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Differential Search Algorithm for Economic Dispatch with Valve-Point Effects

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Abstract

This paper introduces a new method for determining the feasible optimal solution of Economic Dispatch (ED) problems which is using the recently developed Differential Search (DS) algorithm. DS algorithm simulates the *Brownian-like random-walk* movement used by an organism to migrate. DS will seek for the optimal generation scheduling when the specific load is known so that the cost can be minimized without violating any constraints. The cost minimization also will give the significant impact to the total system losses. To demonstrate the effectiveness and feasibility of DS in solving ED, two well-known ED test systems with non-convex solution features have been tested and compared with some of the most recently published ED solution methods in literature. The results of this research show that DS is able to find more economical solution than those determined by other methods.

Keyword: Differential search algorithm (DS), economic dispatch, valve-point effects

1. Introduction

Power system is one of the complex systems of human's invention. One of the most important issue emerged in power system complexity is Economic Dispatch (ED) problem. ED is the fundamental problem which aims to find the optimal power generation to match with the demand at minimum cost by satisfying all the system constraints. In addition, the practical ED problems which are involving non-convex objective functions with equality and inequality constraints including the practical operation constraints of generators such as ramp rate limit, prohibited operating zones and generation limits make it harder to solve the global optimum using conventional methods, especially for larger systems. Small improvements in determining the optimal output scheduling can contribute to significant cost savings. Thus, there are a lot of researches and techniques have been proposed to solve ED problem.

In recent years, various methods have been proposed to solve ED problem in power systems: from analytical technique [1, 2] to artificial intelligence approaches[3-7]. Recently, new computational technique called swarm intelligence becoming the choice of many researchers in solving ED problem, such as particle swarm optimization (PSO) [8, 9], firefly algorithm (FA) [10] and artificial bee colony (ABC) [11, 12]. The modification of PSO namely quantum-behaved PSO (QPSO) [13] and self-organizing hierarchical PSO (SOH-PSO) [14]also have been tempted to solve ED.

Although the said methodologies have been developed for ED, the complexity of the task reveals the necessity for development of efficient algorithms to accurately locating the optimum solution [10].This paper presents an application of Differential Search (DS) algorithm for solving non-convex ED problems with the valve loading effects. In this paper, DS is adopted to find the global optimum results of ED. DS algorithm simulates the Brownian-like random-walk movement used by an organism to migrate.

The layout of this paper is organized as follows: The ED problem is briefly discussed in Section 2. It followed by an overview of DS in Section 3. The proposed DS algorithm for solving ED is presented Section 4, followed by the case study results and discussion which are shown in Section 5. Finally, the conclusion is given in Section 6.

2. Economic Dispatch

In the economic dispatch (ED) problem with valve-point effects, the cost function takes the following form:

$$\min f = \sum_{i=1}^{n} F_i(P_i) \tag{1}$$

$$F_i(P_i) = \alpha_i P_i^2 + \beta_i P_i + \gamma_i + \left|\varepsilon_i \times \sin\left(\delta_i \times \left(P_i^{\min} - P_i\right)\right)\right| \tag{2}$$

where n is the number of generator units, $P_i^{min}$is the lower bound of P_i, α_i, β_i, and γ_i are coefficients of generator i, and ε_i and δ_i are parameters reflecting the valve-point effects. The cost function in (2) is subject to the power balanced constraints and individual generation limits as follow:

$$\sum_{i=1}^{n} P_i = P_D + P_L \tag{3}$$

$$P_{i(\min)} \le P_i \le P_{i(\max)} \quad i = 1, 2, \ldots, n \tag{4}$$

where$P_D$is the total load demand, $P_L$is the total loss and n is the total number of committed generator during the dispatched hour. Since the power loss is cannot avoided in interconnected power system, it must be taken into account to achieve as closed as practical economic dispatch by using the B-coefficient method [15], as follows:

$$P_L = \sum_{i=1}^{n}\sum_{j=1}^{n} P_i B_{ij} P_j + \sum_{i=1}^{n} B_{0i} P_i + B_{00} \tag{5}$$

3. Differential Search Algorithm

DS algorithm is inspired by migration of living beings which constitute superorganisms during climate change of the year. Migration behavior allows them to move from one habitat to more efficient habitat. They start to change their position by moving toward more fruitful areas. The movement of superorganism can be described by a *Brownian-like random-walk* model [16].

It is assumed that random solution of population is corresponding to the artificial-superorganism migration to global optimum solution of the problem. During the migration, the artificial-superorganism tests whether some randomly selected position are suitable for temporarily basis. If the position tested is suitable to stop over for a temporary during the migration, the members of the artificial-superorganism that made the discovery immediately settle at the discovered position and continue their migration from this position. DS search strategy may simultaneously use more than one individual and no inclination to correctly go towards the *best* solution of the problem which makes it has a successful search strategy for finding the solution of multimodal functions. Pseudo-code of DS algorithm can be obtained in [16].

