Dual objective multiconstraint swarm optimization based advanced economic load dispatch

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ABSTRACT

In electric power system, the vital topic to be mooted is economic load dispatch (ELD). It is a non-linear problem with some unavoidable constraints such as valve point loading and ramp rate constraint. For solving ELD problem distint methods were devised and tried for different electric supply systems yielding slow convergence rates. To achieve fast convergence, dual objective multi constraint swarm optimization based advanced economic load dispatch (DOMSOBAELD) algorithm is proposed making use of simulated values of real power outages of a thermal power plant as initial estimates for PSO technique embedded in it and used for optimizing economic dispatch problem in this article. DOMSOBAELD method was developed in the form of amalgamating fluids. Presence of power line losses, multiple valves in steam turbines, droop constraints and inhibited zones were utilized to optimize the ELD problem as genuinely approximate as possible. The results obtained from DOSOBAELD are compared with particle swarm optimization (PSO), PSOIW and differential particle swarm optimization (DPSO) techniques. It is quite conspicuous that DOMSOBAELD yielded minimum cost values with most favourable values of real unit outputs. Thus the proposed method proves to be advantageous over other heuristic methods and yields best solution for ELD by selecting incremental fuel cost as the decision variable and cost function as fitness function.

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1. INTRODUCTION

Due to growing complexity of the power demand the reliability, transmission loss and clear power free of distortion becomes a challenging problem for economic load dispatch (ELD). Slow convergence rate of Soft computing methods and complex computational burden with complex structural algorithm for conventional method lead to complex ELD problem. To overcome these barriers dual objective multi constraint swarm optimization based advanced economic load dispatch (DOMSOBAELD) method is applied in the proposed research work. In this paper, multiple versions of particle swarm optimization techniques are used to ascertain the optimal cost of generation capacity that can be integrated into the existing power system and the results of the proposed algorithm for a 30 bus test case system are reported. A new fictitious code based algorithm is developed, in this paper, for equality constraints [1] other than the penalty function methods that performs better due to its parallel search capability.The effect of multiple valves in steam tubines narrated by Singh and Wang *et al.*, [2-4] yields more perturbation in cost function which can be piece wise linear using conventional economic dispatch techniques. This methodology is so easy that particle swarm optimization (PSO) utilizes some parameters and definitions of the optimization process and then it starts the process with an initial random population involving parallel search technique, named particles. Each of these particles has a feasible solution for the main problem and is processed as a part in 'n' dimensional space. In the variable space, each particle has a position identified by xi and a velocity identified by vi. If a particle has a best position, it is brought over to the next stage. Additionally, best positions are denoted as Pbest and the best position of all particles is denoted as Gbest. The results of generation outages for 6 units obtained through the simulation of aforesaid thermal power plant involving multiple constraints are used as initial estimates for proposed DOMSOBAELD method and final optimal schedules for real power generation, final position of swarm and their velocities are updated using PSO technique involved in DOMSOBAELD approach and are compared with various traditional methods like Lagrange multiplier method [5, 6], PSOIW, DPSO [7, 8] and sequential quadratic programming method referred in [9, 10].

2. RESEARCH METHOD

This section presents and formulates the objective functions viz. cost, emission and combined objective function satisfying multiconstraints involving price penalty factor F_i.The basic economic load dispatch problem incorporating valve point loading described by Sharma and Goyal *et al.*, [11] is formulated through (1) and (2) as under;

$$Z_i = a_i PG_i^2 + b_i PG_i + C_i) + K_i \sin(l_i(P_i - PG_i)) \quad (1)$$

$$J_i = (h_i PG_i^2 + g_i PG_i + q_i) \quad (2)$$

where, Z_i and J_i are cost and emission objective functions and a_i, b_i, c_i, K_i, l_i and h_i, g_i, q_i are cost and emission objective function coefficients. In this dissertation the emission function involves global warming gases like CO, NO_2 and SO_2. The final objective function [12, 13] formulated incorporating penalty factor F_i is formulated in (3) as under;

