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The Effect of Wind Turbine Location on the Economic Load Dispatch Based on Particle Swarm Optimization

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Abstract— The economic load dispatch (ELD) represents one of the basic functions of power system operation and planning. In general, the task of ELD is to allocate optimally loads among on-line generating units in order to minimize the total operational cost subject to power balance, system reserve requirements and other system constraints. Renewable energy resources such as wind power have significant attention in recent years in power system field. It takes part to minimize the fuel consumption in the thermal units. This paper presents the influence of a wind turbine location on the optimization of ELD problem. The particle swarm optimization (PSO) technique is presented to solve this problem. The performance of the presented method is evaluated using two standard systems, and compared with two published methods. The first is evolutionary represented by the genetic algorithm (GA) and the second is determinist represented by the interior point (IP). In addition, a comparison between results obtained of money profits in different buses is done to choose the most cost effective wind penetration site.

Index Terms— Wind power penetration, economic load dispatch, particle swarm optimization technique, distribution network.

1 INTRODUCTION

POWER generation is necessary to supply a large number of consumers and to meet their needs. Designing electrical power generating stations requires efforts to achieve overall economy so that the per unit cost of generation is the lowest possible [1]. This problem named the economic load dispatch (ELD). The ELD problem is a vital tool for economic operation of power system. The main target of ELD of electric power generation is to schedule the outputs of committed generating unit and to meet the load demand at a certain time at minimum operating cost while satisfying various system and generator constraints [2]. Therefore, the ELD problem is considered as a large-scale highly constrained nonlinear optimization problem.

In the literature, many efforts have been made solve ELD problem, employing different kinds of constraints, mathematical programming and optimization techniques. The classical or conventional methods include Lambda Iteration method [3], Interior Point Method [4], Lagrangian relaxation [5], Dynamic programming [6]. The heuristic methods include Evolutionary algorithm [7], Differential Evolution [8], Particle Swarm Optimization (PSO) [9], Genetic Algorithm [10], Simulated Annealing [11] and Tabu Search [12].

With increasing of fuel prices and environmental concerns, the research and application on renewable energy applications have been commissioned in many countries under the consideration of diversifying energy sources. This leads to make further researches to study ELD problem in the case where a wind turbine is integrated into the transmission network [13]. As a result, the fitness function of fuel cost is modified. The influence of wind power penetration on the economic load dispatch consists in distributing the active productions between the power stations of the most economical way, in order to reduce the pollution of power stations and to maintain the stability of the system after penetration of wind energy under constraints bound to the machines active productions, to the energizing balance [14].

Due to the unpredictable nature of wind power, its penetration into traditional fuel based generation systems will cause some effects such as security concerns. Thus, in economic load dispatch with wind power penetration, a reasonable tradeoff between system risk and operational cost is desired. In [15] a modified multi-objective particle swarm optimization algorithm is used to develop a power dispatch scheme which is able to achieve the compromise between economic and security requirements.

In this paper, a wind power is injected in different distribution networks which are connected to the studied power system. At each time, the profit money is calculated. Then, all obtained money profits are compared and discussed to demonstrate the influence of wind turbine location in the optimization of the economic dispatch problem. A particle swarm optimization program is developed and applied on two different typical IEEE networks to calculate the results. The obtained results are compared with the results of two published methods. They are genetic algorithm and the interior point (IP) method.

The paper is organized as follows: Section 2 reviews the economic load dispatch problem. Section 3 describes the characteristics of systems used in this work and wind turbine. Ap-

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plications and simulations results are given in Sections 4. Finally, Section 5 concludes the work.

2 Problem Formulation

2.1 Economic Load Dispatch

The ELD problem formulation as discussed severally [3-12] will now be mathematically described.

2.1.1 Objective Function:

The classical ELD problem of finding the optimal combination of power generation, which minimizes the total fuel cost while satisfying the total required demand, can be mathematically stated as follows [3,16]:

$$C = \sum_{i=1}^{n} C_i(P_{Gi}) = \sum_{i=1}^{n} (a_i + b_i P_{Gi} + c_i P_{Gi}^2) \quad \$/hr \tag{1}$$

Where:

C: total fuel cost ($/hr), C_i: is fuel cost of generator i

a_i, b_i, c_i: fuel cost coefficients of generator i,

P_{Gi}: power generated (p.u)by generator i,

n: number of generator.

