ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 1, Issue 9, November 2013

Flower Pollination Based Dynamic Economic Load Dispatch

P. Aravindhababu

Professor, Department of Electrical Engineering, Annamalai University, Annamalainagar, Tamilnadu, India

ABSTRACT: This paper presents a flower pollination based optimization (FPO) strategy for dynamic economic load dispatch (DELD), which is an expansion of static economic load dispatch. It performs scheduling of generating units to meet the forecasted load demands over a scheduling horizon at minimum generation cost while considering the ramp rate limits. The FPO, inspired from the pollination process of plants, explores for the global best solution. The proposed method partitions the DELD problem into as many as the number of sub-problems, and employs FPO in solving each sub-problem. The simulation results on standard test problem portrays that the proposed method is able to provide the global best solution.

KEYWORDS: dynamic economic load dispatch; economic load dispatch; flower pollination based optimization

NOMENCLATURE

$a_i\ b_i\ c_i$	fuel cost coefficients of the i^{th} generator
$B\ B_o\ B_{oo}$	loss coefficients
DELD	dynamic economic load dispatch
DR_i	down-ramp limits of i^{th} generator in MW/h
$d_i\ e_i$	coefficients of valve point effects of the i^{th} generator
ELD	economic load dispatch
$F_i(P_{Gi})$	fuel cost function of the i^{th} generator in $\$/h$
nt	number of intervals
ng	number of generators
PM	proposed method
P_{Git}	real power generation at i^{th} generator at interval-t
$P_{Gi}^{\min}$ & $P_{Gi}^{\max}$	minimum and maximum generation limits of i^{th} generator respectively
P_{Dt}	total power demand at interval-t
P_{Lt}	net transmission loss at interval-t
UR_i	up-ramp limits of i^{th} generator in MW/h
$\Phi(P_G)$	objective function to be minimized

I. INTRODUCTION

Dynamic Economic Load Dispatch (DELD) performs computation of the most economical generations so as to supply the forecasted power demand over a scheduling period at lowered operating cost, while satisfying several operational constraints that includes the ramp-rate limits of the generators. The ramp-rate constraints influences the scheduling of the subsequent intervals. DELD schedules the generations in advance taking into account the sudden load changes in the subsequent intervals. It is a nonlinear and large dimensional complex optimization problem, whose size exponentially increases with system size and scheduling period [1].

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 1, Issue 9, November 2013

Over the years, many methods were suggested in the literature for solving the DELD problems. At earlier stages, mathematical or heuristically-based approaches, such as gradient projection method [2], linear programming [3], interior point methods [4], etc. were developed. Though they have several advantages such as mathematically proven, suitable for large-scale problems and not requiring any problem-specific parameters, they may land at sub-optimal traps, be sensitive to the initial guess, require functions to be differential, not handle non-convex objective function, etc. To overcome these drawbacks, methods involving artificial intelligence, such as neural networks, fuzzy logic, genetic algorithm, differential evolution and particle swarm optimization were employed for solving the DELD problems [5-7]. Besides hybrid algorithms combining two or more approaches such as evolutionary programming with sequential quadratic programming [8], and Hopfield neural network with quadratic programming [9] were suggested for better results of DELD problems.

Recently, a Flower Pollination based Optimization (FPO), inspired from the pollination process of plants, has been suggested for solving optimization problems [10]. In this approach, problem solutions are denoted by pollens of flowers and the pollination is associated with sharing of pollens between local flowers and also from the global best flower. This paper attempts to apply FPO in solving the DELD problem by dividing the problem into several sub-problems for reducing the computational burden and improving the robustness.

II. Problem Formulation

The DELD problem can be formulated as an optimization problem with an objective of lowering the total generation cost of all ng generating units over the given dispatch period of nt intervals while satisfying several constraints.

Minimize $$\Phi(P_G) = \sum_{t=1}^{nt} \sum_{i=1}^{ng} F_i(P_{Git}) \tag{1}$$

Subject to

$$\sum_{i=1}^{ng} P_{Git} - P_{Dt} - P_{Lt} = 0 \qquad t \in nt \tag{2}$$

$$P_{Gi}^{\min} \le P_{Git} \le P_{Gi}^{\max} \qquad i \in ng, t \in nt \tag{3}$$

$$\begin{aligned} P_{Git} - P_{Git-1} \le UR_i \quad i \in ng \quad t = 2, \cdots, nt \\ P_{Git-1} - P_{Git} \le DR_i \quad i \in ng \quad t = 2, \cdots, nt \end{aligned} \tag{4}$$