4. Economic Dispatch Using DS

In solving ED using DS, a member of an artificial-organism firstly will be initialized. This comprises of the number of generations of the system that will be optimized which resulted a minimum cost by fulfilling all the constraints. The mechanism of finding stopover site at the areas is using a random searching process. Various random processes are utilized in DS until the optimal results are found by the migration of artificial-organisms.

Equations (1)-(2) were applied in the evaluation process of the ED problem. In order to deal with the inequality constraint: upper and lower limits of each generator, normally when the solutions obtained out of these boundaries, the algorithm will choose the boundary values. For equality constraint: power balance constraint, the penalty method has been used. The penalty value is reflected to the power balance mismatch and embedded in the cost function (1) as follows:

$$F = (F) + PF * abs[(\sum_{i=1}^{n} P_i) - P_D - P_L] \quad (3)$$

wherePF is the penalty factor.

The advantage of DS is it has only two control parameter i.e. $p_1$and $p_2$which is normally are set to 0.3 [16] which provides the best solution. DS also is very simple. Nevertheless, to obtain good results, large number of iterations needs to be set in this algorithm.

5. Simulation Results and Discussions

The proposed method has been applied to two test systems: a power system with 13-units and TAIPOWER 40-unit systems. The proposed method is compared with the recent techniques reported in literature.

5.1 13-units system

This test case consists of 13 generating units. The load demand of this test system is 1800 MW. The same parameters data of all units as given in[6] is utilized. Table 1 shows the best, average and worst results of different ED solutions methods. The outcomes of other methods shown in Table 1 have been directly quoted from the corresponding references. It can be seen that the best result of proposed method is slightly better compared to FA.Nevertheless, the overall performance of DS in term of average and worst is much better among the others reported. A detailed power generated by individual unit for proposed method and FA is shown in Table 2.

Table 1: The best, average and worst of different ED solution methods for the 13-units test system

Methods	Best ($/h)	Average ($/h)	Worst ($/h)
CEP [6]	18,048.21	18,190.32	18,404.04
PSO [9, 10]	18,030.72	18,205.78	NA
MFEP[6, 10]	18,028.09	18,192	18,416.89
HS [7]	17,965.62	17,968.563	18,070.176
FA[10]	17,963.83	18,029.16	18,168.80
DS	17,963.8292	17,966.6968	17,968.9467

Table 2: Individual power generation in the best result of proposed DS versus FA for the 13-units system

Unit	DS Power (MW)	FA Power (MW)
1	628.3185307	628.31852
2	149.5996165	149.59952
3	222.7491063	222.74912
4	109.8665494	109.86655
5	60	109.86655
6	109.8665498	109.86655
7	109.8665484	109.86655
8	109.8665493	60
9	109.8665496	109.86655
10	40	40
11	40	40

12	55	55
13	55	55.00009
Total generation (MW)	1800	1800
Cost ($/h)	17963.829207639	17963.8307965424

5.2 TAIPOWER 40-units system

This test case consists of 40 generating units with non-convex fuel cost function incorporating valve loading effects. The required load demand to be met by all 40 generators is 10500 MW. Again, the detailed information of generating units of test system can be obtained in [6]. This test system is more complex than the previous case and any difference between ED solution methods can be better revealed in this test case. The DS has been executed for twenty times with various initialization of starting points. The obtained results of the proposed DS to resolve ED problem for this test system are tabulated in Table 3. In this table, the detailed comparisons of the best, average and worst solutions of the proposed DS and most recently published ED solution methods are shown by referring to the [10]. As seen from Table 3, the best solution of proposed method is better than those of all methods, indicating DS's higher efficiency to solve ED problem comparing with the other methods. Thus, the proposed method is proved to be the best among all methods so far. Due to the space constraint, the detailed results of the optimal solution of the proposed method including generation output of each unit for this test system isnot given.

Table 3: The best, average and worst of different ED solution methods for the TAIPOWER 40-units test system

Methods	Best ($/h)	Average ($/h)	Worst ($/h)
HGPSO	124,797.13	126,855.70	NA
PSO	124,350.40	126,074.40	NA
SPSO	123,930.45	124,154.49	NA
CEP	123,488.29	124,793.48	126,902.89
HGAPSO	122,780.00	124,575.70	NA
FEP	122,679.71	124,119.37	127,245.59
MFEP	122,647.57	123,489.74	124,356.47
IFEP	122,624.35	123,382.00	125,740.63
TM	122,477.78	123,078.21	124,693.81
EP–SQP	122,323.97	122,379.63	NA
MPSO	122,252.26	NA	NA
ESO	122,122.16	122,558.45	123,143.07
HPSOM	122,112.40	124,350.87	NA
PSO–SQP	122,094.67	122,245.25	NA
PSO-LRS	122,035.79	122,558.45	123,461.67

