Analysis of Heating Fault of Pad Mounted Transformer Core in Wind Farm

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Abstract. The Pad mounted Transformer is an important equipment for energy transfer in wind farm. Aiming at three cases of pad mounted transformer core heating faults occurring continuously in a wind farm, oil analysis and disintegration of the fault transformer are carried out, and the fault points causing the heating are found. In order to analyse the mechanism of the fault, the eddy current field analysis model is established by using finite element analysis software ANSYS MAXWELL to analyse the change. Quantitative calculation is carried out for the heating condition of the winding and core of the press. Through analysis, it is determined that there are defects in the manufacturing process of pad mounted transformer, and the reason of heating failure is that the low-voltage winding at the head contacts too closely with the iron core.

1. Introduction

The transformer is an important part of the wind turbine energy conversion process, which converts the electric energy generated by the wind turbine into a high voltage and low current form and delivers it to the grid [1-3]. The iron core is an important component of the transformer's transmission and exchange of energy. In order to prevent the floating core from discharging under the action voltage, the iron core is usually grounded at a single point [4-5].

In actual operation, due to problems in design, manufacturing, materials, etc., there may be iron core heating failure caused by multi-point grounding of the core, poor grounding of the core, short circuit between the core pieces, and short-circuit of the winding [6-9]. According to the degree of iron core heating, it can be divided into low temperature overheating, medium temperature overheating and high temperature overheating. If the iron core heating fault is not controlled and solved, it will cause more faults and the transformer will not operate.

In this paper, the heating failure of three pad mounted transformer cores in a wind farm is analysed. Through oil analysis, on-site disassembly and simulation calculation, it is determined that there is a defect in the pad mounted transformer manufacturing process. The low-voltage winding of the first end is in contact with the iron core too much. Tightness is the cause of fever failure.

2. Fault introduction

In May 2009, the first pad mounted transformer of a wind farm was put into operation. In October 2010, the last pad mounted transformer was put into operation. The wind farm installed a total of 55
sets of the same manufacturer, the same model, and the same batch of wind chassis. The basic parameters of pad mounted transformer are as follows:

- **Model**: ZGS-ZF-1000/38.5
- **Voltage combination**: 38.5kV±2×2.5%/0.62kV
- **Connection group**: D/Yn11
- **Impedance voltage**: 6.31%

The pad mounted transformer is a three-phase, double-winding, oil-immersed, self-cooling, low-loss, fully sealed, maintenance-free power transformer, the overall appearance and around the core as shown in Figure 1.

In May 2016, it was found in the patrol inspection that the no-load oil surface temperature of No. 10 pad mounted transformer of wind power secondary circuit reached 65℃, and the upper insulating ring of phase a low-voltage coil was carbonized and the conductor insulation was damaged by hanging core. Among them, the two adjacent conductors were carbonized from top to bottom.

In January 2017, the voltage of No. 21 pad mounted transformer of secondary circuit of wind power was abnormal. Through the inspection of hanging core, it was found that there were many obvious overheating traces on the core of transformer, the leading out link from the core to the clamp was fused, the phase C winding was overheated, the phase a low-voltage side coil winding was burnt out, and the surface of grade 6 core was obviously burned.

In August 2017, the oil temperature of the No. 2 pad mounted transformer of the second circuit of wind power was overheated again. It was found that the three-phase low-voltage outlet windings of a, B and C were in close contact with the iron core after disassembly, and the insulating cardboard in some areas had been blackened and carbonized.

### 3. Failure cause analysis

The above three fault transformers have the common characteristics: the transformer oil is yellow and the oil has a strong burnt smell, which indicates that the transformer oil is abnormal, such as the oil that was carried out before the disassembly of the No. 10 box transformer in May 2016. Chemical analysis found a large number of hydrogen, hydrocarbons, carbon monoxide, carbon dioxide gas, of which more than 260 hydrogen, more than 1000 total hydrocarbons, and acetylene appeared, oiling report as shown in Table 1.

| Component | No. 10 pad mounted transformer oil sample 1 | No. 10 pad mounted transformer oil sample 2 | Average value |
|-----------|------------------------------------------|------------------------------------------|---------------|
| H2        | 266.02                                   | 273.65                                   | 269.84        |
| CH4       | 574.32                                   | 597.09                                   | 585.71        |
| C2H4      | 168.08                                   | 171.19                                   | 169.64        |
| C2H6      | 267.37                                   | 271.83                                   | 269.6         |
| C2H2      | 1.73                                     | 1.01                                     | 1.37          |
The analysis of the above data by three ratio method shows that there is a problem of low temperature and overheating inside the transformer. The high content of CO, CO2 and CH4 shows that the solid insulating materials (insulating paper, laminated cardboard, wood block, etc.) inside the transformer are cracked. The water and iron produced by the polymer in the cracking process produce H2. The relatively low content of h2c2 indicates that there is no electric fire inside the transformer. It can be concluded that the heating problem of No.10 pad mounted transformer is the result of long-term existence, slow development and gradual accumulation.