$$S_i = Z_i + F_i \times J_i \quad (3)$$

where,

$$F_i = \frac{z_{imax}}{J_{imax}} \quad (4)$$

$$Z_i = a_i PG_i^2 + b_i PG_i + C_i) + K_i \sin(l_i(P_i - PG_i)) \quad (5)$$

$$J_i = (h_i PG_i^2 + g_i PG_i + q_i) \quad (6)$$

The constraints inincorporated in this work are;

a. Equality constraint

$$\sum_{i-1}^{n} PG_i = P_D + TL \quad (7)$$

$$TL = \sum_{m-1}^{6} \sum_{m-1}^{6} PG_m \times PG_n \times B_{mn}$$

where,

P_D = net power demand

TL = transmission loss.

b. Inequality constraint

$$P_i < PG_i < P_j \quad (8)$$

where, PG_i represents the output power of i^{th} generating unit, P_i and P_j are minimum and maximum output Power of i^{th} generating unit respectively.

3. OVERVIEW OF DUAL OBJECTIVE MULTI- CONSTRAINT SWARM OPTIMIZATION BASED ADVANCED ECONOMIC LOAD DISPATCH

Particle swarm optimization [14, 15] formed the behavior of evolutionary techniques for ELD optimization. So in order to obtain optimistic results of nonlinear optimization technique, we incorporate here a ramp rate limit that outsmarts the conventional constraints through improved constriction factor based well defined ramp rate particle swarm optimization technique. This method involves differential particles [14, 15] in search space that randomly update their position using their velocity heuristically following their neighbors so as to obtain position and velocity vectors viz. P_{best} , g_{best} i.e. (P_{1best} , P_{2best} .. P_{ibest}) and (g_{1best} , g_{2best} , g_{ibest}) respectively. The new values of position and velocity are estimated using (9) and (10).

$$Y_{n2}^{(k+1)} = [wY_{nl}^{k} + A_1 Rand_1 (T_0 - S_i^k) + A_2 Rand_2 (g_{best} - S_i^k)] \quad (9)$$

$$\boldsymbol{S_{n1}^{k+1} = S_i^k + V_i^{k+1}} \quad (10)$$

Where, A_1, A_2 are acceleration coefficients

w	= Inertia weight
Y_{n2}^{k+1}	= Updated velocity of the k+1 iteration
S_{n1}^{k+1}	= Updated displacement of the k+1 iteration
T_0	= P_{best} function
S_i^k	= Initial i^{th} particle after k^{th} iteration
A_1 Rand1 $(P_{best} - S_i^k)$	= Particle's Private thinking
A_2 Rand2 $(g_{best} - S_i^k)$	= Collaboration among particles

$$w = w_{max} - \frac{w_{max} - w_{min}}{k} \times n \quad (11)$$

k = Maximum number of iterations
n = Iteration number
$w_{\max}$ = Initial Weight in per unit = 0.85
$w_{\min}$ = Final Weight in per unit = 0.35

To obtain most favourable multivalving effect the ramp rate constraints are applied upon the inequality constraints as under;

$$Max(PG_{i\,min}, P_{i0} - DR_i) \leq PG_{i\,new} \leq Min(PG_{i\,max}, P_{il} + UR_i) \quad (12)$$

Subject to condition
$P_{Gi} - P_{i0} \leq UR_i$ (Generation increases)

$$P_{i0} - P_{il} \leq DR_i \; (Generation\ decreases) \quad (13)$$

where,
P_{i1} = Power generation of i^{th} unit in the current interval.

DOMSOBAELD Algorithm
Step1. Initialize parameters like.
$PG_1, PG_2, PG_3, PG_4, PG_5, PG_6$
Step 2. If Γ_i is better than Γ_0 , then
$\Gamma_i = \Gamma_{0new}$
Else $\Gamma_i = \Gamma_{0old}$
Step 3. Initialize g_{best} values for generating units PG_1 to PG_6

Step 4. Assign best of Γ_{inew} and Γ_{0old} to g_{best}

Step 5. Current position $S_i = Z_i + F_i \times J_i$ and current velocity $Y_{n1} = U_{i\min} + Rand\, i()(U_{i\max} - U_{i\min})$