Improved GA	121,915.93	122,811.41	123,334.00
HPSOWM	121,915.30	122,844.40	NA
IGAMU	121,819.25	NA	NA
HDE	121,813.26	122,705.66	NA
DEC(2)-SQP(1)	121,741.97	122,295.12	122,839.29
PSO	121,735.47	122,513.91	123,467.40
APSO(1)	121,704.73	122,221.36	122,995.09
ST-HDE	121,698.51	122,304.30	NA
NPSO-LRS	121,664.43	122,209.31	122,981.59
APSO(2)	121,663.52	122,153.67	122,912.39
SOHPSO	121,501.14	121,853.57	122,446.30
BBO	121,479.50	121,512.06	121,688.66
BF	121,423.63	121,814.94	NA
GA–PS–SQP	121,458.00	122,039.00	NA
PS	121,415.14	122,332.65	125,486.29
FA	121,415.05	121,416.57	121,424.56
DS	**121,414.6185**	**121,414.8449**	**121,418.8120**

6. Conclusions

In this paper, a new approach to non-convex ED problems based on the DS has been presented. Two well-known test systems have been studied and comparisons of the quality of the solution and performance have been conducted against several of most recently published ED solution methods. Based on simulation study, it can be seen that the quality and reliability of the proposed DS was superior compared to other methods. In future, the proposed DS can be used to solve ED with more practical and complex constraints including prohibited zones, ramp rate limits and etc.

7. References

[1] M. Madrigal and V. H. Quintana, "An analytical solution to the economic dispatch problem," *Power Engineering Review, IEEE,* vol. 20, pp. 52-55, 2000.

[2] J. An, Y. Liu, H. Zhang, and Y. Sun, "Analytical study on economic dispatch," in *Control and Decision Conference (CCDC), 2010 Chinese*, pp. 583-585.

[3] T. Yalcinoz and H. Altun, "Power economic dispatch using a hybrid genetic algorithm," *Power Engineering Review, IEEE,* vol. 21, pp. 59-60, 2001.

[4] T. Yalcinoz, H. Altun, and M. Uzam, "Economic dispatch solution using a genetic algorithm based on arithmetic crossover," in *Power Tech Proceedings, 2001 IEEE Porto*, 2001, p. 4 pp. vol.2.

[5] S. Baskar, P. Subbaraj, and M. V. C. Rao, "Hybrid real coded genetic algorithm solution to economic dispatch problem," *Computers & Electrical Engineering,* vol. 29, pp. 407-419, 2003.

[6] N. Sinha, R. Chakrabarti, and P. K. Chattopadhyay, "Evolutionary programming techniques for economic load dispatch," *Evolutionary Computation, IEEE Transactions on,* vol. 7, pp. 83-94, 2003.

[7] L. d. S. Coelho and V. C. Mariani, "An improved harmony search algorithm for power economic load dispatch," *Energy Conversion and Management,* vol. 50, pp. 2522-2526, 2009.

[8] S. Ahmed Yousuf, "Economic dispatch using particle swarm optimization with bacterial foraging effect," *International Journal of Electrical Power & Energy Systems,* vol. 34, pp. 38-46, 2012.

[9] T. A. A. Victoire and A. E. Jeyakumar, "Hybrid PSO–SQP for economic dispatch with valve-point effect," *Electric Power Systems Research,* vol. 71, pp. 51-59, 2004.

[10] X.-S. Yang, S. S. Sadat Hosseini, and A. H. Gandomi, "Firefly Algorithm for solving non-convex economic dispatch problems with valve loading effect," *Applied Soft Computing,* vol. 12, pp. 1180-1186, 2012.

[11] S. K. Nayak, K. R. Krishnanand, B. K. Panigrahi, and P. K. Rout, "Application of Artificial Bee Colony to economic load dispatch problem with ramp rate limits and prohibited operating zones," in *Nature & Biologically Inspired Computing, 2009. NaBIC 2009. World Congress on*, 2009, pp. 1237-1242.

[12] S. Ozyon, C. Yasar, B. Durmus, and D. Aydin, "The application of artificial bee colony algorithm for the economic power dispatch with prohibited operating zone," in *Innovations in Intelligent Systems and Applications (INISTA), 2012 International Symposium on*, 2012, pp. 1-5.

[13] M. Ke, W. Hong Gang, D. ZhaoYang, and W. Kit Po, "Quantum-Inspired Particle Swarm Optimization for Valve-Point Economic Load Dispatch," *Power Systems, IEEE Transactions on,* vol. 25, pp. 215-222, 2010.

[14] K. T. Chaturvedi, M. Pandit, and L. Srivastava, "Self-Organizing Hierarchical Particle Swarm Optimization for Nonconvex Economic Dispatch," *Power Systems, IEEE Transactions on,* vol. 23, pp. 1079-1087, 2008.

[15] C. Po-Hung and C. Hong-Chan, "Large-scale economic dispatch by genetic algorithm," *Power Systems, IEEE Transactions on,* vol. 10, pp. 1919-1926, 1995.

[16] P. Civicioglu, "Transforming geocentric cartesian coordinates to geodetic coordinates by using differential search algorithm," *Computers & Geosciences,* vol. 46, pp. 229-247, 2012.