A failure analysis of a generator unit shutdown due to short circuit of generator positive and negative collector rings

Shifu Liu¹, Zhunli Qian¹*

¹ Huadian Electric Power Research Institute Co. LTD, Hang Zhou, Zhejiang, 310030, China
* Corresponding author’s e-mail: zhunli-qian@chder.com

Abstract. Taking the short circuit faults of the positive and negative collector rings of a 40MW gas turbine generator as an example, the failure process of the generator's positive and negative collector rings is analyzed, the process of failure occurrence is explained, and the cause of the failure is analysed, the main reason for the failure is that the air inlet filter of the collector ring chamber of the generator is damaged and falls off, and the broken and dropped filter screen enters the collector ring chamber with the wind, which causes a short circuit of the positive and negative collector ring. Finally, the corresponding treatment and preventive measures are formulated.

1. Introduction
At 23:48 on May 1, 2020, units 3 and 4 are running, units 1 and 2 are on standby, unit 3 has a load of 140MW, unit 4 has a load of 89MW, medium-pressure heat supply 15T/H, low-pressure heat supply 20T/H. At 23:48:52, the No. 3 unit's generator-transformer group protection cabinet A and generator-transformer group protection cabinet B both issued the "excitation transformer overcurrent" protection action signal, and the unit tripped.

2. Equipment overview
Unit 3 was put into commercial operation in October 2017. The generator protection of Unit 3 adopts the DGT801UB digital generator and transformer protection device produced by Guodian South, and the excitation transformer protection No. 3 uses the DGT801UD digital transformer protection produced by Guodian South. Device, generator protection A, B cabinet is a dual protection configuration. The No. 3 excitation becomes the ZLSCB-3600 / 6.3 dry transformer produced by Hainan Jinpan Electric Co., Ltd., with a capacity of 3600KVA and a high and low voltage side conversion ratio of 6300/1250. The excitation system of the No. 3 unit uses General Electric's EX2100e excitation system.

The complete set of equipment such as the carbon brush, brush holder, collector ring, filter screen of the collector ring chamber of No. 3 generator is provided by Harbin Electric.

3. On-site inspection
3.1. Action information of A cabinet of generator transformer group protection
At 23:48:52 on May 1, 2020, the cabinet A of the generator-transformer protection group issued the "excited overcurrent" protection action signal.
View the relevant data of the cabinet A at 23:48:52: over-current fixed value 1400A, delay 0.2s, current quick determination value 5530A, delay 0s, phase B current 15.178A on the high voltage side of the excitation transformer (secondary Value), CT transformation ratio 500/5, primary value 1517.8A, failed to reach the fixed value of current quick-break protection, reached the fixed value of overcurrent protection, so the excitation transformer overcurrent protection delay 0.2s action outlet, the unit trips[1].

3.2. Action information of B cabinet of generator transformer group protection

At 23:48:52 on May 1, 2020, the generator-transformer protection cabinet B issued the "excitation transformer overcurrent" protection action signal.

View the relevant data of the generator protection group B cabinet at 23:48:52: the phase B current on the high voltage side of the excitation transformer is 15.569A (secondary value), the CT transformation ratio is 500/5, and the primary value is 1556.9A, which achieves overcurrent protection Set value, the unit trips.

3.3. Action information of generator-transformer fault recorder

Before 23:48:52.120, the high voltage side current of No. 3 excitation transformer is 127.5A (secondary value 0.255A), the excitation current of No. 3 machine is about 806A (secondary value 8.335mA, transmitter output), and the excitation voltage is about 218V (two Secondary value 7.5mA, transmitter output).

After 23:48:52.120, the current on the high voltage side of No. 3 excitation transformer suddenly increased to 1250A (secondary value 2.5A), and continued to rise. The excitation current of Unit 3 is over range (the maximum output of the transmitter is 20mA). The excitation current is about 7659A in terms of current conversion on the high-voltage side. Excitation voltage is about 200V (secondary value 7.2mA, transmitter output) [2].

At 23:48:52.360, the current on the high voltage side of No. 3 excitation transformer rose to 1450A (secondary value 14.5A). The excitation current of Unit 3 is converted to 9246A according to the high-voltage side current. Excitation voltage is about 106V (secondary value 5.7mA, transmitter output), as shown in figure1, figure 2, figure 3.

![Figure 1. Excitation transformer high-voltage side current of fault recorder](image)
At 23:48:52.597, the closing signal of the outlet breaker and the de-excitation switch of the No. 3 generator disappeared, and the high-voltage side current of the No. 3 excitation transformer and the excitation current and voltage of the No. 3 generator fell to 0A.

At 23:48:52.624, the fault recorder received feedback that the generator breaker of No. 3 outlet tripped.

