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

International Journal of Innovative Research in Computer and Communication Engineering

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Website: www.ijircce.com

Vol. 5, Issue 12, December 2017

Power Search Algorithm for Economic Load Dispatch Problems Considering Valve Point Loading Effects

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ABSTRACT: A novel Forward Search Approach (FSA) based Power Search Algorithm (PSA) (PSA-FSA) is proposed in this article to solve various types of Economic Load Dispatch (ELD) problems. This algorithm is formulated in such a way that the search criterion takes place from the minimum to maximum, for finding the best optimum solution with reduced iterations. To validate the proposed PSA-FSA algorithm, a detailed analysis has been carried out for three standard test systems: 13, 38 and 40-unit system. Transmission losses are considered for 13 unit system, 38 and 40 unit system are considered neglecting losses. A comparative evaluation with various algorithms proves the overall performance of the PSA in terms of fuel cost and transmission loss reduction.

KEYWORDS: Economic Load Dispatch (ELD), Power Search Algorithm (PSA), Transmission losses, Valve Point Loading (VPL).

I. INTRODUCTION

Generation of power at a minimum cost is the major expectation from the power utilities. Power system analysis combines extremely nonlinear and computationally troublesome surroundings with a necessity for optimality. In earlier days, the operating price for every generator has been roughly diagrammatic by a single quadratic function and is solved by using the mathematical programming based on the improvement techniques. These mathematical strategies need progressive or marginal fuel value curves that ought to be monotonically increasing to search out global optimum solution. The fuel point functions of generating units are modelled in an additional sensible fashion by merging with the valve-point effects. The impact of valve-point leads to the ripples within the fuel cost function; thereby the total number of optimal point is increased. From the above observations, it is clear that the solutions obtained by mathematical methods for the practical ELD problems are not challenging, since it consists of equality and inequality constraints.

II. RELATED WORK

Many techniques are being proposed over the recent years for obtaining the optimal solution for the various ELD problems. The load demand and also the transmission losses got to be equal with the capacity of the power generated and simultaneously the capability limits of the generators should not be exceeded for safe operation [1]. ELD deals with the determining of optimal solution satisfying the generator constraints [2, 3]. ELD issues are resolved by several standard strategies like gradient method [4], lambda iteration method [5, 6], linear programming [7], quadratic programming [8], Lagrangian-multiplier method [9], and co-ordination equations based classical technique. Due to computational complexity, the aforementioned conventional methods failed to perform in a satisfactory way for solving such problems. Fuzzy Logic Control creates the control action based on the rules created by humans [11, 12]. Artificial Neural Network (ANN), even though enhances the characteristics of the system, its long training time, layer selection

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and the count of neuron makes the method disadvantageous [6, 13, 14]. Depending on the scale of the system and its pathway to revisit the obtained suboptimal solutions, Genetic Algorithm needs an enormous run time [15]. Simulated Annealing technique got failed as it gets trapped in a single local optimal point [16]. For large problems, Evolutionary Programming discussed in [17], has very slow convergence rate. Improved Tabu Search method lowers the system efficiency due to its complicated objective function [18]. Moreover several parameters are to be optimized and it consumes longer time. The theoretical analysis of Ant Swarm optimization [19] is incredibly tough and once the iteration changes, the probability distribution changes. Particle Swarm Optimization [20, 21] shows partial optimism, inability to unravel the problem of optimization and scattering, those that fails to prove its potency. Gravitational Search Algorithm [22], despite the fact that proves to be more effective, attributable to the agents' diversity, it predicts the poor performance of the algorithmic program. Galaxy-based Search Algorithm [23] has been formulated with the idea of modified Hill Climbing algorithm for the nearby search and spiral arms of positive galaxies. The idea of hybrid shuffled differential evolution [24] has been accomplished for big scale monetary dispatch problems. Hybrid differential evolution combining the biogeography based optimization [25] has been designed with the concept of migration and mutation. Improved Coordinated Aggregation based PSO [26] has been developed with the concept of retaining the best position for the solution obtained and attracted by other particles with better achievements. Hybrid EP-EPSO algorithm [27] was formulated for obtaining the optimal solution with the good convergent property. Flower Pollination Algorithm [28] has introduced with the concept of flowering plants' pollination process, which includes the self pollination and cross pollination. Particle Swarm Optimization with vale-point effects [29] has been formulated for achieving the optimum solution for large generator systems neglecting losses. The chaotic differential evolution and quadratic programming [30] combined together for determining the complexity of the system described by the other way the chaotic sequences are replaced by randomization for improving the DE's performance in terms of premature convergence. In this article, the projected algorithmic approach works by the formulation of forward search approach and it is portrayed that PSA-FSA outperforms various algorithms.

III. POWER SEARCH ALGORITHM

PSA is a direct search method for determining the power output and the fuel cost for ELD problems. Here the Forward Search Approach is implemented for obtaining the minimum fuel cost, reduction in total power, fuel cost and transmission loss. Unlike other optimization techniques, this algorithm, being a traditional approach for solving the various ELD problems, it travels through all the points in the search space and gives out the best optimal solution.

A. *Forward Search Approach:*

In this approach, the power output for the ith generator is given in following equation (1).

$$P_i = P_i^{min} * (1 + \kappa + \kappa^2) \quad (1)$$

where Pi is the power out of the ith generator P_i^{min} is the minimum power generation limit for the ith generator and 'k' is a numerical variable. The range for 'k' starts from 0 and it is incremented with 0.001. For maintaining the power demand (P_D), a power balance constraint is introduced. Equation 6 describes the power balance constraint.

