Wind-Thermal Coordination Using Genetic Algorithm

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Abstract- **Economic Dispatch problem is an important analysis in power system operation and planning. The main objective of the Economic Dispatch problem is to determine the optimal combination of power outputs of all generating units so as to meet the required demand at minimum cost while satisfying the various constraints. In this work, Genetic Algorithm is utilized to solve the wind-thermal generation dispatch and to minimize the total production cost. A ten thermal unit incorporating one wind power plant test system is utilized for solving the economic dispatch problem. Different cases of simulations with and without wind power production are simulated and it is compared with the conventional method. The simulation result shows the effect of wind power generation in reducing total fuel cost.**

Index Terms- **Economic dispatch, wind-thermal coordination, Genetic algorithm .**

I Introduction

Nowadays in world, the load on power system enormously increases. The conventional power generation plants never satisfy the power demand. So the power generating sectors turn into renewable energy sources. Electrical power systems are designed and operated to meet the continuous variation of power demand. In power system, minimization of the generation and operation cost is very important. The rise of environmental protection and the progressive exhaustion of traditional fossil energy sources have increased the interest in integrating renewable energy sources into existing power systems. With increasing fuel prices and environmental concerns the governments all over the world has commissioned research on renewable energy applications under the consideration of diversifying energy sources.

Among the various renewable energy sources, wind energy could be in short term, one of the most promising renewable energy sources. It could provide a much greater proportion of energy production in places with good wind. Wind energy is also commonly regarded as problematic for power system operation due to its limited predictability and variability. The output fluctuation of wind energy can be compensated by employing exchange schedules with neighboring systems when there is only limited penetration exceeds specific scale, the often and only solution is to use conventional generation units to cover the variability of wind power.

The Economic Dispatch (ED) of electric power generation is one of the most important optimization problems in power system. Its task is to allocate load over the set of dispatch able units such that the required power is generated at the least cost. Since wind power does not consume fossil fuel, the government has regulated in its renewable energy law that the power grid should buy all electricity produced by renewable energy plant. Thereafter, adoption and variation of high penetration wind power will have notable impact to economic dispatch of power system.

Recently, a global optimization technique known as genetic algorithm has become a candidate for many optimization applications due to its flexibility and efficiency. This thesis focuses on investigating whether the conventional generation system can balance wind power and what the wind power will bring to our power system. Economic dispatch of ten units system incorporating a wind power plant is analyzed using genetic algorithm.

II Problem Formulation

The economic dispatch of generation in a power system incorporating wind power plant involves the allocation of generation among the wind and thermal plants so as to minimize the total production cost while satisfying various constraints. The generation cost of wind power generation is ignored in the optimization process since renewable energy law regulate that all of them must be adopted and there is not fossil fuel cost. After evaluate the interrelation between wind power and conventional plant, the cost of wind power plant will add up to the total cost. The objective of economic dispatch is to minimize the total generation cost of the power system within a defined interval (i.e. one hour) while satisfying various constraints. The economic dispatch problem can be formulated as a constrained optimization problem of the form

$$F_T = \sum_{i=1}^{T} \sum_{i=1}^{NT} F_i\big(P_i(t)\big) \tag{1}$$

where,

NT is the total number of generation units;

F_T is the total fuel cost;

$F_i(Pi(t))$ is the generation cost function of i^{th} unit;

The fuel cost of a thermal generation unit without considering valve point loading effect

$$F_i P_i = a_i + b_i P_i + c_i {P_i}^2 \tag{2}$$

However, when the generation units change its output, there is a nonlinear cost variation due to valve point loading effect. The fuel cost of a thermal generation unit considering nonlinear effect of valve will be nonlinear function as

$$F_i(P_i) = a_i + b_i P_i + c_i {P_i}^2 \left| e_i * \sin\{f_i(P_i^{min} - P_i)\} \right| \tag{3}$$

where

a_i, b_i, c_i, e_i, f_i are the cost coefficients of the i^{th} generating unit

p_i Generation of thermal unit i

Basic constraints:

i Power Balance Constraint:

$$\sum_{i=1}^{NT} P_i(t) + P_{WT}(t) = P_L(t) \tag{4}$$

where

$P_i(t)$ Generation of thermal unit i at hour t.