The photos of No.10, No.21 and No.2 pad mounted transformers are shown in Figure 2-4. The contact between the first end winding and the iron core of the transformer is too close, and the insulating materials between them have obvious traces. The insulating paper and winding insulating materials at the traces are carbonized. It can be seen from the fault conditions of the three transformers that: (1) the fault points are all located in the first end winding and iron core of the low-voltage winding; (2) the low-voltage winding is in close contact with the iron core, so that the heat can not be circulated through the oil; (3) the local heating causes the carbonization of the insulating materials, so that the insulation between the low-voltage winding and the iron core is lost; (4) the parts in close contact with the iron core pass through Large current causes the contact surface between the core and the winding to be ablated, and the large current is discharged into the ground through the core grounding copper to melt the copper bar.

|       | 2454.12 | 2506.39 | 2480.26 |
|-------|---------|---------|---------|
| CO    | 2454.12 | 2506.39 | 2480.26 |
| CO2   | 8806.99 | 8951.55 | 8879.27 |
| Total hydrocarbon | 1011.50 | 1041.12 | 1026.31 |

Figure 2 Disassembly of phase a of No.10 transformer
The following conclusions can also be drawn through the disassembly: the pad mounted transformer problem of the wind farm is not accidental fault, but common in three fault transformers. The close contact between the head end of the low-voltage winding and the lead wire and the iron core at the fault point is not a case, so it is judged that the installation process of the manufacturer is defective.

4. Finite element analysis of core heating
In order to make a comparative analysis of the winding heating when the distance between the transformer winding and the iron core is relatively close, this report uses the finite element analysis software ANSYS Maxwell to establish a simplified two-dimensional axisymmetric vortex flow field analysis model. Under normal circumstances, the winding layout is shown in Figure 5, in which the iron core is a magnetic non-conductive material and the high and low voltage coils are copper conductors.
According to the calculation, the magnetic field line, current density and heating condition under the normal layout are shown in Figure 6.

It can be seen from Figure 6 that the current field distribution of the first and last turns of the low-voltage winding is uneven compared with other windings due to the end effect, and the current is concentrated in the end area close to the iron core, so that part of the first and last turns of the winding becomes a "hot spot".

In order to analyse the heating situation when the low-voltage winding is close to the iron core, this report moves the low-voltage winding inwards 4.5mm from the first, third and fifth turns from the top to the rotation axis, and recalculates the field analysis as shown in Figure 7.
As can be seen from Fig. 7, in the case where the low voltage winding is close to the iron core, the unevenness of the winding current distribution is aggravated. Observing the coils No. 1, No. 3 and No. 5, the unevenness of the current distribution is successively decreased in the case of being also close to the iron core. This is because the No. 1 coil is most affected by the end effect. From the point of view of heat, the area and maximum heat generation of the No. 1 coil heating area are significantly improved compared with normal conditions, and the maximum heat generation is increased from 22.8 W/m$^3$ to 30.2 W/m$^3$.

5. Conclusion

(1) The core heating of pad mounted transformer in the wind farm is caused by the close contact between the low-voltage head end winding and the core. The close contact between the head end of the low-voltage side and the core causes the heating to intensify. At the same time, the transformer oil at the close contact cannot pass through and the heat cannot be effectively distributed. Under the long-term heating effect, the insulation is aging. The current enters the ground through the core of the head end winding of the low-voltage coil, which causes the core ground flat iron to fuse.

(2) The transformer winding shall be kept at a certain distance from the iron core. The close contact between the iron core and the winding not only causes the internal current distribution of the winding to concentrate to the local area, but also causes the expansion of the heating area and the increase of the maximum heating value. The trend of the increase of heating value caused by the close contact between the winding and the iron core is especially significant for the first winding.

(3) For the pad mounted transformer still in operation in the wind farm, the oil chromatography analysis should be strengthened. Once the gas production rate of the characteristic gas increases, it is likely to be caused by the manufacturing process defects of the first end winding. The operation should be stopped immediately and the overhaul treatment should be carried out. In the overhaul, the insulation materials of the low-voltage winding and the surface of the iron core should be replaced and the gap between the first end winding and the iron core should be increased.

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