CHOICE OF WIND TURBINE LOCATION ACCORDING TO ITS INFLUENCE ON THE OPTIMIZATION OF THE ECONOMIC DISPATCH PROBLEM USING GENETIC ALGORITHM METHOD

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Abstract: *The wind turbine location is fundamental to its performance, but there are other factors that should be taken into account when deciding the best position for a wind turbine. This paper gives the best wind turbine location according to its influence on the optimization of the economic dispatch problem; a genetic algorithm (GA) program is developed to solve this problem and the results are verified by interior point (IP) method then a moneys profits comparison between obtained results in different buses is done and a new condition is proposed to choose the wind turbine location.*

Key words*: Economic dispatch, genetic algorithm, interior point, wind turbine location.*

1. Introduction

In all engineering works, the question of cost is of first importance. In most case the cost decides whether a certain project will be carried or not, although political and other considerations may intervene sometimes. The electrical power supplier is required to supply power to a large number of consumers to meet their requirement. While designing electrical power generating station and other systems efforts are made to achieve overall economy so that the per unit cost of generating is the lowest possible [1]. This problem named the economic dispatch problem.

In the literature dedicated to the optimization of cost objective function, many researchers proposed different solutions [2]; a proposition to methodology (GA-Matpower-OPF) that solves OPF (optimal power flow) including both active and reactive power dispatches. It is based on combining the Genetic Algorithm (GA) to obtain a near global solution, and the package of Matlab m-files for solving power flow and optimal power flow problems (Matpower) to determine the optimal global solution. This method was tested on the modified IEEE 57 bus test system. The results obtained by this method are compared with those obtained with GA or Matpower separately [3], other proposition to new methodology for solving dynamic economic dispatch. Comparing with other evolutionary methods like genetic algorithm, particle swarm optimization has been provided for 10-generator system with non-smooth fuel cost functions to illustrate the suitability and effectiveness of the proposed method [4], a proposition to a genetic algorithm hybrid method based approach to optimal load dispatch problem. The load flow in electric network is used to minimize line losses, and, therefore the cost function of electric power production [5]. Dynamic economic dispatch problem in power system considering valve-point effects of generators is a non-smooth, non-convex and multi-dimensional constrained optimization problem [6], in [7] a novel consensus based algorithm is proposed to solve the economic dispatch problem EDP in a distributed fashion, a multi-objective model for the CHPED (combined heat and power economic dispatch) problem is developed in [8] to conventional energy stations, where the competing fuel cost and environmental impact objectives are simultaneously optimized. Others researches are made to study the economic dispatch problem in the case where integrate the wind penetration in the transmission network, they modify then the fitness function of fuel cost; the work presented in [9] introduces a new method for generating correlated wind power values and explains how to apply the method when evaluating Economic Dispatch. A case study is provided to analyze whether considering correlation in the problem has any influence or not. The Influence of Wind Power Penetration on the Economic Dispatch (IWPPED) consists in distributing the active productions between the power stations of the most economic way, to reduce the emissions of the polluting gases and to maintain the stability of the network after penetration of wind energy under constraints bound to the machines active productions, to the energizing balance [10]. The penetration of wind power into traditional fuel based generation systems will also cause some implications such as security concerns due to its unpredictable nature. Thus, in economic power dispatch with power penetration, a reasonable tradeoff between system risk and operational cost is desired, a bi-objective economic dispatch problem considering wind penetration is formulated, which treats economic and security impacts as conflicting objectives. A modified multi-objective particle swarm optimization (MOPSO) algorithm is adopted to develop a power dispatch scheme which is able to achieve the compromise between economic and security requirements. The numerical simulations including sensitivity analysis are carried out based on a typical IEEE test power system to show the validity and applicability of the proposed approach [11]. In this paper, a wind power is injected in different distribution networks which are connected to the studied power system; at each time the cost of optimal power flow OPF is obtained and the profit money is calculated; 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 genetic algorithm program is developed and applied on two different typical IEEE networks to calculate the results. The obtained results are validated by the interior point method; this validation was done by the linear programming LP method in [12].

2. Problem formulation

2.1. Power Flow Equations

The power flow problem may be stated with some precisions. The formulation is based on operational consideration of the power industry as well as mathematical considerations [13].

$$\begin{cases} P_i = \sum_{j=1}^{n} |V_i||V_k|(G_{ik}\cos\theta_{ik} + B_{ik}\sin\theta_{ik}) & (1) \\ Q_i = \sum_{k=1}^{n} |V_i||V_k|(G_{ik}\sin\theta_{ik} - B_{ik}\cos\theta_{ik}) & (2) \end{cases}$$

Vi, Vk, are the voltages in the i-th and k-th bus respectively, the Gik are called conductances, and Bik are called susceptances , θik is the argument.

