Field Modification and Application of ODAF Cooling System for 500kV Transformer

Huo Feng¹; Wu Jianling¹; Liu Shangbin²; Yue Yonggang*¹

¹ Inner Mongolia Extra-high Voltage Power Supply Bureau, Hohhot, Inner Mongolia;
² Inner Mongolia University of Technology, Hohhot, Inner Mongolia
E-mail: huofeng@impc.com.cn

Abstract: A large number of oil flow relays and submersible pumps in the forced oil circulation mode of the main transformer have a huge workload of operation and maintenance. The main transformer of the ODAF cooling system has a large number of oil flow relays, and the submersible pump is prone to malfunction, which resulting in a large amount of maintenance work and the risk of the main transformer being forced to stop. Oil flow baffle and submersible pump running wear debris may affect the normal operation of transformer. This paper, through the field research and application of the transformation of the 500kV main transformer ODAF cooling system, carries out calculation of modification, analysis and calculation of cooling efficiency principle, etc.

1. Introduction
At present, the air cooling system of 500kV transformer in operation basically adopts strong oil air cooling. This type of air cooling system is a cooling system designed and manufactured in the 1990s. It has the characteristics of high reliability of working power supply, low self-cooling performance of cooling system, large amount of maintenance, high energy consumption and noise. The new oil immersed transformer natural cooling / natural oil circulation air cooling system has the advantages of good self-cooling performance, small maintenance, low energy consumption and noise, and is widely used in the new reconstruction and expansion projects. Especially with the implementation of specialized management, the integration of power grid regulation and control, the implementation of unattended substation and other ways, such as oil immersed transformer forced oil circulation air cooling system failure, will cause transformer overload shutdown, affect the safe operation of the power grid and reliable power supply. [1-3] For example, in the early morning of June 1, 2011, the failure of 380V low-voltage outgoing line of a 220kV unattended substation caused the loss of voltage of the station power supply of the substation, resulting in the complete shutdown of the working power supply of the cooling system of two 120 MW strong oil air-cooled transformers, and the transformer tripped [4]. There have been many similar incidents in which the strong oil air-cooled transformer had been forced to shut down due to the problem of power supply or secondary cable failure in the station. With the forced oil circulation in air cooling, far motor and submersible pump entail the frequent start and switch, leading to the frequent failures of fan motor and secondary air cooling controlling system and the tripping operation with the air-cooling. This process triggers the severe damage of the safe and stable operation of the power system [5-9].
2. Calculation of temperature rise

No.1 main transformer of a substation is taken as the object of reconstruction. Model: odfps-250000/500, manufacturer: TBEA Shenyang Transformer Group Co., Ltd., autotransformer single-phase strong oil-air-cooled transformer was put into operation in 2004 and has been in operation for 15 years; model of transformer cooler: yf2-315, 3 sets in total, including 1 set for standby; model of oil pump: qk37-150-b, power: 3kw, 3 sets in quantity; model of air blower: dbf-9q6, 9 sets in quantity; The number of oil flow relays is 3.

2.1. Calculation of temperature rise in cooling mode of ODAF

Oil surface temperature rise:

\[ T_d = \frac{P}{N \times S_n} \times 40 + T \Delta \]

Type: in Td, the temperature rise of the oil level, P, total loss, N, the number of sets of cooler operation, Sn, cooler rated capacity, T \( \Delta \), revised.

Unit heat load of coil surface:

\[ q = \frac{K1K2K3IJWJ}{K5L} \left(1 + \frac{K4}{100}\right) + q \Delta \]

Where, q, unit heat load of coil surface, K1, material temperature coefficient, generally 21.4; K2, turns insulation correction coefficient, generally 1; K3, line insulation correction coefficient; K4, the percentage of additional loss in the wire, generally 25; K5, cover coefficient of line segment; I, the current flowing through the line cake; W, the number of turns in the line cake; J, current density in the line cake; L, the outer surface circumference of the line cake; Q \( \Delta \), oil duct width correction coefficient.

Average temperature rise of coil to oil:

\[ T_x = 0.113q^{0.7} \]

Where: T, the average temperature rise of the coil to the oil; \( q \), unit heat load of coil surface; Coiil temperature rise:

\[ T_w(K) = T_x + T_d \]

The calculated coil temperature rise under the condition of strong oil circulation air cooling is shown in table 1.

| Cooling way | Rated capacity (%) | Oil surface temperature (K) | High voltage coil K | Medium pressure coil K | Exciting coil K | Voltage regulating coil K |
|-------------|-----------------|-----------------------------|---------------------|------------------------|----------------|-------------------------|
| ODAF        | 100             | 38.8                        | 46.5                | 47.8                   | 46.8          | 56                      |

2.2. Calculation of the ratio of heating center to cooling center

According to the actual situation, in the case of pc300/480 piece dispersion, the ratio of heating center and heat dissipation center of this transformer is calculated as follows:

\[ \frac{\text{Heating center}}{\text{The cooling center}} = \frac{\text{The height of the transformer oil base to the heating center}}{\text{The height of the transformer oil bottom plane to the radiator center}} = \frac{3950}{2} - 100 = \frac{1875}{2850} = 0.65 \]
Where, 400 is the size of the transformer outlet connecting tube elevation. By comparing the calculated ratio of heating center and heat dissipation center and combining with the actual situation on site, it is decided that pc300/480 chip radiator is adopted for each single-phase transformer.

