An Event Analysis of Circuit Breaker Tripping Under Equipotential Operation Mode

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Abstract. Under the special operation mode of bypass generation equipotential supply, the equipment joint just repaired and treated forms a small impedance due to excessive antifouling and anti-oxidant. Because both ends of the impedance are equipotential, it cannot be broken down, resulting in the tripping event of standby protection action of the equal bypass circuit breaker.

1. Introduction
The 110kV lines are generally configured distance protection, zero sequence protection. Distance protection contains ground distance and phase to phase distance protection I, II, III section. Zero sequence protection configured as sections I, II, III and IV. Each section protection range is different. Usually Section I protects 80% of the full length of this line. Section II protects 20% of the full length of this line extending to the next section, after that in turn backward extension [1]. Time set on the I section is the protection action inherent time, II section action time than I section action time increase Δt, III time than II section time increase Δt, IV time is the longest. The IV section protection range is the largest. In most cases, when a fault occurs on the line, it is tripped by the circuit breaker protection action of the line nearest to the fault point to isolate the fault. Only when the circuit breaker refuses to move will lead to the upper circuit breaker backup protection action tripped to isolate the fault. It is rare that the III, IV section protection action lead to the circuit breaker tripped [2]. However, on December 12, 2019, a zero sequence current section IV protection trip occurred on a 110kV line.

2. Pre-Event Operating Mode
On December 12, 2018, prior to the incident, a 110kV line at a 220 kV substation was operating in the joint 110 kV II group bus mode, and the 110 kV transfer busbar 115 breaker was in the joint I group bus hot standby state.
3. Overview of Events
On December 13, 2018, when the operating personnel were measuring the temperature of a 110kV line 161 breaker interval, they found that the 110kV line 161 breaker current transformer was severely heated against the breaker side terminal block A and C phase contacts. The operating personnel immediately reported the defective condition and contacted the maintenance professional to enter the site for defect treatment.

During the overhaul process, firstly, 110kV bypass bus 115 circuit breaker from the joint I group bus hot standby to the joint II group bus hot standby state. Afterwards, 110kV bypass bus 115 circuit breaker by joint II group bus hot standby replace 110kV a line 161 circuit breaker operation, 110kV line 161 circuit breaker was transferred from joint II group bus operation to TA maintenance, and maintenance personnel dealt with joint heating defects.

Defect processing is completed, in the reverse for the original way 110kV line 161 circuit breaker by the joint II group bus operation, bypass restoration of hot standby operation process, closed 161 circuit breaker and bypass 115 parallel operation, found that the background electromechanical current indication shows 161 circuit breaker C phase current is 0 and issued TA disconnection alarm signal, A, B, C three phase voltage are normal. The operator contacted dispatch and went to the site to check the primary and secondary equipment after finding the problem, but no abnormality was found, and the infrared temperature measurement showed no abnormality in temperature. During the inspection, 110kV bypass bus 115 circuit breaker zero sequence current IV section protection action, bypass 115 circuit breaker tripped, 161 circuit breaker did not trip, after 110kV line 161 circuit breaker current, voltage display normal, TA break alarm signal reversion, did not cause load loss.

4. The Incident
On December 13, 2018, when the operating personnel were conducting infrared temperature measurement, they found that the current transformer of a line 161 circuit breaker of a 220 kV substation was seriously hot against the primary terminal of phase A and C of the circuit breaker side terminal board. The hot spot temperature was greater than 80 degrees Celsius, and the relative
temperature difference between phase A and B was δ>95%. After finding this defect, the operator immediately reported to the dispatching center. After using the 110kV bypass 115 circuit breaker for 110kV line 161 circuit breaker operation instead, the 161 circuit breaker TA is transferred to the service state and the heat defect is handled by the service professional.

Figure 2. 110 kV line 161 circuit breaker TA against the circuit breaker side terminal block A, C phase contact heat.

On December 13, 2018 at 13:24, the operator reversed the 110kV bypass 115 breaker from the Union I female hot standby to the Union II female hot standby.