Step 6. Update position for each particle where Y_{n2}^{k+1} is the update velocity for each particle

Step 7. If Particle position is greater than or equal to bounds in (12) then stop otherwise go to step 2

4. RESULTS AND DISCUSSION

This section illustrates implementation of DOMSOBAELD algorithm on 6 unit, 30 bus IEEE test case system shown in Figure 1 for forming the combined objective function involving cost and emission level function through a price penalty factor for mitigating the transmission losses and multi constraints through valve point loading (VPL) effect shown in Figure 2 and prohibited operating zones (POZ) marked in Figure 3. Table 1 shows cost coefficient, emission coefficient, minimum and maximum capacity of generating units for cost and emission function. Flow chart for DOMSOBAELD algorithm is presented in Figure 4.

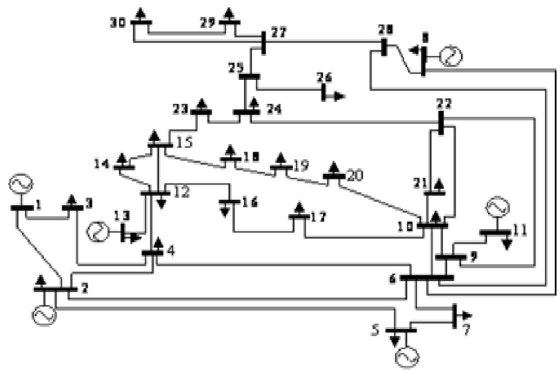

Figure 1. IEEE 30 bus test case systems for DOMSOBAIELD approach

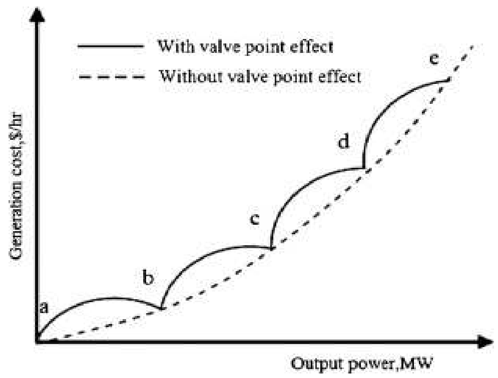

Figure 2. Multi-valve effect of turbine generator units

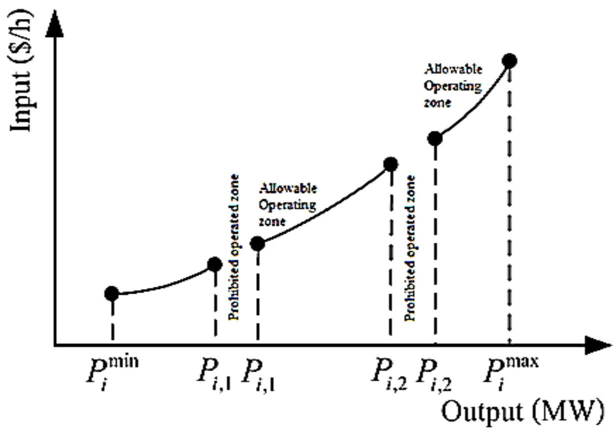

Figure 3. Input output characteristic of generating units with prohibited operating zones

Table 1. Cost coefficients, unit capacity and emission coefficients for IEEE 30 bus test case system with 6 generating units

Unit	a_i	b_i	c_i	$P_{i\,max} = P_i$	$P_{i\,min} = P_i$	h_i	g_i	q_i
1	0.1424	37.439	755.80	125	15	0.0039	0.3266	13.84932
2	0.0958	45.144	455.325	170	10	0.0040	0.32667	13.84932
3	0.0180	39.385	1048.88	225	30	0.00673	0.54771	40.2709
4	0.0025	37.304	1235.55	235	30	0.00103	0.54.651	40.2709
5	0.0111	35.326	1656.56	320	135	0.00501	0.5119	42.88553
6	0.0169	37.250	1355.65	390	130	0.00501	0.5119	42.88553

