

# Research on reactive power coordinated control strategy for large scale wind power grid connected area

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**Abstract.** The impact of large-scale wind power integration on the system stability is studied by taking the grid fault disturbance as the constraint. The reactive power optimization model and algorithm of distribution network with wind farm are studied. The strategy of reactive power coordinated control of thermal power unit near the collection station is proposed, and the coordination of reactive power equipment such as thermal power, wind power and SVC / SVG is studied. In this paper, a reasonable example of a wind farm (including thermal power and wind power) is selected to verify the superiority of the proposed strategy and algorithm.

## 1. Introduction

Reactive power optimization plays an important role in ensuring the overall voltage quality of power grid. Large scale wind power integration brings new challenges to the safe and stable operation of power system, especially the impact of small signal stability on power system. How to make full use of wind power generator and the reactive compensation device to realize the coordination of the wind farm reactive power regulation, how to realize the reactive power coordination between thermal power and wind power, so as to inhibit or avoid large-scale fault system, ensure that the entire power grid reactive power balance and voltage stability is of great significance.

A lot of researches have been done on reactive power control strategy of wind farm cluster. The literature does not take into account DFIG [1] in reactive power output, SVC reactive power regulation; export in accordance with the fan reactive power sensitivity to determine fan reactive power output, so as to realize the reactive power optimization; reference [2] equivalent circuit of doubly fed induction generator based on the analysis of the reactive power limit of wind turbines. And the DFIG loss are optimal reactive power control, but by this method of constant power factor control, only consider the single blower of the reactive power loss minimum, without considering the coordination of the wind farm reactive power, reactive power optimization cannot achieve the overall. A reactive power optimization model of distribution network with multiple wind farms is constructed in the literature [3]. The reactive power output of the wind turbine is only a single unit capacity added, which leads to the low precision of reactive power regulation of the wind farm, thus affecting the reactive power optimization decision of the wind farm cluster. The [4-5] proposed emergency control based on voltage stability of multi agent system, the system on-line coordination mechanism of third kinds of control and multi agent based information system to deal with large scale wind farms impact on voltage stability of



grid connected system; however, the main point of this system is the online system, need database support, not only related to the calculation process the complex[6], and the communication reliability and real-time control, it is difficult to achieve the goal.

In short, the automatic voltage control of wind farm cluster is not perfect, and the coordinated control of various reactive power sources (wind power and thermal power) control strategy is not fully considered. The principle of reactive power distribution in wind farm and booster station is studied in this paper. The wind farm cluster voltage deviation control points to calculate the reactive power demand of the wind field, if DFIG is unable to meet the demand of the network, we should take effective measures to optimize the reactive power, it cannot do without the coordination of DFIG with the support of SVC [6], the only way to reduce fan loss, reactive power optimization purposes. In this paper, the coordinated control method of reactive power and voltage in the wind power plant and the conventional thermal power plant and the conventional substation is discussed.

### 1.1. Coordinated control scheme of reactive power source

- ①The non-full power regulation of wind turbines itself;
- ②Coordination control of reactive power supply in capacitor bank, SVC / SVG and transformer tap in wind farm;
- ③if the reactive power regulation capacity of wind farm cannot play a role, the reactive power regulation capacity of the collection station should be fully developed.
- ④In order to reduce the impact of wind farm fluctuation on regional grid voltage, it is necessary to adjust the capacity of the thermal power generation unit near the collection station.
- ⑤The coordinated control of reactive power supply follows the principle of "priority of discrete equipment and fine coordination of continuous equipment".

