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ROLE OF SR-PSO IN ECONOMIC LOAD DISPATCH

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ABSTRACT

This paper gives an intuition regarding space reduction based particle swarm optimization (SR-PSO) to solve economic load dispatch problem of thermal generating units with valve point effects. In this study, space reduction strategy is devised to accelerate the optimization process and for obtaining the better solution in the search space. Particle swarm optimization is a population based technique that can be applied to a wide range of engineering problems. Particle swarm optimization with a search space reduction strategy enhances the ability of particles to explore the solution spaces more effectively and increases their convergence rate. To demonstrate the qualitiveness and effectiveness of the proposed approach, a test system consisting of three-unit generating units, within co-operation of power balance constraints, operating limits and ramp rate limits are taken into account.. The current proposal reveals the effectiveness and robustness as compared to other heuristic algorithms reported in literature

Key words: Economic load Dispatch (ELD), Particle swarm optimization (PSO), Valve point effect, Ramp Rate Limits.

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NOMENCLATURE

a_i, b_i, c_i Cost coefficients of the i^{th} unit,

e_i , f_i Constants of the valve-point effect of i^{th} unit

$F_i(P_i)$ Cost of producing real power output i^{th} unit,

N Number of generating units

P_D Load demand,

P_L Transmission loss

$P_{i\,\min}, P_{i\,\max}$ Lower and upper generation limits of i^{th} unit

1. INTRODUCTION

Economic dispatch is one of the fundamental optimization issues in power system operation and control. Its main objective is to determine the optimal generation outputs in the most economical manner, while satisfying the physical and operational constraints. In traditional economic dispatch, the cost function is quadratic in nature. In real world power system modeling, a generating unit cannot exhibit a convex fuel cost function. Therefore, non-convex characteristics will come on account of steam valve effect. Considering the valve point effect, ELD problem can be recognized as a non linear, non-convex and large scale optimization problem with complicated constraints which finds the optimal result dispatch a new challenge Improvements in scheduling of the generator power outputs can lead to very important fuel cost savings [1]-[4]. Previous efforts on solving ED problems have been applied classical mathematical programming techniques such as interior point algorithm, linear programming and dual quadratic programming [5]-[7]. In these mathematical techniques, the main assumption is that the fuel cost curve is considered as monotonically increasing one. But, when the problem is highly nonlinear or nonsmooth cost functions, some of these techniques may not be able to produce better solutions. Many of researchers have been directed to implement heuristic optimization techniques unlike conventional mathematical techniques in solving ED problems in power systems [8-9]. Dakuo et al. a hybrid genetic algorithm approach based on differential evolution algorithm have proposed to solve economic dispatch with valve-point effect [10]. Coelhoet al. utilized particle swarm approach based on quantum mechanics and harmonic oscillator potential to solve economic load dispatch with valve-point effects [11]. Al-Sumait et al. used patern search method to solve this problem [12]. Su and Lin investigated to solve economic dispatch using Hopfield model [13]. Zhisheng proposed quantum behaved particle swarm optimization algorithm for economic load dispatch in power system [14]. Bhattacharya and Chattopadhyay utilized biogeography based optimization algorithm to solve complex economic load dispatch problems [15]. Hosseini et al. used a novel mathematical-heuristic method for non-convex dynamic economic dispatch [16]. Subramanian and Anandha kumar used to solve dynamic economic dispatch solution using composite cost function [17]. Hooshmandet al. investigated emission and economic dispatch [18]. Rashedi et al.implemented, a heuristic search algorithm, namely gravitational search algorithm (GSA), motivated by the gravitational law and laws of motion has been proposed by [19]. J.B.Park et al.[20] have been applied PSO technique successfully in solving various nonlinear functions to obtain the optimal results in search space for economic load dispatch problem.

The main objective of this study is to present the use of SRPSO optimization technique to the subject of economic dispatch in power systems. SRPSO has a flexible and well-balanced mechanism to enhance exploration and exploitation abilities In this paper, the SRPSO method has been proposed to solve economic dispatch problem with valve-point effect for three units test systems. In general terms, the contribution of this paper is the new efficient SRPSO approach for ED problem with valve-point effect. The results obtained with the proposed SRPSO approach were analyzed and compared other optimization results reported in literature.

2. PROBLEM FORMULATION

The classical formulation of the standard economic dispatch problem is an optimization problem of determining the schedule of the fuel costs of real power outputs of generating units subject to the real power balanced with the total load demand as well as the limits on generators outputs. In mathematical terms the problem can be defined as following:

$$MinF = \sum_{i-1}^{N} F_i(P_i) \quad (1)$$

Where F_i is the total fuel cost for the generator units, which is defined by

$$F_i(P_i) = a_i + b_i P_i + c_i P_i^2 \quad (2)$$

Where $a_i, b_i,$ and c_i are cost coefficients of i^{th} unit.

