Short circuit current limiting method based on VSC-HVDC current limiting strategy

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Abstract. In this paper, a short-circuit current suppression method based on the adjustment of low-voltage current limiting strategy is proposed, which can suppress the output current of VSC-HVDC system during the fault by adjusting the low-voltage current limiting setting value of the VSC-HVDC control system, so as to achieve the purpose of suppressing the short-circuit current level in the converter station.

1. Introduction

In the operation of power system, short circuit fault is one of the most common faults, and its short-circuit current will have a serious impact on the safe and stable operation of the power system. VSC-HVDC transmission technology has the ability of active and reactive power independent control, passive system power supply and DC networking. It has been widely used in engineering worldwide\textsuperscript{[1-3]}. It provides solutions for new transmission modes such as passive network power supply and asynchronous power grid interconnection and the construction of strong power grid. So far, nearly 30 VSC-HVDC projects and nearly 100 conventional HVDC projects have been put into operation in the world. However, the short-circuit current problem after the VSC-HVDC transmission system is connected to the receiving power grid is still lack of research. The impact of HVDC system, especially the impact of VSC-HVDC system on the short-circuit current level of AC system has gradually become the focus of the industry. Considering the influence mechanism of VSC-HVDC control and protection logic on short-circuit current, the method of restraining the short-circuit current provided by VSC-HVDC control and protection logic is proposed, which is of great significance to ensure the safety and stability of the system \textsuperscript{[4-5]}.

The low voltage current limiting constant value adjustment method for three-phase short-circuit current suppression in the near zone of VSC-HVDC can suppress the output current of the VSC-HVDC system during the fault period by adjusting the low-voltage current limiting setting value of the VSC-HVDC control system on the basis of clarifying the short-circuit current mechanism provided by the flexible direct current control system, so as to achieve the purpose of suppressing the short-circuit current level of the converter station in the near area\textsuperscript{[6]}.
2. Principle of VSC-HVDC output fault current and low voltage limit current link

The current limiting link is usually set in the control system of VSC-HVDC to protect IGBT equipment from over-current damage in case of fault or interference. The maximum limiting \( k_{\text{lim}} \) setting is usually 1-1.2. Therefore, the output current of VSC-HVDC as follows[7]:

\[
\begin{align*}
I_{dc0} &= \frac{\sqrt{P_0^2 + Q_0^2}}{\sqrt{3}U_s} \\
I_{dc_{\text{max}}} &= k_{\text{lim}} \frac{S_{\text{VSC}}}{\sqrt{3}U_s}
\end{align*}
\]

It can be seen from the above formula that after AC system failure, the output current of VSC-HVDC will quickly reach the limit value of limiter. The larger the current limiting value, the greater the output current of VSC-HVDC after fault.

3. Content of short circuit current limiting method

During the fault period, the short-circuit current level in the near zone of the VSC-HVDC control system is closely related to the fixed value of the limiting link of the VSC-HVDC control system, and the output short-circuit current of the VSC-HVDC is related to the flexible direct current capacity and the limiting multiple. The invention aims at the situation that the electric distance between the fault and the converter station is close, and the converter station does not exit during the fault period. Combined with the VSC-HVDC limiting strategy and the calculation method and theory of the short-circuit current in the near zone of the VSC-HVDC system, an adjustment method of the fixed value of the low-voltage current limiting is proposed, which is suitable for the three-phase short-circuit current suppression in the near region of the VSC-HVDC.

This paper proposes a VSC-HVDC short-circuit current suppression method based on the adjustment of low-voltage current limiting setting value.

Step 1: establish the electromagnetic transient simulation data model of VSC connected to power grid;

Step 2: set the station level control mode of flexible direct current transmission system, the typical control mode is sending end (constant DC voltage; fixed reactive power), receiving end (constant active power; fixed reactive power (+50Mvar) or constant AC voltage), and typical parameters are adopted for limiting and setting value;

Step 3: judge whether the single-phase short-circuit current \( I_K \) of the bus in the near area needs to be controlled, and if it exceeds the standard, turn to step 4,

Step 4: adjust the current limiting setting value of VSC converter station to current limiting configuration 1, and judge whether the bus short-circuit current \( I_K \) of the station near the area needs to be controlled after adjustment. If it exceeds the limit, turn to step 5, otherwise turn to step 6;

Step 5: adjust the current limiting value of VSC converter station to current limiting configuration 2;

Step 6: end of method
Establishing VSC simulation data model

Setting typical station level control mode and limiting amplitude

Analysis of short circuit current level of busbar near converter station

Is it necessary to control bus short circuit current $I_k$?