P_{WT}(t) Total actual wind generation at hour t.

$P_L(t)$ System load demand at hour t

ii Generating Limits Constraint:

$$P_i^{min} \le P_i(t) \le P_i^{max}(t) \tag{5}$$

where

$p_i(t)$ is the present output power,

p_i^{min} and p_i^{max}, are the minimum and maximum power outputs of the i^{th} generating unit respectively

III GENETIC ALGORITHM

The Genetic Algorithm (GA) is a search heuristic that mimics the process of natural evolution. This heuristic is routinely used to generate useful solutions to optimization and search problems. Genetic algorithms belong to the larger class of evolutionary algorithms (EA), which generate solutions to optimization problems using techniques inspired by natural evolution, such as inheritance, mutation, selection, and crossover

The basic genetic algorithm steps are

Step1: Construct an initial population (P) of chromosomes by random process.

Step2: Evaluate fitness of each chromosome.

Step3: Genetic mating pool based on fitness function values.

Step4: Select mating pair of chromosomes called parent chromosomes from mating pool.

Step5: Create two child chromosomes from the parent chromosomes by applying genetic operators.

Step6: Repeat Steps (4, 5), till the child population of size P is generated.

Step7: Store the chromosome having the maximum fitness and also the corresponding objective function.

Step8: Repeat Steps (2-7), until the specified numbers of genetic iterations are completed.

Step9: Return the chromosome with highest fitness function as the solution completed

Economic dispatch of power generation is a complex and highly nonlinear optimization problem with equality and inequality constraints. Recently, as an alternative to the conventional mathematical approaches a series of optimization techniques are considered as realistic and powerful solution schemes to obtain the global and quasi global optimums in ED. In this paper GA is utilized for economic dispatch of power system incorporating wind power generation. The population size is 11 and the maximum generation is 50. The GA adopts elitism selection and single point crossover with probability of 0.8. The mutation probability is set to 0.2.

V Result And Discussion

The test system contains ten conventional generation unit with one generating unit and the demand of the system is divided into 24 hours interval for the whole day. system data are listed in Table I and load demand are listed in Table II.

TABLE I

TEN SYSTEM DATA

	Unit-1	Unit-2	Unit-3	Unit-4	Unit-5
Pmax(MW)	470	460	340	300	243
Pmin(MW)	150	135	73	60	73
a($/mwh)	0.00043	0.00063	0.00039	0.00070	0.00079
b($/mwh)	21.60	21.05	20.81	23.90	21.62
c($/h)	958.20	1313.6	604.97	471.60	480.29
d($/h)	450	600	320	260	280
e($/h)	0.041	0.036	0.028	0.052	0.063
	Unit-6	Unit-7	Unit-8	Unit-9	Unit10
Pmax(MW)	160	130	120	80	55
Pmin(MW)	57	20	47	20	55
a($/mwh)	0.00056	0.00211	0.00480	0.10908	0.00951
b($/mwh)	17.87	16.51	23.23	19.58	22.54
c($/h)	601.75	502.70	639.40	455.60	692.40
d($/h)	310	300	340	270	380
e($/h)	0.048	0.086	0.082	0.098	0.094

TABLE II
LOAD DEMAND FOR 24 HOUR

HOUR	LOAD	HOUR	LOAD	HOUR	LOAD	HOUR	LOAD
1	1036	7	1702	13	2072	19	1776
2	1110	8	1776	14	1924	20	2072
3	1258	9	1924	15	1776	21	1924
4	1406	10	2072	16	1554	22	1628
5	1480	11	2146	17	1480	23	1332
6	1628	12	2220	18	1628	24	1184

The forecast output of wind power generation is shown in Fig. 1 wind thermal coordination dispatch is calculated without considering losses using genetic algorithm and it is compared with conventional method. simulation has been carried out for Two dispatch scenarios with and without wind generation are calculated for few trials.

