Influence of Wind Turbine Location in the Optimization of the Economic Dispatch Using Genetic Algorithm Method

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Abstract— **The location of a wind turbine is fundamental to enhance its performance. However, there are other factors that should be taken into account when deciding the best position for a wind turbine. This paper presents the influence of a wind penetration sitting in different distribution networks for the optimization of the economic dispatch problem. A genetic algorithm is developed to solve this problem. A comparison between results of money profits obtained in different buses is done and a new condition is proposed to choose the most cost effective wind penetration site.**

Keywords-Economic dispatch; distribution network; genetic algorithm; wind penetration.

I. INTRODUCTION

The cost issue is of prime importance in all engineering works. In most cases, the cost decides if a project will be realized or not, although political and others considerations may occur sometimes. A power generation is necessary to supply a large number of consumers and to meet their needs. When designing electrical power generating stations, efforts should have been made to achieve overall economy so that the per unit cost of generation is the lowest possible [1].

In the literature, many researches proposed different solutions dedicated to the optimization of the cost objective function [2]. Much of works are made to solve this problem by using different calculation methods, either heuristics or determinists [3], [4], [5], [6], [7]. Further researches are made to study the economic dispatch problem in the case where a wind turbine is integrated into the transmission network [8], [9], [10]. The development of a wind farm is typically initiated by a land owner, a developer or the proactive planning of a local community. In each case, the process starts with finding a site that is suitable for a wind farm development [11]. Site matching of wind turbine generators is investigated based on the appropriate selection of statistical models and means of wind speed data. The wind speed means are computed using arithmetic mean, root mean square and cubic mean cube root. Wind speed frequency distributions are modelled using Weibull and Rayleigh probability density functions. Wind speed data of an existing wind power station, located at Kappadagudda, Karnataka, India, is used for computational purposes [12]. A wide range of studies were conducted on two different sized reliability test systems. The contribution of wind energy conversion systems (WECS) to the reliability performance of a generation system can be quantified and is highly dependent on the wind site conditions [13]. The site matching is based on identifying optimum turbine speed parameters from turbine performance index curve. This latter is obtained from the normalized curves, so as to yield higher energy production at higher capacity factor. The wind speedsare parameterized using cubic mean cube root and statistically modelled using Weibull probability density function. An expression for normalized power and capacity factor, expressed entirely in normalized rated speed, is derived. Wind Turbine Performance Index, a new ranking parameter, is defined to optimally match turbines to a potential wind site. The plots of normalized power, capacity factor and turbine performance index versus normalized rated wind speed are drawn for a known value of Weibull shape parameter of a site [14]. An investigation to optimum sitting of wind turbine generators from the viewpoint of site and wind turbine generator selection is mandatory. The analysis methodology is based on the accurate assessment of wind power potential of various sites. The analytical computations of annual and monthly capacity factors are done using the Weibull statistical model using cubic mean cube root of wind speeds. As many as fifty-four potential wind sites, with and without wind turbine installations, geographically distributed in different states of India were used for the sitting analysis [15]. A study was done to find the best way to distribute wind-generating capacity among several sites by using an electricity-production, cost and reliability model. These benefiting terms are calculated for reducing the fuel cost of conventional generators. It’s also considered that system reliability in terms of energy not served (ENS). The findings indicate that it is beneficial to develop wind power plants at several sites, and that there are many possible combinations of wind locations that can be chosen to obtain diversity benefits. The capacity credit is calculated for the composite wind power plants using two different methods,

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and calculates a trade-off curve between the economically optimal and the most reliable solutions. The chosen methods are a dynamic fuzzy search algorithm and a genetic algorithm. Each procedure produces a solution set that can be analysed further in other contexts, such as voltage and land use constraints. The sensitivity of the fuzzy economic benefit solutions is illustrated to small perturbations of the capacity selections at each wind site. Small changes in site capacity are found and/or locations have small effects on the economic benefit provided by wind power plants [16]. It is demonstrated in [17] that gain in money is obtained whatever is the site of integration of a wind power. 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 linear programming LP method.

II. Problem Formulation

A. 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 [18].

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

V_i, V_k, are the voltages in the i-th and k-th bus respectively, the G_{ik} are called conductances, and B_{ik} are called susceptances , θ_{ik} is the argument.

B. Economic dispatch problem

The optimal power flow OPF problem is to minimize the objective function, fuel cost, while satisfying several equality and inequality constraints [19].

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

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

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

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. Pi is the power output of the i-th generator. The economic dispatch problem is subjects to the following constraints [20]:

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

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

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

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 [8], [9], [10].

C. Genetic algorithm

The use of genetic algorithms to solve problems is not new. GA, were invented by Holland [21] in the early 1970s, it 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.

