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Solving Dynamic Economic Dispatch Problems Facilitating Meta-Heuristic Technique

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***Abstract*:-This paper yields glowworm swarm optimization technique to solve the dynamic economic load dispatch (DELD) problem for minimizing the operation cost in most economical manner. The glowworm swarm based algorithm is considered as meta-heuristic based evolutionary approaches where the agents communicate with each other via bioluminescent glowing, that enables them to explore the objective function more effectively. The effectiveness of the proposed method is demonstrated through five unit test systems. The results are compared with the other optimization technique reported in the literature. The fuel cost and other performance of the given approach has been quite impressive. It is shown that the GSO approach can provide the global or near global optimum solutions with a lesser computational time along with higher efficiency and robustness**.

***Keywords*–*Dynamic economic load dispatch (DELD), glowworm swarm optimization (GSO), luciferin, Valve - point loading effect, Ramp Rate Limits*.**

I. INTRODUCTION

Dynamic economic load dispatch (DELD) plays a significant role in power system operation and control. It is a dynamic problem due to dynamic nature of power system and the large variation of load demand. This absolute problem is normally solved by discretization of the entire dispatch period into a no of small time intervals. The load is assumed to be constant and the system is considered to be in accurate steady state dynamic model which finds the best generation schedule for the generating units in real power system framework. The main objective of the dynamic economic dispatch is to minimizing the generation cost, subject to satisfy the physical and operational constraints. In traditional economic dispatch, the cost function is quadratic in nature. In practice, a generating unit cannot exhibit a convex fuel cost function, so a non-convex characteristics will observe owing to valve point effect. Mathematically, DED problem with valve point effect can be recognized as a non linear, non convex and large scale optimization problem with various complicated constraints, which finds the optimal result dispatch a new challenge. DED has been recognized as a more accurate problem than the traditional economic dispatch problem.

Many classical optimization techniques have been put on to solve the DED problems. The classical mathematical approaches include linear programming [1], nonlinear programming (NLP) [2], quadratic programming (QP) [3] , Lagrange relaxation(LR) [4,5],and Dynamic Programming (DP) [6]. However, most of these techniques are not able to find global optimal solution due to their non linear and non convex characteristics of generator input. Many stochastic search algorithm such as genetic algorithm(GA)[7,8], simulated annealing (SA) [9],evolutionary programming (EP) [10-13],particle swarm optimization(PSO) [14-16], differential algorithm DE [17-18] and clonal selection technique (CSA) [19] have been used in an effective manner to solve dynamic economic load dispatch problems. Recent researches have been directed towards the application of Glowworm swarm optimization (GSO) technique to solve DELD problem. The GSO is an efficient global search technique and may be used to find optimal or near optimal solutions to numerical and qualitative problems. It is easy to implement in most programming languages and has been proved to be quite effective and reasonably quick when applied to a diverse set of optimization problems.

In this paper, the GSO based DELD algorithm has addressed for the determination of global or near global optimum dispatch solution. In the proposed work, the operating limit constraints and valve point loading effects are fully incorporated. It has been shown that the algorithm is capable of finding the global or near global optimum solutions for large optimization problems.

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II. PROBLEM FORMULATION

The main objective of the dynamic economic dispatch is to determine the outputs of all generating units to minimize the operating cost over a certain period of time under various physical and operational constraints. The formulation of DED problem has expressed as given below.

$$Min\,F = \sum_{t=1}^{T}\sum_{i=1}^{N} F_{it}\left(P_{it}\right) \tag{1}$$

F : Total operating cost of all generating units over all dispatch periods.

T : Numbers of hour in the time horizon;
N : Number of generating units;
$F_{it}(P_{it})$: The fuel cost in terms of its real power output P_{it} at a time t

The fuel cost function with valve point effect of the thermal generating unit is expressed as the sum of a quadratics and sinusoidal-functions.

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$$F_{it}(P_{it}) = a_i P_i^2 + b_i P_i + c_i + |e_i(\sin(f_i(P_{i\min} - P_i))| \qquad (2)$$

a_i, b_i , c_i , e_i and f_i are constants of fuel cost function of i_{th} unit.

A. Real power balance constraints

$$\sum_{i=1}^{N} P_{it} - P_{Dt} - P_{lt} = 0, \quad t = 1,2,\ldots T$$

(3)

Where P_{Dt} is the total power demand during *t*th dispatch period. P_{lt} Total transmission loss during *t*th dispatch period

B. Real power operating limits

$$P_{it\min} \le P_{it} \le P_{it\max},\ i = 1,2,\ldots T; \\ t = 1,2,\ldots T \qquad (4)$$

Where $P_{i\min}$ and $P_{i\max}$ are the minimum and maximum real power outputs of *i*th generator respectively.