## 2. reactive power compensation layered coordinated control modelling

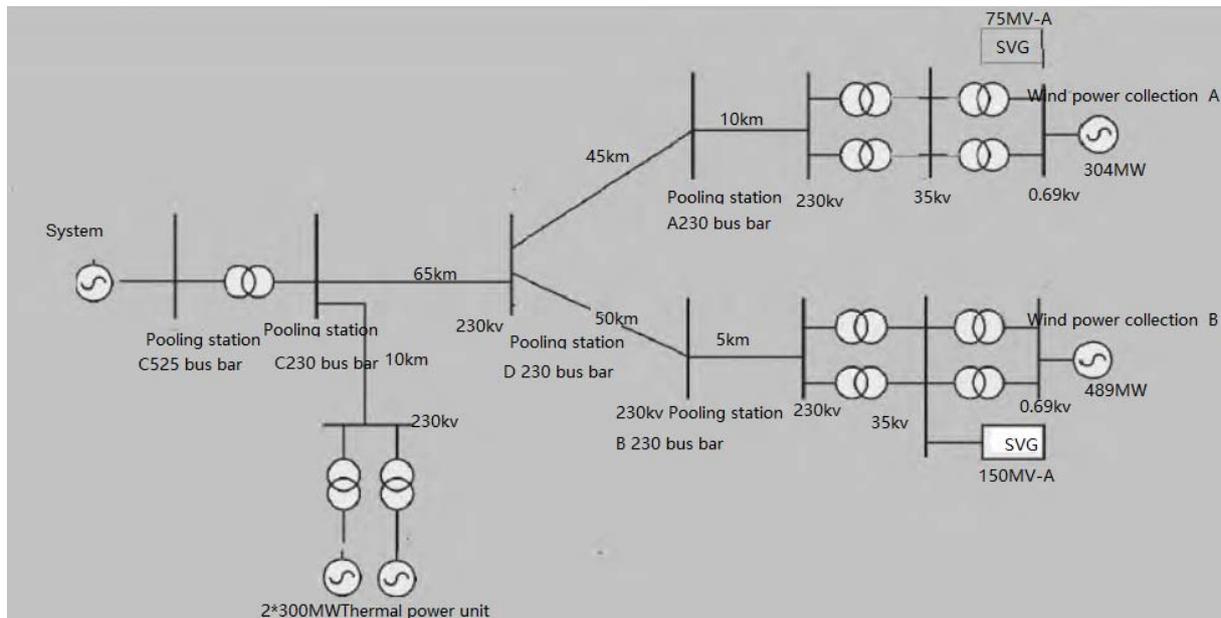
### 2.1. Mathematical model of fans

The relationship between fan output power  $P_{DWG}$  and wind speed:

$$P_{DWG} = \begin{cases} 0, v \leq v_{et} \text{ or } v \geq v_{co} \\ P_r \frac{v - v_{et}}{v_r - v_{et}}, v_{et} < v < v_r \\ P_r, v_r < v < v_{co} \end{cases} \quad (1)$$

$P_{DWG}$  is the actual output power of fan;  $v_{ci}$ , and  $v_{co}$  are cut in wind speed, rated wind speed and cut out wind speed respectively; [7]  $r$  is rated output power of fan. The operation constraints of wind turbines are as follows.

$$\left( \frac{P_n}{1 - s_1} \right)^2 + Q_n^2 = (3U_{st} I_{st})^2 \quad (2)$$



**Figure 1.** Ogy diagram of regional power grid

$$\left(\frac{P_{Ti}}{1-s_i}\right)^2 + \left(Q_{Ti} + 3\frac{U_{Si}^2}{X_{Si}}\right)^2 = \left(3\frac{X_{Mi}}{X_{Si}}U_{Si}I_{Ri}\right)^2 \quad (3)$$

$$Q_{Ti.min} < Q_{Ti} < Q_{Ti.max} \quad (4)$$

$$P_{Ti.min} < P_{Ti} < P_{Ti.max} \quad (5)$$

$Q_{Ti.min}$  and  $Q_{Ti.max}$  are the minimum and maximum values of reactive power output of the I doubly fed induction generator, respectively.  $P_{Ti.min}$  and  $P_{Ti.max}$  are the minimum and maximum values of the active power output of the I doubly fed induction generator respectively.

### 2.2. The mathematical modeling of wind power convergence area

For each large wind power base, how to ensure the voltage safety of the wind power collection area in the normal state and fault state is the most important task. The mathematical model is as follows:

$$\begin{aligned} & \min \{W_p \|U_m^r + C_{mw} \Delta Q_g^w - U_m^s\|^2 + W_q \|Q_g^w\|^2\} \\ & U_m^{\min} \leq U_m^r + C_{mw} \Delta Q_g^w \leq U_m^{\max} \\ & U_h^{\min} \leq U_h^r + C_{hw} \Delta Q_g^w \leq U_h^{\max} \\ & U_w^{\min} \leq U_w^r + C_{ww} \Delta Q_g^w \leq U_w^{\max} \\ & U_l^{\min} \leq U_l^r + C_{lw} \Delta Q_g^w \leq U_l^{\max} \\ & Q_g^{w,\min} \leq Q_g^{w,r} + \Delta Q_g^w \leq Q_g^{w,\max} \end{aligned} \quad (6)$$