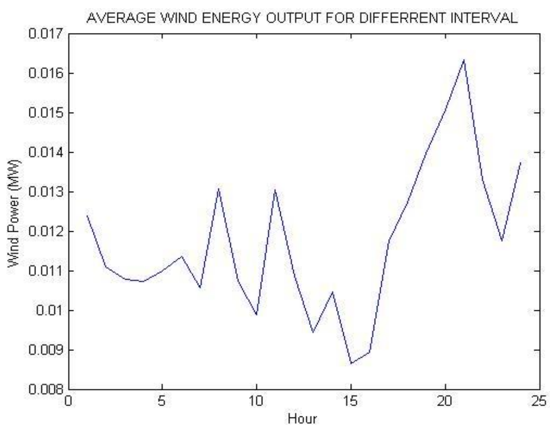

FIG.1 WIND ENERGY OUTPUT FOR 24HOUR

Case 1: Thermal Unit without Wind Generation

For solving the problem of ED without considering the losses for 10 thermal unit. The unit constraints of the thermal units are taken into account in the studied cases. Demand is to be calculated for 24 hr. 11 numbers of chromosomes are selected. If the no of chromosomes are increased then the convergence is not affected much more but the time of convergence is increased. The string length is also chosen 10.Probability of selection for the cross over operation is chosen 0.8. The minimum cost curve converges obtain within the 20-40 iterations. In output tabulation all the generating values are denoted in mega watts (MW) and output is shown in Table III.

Case 2: Thermal Unit with Wind Generation

For solving the problem of ED without considering the losses for 10 thermal unit with an equivalent wind generator. The unit constraints of the thermal units are taken into account in the studied cases. For simplicity, the available wind power generation of the equivalent wind generator is assumed to be changed one hour time period MW for 24 hour time periods. 10 numbers of chromosomes are selected. If the no of chromosomes are increased then the convergence is not affected much more but the time of convergence is increased. The string length is also chosen 10.Probability of selection for the cross over operation is chosen 0.8. the minimum cost curve converges obtain within the 20-40 iterations and output is shown in table IV.

TABLE III
DISPATCH WITHOUT WIND POWER GENERATION

Hour	P1	P2	P 3	P 4	P 5
1	150.00	135.00	141.94	99.47	205.85
2	465.23	228.2	82.79	60.00	73.00
3	404.81	160.2	298.66	60.00	135.33
4	463.45	135.00	147.36	60.00	236.45
5	150.00	413.26	125.00	285.83	82.46
6	160.12	223.59	340.00	300.00	124.27
7	459.05	453.15	333.15	60.00	73.00
8	427.34	457.26	240.15	219.43	73.00
9	271.22	393.61	340.00	300.00	207.15
10	307.27	460.00	216.73	300.00	243.00
11	422.05	460.00	194.07	281.88	243.00
12	332.59	460.00	339.41	300.00	243.00
13	369.50	460.00	202.44	289.88	243.00
14	234.07	460.00	340.00	138.98	205.95
15	153.65	460.00	340.00	265.34	129.07
16	150.00	456.83	336.83	60.00	157.56
17	150.00	399.01	329.09	183.96	125.46
18	308.62	460.00	74.62	88.43	243.00
19	470.00	205.81	207.05	124.71	223.43
20	470.00	372.11	340.00	141.58	203.31
21	268.73	415.21	246.57	241.36	207.14
22	246.95	458.01	73.00	298.01	73.00
23	312.54	135.00	250.40	204.25	73.00
24	150.00	145.59	329.23	60.00	73.00

Hour	P 6	P 7	P 8	P 9	P10
1	57.00	49.32	47.00	20.00	55.00
2	57.00	20.00	47.00	20.00	55.00
3	57.00	20.00	47.00	29.86	55.00
4	57.00	20.00	47.00	20.69	55.00
5	145.35	57.00	67.51	20.00	55.00
6	57.00	47.19	100.91	22.34	55.00
7	110.61	87.41	47.00	28.77	55.00
8	160.00	98.75	118.7	55.31	55.00
9	160.00	130.00	120.00	80.00	55.00
10	160.00	130.00	120.00	80.00	55.00
11	160.00	130.00	120.00	80.00	55.00
12	160.00	121.73	114.48	80.00	55.00
13	160.00	130.00	120.00	80.00	55.00
14	160.00	130.00	120.00	80.00	55.00
15	160.00	130.00	120.00	80.00	55.00
16	73.59	130.00	120.00	80.00	55.00
17	57.00	122.01	62.44	20.00	55.00
18	149.30	31.45	60.59	50.02	55.00
19	160.00	130.00	120.00	80.00	55.00
20	160.00	130.00	120.00	80.00	55.00
21	62.26	25.26	75.09	78.14	55.00
22	147.36	130.00	74.62	74.63	55.00
23	145.66	117.78	92.32	20.00	55.00
24	57.00	20.00	47.00	20.00	55.00