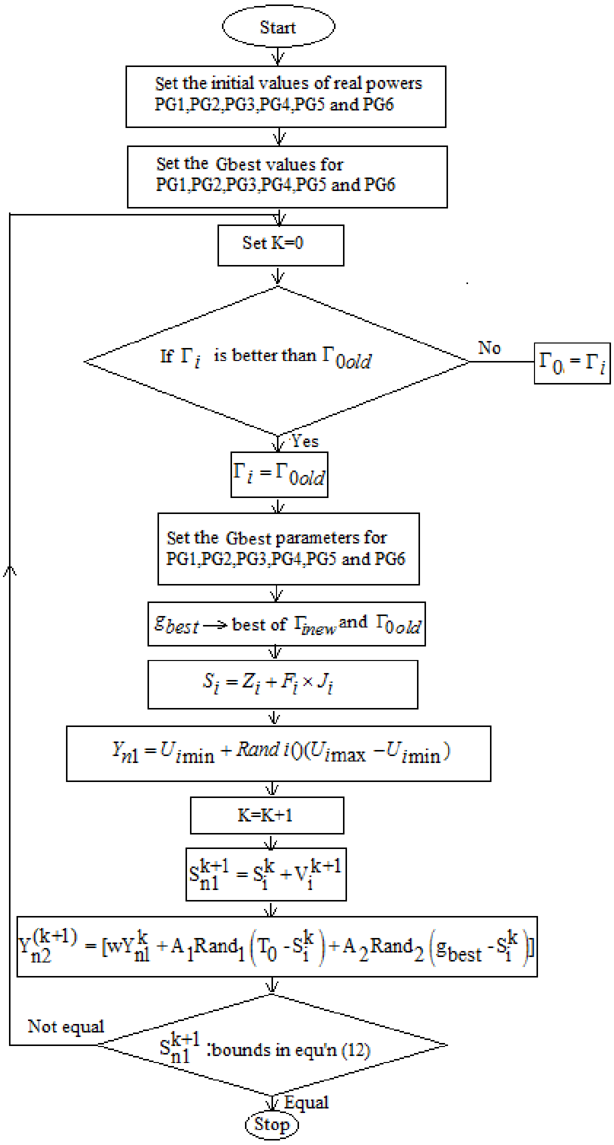

Figure 4. Flow chart for DOMSOBAELD method

Figure 5 shows the simulink model for various objectives of the proposed thermal power plant. Optimal parameters for thermal power plant and the loss coefficients for 6 unit system for inclusion of transmission loss are presented vide Tables 2 and 3 respectively. In this method initial values of real powers for 6 generating units are obtained by simulating the thermal power plant outages involving all the constraints in form an integro differential equation involving automatic load frequency parameters and automatic voltage regulator loop parameters shown in Table 4. These values of real power generations are considered as the initial fitness variables for PSO and using them the final gbest values are obtained and updated particle position and velocities are obtained to estimate the final values of cost, emission and combined objective functions shown in Figures 6-8. The results shown in Figures 6-8 suggest that beyond 200 MW, cost, emission level referred through [16] as well as total objective function yield better performance over the classical methods like lambda iteration, mixed integer with linear programming (MILP) method and quadratic method because of updation of swarm position i.e. $S_{n1}(k+1) = S_i^k + Y_{n2}^{(k+1)}$. It also outperforms heuristic methods like PSO [17-21] PSOIW [22, 23], constriction factor based particle swarm optimization (CPSO) [24] and DPSO [25]. and the results are tabulated in Table 5. Valve point loading effects of turbines [26] and prohibited operating zones analysis [27] are effectively dealt in this dissertation. The ramp rate constraints and multi-valve effects [28, 29] are of paramount importance in realizing the DOMSOBAELD approach.