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

$$F_{it}(P_{it}) = a_i + b_i P_i + c_i P_i^2 + \left|e_i(\sin(f_i(P_{i\min} - P_i))\right| \quad (3)$$

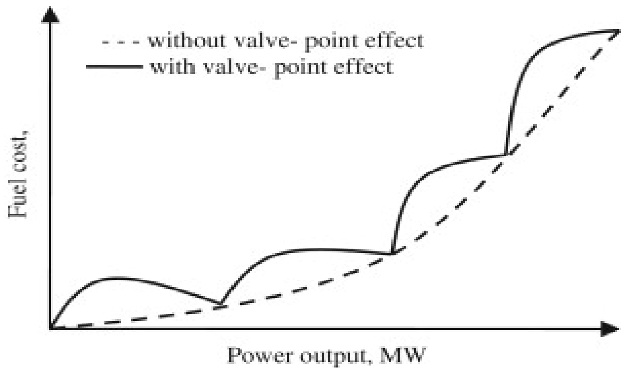

Figure 1 Valve point effect

To minimize the aforesaid objective, the following constraints should be satisfied.

2.1. Real Power Balance

The vital constraint is related to real power balance ensuring that at each time of scheduling, the total thermal power generation is exactly equal to total demand plus total loss.

$$\sum_{i=1}^{N} P_{it} = P_{Dt} + P_{Lt} \quad (4)$$

Where, P_{Dt} is the total power demand during i^{th} period and P_{Lt} is the total transmission loss during i^{th} dispatch period. In this paper transmission loss is not considered.

2.2. Real Power Operating Limits

The power generation of each generator should lie between its lower limits and upper limits, so that

$$P_{it\min} \le P_{it} \le P_{it\max}, \quad (5)$$

$P_{it\min}$ and $P_{it\max}$ are the minimum and maximum power generation of i^{th} unit at t time interval.

2.3. Generator Unit Ramp Rate Limit

The range of actual operation of online generating unit is restricted by its ramp rate limits. These limits can impact the operation of generating unit. The operational decision at the present hour may affect the operational decision at the later hour due to ramp rate limits.

When generation increases

$$P_{it} - P_{i(t-1)} \le UR_i$$

When generation decreases

$P_{i(t-1)} - P_{it} \le DR_i$,

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.

3. OVERVIEW OF PSO

For solving the economic load dispatch problem different PSO algorithms have been applied by researchers in power system operation and control. Particle swarm optimization was first introduced by Kennedy and Eberhart in the year 1995.It is a population based optimization technique. PSO is motivated from the simulation of the behavior of social systems such as fish schooling and birds flocking. It is a simple and powerful optimization tool which scatters random particles, i.e., solutions into the problem space. These particles, called swarms collect information from each array constructed by their respective positions. The particles update their positions using the velocity of articles. Position and velocity are both updated in a heuristic manner using guidance from particles own experience and the experience of its neighbors. The position and velocity vectors of the i^{th} particle of a d-dimensional search space can be represented as vectors $X_i = (x_{i1,} .... x_{in})$, and $V_i = (v_{i1,} .... v_{in})$ respectively, in PSO algorithm. Let Pbest$_i$ = (x_{i1}^{Pbest} ,.........$.x_{in}^{Pbest}$) and Gbest$_i$ = x_{i1}^{Gbest} ,.........$..x_{in}^{Pbest}$) ,respectively ,be the best position of individual i and its neighbors best position .Using information ,the updated velocity of individual i is modified under the following equation in the PSO algorithm

$$V_i^{k+1} = \omega * V_i^k + c_1 * rand_1 (Pbest_i^k - X_i^k) + c_2 * rand_2 (Gbest^k - X_i^k) \qquad (6)$$

Where

V_i^k	Velocity of individual i at iteration k ;
ω	Weight parameter
c_1, c_2	Weight factors
$rand_1, rand_2$	Random numbers between 0 and 1
X_i^k	Position of individual i at iteration k
$Pbest_i^k$	Best position of individual until iteration k
$Gbest^k$	Best position of the group until iteration k

Each individual moves from the current position to the next one by modified velocity using the following equation:

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

4. MODIFIED PSO FOR ED PROBLEMS

A new approach to introduce the PSO algorithm will be explained in solving the ED problems. A suggestion will be addressed on how to deal with the equality and equality constraints of the ED problems when modifying each individuals search point in PSO algorithm. To accelerate the convergence speed, dynamic search space reduction strategy is applied. This strategy is activated, when the performance is not increased during a pre-specified iteration period. In this case, the search space is dynamically adjusted i.e reduced based on the on the distance between the $Gbest$ and the minimum and maximum output of generator j at iteration k,the distance is multiplied by the predetermine step size Δ and subtracted and added for the maximum and minimum output at iteration k as described as follows:

$$P_{j\max}^{k+1} = P_{j\max}^{k} - (P_{j\max}^{k} - Gbest_j^k) \times \Delta \tag{8}$$

$$P_{j\min}^{k+1} = P_{j\min}^{k} + (P_{j\min}^{k} - Gbest_j^k) \times \Delta \tag{9}$$

The modified PSO algorithm can be summarized as follows:

Step 1) Initialization of a group at random while satisfying constraints.

Step 2) Velocity and position updates while satisfying constraints.

