The Different LVRT Control Strategy of Wind Generator Suppressing for Transient Overvoltage by DC Commutation Failure

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Abstract. At present, the characteristics of large capacity DC and high proportion of new energy centralized delivery is showed for power system of China. The ability of UHVDC to transmit new energy is severely reduced for caused transient overvoltage after AC/DC contingencies and further research is urgently needed. Firstly, the transient overvoltage caused by DC commutation failure is analyzed based on the large-scale wind power centralized delivery of the actual power system. Then, the physical mechanisms of transient overvoltage of converter station and wind farms resulted are analyzed by the actual power system DC commutation failure contingencies recorder. The impact of wind generator low voltage ride through (LVRT) active/reactive power characteristics for transient overvoltage is emphatically analyzed. Finally, all the analysis results are verified through simulation of practical case systems. The study can provide technical references to safe and stable operation of the power system in new situation.

1. Introduction
With the continuous operation of UHVDC project and the rapid development of new energy generation, the characteristics of large capacity DC and high proportion of new energy centralized delivery is showed for the current power system [1-3]. "Sanbei area" is the area with the most abundant wind energy resources in China. It has built 10 million kilowatt wind power bases in Hami, Jiuquan, Ningxia, eastern Mongolia, etc. Due to the small local load, the wind power is generally transmitted to the load center in the Middle East through UHVDC with large capacity and long distance to ensure the wind power consumption [4], and form a number of wind external transmission systems by UHVDC such as Qishao, Zhaoyi, Lugu, etc.

At present, there are problems of scale reduction or construction lag in UHVDC supporting thermal power plants. In addition, large-scale wind power grid integration reduces the start-up of conventional power plants, and the short-circuit capacity of the converter station at the transmission delivery is seriously insufficient. Further, the characteristics of wind power base are as follows: many control
objects, lack of effective coordination control, strong coupling of AC and DC. When AC/DC contingencies can cause the transient overvoltage of power system, which causes a large number of wind generator off grid, even grid collapse may be caused [5].

With the increasing proportion of new energy, large-scale wind generator off grid accidents often occur in actual operation [6-7]. This problem has attracted wide attention of scholars at home and abroad. The literature [8] studied on the mechanism and solutions of high voltage wind generators disconnection caused by HVDC bipole blocking. The literature [9] studied the dynamic reactive power response of wind generator for transient overvoltage when AC/DC contingencies. In the literature [10] studied the risk analysis and solutions of wind generators cascading off grid caused by transient overvoltage. A high voltage ride through control strategy of wind generators was studied to suppress for transient overvoltage by HVDC bipole blocking in the literature [11]. The literature [12] proposed an control strategy of suppressing offline for large-scale wind power generators caused by DC commutation.

At present, the problem of wind generators off grid is mostly focused on the phenomenon analysis, and the solutions are mostly from the grid frame reinforcement. In view of the problem that the transient overvoltage caused by commutation failure is in millisecond level, there are few academic researches on the detailed mechanism and solutions of this problem. The impact of wind generator LVRT active/reactive power characteristics on transient overvoltage is emphatically analyzed. The corresponding optimization of active / reactive power control strategy during the Low voltage ride through is given to suppress transient overvoltage by DC commutation failure.

2. Research Conditions

2.1. Transient overvoltage caused by commutation failure

The Qishao HVDC transmission terminal system in Gansu Province is a typical large-scale wind power base centralized UHVDC transmission system. The Qilian converter station is connected to the northwest main power system through three 750kV lines. In 2020, no supporting power supply will be put into operation. The installed capacity of Dunhuang and Mogao wind power in the near area is about 7000MW, and the grid structure of DC near area is shown in Figure 1.

![Figure 1](image_url)

**Figure 1.** The typical structural near the Qishao HVDC delivery system

Taking the Qishao DC power delivery system as an example, when the Qishao DC power is 5000MW and the Dunhuang Mogao wind power is 5000MW. the Qishao DC has a commutation failure, and the transient voltage exceeds 1.3p.u and overvoltage withstanding ability of wind generator. A curve is shown in Figure 2, there is a risk of large-scale fan disconnection and other interlocking faults caused by transient overvoltage.
Figure 2. Transient overvoltage after Qishao HVDC commutation failure

2.2. The basic wind model considering LVRT characteristics

In this paper, PSASP is used as the simulation analysis software, which has developed two kinds of general wind models including 12 type (double-fed wind generator) and 13 type (permanent magnetic synchronous generator), which can simulate the dynamic response characteristics of wind generator in normal and fault state. Figure 3 shows the state relationship of wind generator.

![Diagram of wind generator states](image)

Figure 3. General structure of basic wind generator models

In view of the different low-voltage characteristics of wind generator from different manufacturers, and even the technical route between some manufacturers is quite different. This software has the ability to flexibly simulate different low-voltage active / reactive power characteristics.

![Diagram of LVRT characteristics](image)

Figure 4. LVRT characteristics of different wind generator models

It is shown in Figure 4, take LVRT as an example:

For active power control strategy of wind generator during LVRT: $T_1 \sim T_2$ section is in the low-voltage ride through state, $T_2 \sim T_4$ section is in the low-voltage ride through recovery operation state, where $T_2$ is the recovery starting point, $T_2 - T_3$ is the starting point duration.

