Research on 500kV Transformer on-load Tap Changer Fault Treatment and Physical Properties Testing

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Abstract. This article introduces the intermittent increase of acetylene content in the oil during the operation of a 500kV start-up substation of a power generation company. It is preliminarily judged that there is spark discharge in the oil chromatographic analysis and on-site partial discharge test. After returning to the factory for maintenance and internal inspection, it was found that the movable contact and the fixed contact of the selected part of the on-load tap-changer were not connected in place, which caused intermittent spark discharge and continued to increase acetylene. The problem is solved by adjusting the number of turns of the gear when the tap switch is switched forward and backward, and the transformer resumes normal operation.

Keywords: Transformer; acetylene; partial discharge; spark discharge; on-load tap changer

1. Introduction
The on-load tap changer is one of the important parts of the transformer, which can adjust the operating voltage of the transformer [1-2]. The content of dissolved gas in the oil is an important parameter for evaluating the condition of a transformer to identify the types of electrical, thermal, and aging faults in the transformer [3-5]. In this paper, the intermittent increase of acetylene content in 500kV high-precision transformer oil will be diagnosed through electrical test and oil chromatographic analysis, the hanging cover will find the fault location, and repair and solve the defect.

2. Another section of your paper
The model of Gaobei substation is SZ-39MVA/500, the rated voltage is 530/6.3/3.1 (kV), the connection group is YNyn0(d), which are high-voltage winding, low-voltage winding and built-in balance winding, and the rated capacity is 39000/39000 /13000 (kVA), manufactured in 2005, the position information of the tap changer is shown in Table 1. The 39MW installed capacity of photovoltaics is connected to the grid through the high-backup substation. The circuit breaker between the high-backup substation and the thermal power plant is always in the open state, only when the main transformer of the thermal power unit is out of power At that time, the Gaobei substation was temporarily used to supply power to the factory.

The on-load tap-changer model is UCLRN 380/600 III, combined tap-changer, the switching part is in the independent oil chamber, and the tap selection part is in the main oil of the Gaobei substation.
There are 17 taps in total, and the Gaobei substation operates normally. When the time tap switch is at 13 taps, some fixed contacts 5 are selected to carry current, and fixed contacts 4 are reserved.

### Table 1. Transformer brand information

| Terminal Appears | Voltage (kV) | Current (A) | Contact Position | Tap Position |
|------------------|-------------|-------------|------------------|--------------|
| A, B, C          | 510.13      | 44.14       | 4                | 12           |
|                  | 503.50      | 44.72       | 5                | 13           |
|                  | 496.88      | 45.32       | 6                | 14           |

3. **Brief Description of The Event**

From October 1, 2020, acetylene appears in Gaobei Transformation, and the acetylene content continues to increase. As of October 13, acetylene reached 1.27uL/L, exceeding DL/T722-2014 "Guidelines for the Analysis and Judgment of Dissolved Gases in Transformer Oil" for the first time the standard attention value 1.0uL/L [6], May 20, 2021, The acetylene content increased to 11.06uL/L, the high standby transformer was shut down and returned to the factory for overhaul. Taking October 1, 2020 as the first day, the graph of acetylene content in oil over time is shown in Figure 1.

![Figure 1. Growth trend of acetylene in transformer oil](image)

The growth of acetylene content in Qibei oil can be roughly divided into three stages. The absolute gas production rate in the first stage is 0.84 ml/d; the absolute gas production rate in the second stage is 3.48 ml/d; the absolute gas production rate in the third stage is 15.65 ml/d, which exceeds DL/T 722-2014 "Guidelines for the Analysis and Judgment of Dissolved Gases in Transformer Oil", which stipulates the attention value of 0.2mL/d for the growth rate of acetylene in standard enclosed transformers, and the growth rate of acetylene has accelerated, indicating Transformer failures show a deteriorating trend. It can be seen from the oil chromatographic data that H₂ and C₂H₂ are the main components, and the content of CH₄ and C₂H₄ is low. Typical oil chromatographic data are shown in Table 2. The growth of acetylene is intermittent. According to the characteristic gas method, the internal spark discharge is intermittent and there is no overheating phenomenon; C₂H₂/C₂H₄. The ratio is 8~11, the CH₄/H₂ ratio is 0.04~0.07, the C₂H₆/C₂H₄ ratio is 2~5, and the three ratio code is 211 or 212, which is judged to be a low-energy discharge; the CO₂/CO ratio is 16~20, much greater than 3, preliminary It
is judged that the fault does not involve solid insulating materials, and it is the discharge of bare metal. Various gas content ratio data are shown in Table 3.