Figure 3. 110kV bypass 115 circuit breaker reversing from Union I to Union II hot standby.

From 13:32 to 14:35, a 110kV bypass bus 115 circuit breaker was used to replace a 110kV line 161 circuit breaker by a joint II bus hot standby operation, and a 110kV line 161 circuit breaker was operated from a joint II bus to a cold standby operation.
Figure 4. 110kV bypass bus 115 circuit breaker operated by joint group II bus hot standby on behalf of 110kV a line 161 circuit breaker. 110kV a line 161 circuit breaker from the joint II group bus operation to cold standby.

15:22 to 15:30, the 110kV line 161 circuit breaker from cold standby to circuit breaker maintenance operation, closed a 110kV line 161 circuit breaker 16160 grounding switch, in a 110kV line 161 circuit breaker against the TA side to install a set of three-phase short-circuit grounding wire. After the operation, the maintenance personnel carry out 110kV a line 161 circuit breaker TA terminal board connector heat defect treatment.

Figure 5. 110kV line 161 circuit breaker from cold standby to circuit breaker maintenance.
Heat defect after inspection, found to be due to a 110kV line 161 circuit breaker TA by the breaker side of the terminal board connection surface and bolt dirty resulting in increased contact resistance and heat. Defect treatment method: 1, clean the terminal board; 2, disassemble the terminal board bolts for grinding; 3, in the fixed bolt, lead wire and terminal board contact with Vaseline to prevent rust, water, dust.

![Figure 6. Location of heat generation defect treatment.](image)

After the defect was addressed, dispatch was contacted to prepare to begin the operation of reversing the operating mode back to the original mode. The operation to convert a 110kV line from circuit breaker maintenance to cold standby was completed on December 13, 2018 from 17:28 to 17:36. The operation to convert a 110kV line 161 circuit breaker from cold standby to joint Group II bus operation and 110kV bypass bus 115 The circuit breaker was transferred from the operation of group II busbar to the hot standby of group II busbar.

In closing a 110kV line 161 circuit breaker and bypass 115 circuit breaker parallel operation, the operator found that 161 circuit breaker C phase current is 0 and has TA disconnection alarm signal, A, B phase current display normal, bypass 115 circuit breaker A, B, C three phase current display normal, 110kV bus A, B, C three phase voltage display normal, the operator immediately a 110kV line 161 circuit breaker and bypass 115 circuit breaker first and second equipment for a comprehensive inspection, no abnormalities were found.

During the operator's inspection of the equipment, the operator heard the sound of the circuit breaker breaking, and returned to the main control room to find that the 110kV bypass bus 115 circuit breaker was already in the breaking position. After contacting dispatch, both parties confirmed that no artificial breaking operation had been performed on the 110kV bypass bus 115 circuit breaker. Check the background information, found that it was due to 110kV bypass bus 115 circuit breaker zero sequence IV section protection action, tripped open the bypass 115 circuit breaker, at this time 110kV a line 161 circuit breaker TA disconnection signal has been restored, A, B, C three phase current has been shown to balance.

5. Bypass 115 Circuit Breaker Inspection Status
After the protection action, the protection action of circuit breaker 161 and bypass 115 of a 110 kV line was checked as follows.

The first check was made at the backend machine, where the CT disconnect alarm was issued after the 161 breaker was closed and the 161 breaker CT disconnect alarm reverted after the 115 breaker was tripped.
Figure 7. Backend machine alarm signals.

Checking the protection device information of 161 circuit breakers of a 110kV line, it was found that 161 circuit breakers started to issue protection start signals from 19:45:07:579 after closing was completed, and a total of 7 protection start signals were issued.

Figure 8. Protection information of a 110 kV line 161 protection device.

