Solution to Economic Load Dispatch Problem of a Distributed Generating System using Pattern Search Algorithm

C. Durga Prasad, G.V. Siva Krishna Rao

Abstract: The solution of Economic Load Dispatch (ELD) problem is to allocate the total load demand to committed generating units with an objective to minimize the operating cost without violating the unit and system constraints. The growing power demand, atmospheric pollution and increased population makes it essential to invent a new power system with low pollution and transmission losses. The growing price and limited availability of fossil fuels makes installation of conventional power plants uneconomical. Installation of non-conventional power plants like roof top solar plants is essential to meet the increased load demand and environmental pollution standards. The output of roof top solar systems is intermittent because it depend on atmospheric conditions. To find a solution to economic load dispatch of distributed generation system (ELDDGS) with roof top solar plants is a difficult problem because of its intermittent and scattered nature. This paper will explain a solution to economic load dispatch of a distributed generation system using pattern search algorithm.

Keywords: Economic Load Dispatch, Distributed Generation, Pattern Search Method, Rooftop Solar Power Plants.

I. INTRODUCTION

Economic Load Dispatch (ELD) is one of the major problem in operation of power system because the quality of supply and the profits to supply authorities depends on it. The solution to economic load dispatch problem is to allocate the total load demand of the system to all committed generating units to meet the demand at an economical price without violating the operational constraints of the system. Load demand of a power system is not constant, it changes continuously. To meet this continues load change the generating stations should operate at different output levels in a day. The allocation of this continuously changing load to different committed generating stations to produce the power at economical price is called Economic Load Dispatch. Economic Load Dispatch Problem needs a quick responding algorithm to make the system more reliable and economical. According to The International Energy Agency (IEA) distributed generation is defined as a generating plant, transfer a customer on-site or providing support to a distribution system connected to the grid at distribution-level voltages [1].

Distributed Generation (DG) is simply defined as a decentralized power generation near load centers to a technique used to meet the load demand with the help of locally available sources with less transmission and distribution losses. Electric Power Research Institute (EPRI) defines a distributed generation as the generation from a few kilowatts up to 50 MW [2]. In DG low capacity generating stations of conventional and non – conventional fuel types are installed nearer to load centers. They are very helpful for during grid failures. The generation may be restored in some areas without outside support after a system collapse [4]. They also restore the system within a short time during natural disasters like cyclones and earthquakes. The DG plants are designed to use locally available resources like Gas, water, solar radiation, wind etc. Most of the DG plants are non-conventional type. They generate power at low operating cost without any environmental pollution. But their output is intermittent because it depends on weather.

Conventional power plants are more reliable power sources. But they produce more environmental pollution. Conventional power plants can be used as base load plants because of their consistent nature. Non- conventional power plants produce power without any environmental pollution. Non – conventional power plants cannot be used as base load plants because of their intermittent nature. The inter connection of both conventional and non- conventional power plants is essential to meet the increased load demand, to reduce environmental pollution and cost of power generation[5]. Many recent works have been proposed different optimization methods like Evolutionary Programming (EP), Simulated Annealing (SA), Genetic Algorithm (GA) [6]- [8].

II. PATTERN SEARCH ALGORITHM

Pattern Search was first introduced by Hooke and Jeeves [4] in a paper from 1961. The Pattern Search optimization method is one of the efficient evolutionary algorithm which is suitable to solve a various optimization problems which are difficult to solve with standard optimization methods. Pattern Search Algorithm has the many advantages like simple in concept, easy implementation and computationally efficient. PS algorithm has a flexible and well balanced operator to enhance and adapt the global and fine tune local search. The algorithm starts with establishing a set of points called mesh, around the given point.