C. Generator unit ramp rate limit

$$P_{i(t-1)} - P_{it} \le DR_i; \qquad i = 1,\ldots n \qquad (5)$$

$$P_{it} - P_{i(t-1)} \le UR_i; \quad i = 1,\ldots n \qquad (6)$$

UR_i and DR_i are ramp up and ramp down rate limits of i^{th} generator respectively and these are expressed in MW/h.

The main objective of DELD problem is to determine the optimal schedule of output powers of online generating units with predicted power demands over a certain period of time to meet the power demand at minimum operating cost

III .OVERVIEW OF GLOWWORM SWARM OPTIMIZATION

K.N. Krishnanad and D.Ghose [25] developed a glowworm swarm optimization (GSO) based on the behavior of glowworm (insects). The biological behaviors of the movement of individuals (e.g. ants, honeybee swarm, fish schools) within a group are the main observation in this algorithm. This algorithm consists of agents, which discover the search space and transmit the information regarding fitness with respect to their correct position. The GSO algorithm searches the agents in a group of individuals similar to the other heuristic based optimization methods. All individuals in a swarm approaches to the optimum or quasi-optimum through its randomly chosen direction of luciferin.In GSO algorithm, the search space composed N-dimensional agents called glowworm. Initialize the glowworm randomly in the search space. The position of the glowworm i at time t is $X_i(t) = (x_{i1}(t), x_{i2}(t) \cdots x_{iN}(t))$. The GSO algorithm has described by the set of variables such as position vector $X_i(t)$, luciferin level $l_i(t)$ and neighborhood range $r_i(t)$. The number of luciferin level associated with glowworm i at time t. To update the current position of glowworm i , the fitness value of the liciferin is given as follows:

$$l_i(t) = (1-\rho) l_i(t-1) + \gamma J(x_i(t)) \qquad (7)$$

Where ρ: Luciferin decay constant whose value lies between $\rho \in (0,1)$

γ : Luciferin enhancement constant

J : Objective function

The individual glowworm i encodes the objective function $J(x_i(t)$ at current position $x_i(t)$ into a luciferin values $l_i(t)$ and broadcast the same within its neighborhood. The set of neighborhood $N_i(t)$ is chosen according to higher luciferin value within dynamic search space domain. The chosen numbers of glow in the local decision range is given by the following equation

$$N_i(t) = \left\{ j : \left\| x_j(t) - x_i(t) \right\| < r_d^{'} ; l_i(t) < l_j(t) \right\} \qquad (8)$$

Where, $N_i(t) < r_d^{'}$; $r_d^{'}$ is the local updated decision range. The decision range is bounded by a circular sensor range $r_s (0 < r_d^{'} < r_s)$, $j \in N_i(t)$

$x_j(t)$:Glowworm i^{th} position at t iteration

$l_j(t)$:Glowworm i^{th} luciferin at t iteration

Each glowworm i selects a neighborhood glowworm j with a probability $P_{ij}(t)$ .These movements enables the glowworm into a disjoint subgroup which finds the multiple optimal solutions to the objective function. The selection of the neighborhood glowworm by using probability distribution is given by

$$P_{ij}(t) = \frac{l_j(t) - l_i(t)}{\sum_{k \in N_i(t)} (l_k(t) - l_i(t))} \qquad (9)$$

The updated luciferin movement is given by the following equation

$$x_i(t+1) = x_i(t) + s\left(\frac{x_j(t) - x_i(t)}{\left\| x_j(t) - x_i(t) \right\|} \right) \qquad (10)$$

Where s is called moving step size.

In the last phase, the fitness of luciferin within a dynamic decision domain is upgraded in order to limit the range of communication and the updated local decision range is given by the following equation

$$r_d^{'}(t+1) = \min\left\{ r_s, \max\left\{ \begin{matrix} 0, r_d^{'}(t) + \\ \beta(n_i - |N_i(t)|) \end{matrix} \right\} \right\} \qquad (11)$$

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$r_d^{'}(t+1)$: is the glowworm $i's$ local decision range at the $(t+1)$ iteration

r_s : The sensor range

n_i : The neighborhood threshold value

β : Constant parameter

IV. IMPLEMENTATION OF GSO TO DYNAMIC ELD

This section describes the implementation of GSO algorithm for solving dynamic economic load dispatch problems. This section deals the implementation of the equality and inequality constraints of DELD problems when modifying each individual's search space in the GSO algorithm. For T intervals in the generation scheduling periods, there are T dispatched for the *N* generating units. An array of decision variable vectors can be expressed as

$$P_{it} = \begin{bmatrix} p_{11} & p_{12} \cdots & p_{1N} \\ p_{21} & p_{22} \cdots & p_{2N} \\ \vdots & \vdots & \vdots \\ p_{T1} & p_{T2} & p_{TN} \end{bmatrix}$$

Where P_{it} is the real power output of generator *i* at interval t

A. Initialization of glowworm

In the initialization procedure, the candidate solution of each individual (generating unit's power output) is randomly initialized within the feasible range in such a way that it should satisfy the constraint given by Eq. (4). A candidate is initialized as $P_{it} \sim U\ (P_{it\min,} P_{it\max})$, Where *U* is the uniform distribution of the variables ranging in the interval of $(P_{it\min,} P_{it\max})$.