Type:  $Q_g^{w,r}$ ,  $\Delta Q_g^r$ ,  $Q_g^{w,\min}$ ,  $Q_g^{w,\max}$  for real-time volume, wind farm reactive power regulation, real time limit, the maximum amount of time;  $U_h^{w,r}$ ,  $U_h^r$ ,  $U_h^{\min}$  were collected and the lower limit voltage

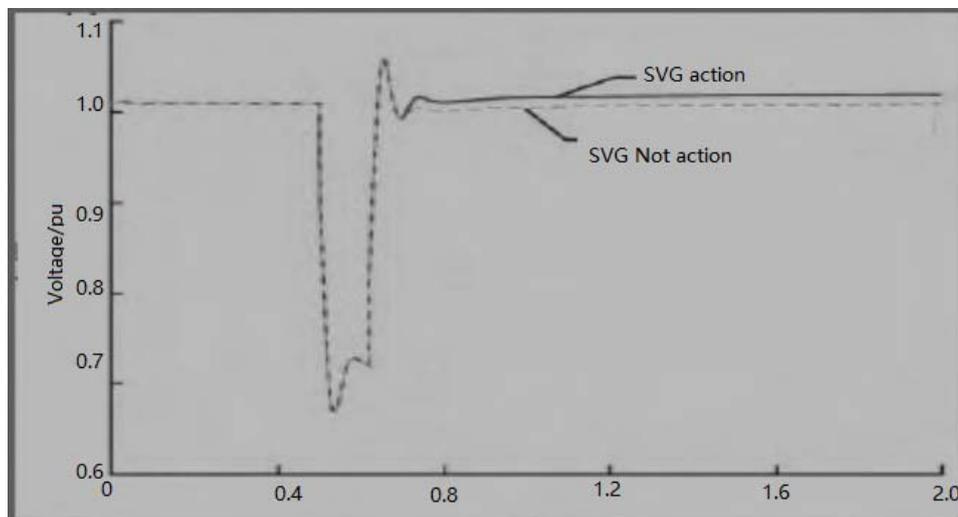
limit measured voltage and voltage high voltage side of the bus station respectively;  $C_{ww}$ ,  $C_{hw}$ ,  $C_{mw}$ ,  $C_{lw}$  wind farm reactive power of wind farm and network and high low side collection station three bus voltage sensitivity.

### 3. Simulation of reactive power coordinated control strategy for wind farm cluster station

Set area network topology diagram of Figure 1 in the wind wire, wind power cluster A using DFIG wind power, cluster B adopts the permanent magnet unit, the installed capacity was 304 MW, 489 MW, a wind farm configuration and dynamic reactive power compensation device, the compensation capacity of about 25% of installed capacity. The simulation of wind farm using 1 installed capacity of a wind turbine, dynamic reactive power compensation capacity by 1 units with a capacity of SVC or SVG replacement.

Building MATLAB simulation model. Consider the establishment of wind farm A and network fault and fault distal proximal, comparison of surrounding wind detected A wind farm voltage drop, wind farm reactive power sources with different control measures, supporting effect of wind farm and network voltage, to prove the validity of the proposed approach.

When the wind power cluster B and the network fault, 0.1s after the removal of the fault, respectively consider the wind farm A field SVC to take the local control mode or remote cluster B SVG support mode, compare the wind farm A voltage response as shown in figure 2. The voltage of the wind farm A and the node voltage drops to about 0.65 during the fault, and the SVG and the fan still have large reactive margin at this time. At the end of the fault, the voltage returned to the normal range, but when the remote SVG action, the wind farm A received wind farm B SVG additional reactive power to improve their own and point voltage level, reduce reactive power level, voltage returned to the normal range.



**Figure 2** wind farm a take different control strategy voltage situation

When the SVG is added, the voltage waveform becomes obvious, and the deviation is very small when the operation time is very small. It shows that SVG plays the role of regulating reactive power, ensuring the quality of voltage, keeping the voltage in the safe and stable range of operation, ensuring the reliable operation of the system.

#### 4. conclusions and recommendations

①When coordinating reactive power output of SVC/SVG and DFIG, the reactive power of DFIG should be adjusted preferentially.

②When the reactive power and voltage adjustment capacity of the regional grid wind farm is insufficient, it is necessary to give full play to the provincial regulation of reactive power regulation capacity.

③When the reactive power and voltage adjustment capacity of the regional grid wind farm is insufficient, the near area thermal power unit can provide part of reactive power.

④Due to many objective reasons, the power grid structure of the wind power base is weaker than that of the wind power base, and the related device technology is not high. In the specific project, the further control measures should be taken according to the actual situation.

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