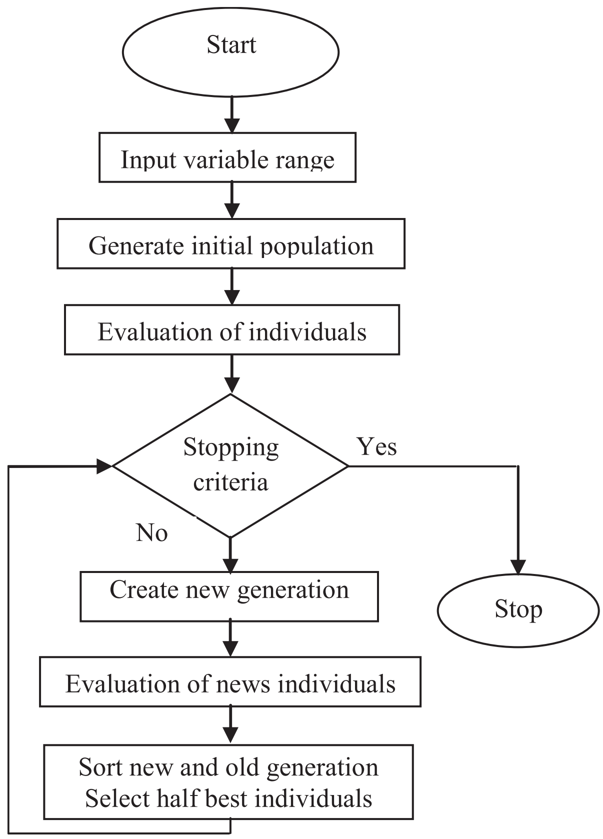

Figure 1. Outline GA for optimization problems.

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 points [22]:

- 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 actually exist in a practical optimization problem.

- GA use probabilistic transition rules, not deterministic one.

III. Characteristics of Networks Test and Wind Turbine

In this work two typical networks IEEE 14-bus and IEEE 30-bus are considered, 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 I and II.

TABLE I. 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 II. 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.

IV. 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 LP method. To choose the best location of wind turbine according to its influence on the economic dispatch problem, it is considered that weather and geographical constraints are given in all buses and the integration of a wind power is possible.

A. 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 [23].

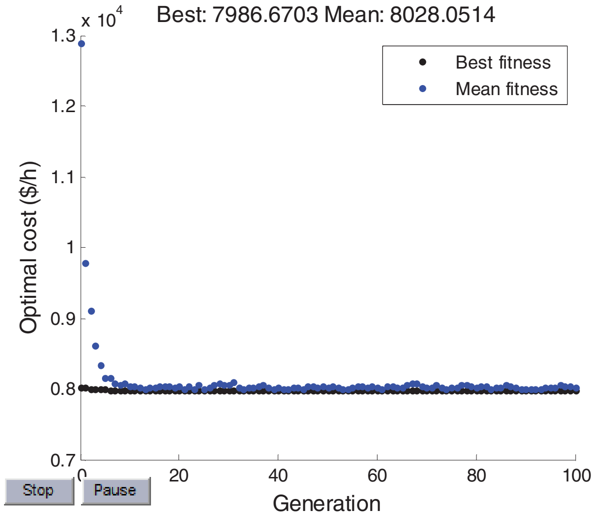

Figure 2. Best value of the fitness function for IEEE 14-Bus by GA method

At all times where the ED problem is calculated, the equality (equation 6) and inequality (equation 5) constraints are checked. The figure 2 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.

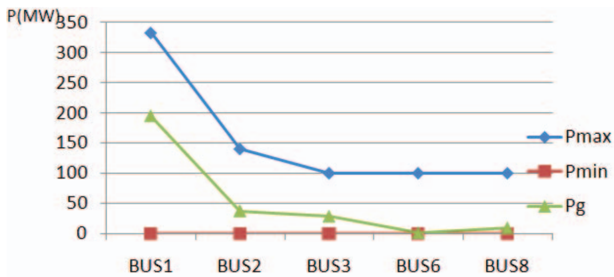

Figure 3. The state of the generated powers obtained by GA compared to the constraints for a network of 14-Bus.

The wind power has been injected from the first bus until the 14th respectively. At each time, the calculated money profits are confirmed by the LP method. The table III summarizes the results (listed from the less to the top value of money profits) and gives the type of each bus.

According to the results of the table III, 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 14 different places.