2.2. Economic dispatch problem

The optimal power flow OPF problem is to minimize the objective function, fuel cost, while satisfying several equality and inequality constraints [14].

$$F_i(P_i) = a_i P_i^2 + b_i P_i + c_i \qquad (3)$$

The minimization of the total function cost of electric energy production consists of solving the following equation:

$$\min\ F = \sum_{i=1}^{i=ng} F_i(P_i) \qquad (4)$$

Where a_i, b_i and c_i are the cost coefficients of the i-th generator and n is the number of generators committed to the operating system. P_i is the power output of the i-th generator. The economic dispatch problem is subjects to the following constraints [15]:

$$P_{imin} \le P_i \le P_{imax} \qquad for\ i = 1 \ldots..ng \qquad (5)$$

$$\sum_{i=1}^{ng} P_i - D - L = 0 \qquad (6)$$

$$where \qquad L = \sum_{i=1}^{ng} B_i P_I^2 \qquad (7)$$

Where D is the load demand and L represents the transmission losses. B represents coefficients of transmission losses. P_{mini} and P_{maxi} are the minimum and maximum generation output of the i-th generator.

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 [9, 10, 11].

2.3. Genetic algorithm

The use of genetic algorithms for problem solving is not new. GA, invented by Holland [16] in the early 1970s, is a stochastic global search method that mimics the metaphor of natural biological evaluation. Since then, the output of research work in this field has grown exponentially although the contributions have been, and are largely initiated, from academic institutions world-wide.

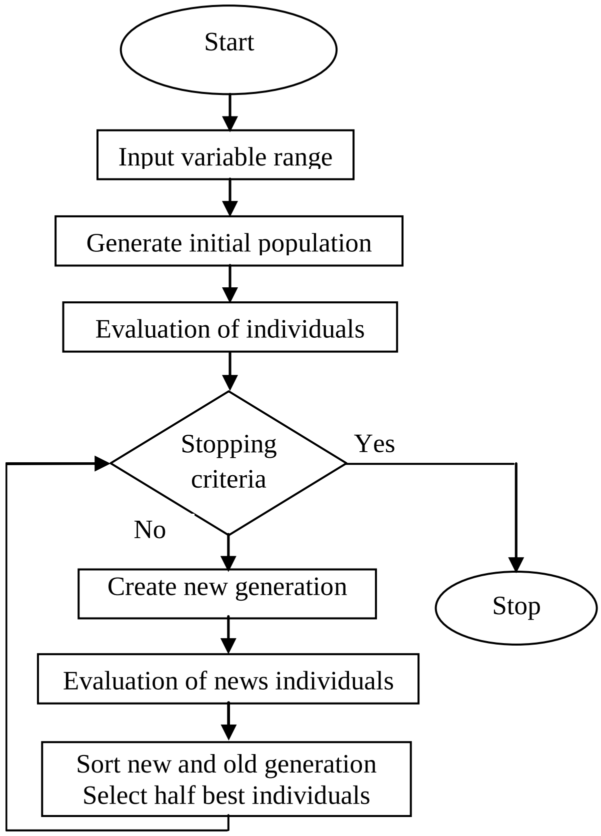

Fig. 1. Outline of GA for optimization problems.

GA operates on a population of candidate solutions encoded to finite bit string called chromosome. In order to obtain optimality, each chromosome exchanges information by using operators borrowed from natural genetic to produce the better solution. Figure 1 shows outline of GA for optimization problems. The GA differs from other optimization and search procedures in four ways [17]:

- GA work with a coding of the parameter set, not the parameters themselves. Therefore GA can easily handle the integer or discrete variables.
- GA search from a population of points, not a single point. Therefore GA can provide globally optimal solutions.
- GA use only objective function information, not derivatives or other auxiliary knowledge. Therefore GA can deal with the non-smooth, non continuous and non-differentiable functions which are actually existed in a practical optimization problem.
- GA use probabilistic transition rules, not deterministic rule.

3. Characteristics

In this work two IEEE typical networks are considered, 14-bus and 30-bus, the first is with 5 generators 20 lines; and the second is with 6 generators and 41 lines. The fuel coefficients values and power limits are given in tables 1 and 2.

