The Economic Dispatch of Power System Considering Wind Power Generation

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Abstract. Currently many kinds of new energy power especially the wind power is developing fast. The wind power has significant advantages in terms of fuel costs and environmental benefits. However, the wind power do brought many difficulties to power system because its output varies from this moment to another, and it is usually hard to predict. This paper describes the relevant characteristics of wind power, and then builds the dynamic mathematic model of power system economic dispatch based on the impact of wind power.

Introduction

In recent several years, the wind power is increasing fast. Wind power is a new kind of renewable power, which is clean and renewable. However, it also brought uncertainty to the grid. Because of the fluctuations of wind, the grid needs to keep a higher spinning reserve level to keep itself steady and safe. Power system can be considered as a contradiction or balance of economy and safety; higher safety level means more cost while economy means dangerous, so it is important for us to decide how to balance the two sides.

The power system dynamic dispatch is an important part of daily schedule; it decides the unit commitment in accordance with the change of load so that the total fuel cost of generation can be minimum while all the constrains can be satisfied. With the research of dynamic dispatch, we can find the best unit commitment for power system with wind power.

The characteristics of wind power output

The output characteristics curve of wind turbines is obtained from experiment; the data is supplied by the manufacturers. It is generally believed that the wind turbines turn on when wind speed is greater than starting speed v_c and shut down when wind speed is less than the cut off speed v_f. The wind power output accords with a curvewhen wind speed is between v_c and v_f.

The output characteristic function of wind power generator can be obtained by the least square method. In order to make the function precise, we separate the function curve into 3 parts. So the output characteristic function of wind power generator is denoted as follows:

$$P_{WT}(t)=\begin{cases}0 & (v(t)<v_c, v(t)>v_f)\\ a_1v(t)^2+b_1v(t)+c_1 & (v_c\le v(t)\le v_1)\\ a_2v(t)^2+b_2v(t)+c_2 & (v_1\le v(t)\le v_2)\\ a_3v(t)^2+b_3v(t)+c_3 & (v_2\le v(t)\le v_f)\end{cases} \tag{1}$$

Which $P_{WT}(t)$ is the output of wind power at moment t; v_c and v_f are starting speed and cut off speed of wind turbines; a、b、c are output parameters of wind turbines; $v(t)$ is the wind speed at moment t.

Impact of wind power integration on dynamic economic dispatch of power system

The output active power fluctuates because the wind speed varies from one moment to another and has a large intermittent. Compared to traditional power, the wind power has a characteristic of uncontrollable and fluctuation. It is always not a big problem when the wind power capacity is small. However, when the percent of wind power grows the impact on power system can not be ignored any longer. To sum up, the main effect is as follows.

Spinning reserve capacity

Although many scholars have put forward many methods for the prediction of wind speed forecast error, but forecast error is too large. In order to use the wind resources, and also ensure the safe and reliable operation of power grid, in the actual operation more spinning reserve capacity is needed.

Total fuel cost

Compared with the thermal power and nuclear power, wind power does not need to purchase any fuel, therefore the operation cost of wind power generation is very low. So we should give priority to the use of wind energy.

The safe and stable operation of power grid

Because the wind varies from minute to minute, in result the wind power output has sharp fluctuations. The fluctuation and intermittence of wind power will make the system does not have enough time and enough reserve to ensure the safe operation of the system. Therefore, when wind power is brought into electric power grid, we should try every measure to make it smooth and steady.

Dynamic economic dispatch model with wind farms

The objective function

As compared with conventional unit operation cost, operation cost of wind farm is very small, it can be neglected. Therefore, the objective function only considers the conventional unit fuel cost and its startup cost. Therefore, the mathematical expression of the dynamic economic dispatch model in wind power grid connected power system can be expressed as follows:

$$\min J = \sum_{t=1}^{T}\sum_{i=1}^{G}[U_i(t)F_i(t)+U_i(t)(1-U_i(t-1))S_i(t)] \tag{2}$$

Which J is total fuel cost; t refers to the time period; i refer to the unit number. $U_i(t)$ refers to the operation condition of uniti at period t,the unit is shutdown when $U_i(t)$ =0 while it is operating when $U_i(t)$ =1. $F_i(t)$ is the fuel cost of unit and $S_i(t)$ is the startup cost of unit.

The constraint conditions

The unit output constraint

$$P_{i,\min} \le P_i(t) \le P_{i,\max} \tag{3}$$

In the formula, $P_{i,\max}$ is the maximum output of unit i while $P_{i,\min}$ is the minimum output.