IV. PSEUDO CODE

Step 1: Enter P_i^{min}, P_i^{max}, P_D and initialize k.
Step 2: Calculate $P_i = P_i^{min} * (1+k+k^2)$).
Step 3: Check the below condition
 if if $P_i \le P_i^{min}$
 then fix $P_i = P_i^{min}$
 end
 if $P_i \ge P_i^{max}$ then fix $P_i = P_i^{max}$
 end
Step 4: Redefine Pi
Step 5: Increment 'k'
Step 6: Find minimum fuel cost and transmission loss.
Step 8: End.

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V. SIMULATION RESULTS

A. *Case Study 1:*

In this test system, 13 generators are chosen considering two different power demands considering transmission losses. The power demands are 1800 MW and 2520 MW. The input data for this test case is taken from [24]. The results obtained by the proposed approach seem to be better than SDE, as reported in the literature. The minimum cost obtained by the PSA-FSA was given by 18,053.01 $/hr for power demand of 1800 MW and 24,317.04 $/hr for power demand of 2520 MW. From table 1, it is observed that the PSA-FSA performs superior when compared to SDE. In terms of fuel cost, the proposed algorithm saves 81.48 $/hr for a power demand of 1800 MW and 197.84 $/hr for a power demand of 2520 MW. On the other side, the transmission loss is also reduced. For a power demand of 1800 MW, the PSA gives a loss of 6.571 MW and for a demand of 2520 MW, it is 11.069 MW.

Table 1 Comparison of various parameters with SDE for case study 1

	P_D = 1800 MW		P_D = 2520 MW	
Unit	**SDE[24]**	**PSA-FSA**	**SDE[24]**	**PSA-FSA**
P1	448.80	586.286	628.32	600
P2	297.93	296.884	299.20	299.266
P3	223.30	117.257	299.20	214.124
P4	109.85	87.943	159.73	160.593
P5	109.85	87.943	159.73	160.593
P6	159.71	87.943	159.73	160.593
P7	109.86	87.943	159.73	160.593
P8	60.00	87.943	159.73	160.593
P9	109.82	87.943	159.73	160.593
P10	40.00	58.629	77.40	107.062
P11	40.00	58.629	113.12	107.062
P12	55.00	80.614	92.40	120
P13	55.00	80.614	92.40	120
Fuel cost ($/h)	18,134.49	**18,053.01**	24,514.88	**24,317.04**
Transmission loss (MW)	19.13	**6.571**	40.43	**11.069**

B. *Case Study 2:*

Here, a 38 generator system neglecting transmission losses is considered for analysis. The total power demand for the system is 6000 MW. The system data is referred from [25]. Table 2 outlines the results obtained by the proposed method compared with various algorithms. From table 2, it is depicted that the PSA-FSA performs better when compared to NEW-PSO, PSO-TVAC, BBO, DE-BBO and EP-EPSO. In terms of fuel cost, the proposed algorithm saves 35,13,914.3 $/hr - 34,44,913.731$/hr – 33,62,099.031 $/hr – 33,61,701.131 $/hr – 33,32,390.931 $/hr when compared with NEW-PSO – PSO-TVAC – BBO – DE-BBO – EP-EPSO. The results obtained with the help of the proposed algorithm prove its robustness when compared with other algorithms reported.

Table 2 Cost comparison for 38-generator system

Algorithms	Fuel cost($/hr)
NEW-PSO [26]	95,96,448.3
PSO-TVAC [26]	95,00,448.3
BBO [25]	94,17,633.6
DE/BBO [25]	94,17,235.7
EP-EPSO [27]	93,87,925.5
PSA-FSA (Proposed method)	**60,55,534.569**

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Vol. 5, Issue 12, December 2017

C. *Case Study 3:*

The proposed PSA-FSA is tested on a 40 generator system. The robustness and the superiority of the proposed PSA-FSA is validated and from the results obtained, it is observed that the algorithm outperforms the other conventional methods. The total demand for the system is 10,500 MW. The input data for this system is taken from [28]. The losses are neglected for the simplicity of the system. Table 3 presents the results for 40 unit system. From the results, it is inferred that the suggested PSA-FSA achieves the lowest cost when compared to other algorithms, by satisfying the generator constraints. From the simulation results obtained, it is clearly observed that the PSA-FSA outperforms the reported algorithms in terms of fuel price. The proposed PSA-FSA saves 648 $/hr compared to PSO, 369 $/hr compared to APPSO, 113 $/hr compared to PPSO and 66 $/hr compared to CDE-SQP. The solution obtained with PSA-FSA is decided to be the most effective and best optimal solution.

Table 3 Simulation results for 40 generator system

Algorithms	PSO [29]	APPSO [29]	PPSO [29]	CDE-SQP [30]	**PSA-FSA (Proposed method)**
Fuel cost($/hr)	122323	122044	121788	121741	**121675**

VI. CONCLUSION AND FUTURE WORK

A novel algorithm referred as PSA-FSA has been presented in this paper to solve various problems in ELD. This algorithm works with the concept of forward search approach. This approach, as it travels through the entire search space, provides the best optimal solution with very less computational time. When compared with the various existing algorithms, it is evident that PSA suits well in reducing the fuel cost and transmission losses. The implementation of PSA for very large scale power systems is the future work.

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ISSN(Online): 2320-9801
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International Journal of Innovative Research in Computer and Communication Engineering

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Website: www.ijircce.com

Vol. 5, Issue 12, December 2017

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