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This current point is the initial starting point given by the user or it could be computed from the previous step of the algorithm. Later the mesh is formed by adding the current point to a scalar multiple of a set of vectors called a pattern. The algorithm checks for the improvement in objective function value with every point in the mesh. If a point in the mesh is found to improve the objective function at the current point, the next point becomes the current point at the next iteration. If the search finds a better point, this point becomes the new base and the search restarts from this point. If a search is not a success, the search direction is changed, or the search perimeter is cut down by reducing the step length. The Pattern Search algorithm is executed by the following steps. The algorithm starts with an initial point X_0 that is assumed as a starting point by the user. During the first iteration, pattern vectors are constructed with a suitable scalar mesh size. In this case the mesh size is assumed as 1 and pattern vectors are created as [1 0], [0 1], [-1 0] and [0 -1]. These vectors are used in all four directions to expand the search. Later the Pattern Search algorithm adds the direction vectors to the initial point X_0 to compute the following mesh points:

$$X_0 + [1\ 0]$$

$$X_0 + [0\ 1]$$

$$X_0 + [-1\ 0]$$

$$X_0 + [0\ -1]$$

The formation of the mesh and pattern vectors are illustrated in the following figure.1. The algorithm computes the objective function value at the mesh points in the following order.

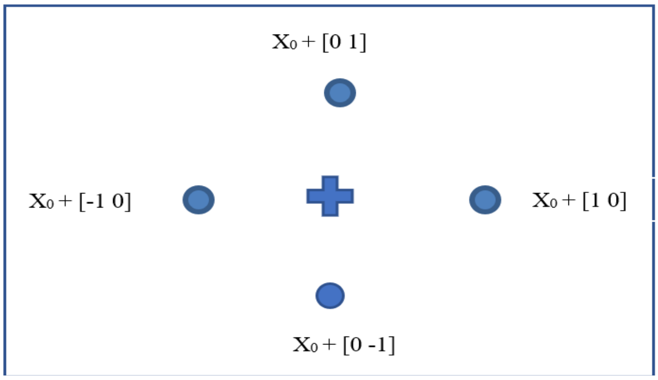

Fig.1 PS Mesh points and Pattern

The PS algorithm polls all the four mesh points by computing their objective function values. The algorithm continuous until it finds the best mesh point with a objective function value smaller than the objective function value of X_0. If there is such a point, then the poll is treated as successful and the algorithm sets this point as equal to X_1.

After every successful poll, the algorithm proceeds to the next iteration and multiplies the current mesh size by 2 (This is called as the expansion factor and normally has a default value of 2). The mesh at next iteration contains the following points: X_1 + 2*[1 0], X_1+2*[0 1], X_1 + 2*[-1 0], and X_1+2*[0 -1]. The PS algorithm polls the mesh points until it finds the one whose value is smaller than the objective function value of X_1. The first such point it finds is called as X2, and the poll is success. Because of the poll is success, the algorithm multiplies the current mesh size by 4 to get a new mesh size at the third iteration because the expansion factor is equal to 4. During second iteration the mesh size is increased by multiplying the current mesh size with mesh expansion factor of 2. The new mesh point are created as

$$X_1 + 2*[1\ 0]$$

$$X_1 + 2*[0\ 1]$$

$$X_1 + 2*[-1\ 0]$$

and $$X_1 + 2*[0\ -1]$$

During third iteration new mesh points are created with mesh expansion factor assumed as 4. The new mesh point are created as

$$X_2 + 4*[1\ 0]$$

$$X_2 + 4*[0\ 1]$$

$$X_2 + 4*[-1\ 0]$$

and $$X_2 + 4*[0\ -1]$$

The algorithm is executed with new mesh points. If the algorithm finds a successful poll the algorithm continuous with new mesh points created by the expansion factor otherwise the new mesh points are created by using a contraction factor, so that the mesh size at the next iteration is smaller than the previous. Because of reduced mesh size the algorithm finds a better solution. The algorithm is executed until it finds the optimal solution for the given objective function. The algorithm is terminated if any of the following conditions are satisfied.

- If the mesh size is less than mesh tolerance.
- If the iteration count of exceeds a predefined value.
- If the total number of evaluations reaches a pre-set value of maximum number of function evaluations.
- If the distance between the two successive polls is less than a set tolerance.
- If the change in objective function value in two successive poles is less than a function tolerance.