Table 1
The fuel coefficient values and power limits Of IEEE 14-Bus Network

bus	a	b	c	Pmin	Pmax
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
The fuel coefficient values and power limits Of IEEE 30-Bus Network

bus	a	b	c	Pmin	Pmax
1	0.00375	2	0	50	200
2	0.0175	1.75	0	20	80
5	0.0625	1	0	15	50
8	0.0083	3.25	0	10	35
11	0.025	3	0	10	30
13	0.025	3	0	12	40

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

4. Simulation Results

A genetic algorithm program is developed to calculate the economic dispatch ED problem and the profit money obtained before wind power injection. All results are validated by IP method. To chose the best location of wind turbine according its influence on the economic dispatch problem, it is considered that weather and geographical constraints are done in all buses and the integration of a wind power is possible.

4.1. For IEEE 14-bus

The best values of the fitness function obtained for IEEE-14 bus are obtained with the following parameters: generation=100, population size= 90, crossover= 0.75 and mutation= 0.07 [18].

At all times when the ED problem is calculated, the equality (equation 6) and inequality (equation 5) constraints are checked. The fig.3 shows that the powers generated (Pg) by the power stations to calculate the best value of ED problem are in the interval specified by the maximum (Pmax) and minimum (Pmin) power constraints. The obtained optimal cost value is then acceptable.

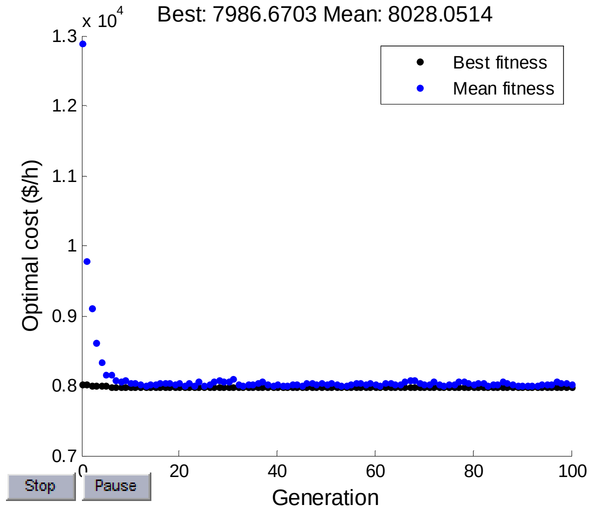

Fig. 2. Best value of the fitness function for IEEE 14-Bus by GA method.

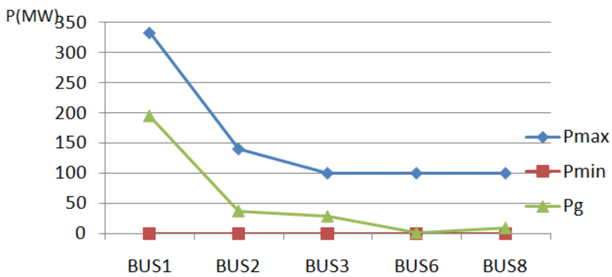

Fig. 3. The state of the generated powers obtained by GA compared to the constraints for a network of 14-Bus.

The wind power has been injected from the first bus until the 14th respectively. At each time the calculated money profit is confirmed by the IP method. The table 3 summarizes the results (listed) and gives the type of each bus. The results are listed from the less to the up value of money profits in order to determine the constraints that affect the money profit.

According to the results of the table 3, it is checked that the money profit value is positive whatever the site of wind power injection is. So, one always have a money profit in fuel cost when the wind power is injected, but what are the constraints to choose the best location of this wind turbine between those of 14 different places. The money profits are calculated by GA method and they confirmed by IP method, the results calculated by those different methods are closed and the small differences between them because the mode of calculation for each method.

Table 3
Cost and the money profit before wind penetration in different buses of ieee 14-bus network

bus	Type	The cost after wind penetration ($/h)	Money profit ($/h)	Confirmation by IP method ($/h)
1	Slack	7986,6703	98.7354	98.7171
2	PV	7981,8934	103.4705	103.5277
6	PQ	7979,0054	106.3585	107.3334
5	PQ	7978,9139	106.4500	107.6043
12	PQ	7978,0519	107.3120	109.1565
7	PQ	7976,9189	108.6450	108.7316
4	PQ	7976,8565	108.5074	108.8202
9	PQ	7976,4175	108.9464	108.8695
11	PV	7976,3507	109.0132	108.7839
8	PQ	7976,2064	109.1575	108.3901
3	PV	7975,9613	109.4026	109.517
10	PV	7975,4976	109.8663	109.4947
13	PQ	7975,3568	110.0071	110.3505
14	PQ	7973,5283	111.8356	111.9412

