Case Analysis of Hall Sensor Fault Causing UHVDC Valve Group Unlocking Failure (Postprint)

Authors: Xie Chao, Li Qiankun, Wang Huiquan

Date: 2019-03-05T00:00:00+00:00

Abstract

Hall sensors are unique open/close position sensing elements for bypass circuit breakers in ultra-high voltage direct current (UHVDC) transmission systems, playing a crucial role in the process of unlocking another valve group when a single valve group is operating within the same pole. This paper analyzes a case of unsuccessful valve group unlocking caused by Hall sensor failure and proposes recommendations for periodic calibration of Hall sensors as an improvement measure.

Full Text

Analysis of UHVDC Valve Group Deblock Fault Caused by Hall Sensor Failure

Xie Chao, Li Qiankun, Wang Huiquan
Guangzhou Bureau, CSG EHV Power Transmission Company, Guangzhou 510663, China

Abstract

Hall sensors serve as specific switch-position sensors for bypass switches in UHVDC transmission systems and play a critical role in the process of deblocking a single valve group while another valve group is operating in the same pole. This paper analyzes a case of valve group deblock failure caused by Hall sensor malfunction and proposes improved recommendations for regular testing and calibration of Hall sensors.

Keywords: UHVDC, Hall sensor, bypass switch, deblock failure

1 Introduction

The Yun-Guang UHVDC transmission project is the world' s first ±800 kV UHVDC transmission project [1], featuring a bipolar four-valve-group design. Each pole consists of two 12-pulse valve groups connected in series, and individual valve group operation can be controlled through the opening and closing of bypass switches connected in parallel with the valve groups [2].

Since bypass switches must interrupt DC current with a rated voltage of 400 kV and rated current of 3,150 A, neither active nor passive DC circuit breakers can directly interrupt such DC current. Therefore, coordination with converter valve groups is required to achieve current transfer [3]. During actual operation of the Yun-Guang UHVDC project, a fault occurred where a bypass switch position sensor failure prevented converter valve deblocking. This paper analyzes this fault and proposes improvements to preventive testing procedures for bypass switches.

2 Fault Description

At 17:46 on April 2, 2014, at a ±800 kV converter station, sequential deblocking of the Pole II high-end valve group was attempted while the low-end valve group was in operation. After bypass switch 0820 (hereinafter referred to as 0820) opened, the Pole II high-end valve group protection 82BPS activated, initiating DC emergency switch-off (ESOF) for the Pole II high-end valve group. 0820 subsequently reclosed, and the sequential deblocking of the Pole II high-end valve group failed.

The DC field bypass switch (BPS) is equipped with bypass switch protection stage I (82BPS-I). The protection operating logic is as follows: The operating criterion for 82BPS-I is: $|IdBPS| > 0.07$ pu (219 A) AND Open Bypass Switch Request = 1 (or Bypass Switch Checkback = 0), with T = 50 ms. In other words, when the valve group protection receives a command from the group control system to open the BPS switch (Group Protection/Group Control_Bypass Switch_Open_Request) or when the BPS switch is in the open position, and the current flowing through the BPS switch IdBPS exceeds 219 A, the 82BPS-I protection will operate after a 50 ms delay to close the BPS switch.

According to waveform Figure 1 [Figure 1: see original paper], at 17:46:07.03002, the valve group protection (=22RG11+R1) (hereinafter referred to as group protection) received a command from the group control system to open bypass switch 0820. At this moment, the digital signal "22RG11+R1/GC_BPS_OPEN_REQ" (i.e., the "Open Bypass Switch Request" signal) in the group protection software program abruptly changed from "0" to "1" , and this command lasted for approximately 100 ms.

After receiving the command to open 0820, the group protection enabled bypass switch protection stage I (82BPS-I) following a 15 ms delay. At 17:46:07.0586, the digital signal "22RG11+R1/GDCP_BPS_Checkback" (i.e., the "Bypass

Switch Checkback" signal, hereinafter referred to as the "Checkback" signal) in the group protection software program abruptly changed from "1" to "0" , as shown by the red digital signal in Figure 2 [Figure 2: see original paper].

During the period when group protection was enabled, the IdBPS current increased from 3,146 A to 3,750 A, continuously satisfying the |IdBPS| > 0.07 pu (219 A) criterion. After a 50 ms delay, at 17:46:07.096, the group protection operated to close 0820, as indicated by the green digital signal in Figure 3 [Figure 3: see original paper], which represents the "22RG11+R1/CLS_BS_REQ" signal.

Based on the above operating sequence analysis, the bypass switch protection stage I (82BPS-I) operated correctly.

3 Fault Analysis and Processing

In UHVDC transmission systems, when one valve group of a pole is in operation and the second valve group is being deblocked, the bypass switch of the second valve group must be opened. Due to the limited arc interruption capability of the bypass switch, precise control by the valve group control system is essential during deblocking of the second valve group. This ensures close coordination between the converter valve firing sequence and the opening time of the bypass switch of the valve group to be deblocked, guaranteeing that the current flowing through the bypass switch is minimized when it opens and that the current is reliably transferred to the converter valves (referred to as the forced phase-shifting process).