Where

$$F_i\left(P_{Git}\right) = a_i P_{Git}^2 + b_i P_{Git} + c_i + \left| d_i \sin\left\{e_i (P_{Gi}^{\min} - P_{Git})\right\}\right| \tag{5}$$

$$P_{Lt} = \sum_{i=1}^{ng} \sum_{j=1}^{ng} P_{Git} B_{ij} P_{Gjt} + \sum_{k=1}^{ng} B_{0k} P_{Gkt} + B_{00} \tag{6}$$

III. Proposed Method

The number of decision variables in DELD problem equals the product of the number of generating plants and the number of intervals over the scheduling horizon, thereby making the solution process very complex involving large computational burden. The proposed method (PM) divides the DELD problem in to a number of sub-problems, each representing an ELD of interval-t and then employs FPO for solving each sub-problem, while at the same time accounting the ramp-rate limits. Each flower [10] in the DELD is denoted to represent the real power generations of each sub-problem as

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 1, Issue 9, November 2013

$$f_i = \left[P_{G1t}, P_{G2t}, \cdots, P_{Gngt}\right] \tag{7}$$

The fitness function is formed for the $t-th$ sub-problem as

$$\text{Maximize} \quad FF = \frac{1}{1+\sum_{i=1}^{ng} F_i(P_{Git}) + K_1 \sum_{i=1}^{ng} (P_{Git} - P_{Dt} - P_{Lt})^2} \tag{8}$$

At a random initial interval $t = t^o$, the lower and upper bounds of the flower is set as

$$\begin{aligned} f^{\min} &= \left[P_{G1}^{\min}, P_{G2}^{\min}, \cdots, P_{Gng}^{\min}\right] \\ f^{\max} &= \left[P_{G1}^{\max}, P_{G2}^{\max}, \cdots, P_{Gng}^{\max}\right] \end{aligned} \tag{9}$$

The FPO is then applied for solving the economic load dispatch (ELD) problem of the initial interval-t. Then the same solution process is continues for the subsequent intervals $t = t+1$, with the lower and upper limits for the flowers, set by accounting the ramp rate limits of Eq. (4) and solved using FPO.

$$\begin{aligned} f^{\min} &= \left[f_1^{\min}, f_2^{\min}, \cdots, f_{ng}^{\min}\right] \\ f^{\max} &= \left[f_1^{\max}, f_2^{\max}, \cdots, f_{ng}^{\max}\right] \end{aligned} \tag{10}$$

Where

$$\begin{aligned} f_j^{\min} &= \begin{cases} P_{Git-1} - DR_i & if \ \left(P_{Git-1} - DR_i\right) \geq P_{Gj}^{\min} \\ P_{Gj}^{\min} & else \end{cases} \\ f_j^{\max} &= \begin{cases} P_{Git-1} + UR_i & if \ \left(P_{Git-1} + UR_i\right) \leq P_{Gj}^{\max} \\ P_{Gj}^{\max} & else \end{cases} \end{aligned} \tag{11}$$

The above FPO based solution process is repeated by incrementing the interval -t till the last interval-nt of the scheduling horizon. Similarly the preceding sub-problems of the initial interval $t = t^o$ is obtained by decrementing the interval as $t = t-1$ and solved using the FPO till the solution for the first interval is obtained. The limits of the flowers during this phase are modified as

$$\begin{aligned} f_j^{\min} &= \begin{cases} P_{Git+1} - UR_i & if \ \left(P_{Git+1} - UR_i\right) \geq P_{Gj}^{\min} \\ P_{Gj}^{\min} & else \end{cases} \\ f_j^{\max} &= \begin{cases} P_{Git+1} + DR_i & if \ \left(P_{Git+1} + DR_i\right) \leq P_{Gj}^{\max} \\ P_{Gj}^{\max} & else \end{cases} \end{aligned} \tag{12}$$

The real power generations obtained for each interval over the scheduling horizon represent the optimal solution of the DELD problem. The solution process, requiring FPO [10], of the PM is explained through the flow chart of Fig .1.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 1, Issue 9, November 2013

