Analysis of the Influence of Commutation Failure on the Converter Valve without Back-Inspection EHV Power Transmission

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Abstract. In the DC transmission system, the inverter side converter valve often has a commutation failure. The commutation failure will cause the valve control to misjudge the converter valve without back-check, which may lead to DC blocking. This paper studies the optimization of the valve control system with measures to improve the DC control system software when the AC system fault AC voltage is higher than the threshold value. It is verified through practical application that the measures are implemented well and can effectively reduce the risk of DC blocking. The measures can provide technical reference for the operation and maintenance of converter station equipment.

Keywords: converter valve, commutation failure, check back.

1. Introduction
At present, conventional DC transmission technology is a mature technology for long-distance, large-capacity power transmission and has been widely used in various power transmission projects. The SCR thyristor converter valve is the core component of the DC transmission project and is responsible for AC/DC conversion. The SCR thyristor converter valve is composed of a certain number of SCR thyristors in series, and a certain amount of redundancy is reserved to ensure that it can withstand the overvoltage generated by lightning strikes, operation, and exchange. [1-15] The valve control system must monitor the number of thyristor failures and block the DC system when the number of redundancies is insufficient to prevent further damage to the converter valve.

Because of its advantages such as large transmission capacity and long transmission distance, high-voltage direct current transmission using grid-commutated converters has become the main means to solve the problem of the reverse distribution of the geographical position of my country's energy centers and load centers. However, the thyristor of its converter device has no self-shutdown capability, so it is easy to cause commutation failure when the receiving end AC system fails. After the first commutation failure occurs, the DC voltage and current fluctuate violently, which will cause an impact on the power grid equipment, and at the same time, it will easily lead to subsequent commutation failures. In severe cases, the DC will be blocked and the transmission power will be interrupted [4]. With the gradual increase in the number of DC transmission lines fed into the AC grid at the receiving end, the AC-DC coupling is becoming tighter. If a single converter station fails for the first time, it may cause the...
The security of my country's AC/DC hybrid power grid poses a serious threat.

Commutation failure is a fault that occurs on the inverter side of the converter valve. It is caused by the turn-off characteristics of the thyristor device. The thyristor that should be turned off does not turn off normally but keeps conducting. This is a kind of unavoidable fault usually occurs when the AC system voltage fluctuates.

2. Valve non-recheck monitoring principle

Most of the SCR thyristor failures are broken down, showing a short-circuit state. The normal thyristor can withstand a certain voltage after it is turned off, and the faulty thyristor cannot withstand the voltage due to a short circuit. During the turn-off period of the thyristor, monitor the voltage of the thyristor, and report a signal when there is voltage. Under normal conditions of the positive transmission channel, if the report signal is not received, it indicates that the thyristor is in a short-circuit state, and the fault is called no return check.

Usually, each thyristor in the converter valve is connected in parallel with a high-voltage circuit board, which is connected to the light receiving board of the valve control system through an optical fiber. When the high-voltage circuit board detects that the forward voltage on both sides of the corresponding thyristor is greater than the threshold (120V), the report signal will be sent to the valve control system through the optical fiber. If the valve control system does not receive the report signal for three consecutive monitoring cycles, it will be judged that the thyristor has no return inspection.

For a 12-pulse converter valve, the entire converter valve consists of 12 bridge arm converter valves. If the number of thyristors in a bridge arm converter valve without back-checking reaches the redundant number, in order to protect the converter valve equipment, the valve control system will trip and block the DC.

3. Analysis of countermeasures for commutation failure

When the AC system has disturbances and voltage fluctuations, the inverter-side converter valve may fail to commutation, which is related to the commutation time and commutation angle of the thyristor, and has no direct relationship with the amplitude of the AC voltage fluctuation.

When the commutation failure occurs, it means that at least one bridge arm converter valve cannot be normally shut off and has been kept in the conducting state. The on state of the thyristor is a short-circuit state, which cannot withstand voltage and cannot generate a report signal. When the conducting state of the thyristor is maintained for three monitoring cycles, it will be judged by the valve control system as no back-check. When the commutation failure maintenance time reaches three monitoring cycles, all the thyristors of the bridge arm converter valve that cannot be closed normally will be judged by the valve control system as no back-check. Then the number of non-rechecks must exceed the redundant number, and the valve control system will trip and block the DC.

