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# Analysis of Box Transformer Oil Chromatographic Abnormal Data in a 35kV Wind Farm

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**Abstract.** The design structure of the high voltage winding of the box transformer lead to high voltage between the high voltage winding layers, and electric field of each layer winding end is over-concentration, and the additional loss of load loss is too high, and thus lead to further the enameled wire of high voltage terminal happens partial discharge seriously and cryogenic overheating are discussed through the defects analysis of box transformer and a series of related experiments, hanging core inspection and analysis. If the hydrogen content is overweight seriously, total hydrocarbons is overweight, and methane gas content of total hydrocarbons is very high, ethylene and acetylene is very low, it can initially determine that low-energy partial discharge fault is inside the device are demonstrated. Finally, the corrective measures for the common problem of this group box transformer are presented.

## Introduction

There are 780 box transformers installed in a wind turbine outlet of wind farm, including 33 types ZGS-ZF-1600/35, box transformers of Dyn11 winding connection. All box transformers were tested routinely from August, 13th to August, 21st in 2012, found in the oil test, 32 box transformers have been appeared the anomalies of $H_2$ gas and total hydrocarbon content is excessive, and therefore it belongs to the family defects. In order to analyze problem easily, It becomes a key target detection to select 18# box transformer. Oil assay data is shown in Table 1.

Table 1 Oil Chromatographic Assay Data（μL/L）

| $H_2$ | $CH_4$ | $C_2H_4$ | $C_2H_6$ | $C_2H_2$ | CO | $CO_2$ | Time | Remarks |
|---|---|---|---|---|---|---|---|---|
| 6.39 | 3.6 | 1.92 | 1.08 | 0 | 18.4 | 245.9 | 09.11.23 | Handover |
| 24920 | 1120 | 5.01 | 607.3 | 1.76 | 276 | 1046 | 12.08.17 | Routine test |
| 37480 | 1120 | 5.6 | 758 | 0 | 200 | 1295 | 12.09.14 | Tracking test |

As can be seen from the oil assay data, $H_2$ is increased constantly, and the content has reached 37480μL/L(procedures standards do not exceed 150μL/L), it explains that the kind of box transformer has serious defects.

## Accident Analysis

Analysis can be learned from No.18 box transformer oil chromatographic data, the content of hydrogen($H_2$) gets 37480μL/L, far more than 150μL/L, there may be moisture or discharge defects; Total hydrocarbons($C_1$+$C_2$) is 1883.6μL/L, also more than 150μL/L and out of limits, in total hydrocarbons, methane($CH_4$) as the leading gas is 1120μL/L, then ethane($C_2H_6$) is 756μL/L, and the levels of ethylene($C_2H_4$) and acetylene($C_2H_2$) is low. It can be determined that it does not exist severe localized overheating and high energy discharge defects, and the ratio rang code are “0, 1, 0”, so the defective nature is that low energy partial discharge exists in the box transformer. Causing this defect, there are two reasons: first, high humidity (serious moisture) caused the discharge of the ”paper” insulation with air hole; second, unreasonable structural design, field strength distorted, centralized caused the partial discharge. In order to test if the “paper” insulation is moist, it proceed absorption ratio, DC leakage and dielectric loss angle test on September 18, the test results are shown in Table 2.

Table 2 The Test Data of Absorption Ratio, DC Leakage and Dielectric Loss Angle

| Absorption Ratio K | | | | |
|---|---|---|---|---|
| Test Site | R15s（MΩ） | R60s（MΩ） | K | Conclusion |
| P-SE | 1000 | 1700 | 1.7 | Qualified |
| S-PE | 1000 | 1400 | 1.4 | Qualified |
| DC Leakage Current | | | | |
| Test Site | Test Voltage(kV) | Leakage Current (μA) | Conclusion | |
| P-SE | 40 | 8 | Good | |
| S-PE | 5 | 4 | Good | |
| Dielectric Loss Angle | | | | |
| Test Site | Test Voltage (kV) | Loss Angle tδ（%） | Capacitance pF | Conclusion |
| P-SE | 10 | 0.955 | 3561 | tδ（%）slightly larger |
| S-PE | 5 | 0.68 | 7469 | tδ（%）slightly larger |

As can be seen from the test data in Table 2, Absorption Ratio, Dielectric Loss Angle and Leakage current are normal, “paper” insulation only exists in the phenomenon of a slight damp, and there may be other causes. So the partial discharge may cause the family defects, in order to verify the inference is correct, planning to do partial discharge test for No. 18 box transformer.

