PARTICLE SWARM OPTIMIZATION TECHNIQUES FOR DYNAMIC ECONOMIC DISPATCH

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Abstract - **This paper presents application of particle swarm optimization (PSO) technique for assessment of Dynamic Economic Dispatch (DED).Using this method, the best minimum of total generation cost can be obtained. DED is used to determine the optimal schedule of on-line generating output so as to meet the load demand at minimum operating cost under various systems and operating cost over the entire dispatch periods. PSO can solve the problems quickly with high quality solutions and stable convergence characteristics, whereas it is easily implemented evolutionary computation techniques. The DED based PSO techniques is a tested on a 26-bus system containing six generator bus, 20 load bus, and 46 transmission lines.**

Keywords: Particle Swarm Optimization (PSO), Dynamic Economic Dispatch (DED)

I. INTRODUCTION

Dynamic Economic Dispatch (DED) schedules the generating outputs of all on-line units over a time horizon by taking the dynamic constraints of generators into account, whereas the traditional Static Economic Dispatch (SED) allocates the outputs of all committed generating units by considering the static behavior of them.

The DED problem is an extension of the SED problem in which the ramp rate limits of the generators are taken into consideration. That makes the DED problem more difficult [1][2]. The ramp rate constraint of generating unit such as its minimum uptime and down time is a dynamic operational constraint and significantly impacts the operation of power system. As a result of these dynamic operational constraint, the operational decision at hour 't' may affect the operational decision at later hour [3]. Generally, the DED problem divides the entire dispatch period into a number of small time intervals and then static economic dispatch is used to solve the problem in each interval [4].

Earlier efforts of solving the DED problem were using classical methods such as Lambda Iterative Method (LIM), gradient projection algorithm, linear programming [5][6][7], dynamic programming [8] and interior point method [9]. These methods have some limitations to give optimal solution due to the non-linear characteristics of generating units.

In order to seek the global optimal solution, the stochastic optimization techniques such as Ant Colony Optimization (ACO), Simulated Annealing (SA), Genetic Algorithm (GA) and PSO has been used. SA method is powerful optimization technique and has ability to find a near optimization problem [10]. GA was invented by Holland [11] in the early 1970s, in which this technique is global search method that mimics the metaphor of natural biological evaluation. On the other hand, ACO was invented by Macro Dorigo and inspired by artificial ants. Artificial ants are able to generate successively shorter feasible tours by using information accumulated in the form of a pheromone trail.

In this paper, applications of PSO have been proposed for assessment the DED problem to minimize the cost of generation. The proposed algorithm was implemented in MATLAB on a Intel Core 2 Duo processor, 1.66 GHz personal computer with 2.512 GB RAM. A 26 bus system containing of six generator bus, 20 load bus and 46 transmission lines is used as case study to show the effectiveness of the PSO technique over DED. The DED is determined by referring to the best minimum of total generation cost. The best minimum of total generation cost is determined by *gbest* value produced from PSO.

This paper is further research from other paper [12]. That paper study the PSO for DED techniques but it use small area bus, which is 9-bus system. In this paper has been done with large area bus, which is 26-bus system. This paper organized as follow: Formulation of DED problem is introduced in section II. The description of PSO and implementation of PSO for the assessment of DED is addressed in section III. The simulations results of power system with various generating units are presented in section IV. Conclusion is presented in section V. Acknowledgement is finally given in the last section.