B. Fitness function evaluation

The fitness value of individual i is calculated the following equation (2). The number of population is equal to the number of fitness evaluation.

C. Calculation of luciferin level

Each glowworm carries a luminescent quantity called luciferin. The number of luciferin level associated with each glowworm i at times t. Put the value of objective function $J(x_i(t))$ into the $l_i(t)$ in equation (7). The number of luciferin level is same as the number of glowworms.

D. Decision of neighborhood

The better the fitness value, the better the level of luciferin. Each glowworm finds all the glowworms which have the brighter luciferin level within the local dynamic decision range $r_d^{'}$. The decision range is bounded by a circular sensor range. The number of brighter glowworm is calculated by the following equation (8).

E. Updated local decision range

At each iteration, the dynamic decision range is upgraded by the equation (9). The suitable value of β is chosen such that how it effects the rate of change over the neighborhood range.

F. Glowworms velocity updated

In this section, each glowworm carries their topical information which enables the glowworm to make their division into a number of subgroups. It gives the multiple local optimal solution of the given objective function. In order to select the proper neighbor, a probability distribution is chosen by the aforesaid equation (10)

G. Position updated of glowworms

The position of each glowworm is usually updated by the equation (11). The resultant position of individuals is being violated their operating limits and to keep the position as the individual within the boundary.

V.SIMULATION RESULTS AND DISCUSSION

The proposed GSO algorithm has been applied to DELD problems by considering five- generating unit systems to investigate the effectiveness and robustness. The result obtained from proposed approach has been compared with EAPSO [20] and other previously developed techniques. The software has been written in MATLAB-7.5 language and executed on a 2.3-GHz Pentium IV personal computer with 512-MB RAM. For implementing the GSO technique in ELD problems, the maximum number of generation (iteration) of 5000 is taken for simulation study of the five unit test systems.

Description of Case Study for the 5-unit Test Systems:

Initially, the proposed GSO technique is applied on a small test system, consisting of five generating unit with a ramp rate limit and valve point effects The system data of this test have been taken from [20].Table I indicates the generator data of system. Table II yields the variation of load demand for 24 hours. The results obtained for this case study are given in table III, which shows that the GSO has better solution without violating any operating constraints The best fuel cost result obtained from proposed GSO and other optimization algorithms are compared in table IV. From table IV, it is clearly visible that the proposed method outperforms all other methods in terms of best fuel cost and simulation time. Fig 1.shows the variation of power generation with time and Fig 2. shows the convergence behavior of the proposed technique.

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TABLE I
Generator data for the 5-unit test system

Units	a_i	b_i	c_i	d_i	e_i	$P_{i\max}$	$P_{i\min}$	DR_i	UR_i
1	25	2.0	0.0080	100	0.042	75	10	30	30
2	60	1.8	0.0030	140	0.040	125	20	30	30
3	100	2.1	0.0012	160	0.038	175	30	40	40
4	120	2.0	0.0010	180	0.037	250	40	50	50
5	40	1.8	0.0015	200	0.035	300	50	50	50

TABLE II
Load Variation for 24hours

Load Demand(MW)							
Hour	Load	Hour	Load	Hour	Load	Hour	Load
1	410	7	626	13	704	19	654
2	435	8	654	14	690	20	704
3	475	9	690	15	654	21	680
4	530	10	704	16	580	22	605
5	558	11	720	17	558	23	527
6	608	12	740	18	608	24	463