**Partial Discharge Test**

Based on previous oil assay and high-voltage test of transformer, it initially concludes that there may be a low-temperature overheating and low energy discharge in transformers[1,2]. The reason may be the high voltage winding structure and material is unreasonable, so that the local electric field strength is too high, the voltage between the high voltage winding layers exceeds the conventional value, and enameled wire is used instead of paper covered wire. It is decided to carry out a partial discharge test.

The test results are as follows: Voltage endurance time 5min, 1.0 Um, the discharge amount range is 1700～2000PC; 1.1 Um, the discharge amount range is 4500～5000PC; 1.2 Um, the discharge amount range is 8500～9000PC.

No national standards for transformers of 35kV voltage class about partial discharge value requirements[3,4]. Only refer to the standard of transformers of 66kV voltage class, partial discharge values of 66kV transformer: under 1.3Um, the partial discharge is not more than 300PC.

Through the analysis of the test results, the box transformer has really existed low-temperature discharge phenomenon. Though in line with the test standard of short-term induction pressure preventative, partial discharge phenomenon is very serious, and it may be accompanied by the problem of electrical insulation. If the high voltage winding uses enameled wire, and the voltage between the layers is too high, this box transformer will run with large security risks[5].

**Load Test**

In order to determine the defect nature of the box transformers and infer the operational life of the box transformers further, and it decided to process winding DC resistance measurements, no-load test, load test, temperature rise test and mechanical size measured at the same time.

The compared value of DC resistance, the ratio value of no-load test data, and the ratio value of load test are shown in Table 3, Table 4 and Table 5.

Table 3 The compared value of the DC resistance

| Test time：August 23,2012， Top oil temperature：22℃ （field test data） | | | | |
|---|---|---|---|---|
| Tap position | R（AB）（Ω） | R（BC）（Ω） | R（CA）（Ω） | ΔR（%） |
| 1 | 8.709 | 8.741 | 8.688 | 0.61 |
| 2 | 8.484 | 8.516 | 8.461 | 0.65 |
| 3 | 8.259 | 8.289 | 8.238 | 0.62 |
| 4 | 8.031 | 8.062 | 8.022 | 0.51 |
| 5 | 7.804 | 7.833 | 7.783 | 0.64 |
| Low voltage side | a o（Ω） | b o （Ω） | c o（Ω） | ΔR（%） |
| | 0.001507 | 0.001505 | 0.001506 | 0.13 |
| Test time：November 23,2009 Top oil temperature：17℃（factory test records） | | | | |
| Tap position | R（AB）（Ω） | R（BC）（Ω） | R（CA）（Ω） | ΔR（%） |
| 1 | 8.860 | 8.944 | 8.879 | 0.94 |
| 2 | 8.627 | 8.710 | 8.646 | 0.96 |
| 3 | 8.396 | 8.475 | 8.421 | 0.94 |
| 4 | 8.165 | 8.233 | 8.183 | 0.83 |
| 5 | 7.931 | 8.005 | 7.949 | 0.93 |
| Low voltage side | a o（Ω） | b o （Ω） | c o（Ω） | ΔR（%） |
| | 0.001511 | 0.001498 | 0.001506 | 0.86 |
| Conclusion: No change in DC resistance. | | | | |

Table 4 The compared value of no-load test

| No-load data Test time：August 23,2012， Top oil temperature：22℃ （field test data） | | |
|---|---|---|
| Test voltage（kV） | No-load losses（Po）W | No-load current（Io）% |
| 690 | 1700 | 0.64 |
| No-load data Test time November 23,2009, Top oil temperature：17℃（factory test records） | | |
| Test voltage（kV） | No-load losses（Po）W | No-load current（Io）% |
| | 1532 | 0.16 |
| Conclusion: Comparing with factory value ,Po increased by 11%,and Io increased by 300% | | |

Table 5 comparison data of load test

| Load test data Test time：August 23,2012， Top oil temperature：22℃ （field test data） | |
|---|---|
| Load losses (Pk75)W | Impedance voltage (Uk%) |
| 20650 | 6.76 |
| Load test data Test time：November 23 2009, Top oil temperature：17℃（factory test records） | |
| Load loses(Pk75)W | Impedance voltage (Uk%) |
| 16557 | 6.65 |
| Conclusion：Comparing with factory value，Pk75 increased by 24.7%；Uk% essentially unchanged。 | |