II. DED PROBLEM FORMULATION

The main objective of DED problem is to determine the optimal output schedule of output powers of on-line generating units over a certain period of time to meet predicted power demands at minimum operating cost. The static economic dispatch problem assumes that the amount of power to be supplied by a given set of units is constant for a given interval of time and attempts to minimize the cost of supplying this energy subject to constraints on the static behavior of the generating units. The objective function of the DED problem is

$$C_T = \sum_{t=1}^{T}\sum_{i=1}^{N} C_i(P_{it}) \tag{1}$$

$$C_i(P_{it}) = a_i + b_i P_{it} + c_i P_{it}^2 \tag{2}$$

Where

T	is the number of intervals in the study period.
N	is the number of generating units
C_T	is the total fuel cost
$C_i\,(P_{it})$	individual generation production cost in terms of real power output Pi at time t
a_i, b_i, c_i	constant of fuel cost function in terms of real power output Pi at time t

The objective function is subjected to the following constraints,

A. Equality constraint

$$\sum_{i=1}^{N} P_{it} = P_{Dt} + P_{Lt}$$

(3)

Where

P_{Dt}	forecasted total power demand at time, t
P_{Lt}	transmission loss at time, t

B. Inequality constraint

Real power operating limits

$$P_{it\,\min} \leq P_{it} \leq P_{it\,\max} \tag{4}$$

Where $P_{it\,\min}$ and $P_{it\,\max}$ are the minimum and the maximum real power outputs of generator *i* that can be supply at time, *t*

III. METHODOLOGY

A. Representation of Particles' Positions

In an initial process of PSO that is *k*=1 the positions or components (generating units) for each particle is randomly initialized within the feasible range such a way that it should satisfy the constraint given by equation (4).

In every j^{th} particle ($X_{j,t}$), there are *N*, total number of generators at every time interval, *t*. The arrangement of generator's components or positions for each particle, *j*, is shown in equation (5).

$$X_j = \begin{pmatrix} S_{11} & S_{12} & \cdots & S_{1T} \\ S_{21} & S_{22} & \cdots & S_{2T} \\ \vdots & \vdots & \ddots & \vdots \\ S_{N1} & S_{N2} & \cdots & S_{NT} \end{pmatrix} \tag{5}$$

Where

$P_{it} = S_{it}$	component or position of a particle, which is the real power output of, ith, generating unit at time interval, t.
j	number of particles.

The best particle, X_j, is selected which gives a minimum value of generation cost function given by equation (1). This shows that the best, X_j, is referred to as, *gbest*, of all particles in the current iteration.

B. Particle Swarm Optimization (PSO)

According to Kennedy and Eberhart [13],[14],[15], the PSO is basically developed through result for a flock of birds, birds find food by flocking (not by each individual). The assumption is a basic concept of PSO. PSO is basically developed through simulation of birds in two-dimension space. The position of each agent is represented by XY-axis position and the velocity (displacement vector) is expressed by vx (the velocity of X-axis) and vy (the velocity of Y-axis). Modification of the agent position is realized by using the position and the velocity information. Each particle knows its best value so far (*pbest*) and its XY position. This information is analogous to personal experiences of each particle. Moreover, each particle knows the best value so far in the group (*gbest*) among *pbests*. The modified velocity of each agent can be calculated using the current velocity and the distance from *pbest* and *gbest* as shown below:

$$V_i^{k+1} = wV_i^k + c_1 rand_1(pbest - S_i^k) + c_2 rand_2(gbest - S_i^k) \tag{6}$$

where

V_i^k	current velocity of agent i at iteration k
V_i^{k+1}	modified velocity of agent i
rand	random number between 0 and 1
s_i^k	current position of agent i at iteration k
$pbest_i$	pbest of agent i
$gbest_i$	gbest of the group
w_i	weight function for velocity of agent i
c_i	weight coefficient for each team

Using the above equation, a certain velocity that gradually gets close to *pbest* and *gbest* can be calculated. The current position (searching point in the solution space) can be modified by the following equation:

$$S_i^{k+1} = S_i^k + V_i^{k+1} \qquad (7)$$

The following weighting function usually utilized in equation (1).

$$w = w_{\max} - \left[\frac{(w_{\max} - w_{\min})}{iter_{\max}}\right] iter \qquad (8)$$