At 23:48:52.680, the fault recorder received feedback that the No. 3 unit de-excitation switch tripped.

During this period, the current and voltage of No. 3 generator terminal almost did not change, and the 6kV bus voltage dropped from 6.4kV (secondary value 59.16V phase voltage) to 5.9kV (secondary value 54.85 phase voltage).
3.4. Inspection of excitation regulator
Excitation regulator reports "EX Tripped on 86G Customer Lockout", "The Exciter has tripped", "Alarm is present on the exciter", the event information listed on the local controller of the excitation device are all kinds of SOE events after the deexcitation switch trips, no protection action and fault information[3]. As shown in figure 4.

3.5. Inspection of excitation regulator
Looking at the monitoring screen, about 23:48:52 on May 1st, there was an arc in the collector ring chamber of the No. 3 gas turbine. The staff further inspected the excitation brush holder and the collector ring body, and found that the surface of the insulating cylinder between the positive and negative electrodes had color changes and flaking caused by heat. There is no obvious burning trace on the surface of the collector ring, carbon brush, brush holder, etc., the contact surface of the carbon brush is smooth, and the length meets the requirements[4].

On-site cranking was stopped, the excitation brush holder was removed and inspected. It was found that the fine metal wire and the fine filter of the air inlet filter were damaged. It was confirmed that the metal wire was the material used for the fine filter of the air inlet filter of the collector ring chamber. The burning point of the discharge was found on the opposite side of the positive and negative poles of the slip ring, as shown in figure 5, figure 6, figure 7, figure 8.
3.6. Test inspection
The insulation resistance of the high voltage side of No. 3 excitation transformer is 1000 MΩ (including the high voltage cable); the direct resistance of the star winding of the excitation transformer high voltage side is 17.8 MΩ (10A). The insulation of the low-voltage side of No. 3 excitation transformer is 20 MΩ (including the low-voltage side cable); the direct resistance of the low-voltage side triangular winding is 2.2 MΩ (10A).

The test data of No. 3 gas turbine rotor winding insulation, direct resistance and zero-speed AC impedance are normal.

4. Cause analysis
(1) The direct cause of the shutdown of the unit: the protection and operation signal of "excitation transformer over-current" was reported in cabinets A and B of the generator-transformer protection group.

(2) Reasons for protecting the "exciting transformer overcurrent" protection action of cabinets A and B: the current on the high-voltage side of the exciting transformer reached the fixed value of the protective action, and the exit of the protective action trips[5].

(3) The cause of overcurrent on the high-voltage side of the excitation transformer: a short circuit occurred between the two collector rings of the generator rotor.

(4) The reason for the short circuit between the two collector rings of the rotor: the fine filter part of the air inlet filter of the generator carbon brush chamber entered the collector ring chamber through the gap at the splice of the filter frame and overlaps between the two collector rings.

(5) The reason why the fine filter part of the screen entered the collector ring chamber: the fine filter part of the air inlet side was damaged and fell off and the fine filter part of the filter was seriously blocked by dust. The splicing gap was sucked into the collector ring chamber by cooling air.

5. Main problems exposed
(1) The hidden troubles were not checked in place. During the maintenance, the risk of aging and falling off of the filter screen was not paid attention to, and the problem of visible gaps at the joint of the filter frame was not paid attention to, and no foreign objects were found to enter the collector ring chamber from this gap, causing failure risk.

(2) The quality of the air inlet filter of the collector ring chamber was poor. There was a problem with the quality of the filter screen. During the use period, the fine filter part of the filter screen was damaged and falls off, and the filter frame had a certain degree of bending, resulting in a gap at the splice of the filter frame.
There was a design defect in the collecting ring chamber filter screen. The filter screen was composed of the middle part of the metal coarse filter and the outside of the filter covered with metal fine filter. During operation, the air volume was large, and after the filter screen was damaged, it was easy to be inhaled into the chamber, resulting in short circuit or grounding of the collecting ring and carbon brush[6].

6. Conclusion
(1) After the surface of the damaged sleeve insulating sleeve is polished, the surface of the sleeve is coated with epoxy resin, and the insulation resistance of the sleeve to the collector ring is measured.
(2) The fine filter of the air inlet filter is removed (confirmed by the manufacturer), and only the coarse filter is retained, which can meet the filtration requirements.
(3) Strengthen the investigation of hidden dangers, focusing on the inspection of Unit 1, to avoid the recurrence of similar problems.
(4) The maintenance regulations were revised, and the maintenance measures of the air inlet filter were refined and strictly implemented. To formulate the technical measures to deal with the abnormal situation of the filter net maintenance in the small chamber of collecting ring.
(5) The product quality of the air inlet filter of the collector ring chamber is strictly controlled.

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