Table 4
The line parameters of IEEE 14-bus network

Bus from	bus to	G pu	1/X pu	y pu
1	2	51,5996	16,9005	54,3133
1	5	18,5082	4,4835	19,0552
2	3	21,2811	5,0513	21,8825
2	4	17,2087	5,6715	18,1299
2	5	17,5593	5,7511	18,4879
3	4	14,9231	5,8469	16,0324
4	5	74,9064	23,7473	78,5805
4	7	0,0000	4,7819	4,7819
4	9	0,0000	1,7980	1,7980
5	6	0,0000	3,9679	3,9679
6	11	10,5285	5,0277	11,6674
6	12	8,1360	3,9092	9,0264
6	13	15,1172	7,6764	16,9545
7	8	0,0000	5,6770	5,6770
7	9	0,0000	9,0901	9,0901
9	10	31,4367	11,8343	33,5904
9	14	7,8672	3,6985	8,6932
10	11	12,1877	5,2064	13,2532
12	13	4,5265	5,0030	6,7468
13	14	5,8503	2,8734	6,5179

The money profit values in different buses are not equal (Table3), and they vary from a value of 13.142 ($/h), this variation value is important; it is necessary than to determine the network parameters influence on the optimal power flow cost.

The table 4 gives the line parameters of IEEE 14-bus.

The best profit money is obtained in the 14th bus (table 3), and it is observed in table IV that this bus is connected with the 9th and the 13th buses. The conductance and admittance of lines connected to the 14th bus are less than other conductance and admittance of lines connected to other buses; this note is true just with load buses PQ but not with control PV and slack buses.

According to the power flow equations (1 & 2), it is noted that the active and reactive powers are according to the admittance lines, when the admittance line increases the load power increases too. Now, according to the economic dispatch equation (3) and the equality constraint (5), if the load power increases, the generated power increases and the cost of fuel increases too.

Similarly, if the admittance lines decrease the cost of fuel decreases

4.2. **For IEEE 30-bus**

The best values of the fitness function obtained for IEEE-30 bus are the one obtained with the following parameters: the generation= 100, population size= 90, crossover= 0.75 and mutation= 0.08 [18].

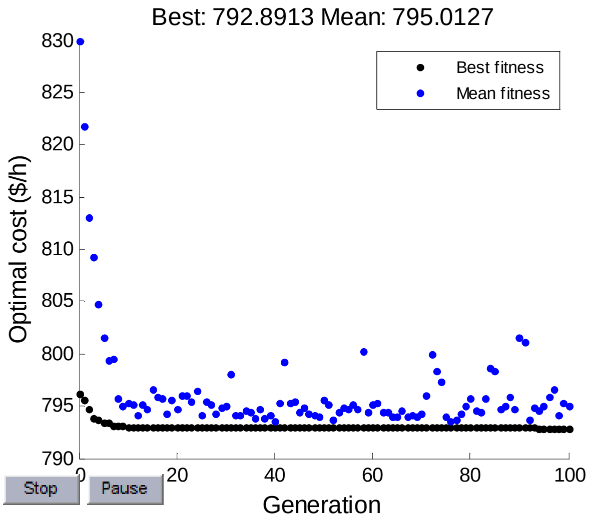

Fig. 4. The state of the generated powers obtained by GA compared to the constraints for a network of 14-Bus.

Each time when the best value of the fitness function is obtained, the equality and inequality constraint are checked and the power generated from the different stations are in the intervals limited by the maximum and minimum power constraints of those stations.

The wind power has been injected from the first bus to the 30th respectively. At each time the money profit is calculated, it is validated by the IP method. The table 5 summarizes the results (listed from the less to the up value of money profits) and gives the type of each bus.

According to the results of the table 5, it is checked that the money profit value is positive whatever the site of wind power injection is. So one always have a money profit in fuel cost, but what are the constraints to choose the best location of this wind turbine between those of 30 different places according to the optimal economic dispatch.

Similar than the money profit obtained in IEEE 14-bus, the obtained money profit values in different buses of IEEE 30-bus are not equal, and the difference between the maximum and the minimum money profit is 3.9848($/h).

The table 6 gives the line parameters of IEEE 30-bus.

The best money profit is obtained in the 30th bus, which is connected with the 27th and the 29th buses (Table 6), where the conductance and the admittance lines connecting them are less than other connections in one bus. This comment is just for load buses *PQ* but not with control *PV* and slack buses.