Checking the 110kV bypass 115 circuit breaker protection letter information, it was found that the 110kV bypass 115 protection device had been issuing protection start signals from 20:04:27:167 until 20:13:24:336 when the last zero sequence overcurrent section IV protection action tripped the 115 circuit breaker, the zero sequence current started 63 times, the fault zero sequence current action current was 0.8A, and the fault phase is phase C. The following figure shows.
The Bypass 115 circuit breaker protection device protection action report is as follows:

The bypass 115 circuit breaker action report shows that the zero sequence overcurrent IV action has a maximum fault phase current secondary of 1.56A and an action current secondary of 0.8A, with the fault phase being phase C.

The fault recording diagram is shown in Figure 5.5. 21, 22 and 23 channels are the 110kV phase A, B and C currents of a line 161 circuit breaker, respectively, 24 channels are the 110kV zero sequence currents of a line 161 circuit breaker, 25, 26 and 27 channels are the 110kV bypass 115 circuit breaker phase A, B and C currents, respectively, 28 channels are the 110kV bypass 115 circuit breaker zero sequence currents, and Channel 65 is the 110kV bypass 115 circuit breaker protection action switching quantity.
According to the fault recording diagram, we can get the secondary measurement values of circuit breaker, 161 breaker \[ I_{\text{Amax}} = 1.232A, I_{\text{Amin}} = -1.232A, I_{\text{Bmax}} = 1.232A, I_{\text{Bmin}} = -1.232A, I_{\text{C}} = 0; \] 115 breaker \[ I_{\text{Amax}} = 1.056A, I_{\text{Amin}} = -1.056A, I_{\text{Bmax}} = 0.88A, I_{\text{Bmin}} = -0.88A, I_{\text{Cmax}} = 2.288A, I_{\text{Cmin}} = -2.288A. \] It can be seen that: 161 breaker A, B, C three phase current and 115 circuit breaker A, B, C three phase current of each is basically balanced.

6. Cause Analysis
When the operator closes a 110 kV line 161 circuit breaker and bypasses 115 circuit breaker in parallel operation, 161 circuit breaker issues a TA disconnection alarm signal and the primary equipment operates as follows:

![Figure 11. Fault recording waveform diagram.](image)

![Figure 12. Schematic diagram of 161 circuit breakers and 115 circuit breakers operating in parallel.](image)
It can be seen that at this time a line of 110kV by 161 circuit breakers and 115 circuit breakers at the same time, 161 circuit breakers and 115 circuit breakers in parallel operation. 110kV a line line current A, B, C three phase current is equal to 110kV a line by 161 circuit breakers and 115 circuit breakers A, B, C three phase current sum.

![Figure 13. Simplified diagram of 161 breaker and 115 breaker operating in parallel.](image)

6.1. Analysis of the cause of a 110kV line 161 circuit breaker protection device sending CT disconnection, while 110kV bypass 115 circuit breaker protection device does not send CT disconnection signal

From the fault recording diagram, we can see that under this operation mode, 161 circuit breaker A and B phases are current basic balance, C phase current is zero, 115 circuit breaker A and B phases are current basic balance, C phase current is obviously large, 161 circuit breaker A, B, C three phase current and 115 circuit breaker A, B, C three phase current sum is basically balanced, we can see that 161 circuit breaker current and 115 circuit breaker currents are both in a state of three-phase unbalance, and both have zero sequence currents generated.

![Figure 14. 110kV protection setting for a line.](image)

In the process of 161 circuit breaker current transformer against the circuit breaker side of the terminal board heat defect treatment, 110kV a line 161 circuit breaker current transformer against the circuit breaker side of the terminal board disassembled grinding, and apply petroleum jelly. The
inspector used excessive Vaseline in the coating process, Vaseline is a greasy petroleum products, mainly senior hydrocarbon alkane, electrical conductivity is not strong and has a certain insulating properties, excessive Vaseline led to a decrease in electrical conductivity, insulation properties rise. As the 161 circuit breaker current transformer terminal board C phase coated with too much Vaseline, constituting an insulating point, when the 161 circuit breaker and 115 circuit breaker parallel operation, the insulating point is equipotential point at both ends, no current through, can not make it breakdown, resulting in 161 circuit breaker C phase current is zero, its differential current reached the action value of TA disconnection (150A), the protection device issued TA disconnection The alarm signal is issued and the zero sequence protection is blocked; while 115 circuit breaker A, B and C phases have current, and the differential current of TA disconnection is small, so the protection device does not issue the alarm signal of TA disconnection and does not block the zero sequence protection. As shown in Figure 15.