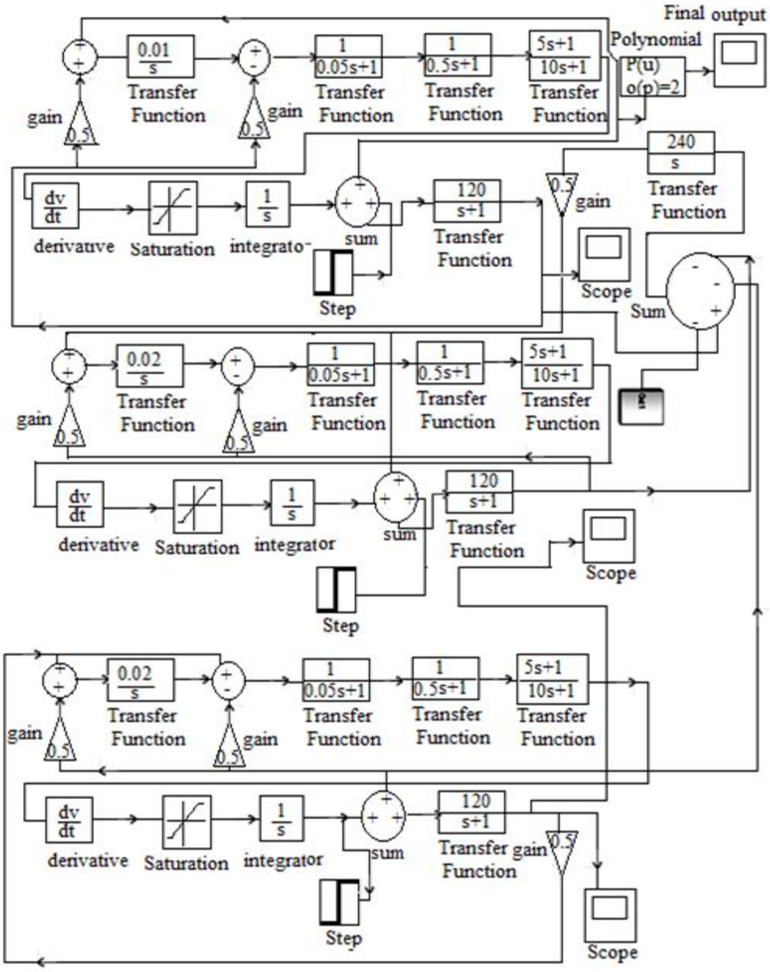

Figure 5. Simulink model for various objectives for a thermal power plant

Table 2. Optimal system parameter incorporating transmission loss

SL.No.	Description of parameters	Symbol used	Optimal value of parameters
1	Constriction factor	CF	2.9
2	Acceleration coefficients	A1, A2	2.1
3	Minimum Inertia weight	W_{min}	0.35
4	Maximum Inertia weight	w_{max}	0.85
5	Number of iterations	K	100
6	Random values	R_1, R_2, R_i	0.3,0.7,0.5
7	Power Demands	PD	1200 MW
8	Power generation of i^{th} unit just before the current interval	P_{i0}	80
9	Down ramp rate limit of i^{th} unit	DR_i	44
10	UP ramp rate limit of i^{th} unit	UR_i	1244

Table 3. Transmission loss coefficient for 6 unit test case thermal system

Unit	B coefficients (B_{ij})					
	1	2	3	4	5	6
1	1.39	0.16	0.14	0.18	0.25	0.21
2	0.16	0.59	0.12	0.15	0.14	0.19
3	0.14	0.12	0.64	0.16	0.23	0.18
4	0.18	0.15	0.16	0.61	0.29	0.24
5	0.25	0.14	0.23	0.29	0.68	0.31
6	0.21	0.19	0.18	0.24	0.31	0.84

Table 4. Parameters of 6 unit test case thermal system

System Frequency (f) = 60 HZ
$Tg1 = Tg2 = 0.8\,S$
$P\ tie\ max = 350\ MW$
$Tr1 = Tr2 = 10\,S$
$Kr1 = Kr2 = 0.5$
$Tt1 = Tt2 = 0.3$
$Kp1 = Kp2 = 120\ Hz/\ PU\ MW$
$Tp1 = Tp2 = 1\,S, a = -0.5; a12\ = -0.5$