### Table 2. Typical oil chromatographic data

| Time       | CH₄ | C₂H₆ | C₂H₄ | C₃H₂ | Total hydrocarbons | H₂ | CO | CO₂ |
|------------|-----|------|------|------|--------------------|----|----|-----|
| 2021.03.08 | 0.55| 0.29 | 0.12 | 2.78 | 3.74               | 9.52| 16.95| 294.59|
| 2021.03.19 | 0.59| 0.49 | 0.15 | 4.98 | 6.21               | 11.11| 14.07| 242.62|
| 2021.03.29 | 0.67| 0.47 | 0.13 | 4.97 | 6.24               | 9.04| 15.74| 288.92|
| 2021.04.13 | 0.53| 0.37 | 0.12 | 3.69 | 4.71               | 11.6| 14.95| 269.03|
| 2021.04.20 | 0.56| 0.43 | 0.14 | 4.33 | 5.46               | 11.5| 16.2| 281.72|
| 2021.04.28 | 0.73| 0.57 | 0.13 | 5.62 | 7.05               | 13.64| 16.52| 286.91|
| 2021.05.04 | 1.01| 0.8  | 0.17 | 7.71 | 9.69               | 26.06| 18.42| 307.43|
| 2021.05.12 | 1.7 | 1.26 | 0.36 | 10.65| 13.97              | 26.3| 18.38| 320.64|
| 2021.05.20 | 1.5 | 1.29 | 0.27 | 11.06| 14.08              | 27.18| 18.61| 299.38|

### Table 3. Various gas content ratio data

| Time       | CO₂/CO | C₂H₆/C₂H₄ | CH₂/H₂ | C₂H₄/C₂H₆ | Three ratio |
|------------|--------|------------|-------|-----------|-------------|
| 2021.03.08 | 17.38  | 9.59       | 0.06  | 2.42      | 211         |
| 2021.03.19 | 17.24  | 10.16      | 0.05  | 3.27      | 212         |
| 2021.03.29 | 18.36  | 10.57      | 0.07  | 3.62      | 212         |
| 2021.04.13 | 18.00  | 9.97       | 0.05  | 3.08      | 212         |
| 2021.04.20 | 17.39  | 10.07      | 0.05  | 3.07      | 212         |
| 2021.04.28 | 17.37  | 9.86       | 0.05  | 4.38      | 212         |
| 2021.05.04 | 16.69  | 9.64       | 0.04  | 4.71      | 212         |
| 2021.05.12 | 17.45  | 8.45       | 0.06  | 3.50      | 212         |
| 2021.05.20 | 16.09  | 8.57       | 0.06  | 4.78      | 212         |

### 4. Maintenance Process

#### 4.1. Body Inspection

Go back to the factory for overhaul of the hanging cover of the Gaobei Substation, and perform vapor-phase drying first, and inspect the body of the device. The appearance inspection of the iron core, clamps, and lead wires showed no abnormalities, the fastening bolts were not loose, the ground insulation resistance of the Gaobei transformer core and clamps was normal, the electrical distance between the lead wires and the iron core and clamps was normal, and the lead wires were firmly fixed and no abnormality was found.