![Schematic diagram of phase C of 161 circuit breaker with 0 current.](image)

**Figure 15.** Schematic diagram of phase C of 161 circuit breaker with 0 current.

6.2. *Analysis of the reasons why 110kV bypass 115 circuit breaker trips while 110kV circuit breaker 161 of a line does not trip*

Before the 110kV bypass 115 circuit breaker is operated instead of 161 circuit breaker, the 115 circuit breaker protection setting area is set to "1" area, the 115 circuit breaker and 161 circuit breaker protection setting is the same, the setting value is shown as follows:
From the fault recording diagram can be seen, when closed on a 110kV line 161 circuit breakers, its zero sequence current value has reached about 1.06A, has exceeded the zero sequence IV section protection action fixed value (0.8A), but in its protection device has issued a TA disconnection signal, blocking the zero sequence protection, so 161 circuit breakers will not trip.

During the parallel operation of a line 161 breaker and bypass 115 breaker at 110 kV, the zero sequence current of 115 breaker increases due to increased line load and reaches the zero sequence overcurrent IV section action value (0.8 A), and the zero sequence IV section action trips the 115 breaker.

After the bypass 115 circuit breaker trips, the insulating point composed of Vaseline coated in phase C of the 161 circuit breaker terminal block is no longer in equipotential relationship at both ends, there is a large potential difference, resulting in the instantaneous breakdown of this insulating point, the 161 circuit breaker three-phase current balance, its TA circuit differential current disappears, and the TA disconnection signal reverts.

6.3. Analysis of the Use of Anti-Fouling And Anti-Oxidation Materials in Equipment Joints

This incident is a special operating mode line backup protection - zero sequence current section IV exit tripping event, although this incident did not cause load loss, but also found the poor conductivity of Vaseline characteristics. In the equipment contact position coated with Vaseline originally for the protection of equipment considerations, not to let the equipment metal exposed position in contact with air oxidation caused by contact resistance increased and lead to heat defects occur.

However, Vaseline has poor electrical conductivity, so more conductive paste is currently used instead of Vaseline. Conductive paste is a good electrical properties of the point contact dressing, suitable for copper - copper, copper - aluminum, aluminum - aluminum bus bar lap surface coating. It can prevent the oxidation and galvanic corrosion of the contact surface of the bus bar by the erosion of the atmosphere and corrosive agents, thus stabilizing the contact resistance of the connection point. Conductive paste can eliminate invisible electrical gaps, so that the contact move closely, even if the connection is very tight, in the conductor contact, there will be visible to the naked eye "pits", which
must be filled with conductive paste. Vaseline also has this effect, but much worse than the conductive paste. Conductive paste can also play a role in heat dissipation, the female contact surface coated with conductive paste can reduce the contact surface temperature of about 10%.

It is recommended that when selecting antifouling and antioxidant, service personnel try to use a conductive paste that is superior to petroleum jelly to avoid the recurrence of such tripping events. Use Vaseline only when conductive paste is not available, and try to avoid applying too much Vaseline at equipment contact locations to reduce the probability of such events.

7. Conclusion
This tripping event is due to the electrical equipment in the special operation mode of equipotential, just overhauled and treated C-phase equipment joints due to the application of excessive anti-fouling, anti-oxidant - Vaseline to form a smaller impedance, but because both ends of the impedance are equipotential and cannot be broken through, thus leading to the bypass 115 circuit breaker backup protection - zero sequence current section IV outlet tripping event occurred, after the bypass 115 circuit breaker tripped, the line three-phase current is balanced.

Reference
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