For reactive power control strategy of wind generator during LVRT: $T_1 \sim T_2$ section is in the middle state of low-voltage crossing, $T_2 \sim T_3$ section is in the recovery state of low-voltage crossing, in which this wind model can describe the different reactive power control fall back.
3. Analysis of transient overvoltage caused by DC commutation failure

Based on the simulation, it is found that the DC transmission capacity of Qishao is mainly limited by the failure of DC commutation. This section analyzes the mechanism of transient overvoltage caused by the failure of DC commutation based on the actual fault recording curve in the literature [12].

**Figure 5.** Respond of DC electrical power system during DC commutation failure

Respond of DC electrical power system are shown during DC commutation failure in Figure 5. From the figure, it can be found that the DC line current and the DC line consumes reactive power increase rapidly at the beginning of the fault. At this time, the DC system absorbs a large amount of reactive power from the AC system. This is the cause of low voltage in the transmission system and lead to LVRT of the wind generators around the DC.

**Figure 6.** Respond of wind generator during the DC commutation failure

From the Figure 6, it can be found that when the wind turbine enters into LVRT, the active power decreases rapidly of wind generator and support a large amount of reactive power from the wind generators. When the system voltage is restored, the wind generator go out LVRT. The active power of the wind generator slowly recovers to the steady-state value, and reduce the loss of reactive power. At the same time, the reactive power cannot be returned to the non-generating reactive state in time. This is the first reason for the transient overvoltage of the wind generator. Moreover, it can be found that when the voltage of the transmission system is restored, the DC power is 0, and no reactive power is consumed. A large surplus of filter reactive power will be sent to the AC system. This is the second reason for the transient overvoltage of the wind generator.
4. The influence of the control characteristics of LVRT for the transient overvoltage

Based on the above-mentioned Qi Shao DC wind power delivery system, the DC operating power is 5000MW, the wind power of Dunhuang and Mogao main transformer on line is 3000MW and 2000MW, respectively.

All wind farms are modeled by single machine equivalent model and controlled by a set of model parameters in the DC near area. The new developed wind generator model is used to emphatically analyze the influence of active / reactive power control strategy during LVRT and active / reactive power control strategy during LVRT recovery for the transient over-voltage of the system based on PSASP software. Related research ideas and conclusion are shown in Figure 7 to Figure 14.

4.1 The active power control strategy during LVRT

In this section, the constant active current control strategy is adopted for the wind generator during the LVRT. The sensitivity analysis is carried out for the influence of DC commutation failure over-voltage under different active control target values (Ip =0.4Ip0, 0.6Ip0, 0.8Ip0) in Figure 7, in which Ip0 is the steady-state active current value of the wind generator.

4.2 The active power control strategy during LVRT recovery

This section analyzes the influence of different active recovery rates for the transient overvoltage of the system after the completion of LVRT, and compares the direct recovery of active power and the recovery according to a certain slope (Kp= 1 pu/ s, Kp=0.5 pu / s) on the completion of LVRT recovery in Figure 9.

4.3 The reactive power control strategy during LVRT

In this section, the constant reactive current control strategy is adopted for the wind generator during the LVRT. The sensitivity analysis is carried out for the influence of DC commutation failure
overvoltage under different coefficient of reactive support (Kq =0, Kq=0.5, Kq=1) in Figure 11, in which Kq is the coefficient of reactive support of the wind generator during LVRT.

Figure 11. The different coefficient of reactive support during LVRT

Figure 12. Transient Voltage Responser with the different coefficient of reactive support

4.4 The reactive power control strategy during LVRT recovery

This section analyzes the influence of different reactive recovery rates for the transient overvoltage of the system after the completion of LVRT, and compares the direct recovery of reactive power (Tq=0 s) and the recovery according to a certain slope (Tq= 0.025 s, Tq=0.05 s) on the completion of LVRT recovery in Figure 13, in which Tq is inertia time constant of the reactive recovery rates after LVRT.

Figure 13. The different reactive recovery rates during LVRT recovery

Figure 14. Transient Voltage Responser with the different reactive recovery rates

This paper can get the following conclusion based on the above research:

1) Under the condition of ensuring reactive power support, the more active power during the LVRT and the faster active power recovery rates after the LVRT will obviously suppress the transient overvoltage rise after the DC commutation failure from Figure 8 and Figure 10.

2) Under the condition of ensuring the same reactive power recovery rates after LVRT, the different reactive support during LVRT only affects the wind voltage during LVRT and no affect for the transient overvoltage in the later period from Figure 12.

3) Under the condition of ensuring the same reactive power support during LVRT, the faster reactive power recovery rates after the LVRT will obviously suppress the transient overvoltage rise after the DC commutation failure from Figure 14.

This study can provide technical references to safe and stable operation of the power system in new situation. The actual wind generator can be transformed to suppress the transient overvoltage caused by commutation failure based on the research of this paper.
5. Conclusion
In this paper, the phenomenon of transient overvoltage caused by DC commutation failure is explained based on Qi Shao DC. Moreover, the mechanism of transient overvoltage caused by the failure of DC commutation is analyzed based on the actual fault recording curve. In view of the problem that the transient overvoltage caused by commutation failure is in millisecond level, and the general emergency control can't take action. This paper emphatically analyze the influence of active / reactive power control strategy during LVRT and active / reactive power control strategy during LVRT recovery for the transient over-voltage of the system based on PSASP software, in which can provide technical references to safe and stable operation of the power system in new situation.

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