2.1.2 Constraints:

The economic load dispatch problem is subjects to the following constraints [3, 17]:

Power balance constraint: The total power generated must supply the total load demand and the transmission losses.

$$\sum_{i=1}^{n} P_{Gi} - P_D - P_{Loss} = 0 \tag{2}$$

Where, P_D is the total load demand (p.u.) and P_{Loss} is the transmission losses (p.u.). The transmission losses are given by [18]:

$$P_{Loss} = \sum_{i=1}^{n_l}\sum_{j=1}^{n_l}\left[A_{ij}\left(P_iP_j + Q_iQ_j\right) + B_{ij}\left(Q_iP_j - P_iQ_j\right)\right] \tag{3}$$

Where:

$$P_i = P_{Gi} - P_{Di}, \quad Q_i = Q_{Gi} - Q_{Di} \tag{4}$$

$$A_{ij} = \frac{R_{ij}}{V_iV_j}\cos(\delta_i - \delta_j), \quad B_{ij} = \frac{R_{ij}}{V_iV_j}\sin(\delta_i - \delta_j) \tag{5}$$

n_l : number of buses
R_{ij} : series resistance connecting buses i and j
V_i : voltage magnitude at bus i
δ_i : voltage angle at bus i
P_i : real power injection at bus i
Q_i : reactive power injection at bus i

Maximum and minimum limits of power generation: The power generated PGi by each generator is constrained between its minimum and maximum limits, i.e.,

$$P_{Gi\min} \le P_{Gi} \le P_{Gi\max}, \quad Q_{Gi\min} \le Q_{Gi} \le Q_{Gi\max}, \quad i = 1,\ldots,n \tag{6}$$

Where P_{Gimin} is the minimum power generated and P_{Gimax} is the maximum power generated.

The distribution networks are considered for the grid system as loads, when the wind power is injected in a distribution network (i.e. in a bus of transmission network), the load will decrease and the objective function remains and don't change as in [15], [17], [19].

2. 2 Particle Swarm Optimization Technique (PSO)

Particle swarm optimization (PSO) is a population based stochastic optimization technique developed by Kennedy and Eberhart in 1995 [20], inspired by social behavior of bird flocking or fish schooling.

PSO shares many similarities with evolutionary computation techniques such as genetic algorithms (GA). The system is initialized with a population of random solutions and searches for optima by updating generations. However, unlike GA, PSO has no evolution operators such as crossover and mutation.

The main features of the PSO technique can be summarized as follows [20]:

- PSO utilizes several searching points like GA and the searching points gradually get close to the optimal point using their personal best (pbests) and the global best (gbest).
- It is based on a simple concept. Therefore, the computation time is short and it requires little memory.
- It has a well-balanced mechanism to utilize diversification and intensification in the search procedure efficiently.
- It is originally developed for non-linear optimization problems with continuous variables. However, it is easily expanded to treat problems with discrete variables.
- There are few parameters to adjust. One version, with slight variations, works well in a wide variety of applications.

In a physical n-dimensional search space, parameters of PSO technique are defined as follows [20]:
$X_i = (x_{i1},\ldots,x_{in})$: Position individual i.
$V_i = (v_{i1},\ldots,v_{in})$: Velocity individual i.
$Pbest_i = (X_{i1}^{Pbest},\ldots,X_{in}^{Pbest})$: best position of individual i.
$Gbest_i = (X_{i1}^{Gbest},\ldots,X_{in}^{Gbest})$: best position neighbors of individual i.

Using the information, the updated velocity of individual i is modified by the following equation in the PSO algorithm [20]:

$$v_i^{k+1} = w.v_i^k + c_1.r_1.(pbest_i^k - x_i^k) + c_2.r_2.(gbest_i^k - x_i^k)$$

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(7)

Where,

w : weight parameter
v_i^k : velocity of particle i at iteration k,
x_i^k : position of particle i at iteration k,
r_1, r_2 : random number between 0 and 1,
$pbest_i^k$: pbest of particle i,
$gbest_i^k$: gbest of the population,
c_1, c_2 : acceleration constants.

The individual moves from the current position to the next position by the following equation:

$$X_i^{k+1} = X_i^{k+1} + V_i^{k+1} \tag{8}$$

The concept of modification of searching points described by Equations (7) and (8) is shown in Fig. 1.