Minimum uptime and downtime constrains

$$\begin{aligned} X_{ioff}(t) &\ge T_{i,off} \\ X_{ion}(t) &\ge T_{i,on} \end{aligned} \tag{4}$$

Which $X_{ion}(t)$ is the operation time of unit i at period t and $X_{ioff}(t)$ is the shutdown time.

Balance of power constrains

$$P_{LD}(t) = \sum_{t=1}^{N} U_i(t)P_i(t) + P_w(t) \tag{5}$$

Which $P_{LD}(t)$ is the total load at period t.

Spinning reserve constrains

$$\sum_{i=1}^{N} U_i(t)P_i(t) \geq P_{LD}(t) + R(t) \tag{6}$$

Climbing speed constrains

$$-P_{i,down} \leq P_i^t - P_i^{t-1} \leq P_{i,up} \tag{7}$$

Which $P_{i,u}$ and $P_{i,down}$ refer to the maximum output change of unit i at one period.

Examples and conclusions

Based on the example of IEEE-10 unit, we add 100 Folland wind turbines which stand-alone capacity is 1500KW. The parameters of thermal power units are in the literature [6]. The spinning reserve capacity is set to 5% $P_{LD}(t)$ and 10% $P_{LD}(t)$. Prediction of wind power output and load are shown in table 1.

Table 1. Load and predicted wind power output in every period

Time	Load	Wind Power
1	700	72
2	750	106
3	850	113
4	950	103
5	1000	139
6	1100	116
7	1150	122
8	1200	88
9	1300	53
10	1400	41
11	1450	55
12	1500	53
13	1400	72
14	1300	116
15	1200	77
16	1050	64
17	1000	106
18	1100	142
19	1200	116
20	1400	124
21	1300	135
22	1100	122
23	900	92
24	800	57
25	700	72
26	750	106
27	850	113
28	950	103
29	1000	139
30	1100	116
31	1150	122
32	1200	88
33	1300	53
34	1400	41
35	1450	55
36	1500	53
37	1400	72
38	1300	116
39	1200	77
40	1050	64
41	1000	106
42	1100	142
43	1200	116
44	1400	124
45	1300	135
46	1100	122
47	900	92

With the data we calculate the total fuel cost in the following 4 cases: the wind power is employed and the spinning reserve is set to 5% $P_{LD}(t)$; the wind power is notemployed and the spinning reserve is set to 5% $P_{LD}(t)$; the wind power is employed and the spinning reserve is set to 10% $P_{LD}(t)$; the wind power is notemployed and the spinning reserve is set to 10% $P_{LD}(t)$. The calculation results show that when the wind generation is employed, the minimum fuel cost is calculated as 516292$, which is significantly less than the cost 565194$ when wind generation is not employed. However, when the wind power is considered, the grid needs more spinning reserve capacity to ensure its stable operation. As calculated, the total fuel cost when the reserve capacity is set to 5% $P_{LD}(t)$ is slightly larger the cost when the reserve capacity is set to 10% $P_{LD}(t)$. Therefore, in order to ensure the integration of wind power system stability, the spinning reserve capacity increase has brought about increased costs.

References

[1] Guo Yongji: Power System Reliability Analysis. TsinghuaUniversity Press

[2] Su Peng, Liu Tianqi: Determanition of Reserve Capacity For Wind Power. Grid Technology. ,2010,34(12):158-162.

[3] Bilinton R, Allan R N. Reliability evaluation of power systems [M]. New York:Plenum, 1996.

[4] Bunn D W. Forcasting load and prices in competitive power markets [J]. Proc IEEE, 2000, 88(2):163-169.

[5] Bouffard F, Galiana F D. Stochastic security for operations planning with significant wind generation [J]. IEEE Trans. Power system, 2008, 23(2):306-316.

[6] Miguel A. Ortega, Daniel S. Kirschen. Should the spinning reserve procurement in systems with wind power generation be deterministic or probabilistic? International conference on supergen.

[7] Reliability assessmentof wind power generation system based on Monte-Carlo simulation) [J]. Electric Power Automation Equipment, 2004, 24(12): 70-731

[8] Yang Xiuyuan, Xiao Yang, ChenShuyong). (Wind speed and generated power forecasting inwind farm) [J]. Proc. CSEE, 2005, 25(11): 1-51

[9] Castro S F, Allan R N. Generation availability assessment ofwind farms [J]. IEE Proc-Gener,Transm, Distrib, 1996,143(5): 507-518.

[10]SoderL. Reserve margin planning in awind-hydro-thermalpower system [J]. IEEETrans. on Power Systems, 1993, 8(2): 564-571.