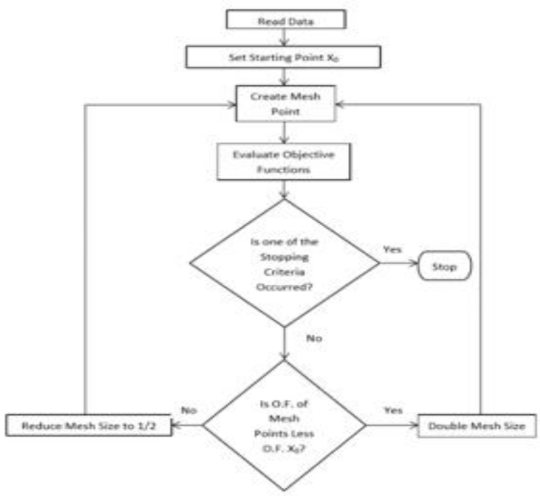

Fig.2 Flow Chart of Pattern Search Algorithm

III. PROBLEM FORMULATION

The aim of Economic Load Dispatch of a Distributed Generation System(ELDDGS) is to minimize the fuel cost of the system by considering all constrains of the individual generating plants and overall system. The objective function value to be minimized to minimize the total fuel cost of all power plants. In this case the output of Distributed Generated Sources are taken as constant and they are treated as a negative load on system.

$$\min \ F_t = \sum_{i=1}^{N} F_i(P_i)$$

Where

F_t - Total fuel cost of all committed generators

N - Total number of committed generators

P_i - Active power output from i th generator

The fuel cost of individual generator is represented by the following quadratic equation

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

Where a_i, b_i and c_i are fuel cost function coefficients of individual generators.

The inequality constraint is

$$P_{i\ min} \leq P_i \leq P_{i\ max}$$

The equality constraint is

$$\sum_{i=1}^{N}(P_i) = P_D + P_{Loss} - \sum_{j=1}^{M}(P_{DGj})$$

Where

P_D = total power demand of system

P_{Loss} = total power transmission loss

P_{DGj} = Active power output of j^{th} Distributed Generator

IV. SIMULATIONS AND EXPERIMENTAL RESULTS

The cost coefficients and min. and max. limits of generating plants are shown in the following Table-I.

Table- I. Cost Data of 13 generating units

Unit No.	$P_{i.min}$ (MW)	$P_{i.max}$ (MW)	a_i ($)	b_i ($/MW)	c_i ($/MW^2$)
1	0	680	550	8.10	0.00028
2	0	360	309	8.10	0.00056
3	0	360	307	8.10	0.00056
4	60	180	240	7.74	0.00324
5	60	180	240	7.74	0.00324
6	60	180	240	7.74	0.00324
7	60	180	240	7.74	0.00324
8	60	180	240	7.74	0.00324
9	60	180	240	7.74	0.00324
10	40	120	126	8.6	0.00284
11	40	120	126	8.6	0.00284
12	55	120	126	8.6	0.00284
13	55	120	126	8.6	0.00284

The individual outputs and total fuel cost of 13 unit system using Pattern Search algorithm and their comparison with the results obtained by existing methods are shown in Table-II.

Table- II. Fuel Cost and results comparison of 13 unit system.

Description		GA Method[6]	Proposed Method
Generation of Units (MW)	PG1	508.90	506.93
	PG2	242.71	253.45
	PG3	253.45	253.45
	PG4	95.66	99.36
	PG5	98.66	99.36
	PG6	89.57	99.36
	PG7	100.89	99.36
	PG8	99.73	99.36
	PG9	120.21	99.36
	PG10	40.03	40
	PG11	40.08	40
	PG12	55.10	55
	PG13	55.00	55
Demand (MW)		1800.00	1800
Fuel Cost ($/hr)	Best	17934.29	17932.47
	Average	17938.94	17932.47
	Worst	18015.95	17932.47
Execution Time in second		4.90	0.061