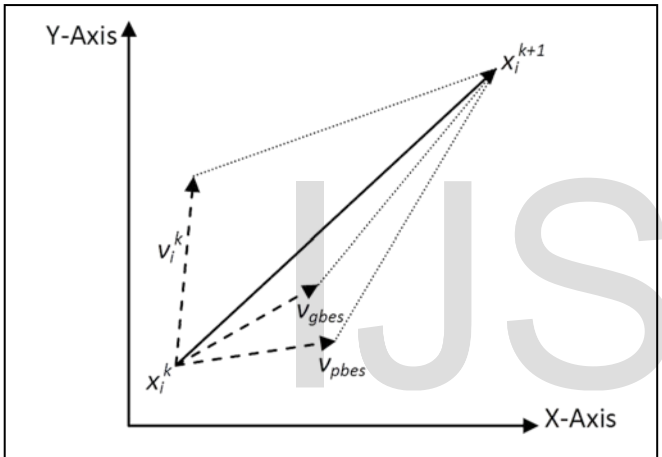

Fig. 1. Mechanism of PSO

The general particle swarm optimization algorithm may be applied to any optimization problem. The steps of the algorithm can be represented as the flow chart shown in Fig. 2.

3 Characteristics of Test Networks and Wind Turbine

For the sake of clear comparison with other published methods, the same test networks used in [14] are used in this paper. So, two typical networks IEEE 14-bus and IEEE 30-bus are considered, the first one is with 5 generators 20 lines while the second one is with 6 generators and 41 lines. The fuel coefficients values and power limits are given in Tables 1 and 2.

The wind turbine used in this work is of 2.7MW.

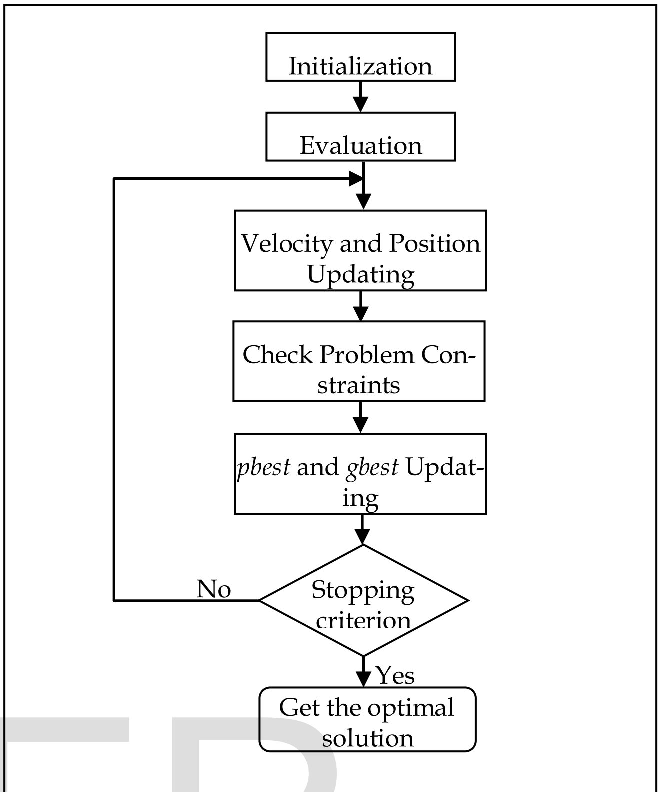

Fig. 1. Flowchart of PSO algorithm

TABLE 1
FUEL COST COEFFICIENTS AND POWER LIMITS OF IEEE 14-BUS NETWORK

Bus	a	b	c	P_{min}	P_{max}
1	0.0430293	20	0	0	332.4
2	0.25	20	0	0	140
3	0.01	40	0	0	100
6	0.01	40	0	0	100
8	0.01	40	0	0	100

TABLE 2
FUEL COST COEFFICIENTS AND POWER LIMITS OF IEEE 30-BUS NETWORK NETWORK

Bus	a	b	c	P_{min}	P_{max}
1	0.00375	2	0	50	200
2	0.0175	1.75	0	20	80
3	0.0625	1	0	15	50
6	0.0083	3.25	0	10	35
8	0.025	3	0	10	30
1	0.025	3	0	12	40

4. RESULTS

The PSO is developed to calculate the ELD problem and the profit money obtained before wind power injection. All results are compared with the results of interior point (IP) and genetic algorithm (GA) methods. To study the influence of wind turbine on the economic load dispatch problem, it is considered that weather and geographical constraints are given in all buses and the integration of a wind power is possible.