During the commutation failure, the thyristor is fault-free, but because it cannot be turned off, it is judged by the valve control system as no backcheck, but the commutation failure is unavoidable, and the commutation failure will have a fatal impact on the operation of the converter valve. In order to eliminate this effect, an AC low-voltage signal is introduced. When an AC low-voltage signal occurs, the valve control system blocks the thyristor monitoring function, and does not monitor the state of the thyristor to maintain the operation of the converter valve. When the DC control system detects that any phase voltage on the AC side of the converter transformer is less than the threshold value or the maximum value of the three-phase voltage is less than the threshold value, it sends a low AC voltage signal to the valve control system, and the valve control system blocks the thyristor monitoring function.

When the voltage fluctuation occurs in the AC system, the commutation failure does not necessarily occur. When the commutation fails, there must be voltage fluctuations in the AC side system, which is not directly related to the amplitude of the AC voltage fluctuations, which makes it difficult to obtain a suitable AC low voltage threshold, and it is difficult to characterize all commutation failures through the AC low voltage. In this way, under certain circumstances, when the commutation fails, the AC voltage...
fluctuation does not reach the threshold, and the AC low voltage signal is not sent, the valve control system will continue to monitor the state of the thyristor, and if the number of non-rechecks exceeds the redundant number, a trip will occur, DC blocking.

4. Case analysis and improvement measures
A phase A fault of a 500kV line in the network tripped, a commutation failure occurred in a DC double-circuit quadrupole, a converter station B-return pole 1Y4 converter valve no thyristor redundancy appeared, a converter station B-return pole 1 valve control system 1 (Main system) tripped, and a converter station B returned to pole 1 back to the standby state.

Judging from the fault record of the second circuit pole 1, the AC voltage of the second circuit pole 1 has been distorted, but no AC low voltage signal is detected, and the second circuit pole 1 Y4 bridge arm has a trip signal after three consecutive cycles of conduction. As shown in Figure 1.

![Figure 1. B-return pole 1 fault recording waveform (trip)](image)

Judging from the fault record of the second pole 2, the AC voltage of the second pole 2 has been distorted, and an AC low voltage signal is detected. Although the second pole 2 Y4 bridge arm is also turned on for three consecutive cycles, the AC low-voltage signal blocks the thyristor monitoring function, the valve control system does not send a trip signal, and the DC system recovers from the commutation failure and continues to run. As shown in Figure 2 below.
During a 500kV line failure, the AC voltage of a converter station dropped to near the threshold (0.8pu), and a total of 8 sets of DC double-circuit four-pole DC control systems sent 5 sets of AC low-voltage signals to the valve control system. The 3 sets of DC control systems did not send out AC low voltage signals because the AC voltage was near the critical value (the criterion was not met), of which one set was the B-return pole 1 operating system, and the other two were the A-return pole 1 and the B-loop Pole 2 backup system (no impact). Since the B-return pole 1 valve control system did not receive the AC low voltage signal, it continued to monitor the converter valve without back-check signal, and judged that a large number of thyristors had no back-check and exceeded the trip limit, and the valve control system issued a trip request.

According to the above analysis, in the AC system failure, especially the AC voltage amplitude is not lower than the threshold value (0.8pu), the DC system has a greater risk of commutation failure leading to DC blocking.

Improvement measures: As the AC power grid is too complex, the time of failure and the voltage drop at the time of the failure cannot be determined. In addition, the commutation failure is not directly related to the amplitude of AC voltage fluctuations, so it is difficult to obtain a suitable AC low voltage threshold. Before or in the early stage of commutation failure, the DC control system can quickly predict or judge whether commutation failure occurs, and send out signals such as "commutation failure prediction signal" and "commutation failure detected". During the commutation failure period, the "commutation failure prediction signal", "commutation failure is detected" and other signals are used to block the valve control system thyristor monitoring function. In order to further improve the reliability, the "commutation failure is detected" signal is changed to the original AC low voltage signal phase OR, and then output a new AC low voltage signal to the valve control system. The schematic diagram of the software logic improvement of the DC control system is shown in Figure 3.

![Figure 2. B-Return Pole 2 Fault Recording Waveform](image)
In this way, only the DC control system software needs to be modified, and no other equipment software and hard wiring need to be modified, which greatly reduces the difficulty of implementation. Since the implementation of this measure, there has not been a similar fault trip in 5 years.

5. Conclusion
Commutation failure will cause the valve control system to misjudge that the converter valve has no back-check, and the adopted AC low-voltage signal blocking thyristor monitoring function has imperfect anti-error measures, resulting in commutation failure when the voltage disturbance amplitude is above the threshold. DC blocking. After the implementation of improved measures to increase the commutation failure signal blocking thyristor monitoring function, the effect is very outstanding, and the stable operation of the DC system is guaranteed.

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