TABLE IV
DISPATCH WITH WIND POWER GENERATION

Hour	P 1	P 2	P 3	P 4	P 5
1	176.44	135.00	139.29	184.86	73.00
2	150.00	385.95	118.09	60.00	129.06
3	417.20	135.00	146.65	153.52	146.66
4	335.50	405.33	73.00	125.59	194.89
5	150.00	292.70	294.75	219.89	87.79
6	459.58	337.19	73.00	160.82	237.96
7	298.51	395.23	240.62	264.43	102.52
8	470.00	232.21	224.28	184.36	129.39
9	225.58	416.54	261.23	174.79	206.87
10	394.59	317.39	312.99	178.28	210.75
11	374.75	308.35	340.00	300.00	243.00
12	439.52	460.00	226.78	275.76	231.83
13	272.57	403.14	297.13	276.47	243.00
14	428.24	218.32	189.00	242.42	233.91
15	200.16	382.18	183.03	180.15	222.67
16	158.84	229.67	229.06	300.00	81.84
17	458.39	227.17	177.23	67.73	138.92
18	457.74	359.00	103.72	129.57	125.80
19	226.63	232.92	265.45	232.75	186.75
20	229.23	460.00	310.12	256.35	171.00
21	470.00	297.19	262.59	299.47	243.00
22	266.70	172.67	313.09	161.92	191.61
23	231.83	220.35	308.96	60.00	73.00
24	150.00	382.23	270.87	60.00	73.00

Hour	P 6	P 7	P 8	P 9	P10
1	89.73	92.01	47.00	20.00	55.00
2	58.77	20.00	47.00	20.00	55.00
3	57.00	20.00	47.00	20.00	55.00
4	57.00	69.79	108.50	73.45	55.00
5	108.65	111.38	105.83	42.60	55.00
6	160.00	102.28	120.00	42.73	55.00
7	125.16	76.41	47.08	20.00	55.00
8	112.26	117.16	47.00	27.40	55.00
9	86.44	130.00	76.44	64.14	55.00
10	160.00	130.00	120.00	80.00	55.00
11	160.00	130.00	120.00	80.00	55.00
12	160.00	130.00	120.00	80.00	55.00
13	129.62	122.57	120.00	80.00	55.00
14	160.00	130.00	120.00	80.00	55.00
15	126.22	95.95	120.00	30.76	55.00
16	146.90	40.85	110.17	39.86	55.00
17	123.37	20.00	47.00	47.11	55.00
18	83.02	130.00	120.00	65.31	55.00
19	160.00	130.00	120.00	80.00	55.00
20	160.00	130.00	120.00	80.00	55.00
21	160.00	130.00	120.00	80.00	55.00
22	158.01	128.01	118.01	20.00	55.00
23	60.59	123.66	51.65	65.92	55.00
24	110.77	94.47	109.23	56.72	55.00

TABLE V
COMPARISON OF CONVENTIONAL METHOD AND GENETIC ALGORITHM

	Conventional method	Genetic algorithm (GA)
Thermal unit with-out wind generation (Cost of Generation ($/day):	1069061.60	1065093.36
Thermal unit with wind generation (Cost of Generation ($/day):	1069055.49	1060062.98

VI CONCLUSION

In this work, the formulation and implementation to solve the economic dispatch problem of a power system incorporating thermal power plant and wind power generation using Genetic Algorithm is carried out. The simulation results, for with/without wind power generation, shows that total system operating costs and consumption of fossil fuel can be reduced notably by utilizing wind power generation. The cost of the best solution without wind power generation is 1065093.36 ($/day) while the cost for best solution with wind power generation 1060062.98 ($/day) and also genetic algorithm is compared with conventional method and gives better optimal solution to the corresponding cases.

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