The specific principle is as follows: When one valve group is already in the deblocked state, the converter valves are not deblocked. After receiving the open command, the valve group bypass switch initiates its operating mechanism to open. At 40 ms into the switch operation, the switch position detection unit sends a corresponding analog signal to the valve group control system, indicating that the switch will open in 10 ms. Upon receiving this analog signal, the valve group control system immediately releases firing pulses and maintains a firing angle of 70°. Since the DC side of the valve group to be deblocked is short-circuited by the bypass switch, the current contributed by the deblocking valve group to the bypass switch is opposite in direction to the current generated by the other valve group. Tests have shown that the inrush current generated 10 ms after deblocking with a 70° firing angle can transfer the current from the bypass switch to the converter valves, and the current flowing through the bypass switch can meet the switch' s arc extinguishing capability requirements. The valve group bypass switch reliably opens 10 ms after converter valve deblocking, and the valve group control system then delays 6 ms before switching the firing angle from 70° to normal operation according to whether it is on the rectifier or inverter side, successfully deblocking the second valve group. The software logic of the group control system is shown in Figure 4 [Figure 4: see original paper].

As shown in Figure 5 [Figure 5: see original paper], when the Pole II high-end valve group initiated the deblocking sequence and issued the open 0820 command, the group control system did not receive the 0820 open position signal within 65 ms (the time interval from when group protection received the 0820 open command to when bypass switch protection stage I operated is 15 ms + 50 ms = 65 ms). This prevented the group control system from initiating the forced phase-shifting process in time, causing the current flowing through 0820 to remain above 3,125 A without decreasing. Consequently, the bypass switch protection stage I of the group protection operated, reclosing 0820 and initiating valve group ESOF. Additionally, Figure 5 shows that during the fault, the 0820 open position signal was delayed by approximately 143 ms before being fed back to the group control system. Under normal conditions, the bypass switch open position signal should be fed back to the group control system approximately 40 ms after the deblocking command is issued.

The position transmitter of the bypass switch itself can transmit a 4–20 mA analog current signal to represent changes in switch position during opening and closing operations. Therefore, by comparing the delay times of the group protection "Checkback" signal and the group control system "CLOSED" signal, it was found that the position transmitter in the bypass switch mechanism box was not functioning properly, and the group control system was receiving position signals from the measurement and control device via fieldbus. Therefore, the preliminary conclusion was that the position transmitter sending signals to the group control system had malfunctioned.

Since the position signal must be sent to the group control system 10 ms before the bypass switch completes its opening operation, conventional auxiliary contacts of circuit breakers cannot be used for signal transmission. The position signal received by the group control system is actually transmitted by a Hall sensor fixed to the circuit breaker.

Hall sensors are a common type of sensor with unique magnetic field sensing capabilities, featuring simple circuit structure, low noise, small size, wide dynamic range, broad frequency response, and long service life. Magnetic fields can be used as information carriers to convert non-electrical, non-magnetic physical quantities such as displacement, force, acceleration, angle, angular velocity, and rotational speed into electrical signals in measurement applications [4].

Based on the characteristics of Hall sensors, they are well-suited for non-contact position signal detection before the bypass switch is fully opened. When the circuit breaker opens or closes, the permalloy sensor head fixed on the circuit breaker lever moves with the lever' s motion, as shown in Figure 6 [Figure 6: see original paper].

The key characteristic of permalloy is its high magnetic permeability in weak magnetic fields. When it quickly passes over the Hall sensor element (see arrow in Figure 6), the Hall sensor generates a 4–20 mA analog current signal. By varying the installation position of the sensor head, signals reflecting any stroke of the circuit breaker' s opening or closing can be transmitted.

After replacing the Hall sensor element, remote opening and closing operations were performed again, and waveforms were recorded during the operation. Analysis of the recorded waveforms revealed that the coordination timing between 0820 and the control and protection system met the program requirements, as detailed in Figure 7 [Figure 7: see original paper]. The valve group was successfully deblocked after replacement.

4 Conclusion

Analysis of this unsuccessful valve group deblocking case demonstrates that the position transmitter of the bypass switch plays a critical role in the control system when one valve group of a pole is operating and the second valve group is being deblocked. Currently, various circuit breaker testing procedures do not include inspection requirements for position transmitters based on Hall sensor principles. In conventional preventive test items, circuit breaker opening and closing time measurement only covers contact operation time, with no measurement requirements for signal transmission time. Therefore, it is recommended that during preventive testing of bypass switches, the position signal transmission time should also be measured to ensure proper output of open and close position signals.

References

[1] Xu Aidong, Liu Yongjun, Wu Xiaochen. Study on security and stability control strategy for ±800 kV Yun-Guang UHVDC transmission[J]. Southern Power System Technology, 2008, 2(5): 14-18.

[2] Gao Wen. Development and structure analysis of the switchgear applied to UHVDC transmission system[J]. High Voltage Apparatus, 2012, 48(11): 134-138.

[3] Chen Yuzhong. Design of the velocity measuring system of Hall sensor[J]. Science Technology and Engineering, 2010, 30(10): 7529-7532.

[4] Wang Bangtian. Technology of HVDC circuit breaker[J]. High Voltage Apparatus, 2010, 46(9): 61-64, 68.

Note: Figure translations are in progress. See original paper for figures.