Where

$w_{\max}$ maximum inertia weight

$w_{\min}$ minimum inertia weight

$iter_{\max}$ maximum iteration number

$iter$ current iteration number

The basic PSO procedure is outlined in the general flow chart shown in Figure 1

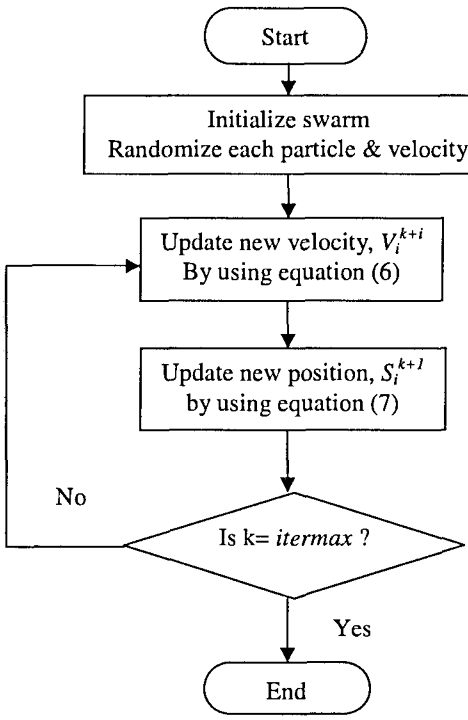

Figure 1: Flow chart basic procedure of PSO

C. DED based on PSO technique

The procedure of PSO techniques that used to solving the DED for every time intervals are represents in terms of flow charts shown in Figure 2.

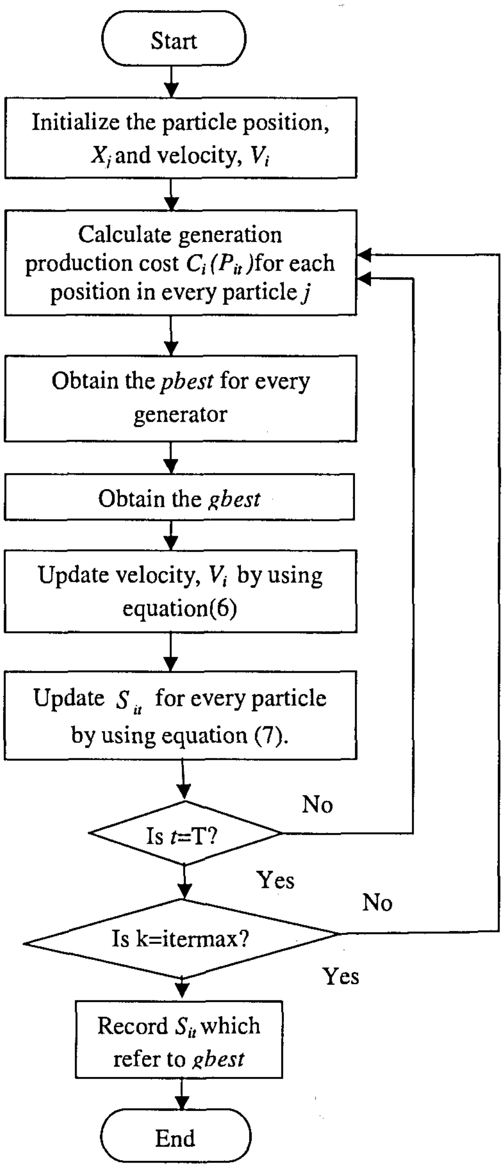

Figure 2: Flow chart of DED based on PSO

The procedures of PSO technique that used for solving the DED for every time interval are explained as follows:

1. Initialize the particle, X_j and velocity, V_i. The velocity, V_i should be in the range of $[Vmax, Vmin]$ and each particle should satisfy the constraint given by equation (4).
2. Calculate individual generation production cost $C_i(P_{it})$ for each position or generator, S_i in every particle, j.
3. Obtain the *pbest* for every generator which refers to the minimum generation fuel cost.
4. Obtain the *gbest* from the *pbest* which refers to the minimum generation fuel cost.
5. Update V_i by using equation (6). If $V_i < V_{i\min}$ then, $V_i = V_{i\min}$. On the other hand, if $V_i > V_{i\max}$ then, $V_i = V_{i\max}$.
6. Update S_{it} for every particle by using equation (7). Check whether each generator's output is within its operating limit. If $S_i < S_{i\min}$ then, $S_i = S_{i\min}$. Besides that, if $S_i > S_{i\max}$ then, $S_i = S_{i\max}$.
7. Go to the next time interval, t. Repeat procedure b) – f) until $t = T$.
8. Repeat procedure b) – g) until $k = itermax$.
9. Record the $S_{i,t}$ which refers to *gbest*.

IV. RESULT AND DISCUSSION

The six unit generator system in the IEEE 26 bus system is used to demonstrate the performance of particle swarm optimization (PSO) to determine the dynamic economic dispatch (DED) of each generator at every time interval. The system consists of 6 units of generator, 20 load bus and 46 transmission lines. The load demand for the time intervals of 24 hours is given in Table 2. The input data for the six generators system are tabulated in Table 1.

TABLE 1
GENERATOR DATA AND COST COEFFICIENTS FOR IEEE 26 BUS TEST SYSTEM.

Quantities	a_i \$/h	b_i \$/MWh	c_i \$/MW²h	P_{imin} MW	P_{imax} MW
Unit 1	240	7	0.0070	100	500
Unit 2	200	10	0.0095	50	200
Unit 3	220	8.5	0.0090	80	300
Unit 4	200	11	0.0090	50	150
Unit 5	220	12	0.0080	50	200
Unit 6	190	12	0.0075	50	120

TABLE 2 LOAD DEMAND FOR 24 HOURS.

Time (h)	Load (MW)	Time (h)	Load (MW)
1	955	13	1190
2	942	14	1251
3	935	15	1263
4	930	16	1250
5	935	17	1221
6	963	18	1202
7	989	19	1159
8	1023	20	1092
9	1126	21	1023
10	1150	22	984
11	1201	23	975
12	1235	24	960

The simulation results of DED based PSO is obtained from a personal computer with Intel Core 2 Duo processor 1.66 GHz and 2.512GB RAM memory. The DED based PSO algorithm is written in MATLAB programming language. The parameters which is used in the PSO is given in Table 3.

TABLE 3 PSO PARAMETERS.

Particle, *m*	6
Maximum iteration, *itermax*	300
Maximum velocity, *Vmax*	20
Minimum velocity, *Vmin*	-20
Maximum inertia weight, *Wmax*	0.9
Minimum inertia weight, *Wmin*	0.4
c_1	1.4
c_2	1.4

The PSO process has been simulated eleven times to determined the best result, lowest total cost. As shown in the Table 4, the lowest optimal total cost function for one day has been recorded 2nd process,\$226,080.

TABLE 4 PSO PROCESS FOR ELEVEN TIMES.

Process	Total Cost ($/h), C_T	CPU time (sec)
1st PSO process	240230	23.45628
2nd PSO process	226080	24.53537
3rd PSO process	231520	23.46729
4th PSO process	240030	23.1643
5th PSO process	233790	23.59199
6th PSO process	233190	24.46867
7th PSO process	231560	23.55283
8th PSO process	231820	25.59215
9th PSO process	245500	23.33257
10th PSO process	240090	24.4861
11th PSO process	237420	23.54972

The MW for every generating unit is represented by P_1, P_2, P_3, P_4, P_5, and P_6. The MW optimal generating units for every time interval are given in Table 5 and Table 6. As shown in the Table 6, the optimal total cost function for one day is $226,080. As shown in Table 5 and Table 6, maximum of the optimal total cost function has been recorded at 14th hour that is $15,371.41. Besides that, minimum of the optimal total cost function has been recorded at 20th hour that is $8582.599. The MW optimal generating unit for each hour satisfies the system constraint which is given by equation (4).