4.1 For IEEE 14-bus system

The best values of the PSO fitness function obtained for IEEE-14 bus are obtained with the parameters shown in Table (3):

TABLE 3
PSO PARAMETERS FOR IEEE 14-BUS SYSTEM

	PSO Parameters	
IEEE 14-bus	Number of Particles in the Swarm	80
	Number of Iterations	100
	w_{max}	0.9
	w_{min}	0.4

Before wind penetration, the best value obtained for the cost for the IEEE 14-bus system is 7991.2311 \$/h. Then, the wind power has been injected from the first bus until the 14th respectively. At each time, the money profits (the difference between the cost before wind penetration and after wind penetration) are calculated. The results are shown in Table 4.

TABLE 4
THE COST AND PROFIT MONEY BEFORE AND AFTER WIND PENETRATION FOR IEEE 14-BUS SYSTEM USING PSO METHOD

Bus	The cost before wind penetration (\$/h)	The cost after wind penetration in different buses (\$/h)	Profit money (\$/h)
1	7991.2311	7893.1991	98.0320
2	7991.2311	7888.0046	103.2265
3	7991.2311	7881.8568	109.3743
4	7991.2311	7883.1002	108.1309
5	7991.2311	7885.2183	106.0128
6	7991.2311	7885.6550	105.5761
7	7991.2311	7882.7909	108.4402
8	7991.2311	7882.9300	108.3011
9	7991.2311	7882.5570	108.6741
10	7991.2311	7881.9310	109.3001
11	7991.2311	7882.5745	108.6566
12	7991.2311	7884.1289	107.1022
13	7991.2311	7881.4521	109.7790
14	7991.2311	7879.6299	111.6012

From Table 4, one can notice that the cost decreases whatever the site of wind turbine, therefore there is always a money profit in fuel cost. However, the money profit values in different buses are not equal. The best money profit is obtained in the 14th bus (table 4). Therefore, according to the ELD solution, the best location of the wind turbine is at bus 14th.

4.2 For IEEE 30-bus system

The best values of the PSO fitness function obtained for IEEE-30 bus are obtained with the parameters shown in Table (5).

TABLE 5
PSO PARAMETERS FOR IEEE 30-BUS SYSTEM

	PSO Parameters	
IEEE 30-bus	Number of Particles in the Swarm	80
	Number of Iterations	100
	w_{max}	0.85
	w_{min}	0.3

Before wind penetration, the best value obtained for the cost for the IEEE 30-bus system is 793.4271 \$/h. Then, the wind power has been injected from the first bus until the 14th respectively. At each time, the money profits (the difference between the cost before wind penetration and after wind penetration) are calculated. The results are shown in Table 6.

TABLE 6
THE COST AND PROFIT MONEY BEFORE AND AFTER WIND PENETRATION FOR IEEE 30-BUS SYSTEM USING PSO METHOD

Bus	The cost before wind penetration (\$/h)	The cost after wind penetration in different buses (\$/h)	Profit money (\$/h)
1	793.4271	784.8038	8.6233
2	793.4271	784.4361	8.9910
3	793.4271	784.2165	9.2106
4	793.4271	784.0926	9.3345
5	793.4271	783.6670	9.7601
6	793.4271	783.9289	9.4982
7	793.4271	783.7370	9.6901
8	793.4271	783.7270	9.7001
9	793.4271	783.7669	9.6602
10	793.4271	783.7055	9.7216
11	793.4271	783.7497	9.6774
12	793.4271	783.9281	9.4990
13	793.4271	783.8603	9.5668
14	793.4271	783.8269	9.6002
15	793.4271	783.7119	9.7152
16	793.4271	783.8691	9.5580
17	793.4271	783.7281	9.6990
18	793.4271	783.5304	9.8967
18	793.4271	783.4490	9.9781
20	793.4271	786.8581	6.5690
21	793.4271	783.6569	9.7702
22	793.4271	783.6261	9.8010

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23	793.4271	783.5281	9.8990
24	793.4271	783.5040	9.9231
25	793.4271	783.5467	9.8804
26	793.4271	783.4260	10.0011
27	793.4271	783.6290	9.7981
28	793.4271	783.7231	9.7040
29	793.4271	783.4159	10.0112
30	793.4271	783.4464	9.9807

From Table 6, one can notice that the cost decreases whatever the site of wind turbine, therefore there is always a money profit in fuel cost. However, the money profit values in different buses are not equal. The best money profit is obtained in the 29th bus (table 6). Therefore, according to the ELD solution, the best location of the wind turbine is at bus 29th.

From the results of Tables 4 and 6, when a wind turbine with P MW was injected in a distribution network i (i.e in the i-th bus of transmission network), the load of this bus decrease P MW because it is compensated by the wind penetration. This will lead to decrease the total power generated by different thermal station, so the cost of fuel decrease automatically.