TABLE III. THE COST AND THE MONEY PROFIT BEFORE WIND PENETRATION IN DEFERENT BUSES OF IEEE 14-BUS NETWORK

bus	Type	The cost after wind penetration ($/h)	Money profit ($/h)	Confirmation by LP method ($/h)
1	Slack	7986,6703	98.7354	98,74
2	PV	7981,8934	103.4705	103,51
6	PQ	7979,0054	106.3585	107,16
5	PQ	7978,9139	106.4500	107,6
12	PQ	7978,0519	107.3120	108,99
7	PQ	7976,9189	108.6450	108,75
4	PQ	7976,8565	108.5074	108,79
9	PQ	7976,4175	108.9464	108,91
11	PV	7976,3507	109.0132	108,71
8	PQ	7976,2064	109.1575	108,41
3	PV	7975,9613	109.4026	109,51
10	PV	7975,4976	109.8663	109,51
13	PQ	7975,3568	110.0071	110,21
14	PQ	7973,5283	111.8356	111,91

TABLE IV. 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 (table III), and they vary from a value of 13.142 ($/h), this variation in values is important; it is necessary than to determine the network parameters influence on the optimal power flow cost.

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

The best money profit is obtained in the 14th bus (table III), 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.

B. 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 [21].

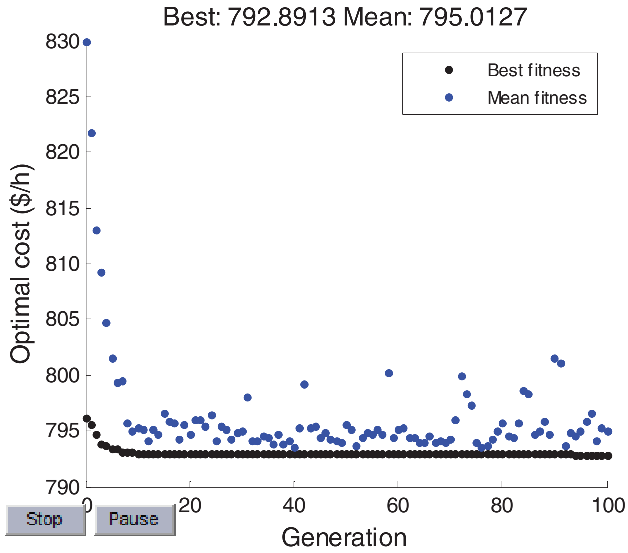

Figure 4. Best value of the fitness function for IEEE 30-Bus by GA method

Each time when the best value of the fitness function is obtained, the equality and inequality constraints 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 LP method. The table V summarizes the results (listed from the less to the top value of money profits) and gives the type of each bus.

According to the results of the table V, it is checked that the money profit value is positive whatever the site of wind power injection is. Hence, 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 VI 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 VI), 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 V. 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 LP method ($/h)
20	PQ	795,5665	6,28	9,87
1	REF	792,8913	8,9481	9,67
2	PV	792,5346	9,3119	9,27
3	PQ	792,3444	9,5021	9,44
13	PV	792,2852	9,5613	9,53
12	PQ	792,2791	9,5674	9,54
4	PQ	792,238	9,6085	9,59
16	PQ	792,1632	9,6833	9,78
6	PQ	792,1467	9,6998	9,67
11	PV	792,1444	9,7021	9,65
10	PQ	792,1352	9,7113	9,68
9	PQ	792,1346	9,7119	9,67
8	PV	792,1319	9,7146	9,67
14	PQ	792,1035	9,743	9,69
28	PQ	792,0946	9,7519	9,78
17	PQ	792,0584	9,7881	9,72
27	PQ	792,0149	9,8316	10,03
22	PQ	791,981	9,8655	9,81
21	PQ	791,9758	9,8707	9,82
15	PQ	791,9722	9,8743	9,79
7	PQ	791,9571	9,8894	9,82
5	PV	791,9321	9,9144	9,83
18	PQ	791,9304	9,9161	9,89
23	PQ	791,8919	9,9546	9,89
25	PQ	791,8757	9,9708	9,89
19	PQ	773,7215	9,9942	9,92
24	PQ	791,8327	10,0138	9,94
29	PQ	791,7576	10,0889	10
26	PQ	791,7259	10,1206	9,89
30	PQ	791,5817	10.2648	10,17

C. Interpretations

When a wind power is injected inthe grid, the power generated by the thermal stations and the required fuel in those thermal stations decreases, because a part of the power generated by the thermal stations is compensated by this wind turbine produced power, and 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 VI. 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

V. CONCLUSION

The influence of a wind turbine location on the optimization of the economic dispatch was presented in this paper. A wind power was chosen and connected to two different IEEE systems. This wind turbine was moved from a bus to another and the money profit was calculated at each time. 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 integration. The results were validated by the linear programming method. Finlay this paper proposes to add the economic dispatch problem, with constraints, in the choice of the best wind power location.

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