TABLE 5 MW OPTIMAL GENERATING (P_1, P_2, P_3) UNIT FOR 24 HOURS.

Number of hour	P_1 (MW)	P_2 (MW)	P_3 (MW)
1	359.1641	120.2771	84.21015
2	413.1039	113.1636	142.0225
3	445.2554	87.48803	127.5955
4	435.829	138.5966	116.7169
5	390.8963	102.7473	105.3738
6	205.6532	62.42165	80
7	405.7597	50.8618	224.3258
8	290.2509	110.7255	104.7494
9	149.0674	167.6418	269.3963
10	284.5464	91.36361	94.39297
11	146.4116	163.3721	190.4954
12	172.5616	70.21018	226.4473
13	154.4255	120.6412	213.6214
14	184.3561	79.49788	109.2248
15	151.9098	110.2697	192.8258
16	362.35	99.46113	233.9398
17	165.7748	113.0828	105.544
18	204.8193	135.9924	171.3571
19	100.7039	164.6559	125.6785
20	155.6273	50	122.9344
21	215.7343	100.7214	115.4135
22	177.1054	151.1727	85.95747
23	387.6258	150.8839	172.5534
24	156.5341	64.6925	106.6336

TABLE 6 MW OPTIMAL GENERATING (P_4, P_5, P_6) UNIT FOR 24 HOURS.

Number of hour	P_4(MW)	P_5 (MW)	P_6 (MW)	Cost ($/h), $C_i(P_u)$
1	114.3675	96.40886	63.11079	9066.631
2	50	150.524	93.01286	10781.27
3	115.386	112.5179	82.85117	9591.527
4	94.1102	131.4118	61.7133	12872.06
5	89.59733	54.48448	72.45803	9429.837
6	70.07551	74.43989	50	12427.31
7	97.96798	137.1254	76.58473	10884.47
8	67.48676	146.866	62.01292	11918.23
9	72.13339	129.4762	76.43829	9586.363
10	57.69211	75.78194	91.92321	11893.52
11	125.6878	72.28399	65.83565	11276.21
12	76.07823	76.41809	95.77497	12953.47
13	86.3198	127.0105	91.56753	9539.322
14	75.50339	112.4374	56.53026	15371.41
15	114.3694	79.18545	53.44169	13421.61
16	67.89791	96.39237	80.49953	13614.44
17	101.6668	118.4782	65.88113	9932.192
18	85.5909	95.05957	53.42904	12593.09
19	92.73721	78.57655	63.53814	12964.89
20	116.6065	74.60443	73.90289	8582.599
21	113.2756	54.89832	55.75216	13458.21
22	89.51223	141.9812	73.12519	8680.075
23	103.9107	165.1102	76.90233	9271.699
24	52.55217	107.6041	78.29925	13380.16

Table 7 COMPUTING TIME AND TOTAL GENERATION COST.

Technique	Total Generation Cost ($/h)	Computing Time (s)
PSO	$226,080	24.53537

For further analysis, the number of particle has been varied in order to minimize the optimal total cost in one day. As shown in the Table 8, the simulation cannot be run when number of particles below of six. Besides that, additional the numbers of particles show that there are no big changes in cost when using number of particles larger than six.

Table 8 NUMBER OF PARTICLES AS THE CONTROL VARIABLE

Number of particle	Total Cost ($/h), C_T	CPU time (sec)
< 6	ERROR	
6	226080	24.535372
7	228970	24.319859
8	237090	25.259725

V. CONCLUSION

This paper has suggested PSO techniques for solving DED problem of a power system. Dynamic economic dispatch is a complex optimization problem whose importance may increase as competition in power generation intensifies. In the PSO method, there is only one population, in each iteration, that moves towards the global optimal point. It was also effectively used in solving complex problems in the power system field. It is faster in finding quality solution compared to any evolutionary computation technique. The application of PSO in the DED has proven to be an efficient and acceleration tool for solving the DED problem.

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