#### 4.2. Tap changer inspection

The inside of the tap changer oil chamber is clean, and no abnormalities are found in the switching contacts and transition resistance. The operating mechanism gear 13 is consistent with the upper gear box 13. No abnormality was found in the visible part of the windings and the lead of the tap changer. The lead terminal and the switch contact are connected normally, and the transition resistance connection of the switch itself is fastened normally. The Gaobei substation runs for a long time at 13 tap, and the two moving contacts of the tap switch selection part are in contact with the fixed contacts 4 and 5 for a long time. The inspection found that the moving contact and the fixed contact 5 are overlapped, and the contact is good. The tap changer adjusts the number of rotations of the drive shaft from the odd number to the even number to 12.7 turns, and the even number to the odd number to 16 turns.
The moving contact and the fixed contact A and B are not in place, and the overlapping moving contact is about 1/4, not completely in contact, but there is no obvious discharge or overheating trace on the surface. The moving contact and the 4 fixed contact C phase are not overlapped, and there is a black substance.

Use a multimeter to measure the ABC three-phase contact resistance between the moving contact and the fixed contact 4. The A-phase resistance is 0.2Ω, the B-phase resistance is 0.1Ω, and the C-phase resistance is infinite, as shown in Table 4 below:

| Measuring Position                  | 4A moving contact and fixed contact | 4B moving contact and fixed contact | 4C moving contact and fixed contact |
|-------------------------------------|-------------------------------------|-------------------------------------|-------------------------------------|
| Contact Resistance(Ω)              | 0.2                                 | 0.1                                 | gigantic                            |

Separate the moving contact and the 4C fixed contact, wipe the black material on the surface of the contact, and check the 4C phase of the contact again. It is found that the discharge corrosion pit is about 5mm in width, 12mm in length, and 1mm in depth.

5. Analysis of the cause of the failure

The schematic diagram of the on-load tap changer wiring at 13 taps is shown in Figure 2. The red part represents the path through which the current flows when the full load shift is in 13 gears. The current flows through the high-voltage winding → switching part X fixed contact selection part, select part of the fixed contact 5 voltage regulating winding → the neutral point, the current of the contact 5 is about 44.72A, and the contact 4 does not directly carry current. The fixed contact 4 has a potential of 3.83kV. Since the C-phase moving contact H and the fixed contact 4 are not in contact, the C-phase moving contact H is in a floating state. Due to the existence between the moving and fixed contacts.

At the potential difference, a discharge occurs, ablating the part, and at the same time cracking the oil to generate acetylene gas. During the partial discharge test, since there is a discharge between the moving contact H of the C phase and the fixed contact 4, a large partial discharge can be detected.

![Figure 2. Schematic diagram of tap changer](image-url)
6. On-site Handling
Grind the 4C fixed contact. Remove the fixing bolts of the vertical operating lever and the control box, as shown in Figure 3, adjust the number of rotations of the operating lever when the on-load tap changer is switched, and when the single-numbered position is switched to the even-numbered position after adjustment, rotate 10.2 times, In line with the 10.2±1 requirement of tap changer manufacturer's tap changer single-dual tap changer. After the adjustment, when the even number gear is switched to the odd number gear, the rotation is 11.4 turns, which meets the 11.4±1 requirements of the tap changer manufacturer's tap switch double-single. After the treatment, the moving contact and the fixed contact 4 are in good contact.

![Fastening Bolt](image)

**Figure 3.** Fastening bolts of control box and joystick

Adjust the tap switch from gear 1 to gear 17 manually and electrically, and then back to gear from 17 gears. Each time you switch the tap switch, use an endoscope to confirm that the moving contact and the fixed contact are in good contact.

Manually adjust the gear position positively and negatively, and use an endoscope to observe that the movable contact and the fixed contact of the selected part of the ABC three-phase are in good contact. Carry out partial discharge test, on-load tap changer transition resistance and transition waveform test, winding DC resistance, winding voltage ratio test, 24 hours 1.0 times overcurrent test, the data are all qualified. After the partial discharge test, the no-load test and the over-current test are finished, the oil samples are taken by standing for 24 hours, and the oil chromatographic data are all qualified.

7. Conclusions
After the on-load tap-changer is processed, the high-standby substation is put into operation again and the operation is normal.Confirm that the 4C moving contact and the fixed contact of the selected part of the on-load tap changer are not in good contact, causing internal spark discharge and intermittent growth of acetylene in the oil. By adjusting the number of rotations of the transmission rod when switching the tap switch, this problem can be effectively solved, and the risk of deterioration of the body oil and further expansion of the fault due to long-term discharge is avoided.
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