4.3 Comparison with Other Methods

Tables 7 and 8 show the profit money using the PSO technique in comparison with other published methods. These methods are IP [14] and GA [14]. These comparisons show the superiority of the presented method over other methods.

With the development of modern power systems, ELD problem has received an increasing attention. The economic load dispatch aims to minimize the fuel cost while provides consumers with adequate and secure electricity. The integration of a wind penetration in a distribution network was considered as a new solution to minimize the cost of fuel which used to generate the electricity from the thermals stations, according to its operating principle where it is based on a renewable energy that is always free, and to the necessary results of money profit obtained. The above results show that the fuel cost for the thermal station decreases and gain money is obtained whatever is the site of integration of a wind penetration.

TABLE 7
THE PROFIT MONEY IN DEFERENT BUSES OF IEEE 14-BUS SYSTEM GIVEN BY DIFFERENT METHODS

Bus	Profit money by PSO ($/h)	Profit money by GA ($/h) [14]	Profit money by IP ($/h) [14]
1	98.0320	98.4345	98.7171
2	103.2265	103.4705	103.5277
3	109.3743	109.4026	109.5170
4	108.1309	108.5074	108.8202
5	106.0128	106.4500	107.6043
6	105.5761	106.3585	107.3334
7	108.4402	108.6450	108.7316
8	108.3011	109.1575	108.3901
9	108.6741	108.9464	108.8695
10	109.3001	109.8663	109.4947
11	108.6566	109.0132	108.7839
12	107.1022	107.3120	109.1565
13	109.7790	110.0071	110.3505
14	111.6012	111.8356	111.9412

TABLE 8
THE PROFIT MONEY IN DEFERENT BUSES OF IEEE 30-BUS SYSTEM GIVEN BY DIFFERENT METHODS

Bus	Profit money by PSO ($/h)	Profit money by GA ($/h) [14]	Profit money by IP ($/h) [14]
1	8.6233	8.9585	8.9709
2	8.9910	9.3119	9.3099
3	9.2106	9.5021	9.4933
4	9.3345	9.6085	9.6349
5	9.7601	9.9144	9.8687
6	9.4982	9.6998	9.7157
7	9.6901	9.8894	9.8626
8	9.7001	9.7146	9.7067
9	9.6602	9.7119	9.7061
10	9.7216	9.7113	9.7102
11	9.6774	9.7021	9.6841
12	9.4990	9.5674	9.5959
13	9.5668	9.5613	9.5743
14	9.6002	9.7430	9.7445
15	9.7152	9.8743	9.8370
16	9.5580	9.6833	9.7214
17	9.6990	9.7881	9.7621
18	9.8967	9.9161	9.9353
18	9.9781	9.9942	9.9622
20	6.5690	6.2800	9.9038
21	9.7702	9.8707	9.8519
22	9.8010	9.8655	9.8436
23	9.8990	9.9546	9.9313
24	9.9231	10.0138	9.9816
25	9.8804	9.9708	19.8340
26	10.0011	10.1206	9.9311
27	9.7981	9.8316	10.2133
28	9.7040	9.7519	9.8168
29	10.0112	10.0889	10.0380
30	9.9807	10.0890	10.2042

5. CONCLUSION

The influence of a wind turbine location on the optimization of ELD problem is presented in this paper where particle swarm optimization technique is used to calculate the optimal cost. The presented method is applied on IEEE 14-bus and IEEE 30-bus systems. For each system, the optimal cost is calculated before and after the integration of wind power where the wind generator is moved from bus to another. At each time, the cost and the money profit are calculated. The best location of this wind generator was determined and discussed according to the best money profit value. The results of the presented method are compared with other published methods. The results show the superiority of PSO over GA and IP methods where PSO gives better performance over GA and IP for all cases. From the results, we can conclude that the fuel cost for the thermal stations decreases with integration of wind power whatever is the site of this integration. Finlay, it is suggested that to add the economic load dispatch problem, with constraints, in the choice of the best wind turbine location.

REFERENCES

[1] B. Zhou, K.W. Chan, T. Yu and C. Y. Chung, “Equilibrium-Inspired Multiple Group Search Optimization with Synergistic Learning for Multiobjective Electric Power Dispatch,” IEEE Transactions on Power Systems, vol. 28, pp. 3534-3545, 2013.