Table 5.
The Cost And The Money Profit Before Wind Penetration In Deferent Buses Of IEEE 30-Bus Network

Bus	Type	The cost after wind penetration ($/h)	profit money ($/h)	confirmation by IP method ($/h)
20	PQ	795,5665	6,28	9,9038
1	REF	792,8913	8,9481	8,9709
2	PV	792,5346	9,3119	9,3099
3	PQ	792,3444	9,5021	9,4933
13	PV	792,2852	9,5613	9,5743
12	PQ	792,2791	9,5674	9,5959
4	PQ	792,238	9,6085	9,6349
16	PQ	792,1632	9,6833	9,7214
6	PQ	792,1467	9,6998	9,7157
11	PV	792,1444	9,7021	9,6841
10	PQ	792,1352	9,7113	9,7102
9	PQ	792,1346	9,7119	9,7061
8	PV	792,1319	9,7146	9,7067
14	PQ	792,1035	9,743	9,7445

28	PQ	792,0946	9,7519	9,8168
17	PQ	792,0584	9,7881	9,7621
27	PQ	792,0149	9,8316	10,2132
22	PQ	791,981	9,8655	9,8436
21	PQ	791,9758	9,8707	9,8519
15	PQ	791,9722	9,8743	9,837
7	PQ	791,9571	9,8894	9,8626
5	PV	791,9321	9,9144	9,8687
18	PQ	791,9304	9,9161	9,9353
23	PQ	791,8919	9,9546	9,9313
25	PQ	791,8757	9,9708	19,834
19	PQ	773,7215	9,9942	9,9622
24	PQ	791,8327	10,0138	9,9816
29	PQ	791,7576	10,0889	10.038
26	PQ	791,7259	10,1206	9,9311
30	PQ	791,5817	10.2648	10,2042

When a wind power is injected to the power system the power generated by the thermal stations and the fuel demanded in those thermal stations decrease, because a part of the power generated by the thermal stations is compensated by this wind turbine injected, then the fuel cost decreases too.

According to the power flow equations, it is noted that the active and reactive powers are according to the admittance lines, when the admittance line increases the load power increases too. Now, according to the economic dispatch equation and the equality constraint, if the load power increases, the generated power increases and the cost of fuel increases too.

Similarly, if the admittance lines decrease the cost of fuel decreases.

Table 6.
The line parameters Of IEEE 30-Bus Network

Bus from	bus to	G p.u	1/X p.u	y p.u
1	2	52,0833	17,3913	54,9102
1	3	22,1239	5,3996	22,7733
2	4	17,5439	5,7571	18,4643
3	4	75,7576	26,3852	80,2209
2	5	21,1864	5,0429	21,7783
2	6	17,2117	5,6721	18,1223
4	6	84,0336	24,1546	87,4362
5	7	21,7391	8,6207	23,3860
6	7	37,4532	12,1951	39,3886
6	8	83,3333	23,8095	86,6680
6	9	1/0,00	4,8077	4,8077
6	10	1/0,00	1,7986	1,7986
9	11	1/0,00	4,8077	4,8077
9	10	1/0,00	9,0909	9,0909
4	12	1/0,00	3,9063	3,9063
12	13	1/0,00	7,1429	7,1429
12	14	8,1235	3,9078	9,0145
12	15	15,1057	7,6687	16,9409
12	16	10,5820	5,0327	11,7178
14	15	4,5249	5,0075	6,7491
16	17	12,1359	5,2002	13,2031
15	18	9,3197	4,5767	10,3828
18	19	15,6495	7,7399	17,4589
19	20	29,4118	14,7059	32,8834
10	20	10,6838	4,7847	11,7062
10	17	30,8642	11,8343	33,0553
10	21	28,7356	13,3511	31,6858
10	22	13,7552	6,6711	15,2875
21	22	86,2069	42,3729	96,0577
15	23	10,0000	4,9505	11,1583
22	24	8,6957	5,5866	10,3356
23	24	7,5758	3,7037	8,4326
24	25	5,3050	3,0377	6,1132
25	26	3,9308	2,6316	4,7304
25	27	9,1491	4,7916	10,3279
28	27	1/0,00	2,5253	2,5253
27	29	4,5496	2,4079	5,1475
27	30	3,1230	1,6592	3,5364
29	30	4,1684	2,2060	4,7162
8	28	15,7233	5,0000	16,4991
6	28	59,1716	16,6945	61,4816

5. Conclusion

The choice of a wind turbine location according to its influence on the optimization of the economic dispatch was presented in this paper, a wind turbine was chosen and connected to different buses of two different IEEE networks. This wind turbine was moved from a bus to another and at each time the money profit was calculated. The best location of this wind turbine was determined and discussed according to the best money profit value. A genetic algorithm program was developed to calculate the optimal economic dispatch before and after the wind power penetration and the results were checked by the interior point method. Finlay this paper proposes to add the influence of wind turbine location on the optimization of the economic dispatch problem, with constraints, in the choice of the best wind power location.

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