Analysis and preventive measures of a shutdown accident caused by high voltage insurance slow melting of a voltage transformer used in excitation system

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Abstract. The voltage transformer (TV) excitation system high-voltage fuse is divided into two cases: one is a short-time fast fuse in the high-voltage fuse, and the voltage on the secondary side of the transformer should drop to zero in an instant. The second is that the high-voltage insurance is slowly fused for a long time, and the voltage on the secondary side of the voltage transformer drops slowly, resulting in the excitation system erroneously strong excitation, the terminal voltage rises, the over-excitation protection action chain reaction, and even the accidental trip. In recent years, the shutdown accidents frequently occur in China due to the high voltage insurance slow-melting of excitation voltage transformers. In this paper, the author analyzes the accident caused by the slow melting of TV high voltage insurance for excitation of one-million-kilowatt units in a company, and puts forward some preventive measures.

1. Introduction
The excitation system provides a stable excitation current for the generator and maintains the generator terminal voltage at a given value. When the generator load changes, the terminal voltage is kept constant by adjusting the strength of the magnetic field, and the reactive power distribution between parallel operating units is reasonably distributed. The generator voltage is measured by the excitation regulator with excitation TV, and the measured generator voltage is compared with the given value of the generator voltage, so as to control the generator voltage and stabilize the generator voltage[1]

In order to reduce the influence of short circuit inside generator TV on generator operation, a high-voltage fuse is generally installed on the high-voltage side of generator TV. If the excitation TV or TV high-voltage fuse fails in operation and the generator voltage drops or disappears, the excitation system will immediately increase the excitation until the relay protection action such as overvoltage of the generator trips. For this reason, the excitation regulator needs to have the excitation TV break protection function[2].

2. Overview of accident
Unit 3 of a company is 1000MW unit, and the excitation device is ABB UNITROL 6800 product. The generator outlet is equipped with 3 groups of TV, and TV1 is dedicated for interturn protection. TV2 is used for generator and transformer group protection cabinet A, fault recorder and excitation regulator channel 1 in generator group; TV3 is used for t generator and transformer group protection...
cabinet B and excitation regulator channel 2. At 23:34 on April 5, 2019, the stator voltage of no. 3 generator was 29.2kV, the stator current was 12567A, and the excitation current was 5536A. The generator unit tripping occurred due to the protection action of the generator and transformer group protection cabinet B "over-excitation inverse time limit".

9 high-voltage fuses of voltage transformers at the outlet of generators is replaced. The internal anti-slow melting logic parameters of the excitation regulator are changed from 5% to 3%, and simulating the completion of channel switching under the parameter of 3%. Unit 3 has been connected to the network at 17:42 on April 6, 2019.

3. On-site investigation

3.1 the action information of generator and transformer group protection cabinet A

On the spot, the action information of generator and transformer group protection cabinet A is checked. On April 5, 2019, at 23:00, 26:00 and 07 seconds, a "TV wire break" signal was sent out. Checked the fixed value of the device, When the pressure difference between phases reaches 6V, it will be compared with ordinary U2. If ordinary U2 > 0.5V, the protection device will report ordinary PT wire break and send a signal. If ordinary U2 < 0.5V, the protection device reports special PT wire breaking and interturn locking protection[3].

On the spot, the action information of generator and transformer group protection cabinet A is checked. On April 5, 2019, at 23:00, 26:00 and 07 seconds, a "TV wire break" signal was sent out. Checked the fixed value of the device, When the pressure difference between phases reaches 6V, it will be compared with ordinary U2. If ordinary U2 > 0.5V, the protection device will report ordinary PT wire break and send a signal. If ordinary U2 < 0.5V, the protection device reports special PT wire breaking and interturn locking protection[3].

3.2 the action information of generator and transformer group protection cabinet B.