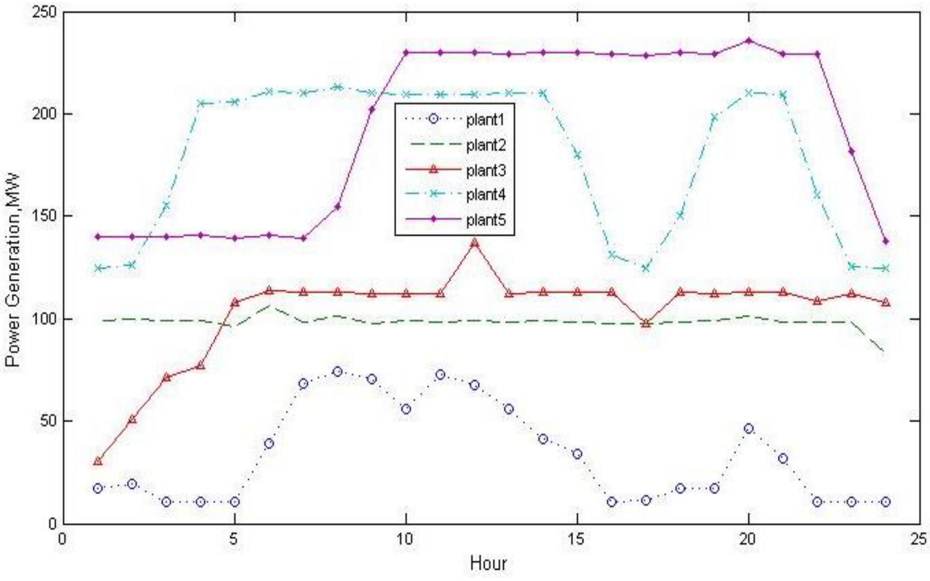

Fig.1.Power Generation of five unit systems with time

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TABLE III
Best Solution of Proposed Method for five unit systems

Hour	Unit 1 (MW)	Unit 2 (MW)	Unit 3 (MW)	Unit4 (MW)	Unit5 (MW)	Load (MW)
1	17.2944	99.1647	30.1945	124.5679	139.7079	410.7399
2	19.2021	99.7085	51.1479	126.0288	139.9210	435.8877
3	10.6900	98.7549	71.6084	155.4974	139.8204	475.7750
4	10.5866	98.7642	77.4776	204.7948	140.4001	531.0706
5	10.3069	96.2009	108.1316	205.9634	139.6188	559.3281
6	39.4206	106.5602	113.3428	210.7621	140.3704	609.9846
7	68.2616	98.1121	112.8731	210.1602	139.0849	628.0831
8	74.2339	101.0520	113.2912	213.1890	154.8241	655.9041
9	70.3845	97.9287	112.3251	209.8157	202.0374	692.0525
10	55.8620	98.8737	112.3839	209.7366	229.5768	706.1667
11	72.4644	98.3169	112.5360	209.5947	229.5910	722.6415
12	67.7412	98.7137	136.9351	209.7345	229.5732	743.0782
13	56.0396	98.5365	112.3371	210.0573	229.4653	706.5003
14	41.0388	98.7888	112.9186	209.9416	229.7016	691.9781
15	34.2447	98.5367	112.7467	180.2379	230.1968	655.5823
16	10.8238	97.3308	112.5992	131.5030	229.1279	581.2506
17	11.0130	97.7050	97.7086	124.3342	228.4528	559.2045
18	17.2650	98.5567	112.9927	150.5157	230.2600	609.4548
19	17.1378	98.9317	112.3211	198.3132	229.4672	655.5492
20	46.6632	101.2134	112.8768	210.1392	235.5337	706.1987
21	31.8222	98.3838	113.0804	209.5952	229.4778	681.7967
22	10.4036	98.3138	108.6966	160.1477	229.0916	606.5144
23	10.7665	98.5560	112.1879	125.0940	181.7279	528.1315
24	10.5248	82.8039	108.1656	124.9296	137.7758	464.0102

TABLE IV
Comparison of Various Methods

Methods	Minimum Cost($/h)	Simulation time(sec)
MSL[24]	49216.81	1.4
SA[21]	47356.00	351.98
APSO[22]	44678	--
SOA-SQP[23]	40701.42	---
EAPSO[20]	43784	2.00
GSO	43414.12	1.39

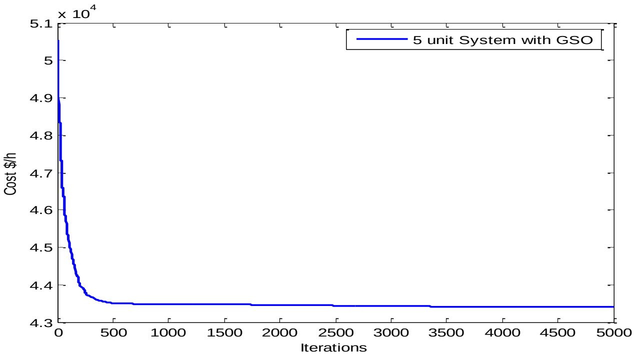

Fig.2.Convergence behavior of proposed GSO

VI. CONCLUSION

A simple and an efficient optimization technique based on GSO is addressed for solving DELD problems, taking account of the valve point effect. By considering a five-unit test system, it is observed that the proposed algorithm has better convergence characteristics, robustness and computational efficiency as compared to other heuristic methods. It is also clear from the result obtained that by different trials, the proposed GSO technique can avoid the shorting of premature convergence of other optimization to obtain good quality results. When more complex fuel cost characteristics is considered, the solution quality and computational efficiency are significantly better than other methods. Because of these dominant characteristics, GSO becomes an important tool for solving more complex optimization problems in power system.

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