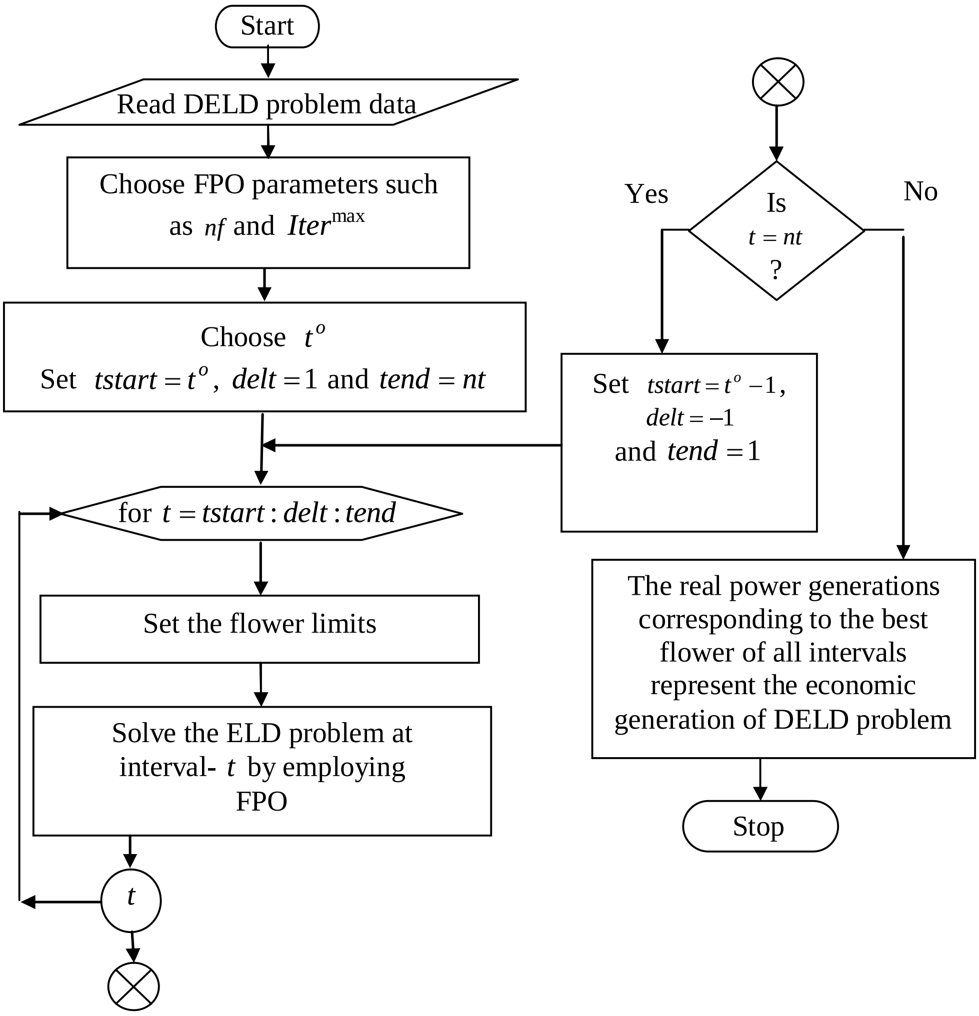

Fig 1 Outline of the PM

IV. Simulation Results

The PM is applied on a test system possessing 10 generating units. The economic generations obtained by the PM for the test system are furnished in Table 1. The fuel cost of the PM is compared with existing published methods of GA and AIS in Table 2. This table shows that the fuel cost of PM is much lower than the existing methods.

ISSN(Online): 2320-9801
ISSN (Print): 2320-9798

International Journal of Innovative Research in Computer and Communication Engineering

(An ISO 3297: 2007 Certified Organization)