Y

Adjust the current limiting setting value of converter station to current limiting configuration 1

N

Is it necessary to control bus short circuit current $I_k$?

Y

Adjust the current limiting setting value of converter station to current limiting configuration 2

N

End of method

Fig. 1 Method flow chart

4. Application of the method in actual power grid

In this paper, the applicability of the proposed method is analyzed by taking the calculation scenario of AC short circuit current of a domestic VSC-HVDC project as an example. The structure of VSC-HVDC near area grid is shown in the figure below, in which node 4 is the receiving end of VSC-HVDC. The control mode and setting value are as follows:

Flexible direct operation mode: constant active / reactive power.
Flexible straight operation condition: bipolar ($P = 3000$MW; $q = 50$Mvar).
Based on the method proposed in this paper, firstly, the simulation model of the VSC-HVDC converter station is established. In order to improve the calculation efficiency, the simplified equivalent network is adopted in the AC system. Through time domain simulation, the three-phase short-circuit current level of the node bus near the converter station is analyzed.

The simulation results show that the short-circuit currents of 4, 5 and 3 phases are 42.85 kA, 52.3 kA and 39.44 kA respectively. Taking the three stations as an example, the effects of adjusting the parameters of VSC-HVDC limiting link, adjusting the fixed value of low-voltage current limiting in sections, restraining the short-circuit current contributed by flexible direct current and the short-circuit current level of near-field stations are studied.

Two current limiting configurations:

| Tab.1 Current limiting configuration 1 | 1  | 2  | 3  | 4  |
|--------------------------------------|----|----|----|----|
| Voltage (p.u.)                       | 0.2| 0.5| 0.8| 1.0|
| Current amplitude (p.u.)             | 0.15| 0.8| 1.0| 1.1|

| Tab.2 Current limiting configuration 2 | 1  | 2  | 3  | 4  |
|--------------------------------------|----|----|----|----|
| Voltage (p.u.)                       | 0.2| 0.5| 0.8| 1.0|
| Current amplitude (p.u.)             | 0.10| 0.6| 0.8| 1.1|

The simulation results are as follows

| Tab.3 The current limiting configuration 1 is adopted for short-circuit current level |
|-------------------------------------------------------------------------------------|
| control mode | Short circuit current before / after three phase current limiting (kA) |
|---------------|---------------------------------------------------------------------|
| Active priority | Failure point | point 4 | point 5 | point 3 |
|                | Contribution of VSC/kA | 42.85/41.0 | 52.3/49.9 | 39.44/37.3 |
|                | 4.04/0.56 | 4.04/0.56 | 4.04/0.56 |

| Tab.4 The current limiting configuration 2 is adopted for short-circuit current level |
|-------------------------------------------------------------------------------------|
| control mode | Short circuit current before / after three phase current limiting (kA) |
|---------------|---------------------------------------------------------------------|
|               |                                                                      |
### Table

| Active priority | Failure point | point 4 | point 5 | point 3 |
|----------------|---------------|---------|---------|---------|
| Contribution of VSC/kA | 42.85/40.2 | 52.3/48.8 | 39.44/36.2 |

According to the above table, when the short-circuit current exceeds the standard, the three-phase short-circuit current level near the VSC-HVDC access point can be significantly reduced by setting the low-voltage current limiting link in current limiting configuration 1 and current limiting configuration 2. It can prove the effectiveness of the proposed method.

### 5. Conclusion

This paper presents a method of adjusting the setting value of low-voltage current limiting, which is suitable for three-phase short-circuit current suppression in the near zone of VSC-HVDC. On the basis of clarifying the mechanism of short-circuit current provided by flexible direct current control system, the output current of VSC-HVDC system during fault can be suppressed by adjusting the setting value of low-voltage current limiting of VSC-HVDC control system, so as to achieve the purpose of restraining short-circuit current level near converter station.

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