From the comparative test data in Table 3, Table 4 and Table 5, the data of No.18 box transformer's windings and the core is normal in the DC resistance, indicating that substantially unchanging in the resistance loss; there is an abnormality in the no-load test data, the no-load loss is increased from 1532W of the original factory to 1700W, No-load current is increased from 0.16% to 0.64%, indicating that the gap of the core increases due to the vibration in operation.

## Temperature Rise Test

To further verify the above conclusions and judge life issues of the box transformers, it decided to carry out the temperature rise test. Table 6 is the temperature rise test data:

In the Table 6, T1~T6 mean the temperature of the six thermometers; T is the room temperature, and $T_{top}$ is the oil top temperature.

The temperature rise process only 6 hours, the top oil temperature has reached 86 °C, the temperature rise values is still rising, because the load loss under the rated current is still on the rise, fearing the burning of the transformer winding caused by overheating, so it decided to no longer continue the temperature rise test. By calculation shows that the top oil temperature rise ΔK = 86-24 = 62 °C, exceeding (standard 55 °C).

Table 6 Temperature rise test data of No.18 box transformer

| Time | Voltage (V) | Current (A) | Loss (kW) | T1 (°C) | T2 (°C) | T3 (°C) | T4 (°C) | T5 (°C) | T6 (°C) | T (°C) | $T_{top}$ (°C) |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 7:55 | 2468 | 27.69 | -21.09 | 20 | 18 | 21 | 21 | 19 | 19 | 19 | 21 |
| 8:25 | 2441 | 27.3 | -23.44 | 23 | 20 | 21 | 23 | 23 | 21 | 20 | 30 |
| 8:55 | 2484 | 27.79 | -22.32 | 27 | 24 | 22 | 26 | 26 | 23 | 20 | 39 |
| 9:25 | 2464 | 27.58 | -23.83 | 30 | 28 | 25 | 30 | 31 | 26 | 21 | 42 |
| 9:55 | 2466 | 27.54 | -24.14 | 37 | 34 | 29 | 36 | 36 | 29 | 22 | 50 |
| 10:25 | 2446 | 27.34 | -24.46 | 40 | 39 | 31 | 39 | 41 | 32 | 22 | 55 |
| 10:55 | 2452 | 27.36 | -24.74 | 41 | 43 | 34 | 43 | 44 | 34 | 22 | 62 |
| 11:25 | 2477 | 27.62 | -25.02 | 48 | 47 | 36 | 46 | 49 | 39 | 22 | 66 |
| 11:55 | 2507 | 27.94 | -25.28 | 50 | 50 | 38 | 48 | 51 | 39 | 23 | 71 |
| 12:25 | 2525 | 28.12 | -25.54 | 52 | 52 | 40 | 50 | 54 | 41 | 23 | 75 |
| 12:55 | 2521 | 28.05 | -25.69 | 55 | 55 | 41 | 55 | 57 | 44 | 24 | 79 |
| 13:25 | 2474 | 27.55 | -25.81 | 57 | 56 | 42 | 56 | 60 | 45 | 24 | 81 |
| 13:55 | 2467 | 27.44 | -25.91 | 58 | 58 | 44 | 57 | 60 | 48 | 24 | 82 |

## Conclusions

Abnormal reason of the batch box transformers oil chromatographic data is that the end of the high voltage winding occurred severe low-temperature partial discharge. Leading to the occurrence of this phenomenon for three reasons: (1) The structure is irrational, the high voltage winding of the batch box transformers for a period of 13 layers, the electric field of the winding ends concentrate excessively, the voltage between layers reached 5250V; (2) Material selection is improper, the high voltage winding of the batch box transformers used enameled insulated copper wire; (3) Core silicon steel sheets stacked bad process, cause that no-load loss and load loss increases after running, result in excessive temperature rise and local overheating.

These three defects can not only make oil chromatography abnormal, and long-term run with these defects will cause insulation breakdown between the turns and layers of the winding partial, so that the box becomes burned. To avoid batch box transformers accident, it must be rectified as soon as possible.

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