Step 3) Updates *Pbest* and *Gbest*

Step 4) Activation of space reduction strategy

Step 5) Go to step 2 until satisfying stopping criteria.

5. SIMULATION RESULTS AND DISCUSSION

In this study, proposed SRPSO algorithm has been applied to ELD problems by considering three unit test systems to investigate the effectiveness and robustness. The results obtained from proposed approach have been compared with previously developed well known techniques; those are reported in the literature. 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 SRPSO technique in ELD problems, the optimal parameters setting of SRPSO algorithm has been applied to obtain better optimal solutions. The following parameters are judiciously chosen for obtaining optimal results. The values of $c_1 = c_2 =$ 2, $\omega =$ 1.0 to 0.1 and Δ varies from 0.01 to 0.8 with 0.01 increments. The maximum number of generations (iterations) of 3000 is taken in this simulation study for the test systems only.

5.1. Description of the Test Systems

Initially, the proposed SRPSO technique is applied on a small test system, consisting of three generating units with a ramp rate limits and valve point effects. The generator cost coefficients, power generation limits and ramp rate limits are taken from [24]. In this study, transmission losses are neglected. Here the total demand for the three generating units is taken as 850 MW. Table I indicates the generator data of three units test systems. while the optimal power dispatch results for this case study are shown in Table II. It is seen from Table II that the power output of the generating units satisfies the generation limits and total demands. Hence, MPSO has better solution without violating any system operating constraints. The best fuel cost in 50 independent runs for the proposed system is compared with other evolutionary approaches which are reported and shown in Table III. The optimal fuel cost of the given approach in 50 independent runs is found to be **8234.01($)**. It is clearly visible from Table III, that the proposed method yields the best among all the techniques considered.

Table 1 Generator datas of the test case i

units	a_i	b_i	c_i	e_i	f_i	$P_{i\min}$	$P_{i\max}$
1	561	7.92	0.0015	300	0.031	100	600
2	78	7.97	0.0048	150	0.063	50	200
3	310	7.85	0.0019	200	0,042	100	400

Moreover, it is cleared that the CPU time consumption of the given approach is less than the other techniques and it can avoid premature convergence and posses good convergence speed.Fig.1 shows the valve point effect while fig.2shows the convergence behavior of SRPSO algorithm .From the convergence behavior, it is quite evident that the proposed method has the good convergence characteristics as compared to other approaches .

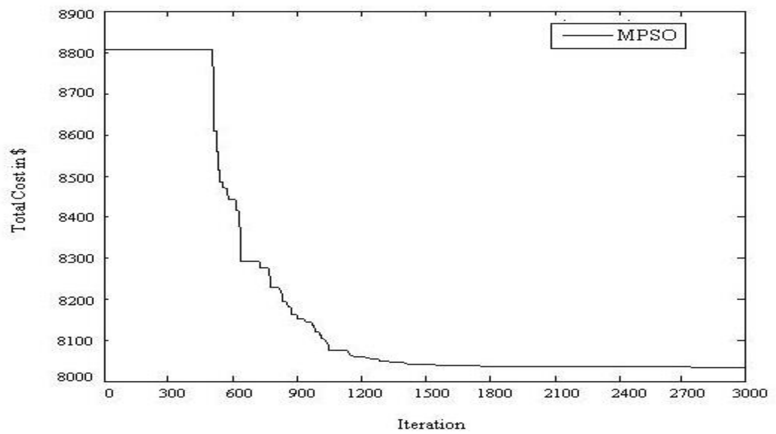

Figure 2 Convergence behavior of proposed approach

Table 2 comparison of optimal power of different methods

Methods	P1(MW)	P2(MW)	P3(MW)	TD(MW)
GA [21]	398.7	50.1	399.6	884.500
EP [21	300.264	149.736	400.000	850.000
EP-SQP[21]	300.267	149.733	400.000	850.000
PSO [21]	300.268	149.732	400.000	850.000
PSO-SQP[21]	300.267	149.733	400.000	850.000
PS [12]	300.266	149.733	399.999	849.999
GSA [23]	300.210	149.795	399.995	850.001
SRPSO	300.001	149.750	400.249	850.000

Table 3 Comparison of Proposed Method For Test Case I

Methods	Total cost($/h)	Simulation time (sec)
GA [21]	8222.07	---
EP [21	8234.07	---
EP-SQP[21]	8234.07	---
PSO [21]	8234.07	---
PSO-SQP[21]	8234.07	---
GAB[24]	8234.08	32.46
GAF[24]	8234.07	24.65
MFEP[24]	8234.08	6.31
IFEP[24]	8234.07	6.11
PS [12]	8234.05	---
GSA[23]	8234.10	---
SRPSO	8234.01	6.10

6. CONCLUSIONS

This article yields a novel SRPSO method to solve the non-convex ED problem of three thermal units with valve point effect for determination of global or near global optimum solution. The feasibility of MPSO method has been verified on three-unit test systems. It is quite apparent from the comparison results that the proposed method imparts better performance with respect to solution quality, simulation time and effort as compared to other well known evolutionary algorithms.

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