The Convergence characteristic of Pattern Search algorithm for 13- unit system is shown in Fig.3

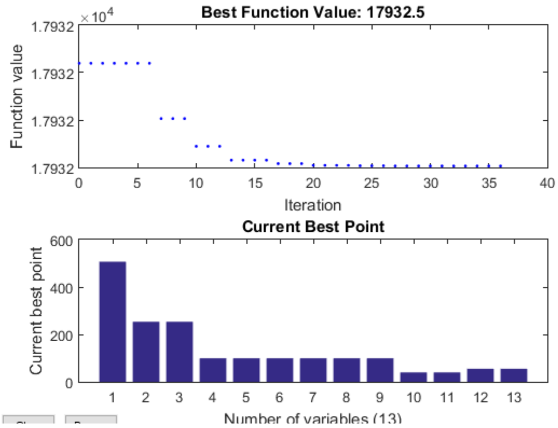

Fig. 3. Convergence characteristic of Pattern Search Algorithm for 13- unit system

V. CONCLUSION

The penetration of Distributed Generation Sources is increasing day by day to meet increased load demand and to reduce pollution levels. Pattern Search algorithm is proposed to solve Economic Load Dispatch problem of a Distributed Generation System(ELDDGS). This paper demonstrates pattern search method to solve ELDDGS problem by satisfying all constrains. The proposed PS method is applied on a 13- unit system and the results were compared with the outputs submitted by existing methods available in literature.

The comparison of outputs shows that Pattern Search algorithm is a simple and fast solution technique. It is a better method to solve economic load dispatch problems of a distributed generating system compared with existing methods available in literature. It converges in a short time and gives a better results. The proposed technique was implemented with the help of an Intel core i5, 1.6Ghz, 8GB RAM personal computer in MATLAB 2015a environment.

REFERENCES

1. Distributed Generation in Liberalized Electricity Market, IEA Publication (2002), available at: http://www.iea.org/dbtw-wpd/textbase/nppdf/free/ 2002 / distributed2002.pdf.
2. A. Thomas, A. Goran, S. Lennart, "Distributed generation: a definition", *Electric Power System Res*earch, vol. 57, pp. 195-204, Dec 2001.
3. W. El-Khatan and Salama MMA, "Distributed generation technologies, definitions and benefits," *Electrical Power System Research*, vol. 71, pp. 119–128, Jan 2004.
4. L.L.Lai and T.F.Chan, "*Distributed Generation: induction and permanent magnet generators*", Wiley, 2007.
5. C . Durga Prasad and Prof. G.V. Siva Krishna Rao, "Dynamic Economic Load Dispatch of a Distributed Generation System", International Journal of Electrical Engineering & Technology (IJEET), Volume 9, Issue 4, July-August 2018, pp. 67–73,
6. N. Sinha, R. Chakrabarti and P. K. Chattopadhyay, "Evolutionary programming techniques for economic load dispatch," in *IEEE Transactions on Evolutionary Computation*, vol.7,no.1,pp.83-94,Feb.2003.
7. D. C. Walters and G. B. Sheble, "Genetic algorithm solution of economic dispatch with valve point loading," in *IEEE Transactions on Power Systems*, vol.8,no.3,pp.1325-1332,Aug.1993. K. P. Wong and C. C. Fung, "Simulated annealing based economic dispatch algorithm," in *IEE Proceedings C - Generation, Transmission and Distribution*, vol. 140, no. 6, pp. 509-515, Nov. 1993.
9. Sheikh, M. M., Manzoor, N., Ashraf, J., Adnan, M., Collins, D., Hameed, S., Manton, M. J., Ahmed, A. U., Baidya, S. K., Borgaonkar, H. P., Islam, N., Jayasinghearachchi, D., Kothawale, D. R., Premalal, K. H. M. S., Revadekar, J. V. and Shrestha, M. L., 2015, "Trends in extreme daily rainfall and temperature indices over South Asia", *Intl. J. Climatol.*, **35**, 1625-1637.

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