Vol. 1, Issue 9, November 2013

Table 1 Economic generations

Hour	P_D (MW)	Optimal Generations (MW)									
		P_{G1}	P_{G2}	P_{G3}	P_{G4}	P_{G5}	P_{G6}	P_{G7}	P_{G8}	P_{G9}	P_{G10}
1	1036	150	135.22	90.62	83.56	175.84	124.19	129.80	71.15	52.10	43.39
2	1110	150	135	137.52	62.73	178.36	158.76	129.59	87.48	49.42	43.40
3	1258	150	135	184.14	112.76	223.11	157.65	104.19	117.47	58.32	43.41
4	1406	209.27	135	241.13	150.15	238.26	159.97	108.47	104.40	52.05	43.40
5	1480	193.32	135	313.13	162.25	223.84	138.23	129.99	100.49	80	43.39
6	1628	219.23	194.64	337.19	201.24	204.93	147.10	129.57	120	80	43.40
7	1702	204.11	255.46	326.34	244.35	224.30	148.03	129.81	120	59.73	43.41
8	1776	215.26	299.67	303.46	266.84	234.13	143.72	129.80	120	79.30	43.41
9	1924	263.42	303.42	340	299.94	243	160	129.95	120	80	54.97
10	2022	336.69	336.80	340	300	243	160	130	120	80	55
11	2106	370.72	395.36	340	300	243	160	130	120	80	55
12	2150	369.65	444.45	340	300	243	160	130	120	80	55
13	2072	340.13	388.42	340	300	243	160	130	120	80	55
14	1924	279.14	345.21	308.43	273.57	242.74	160	129.96	120	79.97	54.90
15	1776	215.07	289.61	301.63	297.31	241.12	158.44	129.70	106.68	52.04	43.44
16	1554	150	214.16	240.72	248.43	222.89	148.35	129.76	120	79.90	43.44
17	1480	196.34	136.22	190.54	242.59	230.30	160	129.67	120	69.70	43.43
18	1628	234.12	216.05	211.34	254.34	227.56	160	129.93	120	80	43.41
19	1776	276.18	219.36	269.62	294.58	242.41	160	129.70	120	80	43.41
20	1972	331.13	293.72	334.25	300	242.89	160	129.90	120	80	55
21	1924	261.45	305.25	339.74	300	243	160	129.94	120	80	55
22	1628	208.82	225.02	261.24	288.37	224.89	123.55	129.96	120	52.03	43.40
23	1332	150	153.34	188.56	242.58	181.50	104.82	129.60	120	50.07	43.41
24	1184	150	135	129.48	239.22	157.19	122.90	99.60	91.69	40.70	43.42

Table 2 Comparison of fuel cost of DELD

Fuel Cost ($\$/day$)		
PM	GA [5]	AIS [11]
2516594	2516800	2519700

V. Conclusion and Future Work

The FPO, inspired from the pollination process of plants, searches for optimal solution for multimodal optimization problems. A novel methodology using FPO was developed for solving DELD problem, which is a complex non-linear optimization problem involving large number of decision variables and the ramp rate constraints. The problem is split into a number of sub-problems and each sub-problem is solved using FPO. The simulation results on a standard test system clearly exhibits the robustness and computational efficiency of the proposed method. The method can be extended to include emissions in the solution process.

ACKNOWLEDGEMENTS

The author gratefully acknowledges the authorities of Annamalai University for the facilities offered to carry out this work

REFERENCES

1. Wood AJ and Woolenberg BF, 'Power generation, operation and control', John Willey & Sons, New York, 1996.
2. G.P Granelli, P Marannino, M Montagna and A Silvestri, 'Fast and efficient gradient projection algorithm for dynamic generation dispatching', IEE Proc Gener Transm Distrib., Vol. 136, No. 5, pp. 295-302, 1989.
3. C.B Somuah and N Khunaizi, 'Application of linear programming redispatch technique to dynamic generation allocation', IEEE Trans Power Syst., Vol. 5, No.1, pp. 20-26, 1990.
4. X.S Han and H.B Gooi, 'Effective economic dispatch model and algorithm', Elect Power Energy Syst., Vol. 29, pp. 113–120, 2007,
5. Basu M, 'Dynamic economic emission dispatch using nondominated sorting genetic algorithm-II', Elect Power Energy Syst., Vol. 30, pp.140-149, 2008.
6. R Balamurugan and S Subramanian, 'An improved differential evolution based dynamic economic dispatch with non-smooth fuel cost function', Journal of Electrical Systems, Vol. 3, No. 3, pp. 151-161, 2007.
7. C.K Panigrahi, P.K Chattopadhyay and R Chakrabarti, 'Load dispatch and PSO algorithm for DED control', Int J Autom Control, Vol. 1, No. 2-3, pp. 182-194, 2007.
8. D Attaviriyanupap, H Kita, E Tanaka and J Hasegawa, 'A hybrid EP and SQP for dynamic economic dispatch with nonsmooth incremental fuel cost function', IEEE Trans Power Syst., Vol. 17, No. 2, pp. 411-416, 2002.
9. AY Abdelaziz, MZ Kamh, SF Mekhamer and MAL Badr, 'A hybrid HNN-QP approach for dynamic economic dispatch problem', Elect Power Syst Res., Vol. 78, No.10, pp. 1784-1788, 2008.
10. Yang X. S, 'Flower Pollination Algorithm for Global Optimization', Unconventional Computation and Natural Computation, Lecture Notes in Computer Science, Vol. 7445, pp. 240-249, 2012.
11. M. Basu, 'Artificial Immune System for Dynamic Economic Dispatch', International Journal of Electrical Power & Energy Systems, Vol. 33, No.1, pp. 131-136, 2011.