.404
		Total Cost Rs/hr	39054.2076	37399.6	36216.6	36044.9
		Computational Time in Sec	528.8	268	670.44	796.87

Table No. 4 Optimum Power Dispatch Results By Jaya Optimization Algorithm For 5 Units , IEEE 14 Bus System

Load Demand	P1	P2	P3	P4	P5
175 MW	63.939	44.672	38.7608	10.0975	20.2947
225 MW	75.1286	61.5239	50.3842	10.0148	32.249
250 MW	85.5292	68.5136	54.4118	10.0109	38.0681
275 MW	89.4424	70	59.9632	21.6636	40

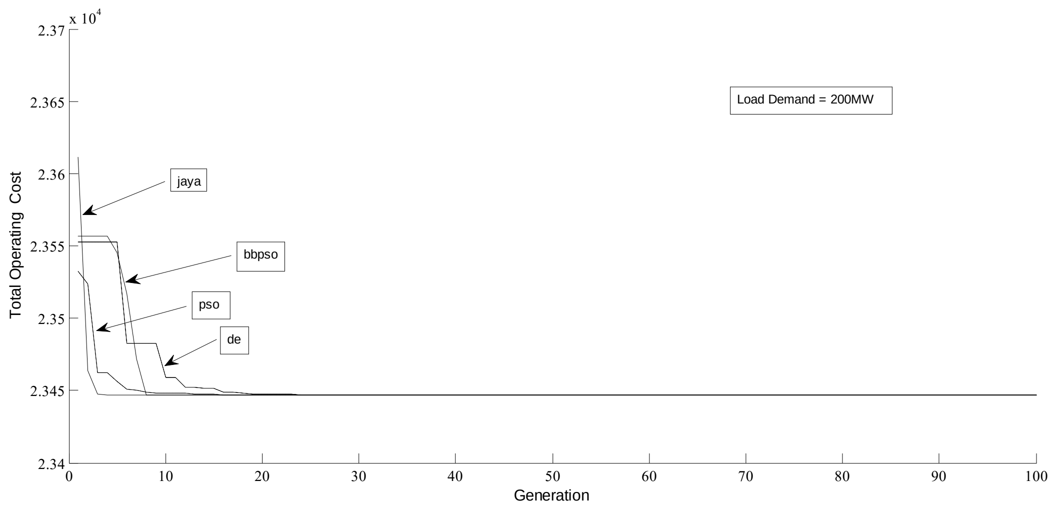

Fig. 2 Convergence of three generating units, IEEE 6 bus system

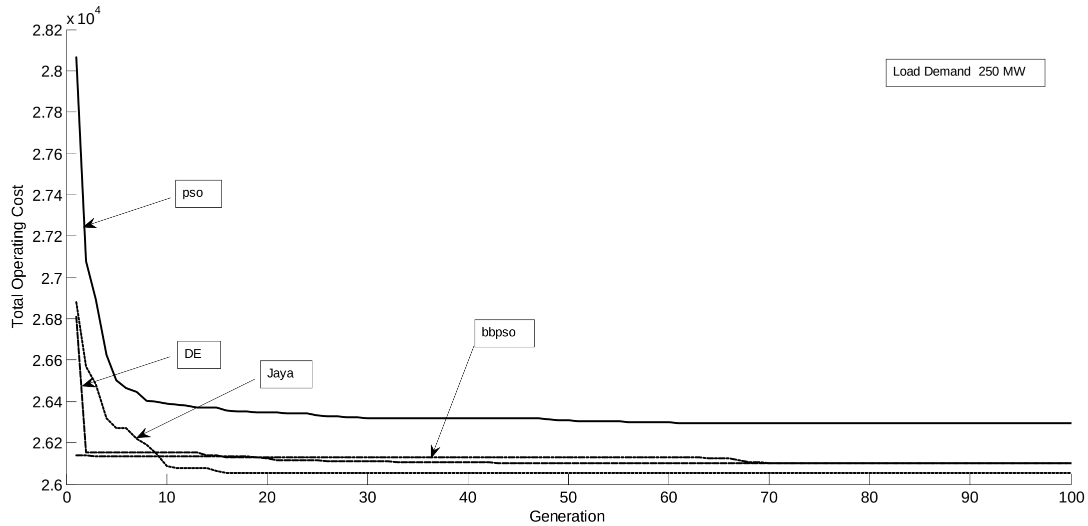

Fig.3 Convergence of five generating units, IEEE 14 bus system

6. Conclusions: -In this paper PSO and BBPSO, DE, Jaya algorithm has been applied for CEED problem, for IEEE -14 test system with five generating units. On comparing results for various load it is found that Jaya algorithm giving better results than DE,PSO,BBPSOalgorithm in total operating cost This shows the effectiveness and applicability of Jaya algorithm to achieve objective of CEED i.e. minimum fuel cost operation with minimum emission while considering constraints of the system

Appendix:-

Table No 5 Fuel Cost coefficient

Generator Unit	Fuel Cost Coefficient			P_{Gmin}	P_{Gmx}
	a_i	b_i	c_i		
G_1	0.0301	27.5	750	50	90
G_2	0.0195	27.3	1400	30	70
G_3	0.0203	30.0	1050	30	60
G_4	0.0507	26.5	450	10	50
G_5	0.0264	27.5	950	10	40

Table No 6Emission Coefficient (NO_x)

Generator Unit	Fue l Emission Coefficient			P_{Gmin}	P_{Gmax}
	d_i	e_i	f_i		
G_1	0.00419	-0.3276	35.859	50	90
G_2	0.00403	- 0.1032	56.300	30	70
G_3	0.00551	-0.2056	52.099	30	60
G_4	0.00483	0.0555	30.266	10	50
G_5	0.00600	0.0100	41.859	10	40

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