On the spot, checked the action information of generator and transformer group protection cabinet B. On April 5, 2019, at 23:26 and 14 seconds, the signal of "over excitation fixed time limit action" is sent out from generator protection B cabinet. The setting value of "a message for action within a fixed time limit after excitation" is U/f=1.07 times, and the action time of tf1 is 5s. The CPUA data of transformer group protection cabinet B at 23:26 and 14 seconds on April 5: U/f=1.07 times; CPUB data: U/f=1.0701 times. U/f > 1.07 times, so the signal is sent out correctly.

At 23:34 and 13 seconds on April 5, 2019, over excitation inverse time protection of generator and transformer group protection cabinet B is acted, and unit 3 tripped. The setting value of "trip in over-excitation inverse time-limit action" is U/f=1.08 times, and tf1 action time is 83s. checked the CPUA data of transformer group protection cabinet B at 23:34 and 13 seconds on April 5, 2019: voltage U/f=1.0808 times; CPUB data: voltage U/f=1.0807 times. Voltage U/f > 1.08 times, so the protection action is correctly.

3.3 the action information of generator fault recorder

Checked the mode of starting recording wave of fault recorder before failure (17:43:24, 101.2ms, April 5), generator TV2 B phase voltage is 58.59V, three-phase voltage balance and amplitude is normal, indicating that the primary fuse of TV2 B phase is in good condition.

Consulted the recording file at 23:26 and 07 seconds when the fault occurred. The recording was started by the switch of the engine TV disconnection. At the starting time, the TV2 voltage value was Ua=58.88V, Ub=53.22V, Uc=58.21V. Active power is 638.171MW, reactive power is 80.635MVar. Consulted the recording file at 23:00 and 13:00 when the fault occurred. The recording is started by the generator over the excitation protection switch. At the starting time, the TV2 voltage is Ua=62.95V, Ub=55.24V, and Uc=62.21V. Active power 622.047MW, reactive power 426.486MVar.
3.4 The inspection of excitation regulator

Checked the display panel of the excitation regulator on the spot. At April 5 at 23:32 and 27 seconds (the clock timing is not correct), tripping instruction from generator and transformer group protection is sent out. The excitation regulator receives the external trip instruction and conducts the inverter demagnetization.

Checked the fusing logic of excitation regulator against TV high voltage fuse, the excitation regulator of unit 3 adopts the method of comparing the terminal voltage with the synchronous voltage or the standby channel terminal voltage to detect TV high voltage insurance slow fusion. The specific logic is as follows.

- The terminal voltage of the standby channel is higher than that of the operating channel and the difference value exceeds the set parameter by 5%; The synchronous voltage of this channel is higher than the terminal voltage and the difference value exceeds the set parameter by 5%. If the above two conditions are met, the TV disconnection signal is sent out after the delay of 2s, and the channel switch will be conducted at the same time[4].

3.5 The inspection of TV cabinet at generator outlet

On site, check the primary fuse of the voltage transformer at the outlet of the generator. Its rated voltage is 35kV and rated current is 0.5A. To test and analyze the high-voltage fuse, the TV2 B phase high-voltage fuse is damaged, and the rest 8 high-voltage fuse's resistance is around 388 Ω, the measurement of generator stator insulation is qualified, Outlet TV insulation is qualified and variable ratio measurement is correct. Through consulting materials and consulting manufacturers, we know that the material of the fault fuse is constantan. The breakdown inspection of the failed fuse shows that the internal fuse has been fused, as shown in figure 1.

![Fuse of hv fuse.](image)

Figure 1. Fuse of hv fuse.

4. Cause analysis

(1) The direct reason for the shutdown of the unit is the protection action of the transformer group protection B cabinet "over-excitation inverse time limit".

(2) The reason for the protection action of "over-excitation inverse time limit" in the protection cabinet B of the transformer group is that the over-excitation reaches the fixed value of the protection action and the protection action exits tripping.