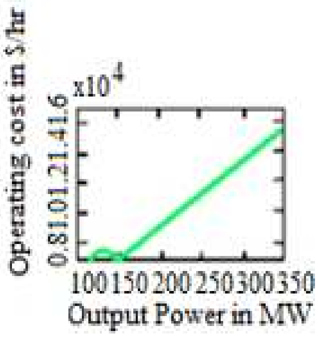

Figure 6. Operating cost function vs output power

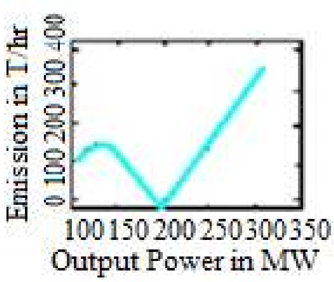

Figure 7. Emission level vs. output power

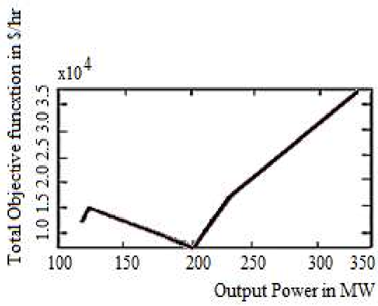

Figure 8. Total objective function vs. output power

Table 5. Result of 6 unit systems for a load demand of 1200 MW

Unit Output	PSO	PSOIW	DPSO	DOMSO BAELD
PG1 (MW)	49.22	50.02	93.02	120
PG2 (MW)	18.84	20.88	100.02	130
PG3 (MW)	108.85	110.09	95.00	150
PG4 (MW)	58.88	60.34	150.47	200
PG5 (MW)	208.81	210.62	200.05	250
PG6 (MW)	307.13	308.58	270.55	350
Loss (MW)	53.78	56.89	60.57	45.59
Total Power Output	807.51	819.42	971.68	1200
Fuel cost ($/hr)	61115	61209	63629.2	59626
Emission (T/hr)	1026.23	1033.47	1043.458	1020.3
Total cost ($/hr)	100611	100719	100611	100922

5. ANALYSIS OF VARIOUS OBJECTIVE FUNCTIONS

Various objectives targeted through DOMSOBAELD optimization approach were found to satisfy various nonlinear constraints like prohibited operating zones, valve point loading and Ramp rate constraints along with equality and inequality constraints. The results obtained through a P5 machine employing Matlab 2016 yields better result in comparison to other heuristic methods for optimum operating cost, emission level and total objective function with respect to real power variation of various generating units.

6. CONCLUSION

The DOMSOBAELD technique illustrated an advanced PSO technique involving multi valve effects, droop constraints and power system swarm optimization tool box for analysing the economic dispatch problem and the results were verified with other heuristic methods using matlab simulation for multi-objective problem involving particle swarm optimization technique, PSOIW technique and differential particle swarm optimization technique. The simulink model is used for comparing the results of various heuristic methods described earlier. The optimal values of generating units t give rise to cost of generation, emission level and combined objective response in DOMSOBAELD analysis.This method proved to be efficient and beneficial over lambda iteration method, mixed integer linear programming method (MILP), quadratic programming method and soft computing methods like particle swarm optimization, constriction factor based particle swarm optimization (CPSO) and differential particle swarm optimization (DPSO). in terms of convergence time for most favourable solution. The DOMSOBAELD technique would be applied to electromagnetic based particle swarm optimization dispatch problems in upcoming paper involving formidable prohibited operating zones. The recent work has basic constraints like valve point loading resulted out of multi-valve effect, ramp rate constraints, less formidable prohibited operating zones, equality and inequality constraints. However, this method in conjunction with electromagnetic based dispatch can be utilized to handle constraints coming out of tie line in multi area economic dispatch, multi fuel option constraint, penalty factor constraint and different tie line capacity constraints resulted out of varying load behaviour. The correlation of particle position and particle velocity with aforesaid multiple constraints decides and P best values which are not being used by any other heuristic methods. As a result of this, fast convergence is obtained in this method resulting thereby better simulation results so as to reduce simulation time required for obtaining response characteristic of system model involving multiple heuristic subsystems.

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