New modified plate radiator is arranged 14 groups on the high voltage side of the transformer and 10 groups are arranged in the low voltage side of the transformer. Plate radiator adopt the way of mount respectively in bus lines up and down, up and down combining-flow pipeline connection transformer oil in and out of the mouth up and down, up and down combining-flow pipeline through on-site support steel stents made in advance based on the pier concrete. Each of the two groups is equipped with a cfz-9q8 blower device at the bottom, a total of 12, the blower adopts the bottom blowing type. After this modification, the transformer is compact in structure and beautiful in layout.

The elbow pipe at the junction pipe and the transformer inlet shall be made in accordance with the corresponding size of the oil pump with low speed, low flow and low noise, and the number shall be 4. Once the transformer cooling system is abnormal and the oil temperature is too high, butterfly valves at both ends of the elbow can be closed quickly and 4 oil pumps can be replaced. This plan does not need power cut, in case of emergency. During the transformation, the corresponding electrical control components need to be installed in the air cooling control cabinet.

3. Effect Analysis after Modification

(1) Select the operation conditions of the main transformer, such as the operation load and the operation environment temperature before and after the modification, and compare the cooling effect of the forced oil air cooling mode before the modification with the natural cooling mode after the modification. As shown in Figure 5, the oil temperature and winding temperature after the modification have a slight downward trend. Compare the cooling effect of the modified natural cooling mode with that of the modified natural air cooling mode, as shown in Figure 6, the oil temperature and winding temperature after the modification have a significant downward trend, with the minimum oil surface temperature decreasing by 9.1 ℃ and the maximum by 10.45 ℃.

![Figure 1](image1.png)

Figure 1. Effect comparison of different cooling methods before and after air cooling modification

(2) Compared with the strong oil air cooling mode before the modification, the heat dissipation effect of the natural air cooling mode after the modification is improved by a small margin. Compared with the strong oil air cooling mode before the modification, the heat dissipation effect of the natural air cooling mode after the modification is obvious. Compared with the 6-degree rule of transformer [10], the insulation life of transformer after modification is extended to a certain extent.
(3) According to a large number of operating conditions after the modification of the main transformer, if the operation is in the state of small load and low oil temperature, there is no need to start the fan, and a large amount of power loss will be saved after the modification of the transformer.

(4) According to the actual monitoring data on site, the temperature rise of oil surface and winding after modification of transformer meets the requirements of national standard: oil surface temperature rise≤55k, winding temperature rise≤60K. The operation of the main transformer cooling system after modification is better than that of the transformer before modification, and it has the conditions of unattended operation.

4. Conclusions
In this paper, the on-site modification of the ODAF cooling system of 500kV main transformer is studied, and the temperature rise calculation of the on-site modification of the system is carried out. According to this study, a targeted transformation plan is formulated to achieve the purpose of on-site transformation of the main transformer cooling system into a natural air cooling system after field verification; the cooling effect of the modified cooling system meets the requirements of field operation.

About the author:
Huo Feng (1972 - ), senior engineer, master, engaged in safety operation and maintenance management of power transmission and modification equipment
E-mail: huofeng@impc.com.cn, Inner Mongolia EHV Power Supply Bureau, Hohhot, Inner Mongolia, 010080

References
[1] Zhao Jianli, Kou Zheng, Huang Linxin. Simulation calculation and analysis of cooling system modification of strong oil air-cooled transformer [J]. Transformer, 2019,56 (09): 68-73 + 88
[2] Li Junjun, Xing Feng, Chu Wenchao. Analysis of field modification of 220 kV heavy load transformer strong oil air cooling system [J]. Inner Mongolia power technology, 2019,37 (03): 47-51 + 59
[3] Zhang Lei, Cheng Zhipeng. Theoretical analysis and calculation of air cooling modification of 500kV strong oil circulating transformer [J]. Electronic technology and software engineering, 2018 (14): 235-237
[4] Zhou Duosi, Liu Chunyan, Tang Langlang. Analysis of the total stop fault of cooling power supply of forced oil-air-cooled transformer [J]. Hunan electric power, 2012,32 (06): 49-50 + 53
[5] Xiong Hongying, Liu Quan. Study on response measures for complete shutdown of main transformer strong oil circulation air cooling under integrated regulation and control mode [J]. Engineering technology research, 2017 (10): 126-127
[6] Chen Chunjiang. Discussion on common problems in operation of strong oil air-cooled transformer [J]. Science and technology and innovation, 2017 (04): 42 + 46
[7] Huang zuolin. Analysis of fluid and heat transfer of transformer with strong oil oriented cooling mode [J]. Journal of electrical engineering, 2015,10 (12): 50-57
[8] Xing Zhiqiang. Treatment of cooling system failure of forced oil air-cooled transformer [J]. Science and technology and enterprise, 2015 (13): 239
[9] Yao Yi. Analysis and treatment of complete shutdown accident of cooler of main transformer with strong oil and air cooling [J]. Science and technology innovation and application, 2013 (25): 120
[10] GB / T 15164-2016 power transformers Part 7 load guide for oil immersed power transformers