(3) The cause of over-excitation protection action: the generator export TV2 B phase secondary voltage is reduced, reduced from 58V to 53V, the excitation system failed to identify the occurrence of
slow melting of the TV primary fuse, and the excitation channel was not switched. The outlet voltage of the generator continued to be adjusted according to the PID, and the output voltage of the generator was automatically increased to meet the requirements of the outlet voltage of the generator. As a result, the outlet voltage of the engine reached 29.2kv, and U/f reached the limit value of 1.08 times of the over-excitation protection.

4. the cause of the PT slow-melting, which the excitation system failed to determine: the operating channel voltage Ua=62.95V, Ub= 55.24V, Uc= 62.21V; The voltage difference with the standby channel and the synchronous voltage reached 4.15%, the setting parameter of internal anti-slow melting logic (5%) is not reached, and the TV slow melting cannot be judged, so the channel switch is not carried out.

5. Reason for TV slow-melting: the selected fuse specification (0.5A) is too small, and a large current goes through for a long time (the fuse fuse is found to be black after disintegration).

6. the reason of generator TV break in cabinet A of transformer group protection: the primary fuse of TV2 B phase TV at the generator outlet appears slow melting, the voltage of TV2 B phase TV decreases and reaches the fixed value of protection , so the protection action is correct.

5. Major problems exposed

1. the excitation system parameter setting is not reasonable, although the excitation slow-melting caused by the machine has been reversed measures, but the implementation of the reverse measures failed to fully digest and strictly implemented[5].

2. the internal reverse measures of the power plant are not in place, and the primary fuse of the TV of the newly put into production unit does not use the product with the specification of 1A according to the standard of the operating unit. by default, the fuse with the specification of 0.5A is configured with the equipment.

3. the hidden trouble of the new unit is not thoroughly checked, the existing problems: (a) the TV disconnection signal is not connected to the DCS light brand, which can not be displayed to remind the operation personnel; (b) the analog value and switching value of the fault recorder could not be displayed; (c) the excitation system clock is not accurate.

4. the accident handling capacity of operating personnel needs to be strengthened, and it fails to timely detect the abnormal phenomenon of large increase of the unit's reactive power, excitation voltage and other electrical simulation quantity.

6. Handling and preventive measures

1. all the primary fuses with the specification of 0.5A TV have been replaced with the specification of 1A, the internal anti-slow melting logic parameters of the excitation regulator have been changed from 5% to 3%, and the new parameter test has been simulated. Channel switching can be completed, and the unit starts to run with the network.

2. Hidden trouble detection needs to be strengthened, focusing on unit 4 which will be put into commercial operation, to avoid the recurrence of similar problems.

3. taking advantage of the shutdown opportunity of the unit, the known defects of the new unit should be timely eliminated, and carrying out hidden trouble investigation for possible problems.

4. the internal anti-slow melting logic parameters of the excitation regulator should be studied and optimized, so as to make the anti-slow melting parameters, V/Hz limit and over-excitation protection match reasonably, and ensure the safe and stable operation of the unit.

5. the product quality of TV primary fuse should be strictly checked, and the factory report, fuse fusing characteristic curve, qualification certificate, manufacturer, production date must be complete[6].

6. The maintenance system of TV primary fuse is established, replacing the TV primary fuse at the generator outlet is regularly, measured the resistance value of TV primary fuse of units is to be put into operation regularly, the measurement data are compared and analyzed to avoid the fuse with hidden trouble being put into operation.
(7) the skill training of electrical technicians needs to be strengthened, improving the accident handling ability of operation personnel. the analysis ability of abnormal phenomena of maintenance personnel needs to be improved, and equipment hidden trouble detection work needs to be implemented.

7. The conclusion
High voltage insurance slow melting of the voltage transformer used in excitation is a very special operating condition, in which the running unit has a high risk of misexcitation resulting in machine jump. In recent years, this condition has also occurred many times in the actual operation of large domestic units. Therefore, the author believes that it is necessary to comb and analyze this working condition and take targeted preventive measures to effectively reduce the equipment risk under this working condition.

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