[2] M. A. Abido, “Multiobjective Evolutionary Algorithms for Electric Power Dispatch Problem,” IEEE Transactions on Power Systems, vol. 10, pp. 315-329, 2006.

[3] J. Zhu, Optimization of power system operation, John Wiley inc., 2009.

[4] X. S. Han and H. B. Gooi, “Effective economic dispatch model and algorithm,” International Journal of Electrical Power and Energy Systems, vol. 29, no. 2, pp. 113–120, 2007.

[5] Z. Li, W. Wu, B. Zhang, H. Sun and Q. Guo, “Dynamic Economic Dispatch Using Lagrangian Relaxation With Multiplier Updates Based on a Quasi-Newton Method,” IEEE Transactions on Power Systems, vol. 28, pp. 4516-4527, 2013.

[6] Y. Xu, W. Zhang and W. Liu, “Distributed Dynamic Programming-Based Approach for Economic Dispatch in Smart Grids,” IEEE Transaction on Industrial Informatics, vol. 11, no. 1, pp.166-175, 2015.

[7] S. Hazra, P. Roy and A. Sinha, “An efficient evolutionary algorithm applied to economic load dispatch problem,” Third International Conference of Computer, Communication, Control and Information Technology (C3IT), 7-8 Feb. 2015, pp. 1-6.

[8] A.A. Abou El Elaa, M.A. Abidob and S.R. Speaa, “Differential evolution algorithm for emission constrained economic power dispatch problem,” Electric Power Systems Research, vol. 80, pp. 1286-1292, 2010.

[9] S. Agrawal, T. Bakshi and and D. Majumdar “Economic Load Dispatch of Generating Units with Multiple Fuel Options Using PSO,” International Journal of Control and Automation Vol. 5, No. 4, Dec., 2012.

[10] B. Goswami and V. Agrawal,” Security Constrained Economic Dispatch using a hybrid Fuzzy Genetic Algorithm approach,” International Conference on Computer Communication and Informatics (ICCCI), Jan. 4-6, 2013, pp. 1-6.

[11] S. Padmini, S. Dash, Vijayalakshmi, S. Chandrasekar, “Comparison of Simulated Annealing over Differential Evolutionary technique for 38 unit generator for economic load dispatch problem,” National Conference on advances in electrical energy applications, Jan., 2013.

[12] S. Pothiya, I. Ngamroo and W. Kongprawechmon, “Application of multiple tabu search algorithm to solve dynamic economic dispatch considering generator constraints”, Energy Convers. Manage., vol. 49, no. 4, pp. 506-516, 2007.

[13] H. Gangammanavar, S. Sen and V. Zavala, “Stochastic Optimization of Sub-Hourly Economic Dispatch With Wind Energy,” IEEE Transactions on power systems, vol. pp (in press), no. 99, 2015.

[14] A.Khattara, A. Aboubou, M. Bahri, et al, “Influence of Wind Penetration in the Optimization of the Economic Dispatch,” 1st International Conference on Renewable Energies and Vehicular Technology, 2012, pp. 415-419.

[15] L. Wang and C. Singh, “Tradeoff Between Risk and Cost in Economic Dispatch Including Wind Power Penetration Using Particle Swarm Optimization,” IEEE International Conference on Power System Technology (PowerCon2006), Oct. 22-26, 2006, pp. 1-7.

[16] D. Obioma and A. Izuchukwu, “Comparative Analysis of Techniques for Economic Dispatch of Generated Power with Modified Lambda-iteration Method,” 2013 IEEE International Conference on Emerging & Sustainable Technologies for Power & ICT in a Developing Society (NIGERCON), 2013, pp. 231-237.

[17] A.Khattara, A. Aboubou, M. Bahri, et al, “Influence of Wind Turbine Location in the Optimization of the Economic Dispatch Using Genetic Algorithm Method,” 4th International Conference on Power Engineering, Energy and Electrical Drives (POWERENG2013), Turkey, May 13-17, 2013, pp. 1498-1503.

[18] Hadi Saadat, "Power System Analysis", 2nd Edition, McGraw-Hill, 2004.

[19] V. Miranda, and P. S. Hang, “Economic Dispatch Model with Fuzzy Wind Constraints and Attitudes of Dispatchers,” IEEE Transactions on power systems, vol. 20, no. 4, pp. 2143 – 2145, Nov. 2005.

[20] J. Kennedy and R. Eberhart, “Particle swarm optimization,” in Proc.IEEE Int. Conf. Neural Networks (ICNN’95), vol. IV, Perth, Australia,1995, pp. 1942–1948.

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