

Harm and Preventive Measures of Transformer Outlet Short Circuit

Hua Zhang¹, Qinghao Wang¹, Guobin Liu¹, Tianshu Hai¹, Hainan Su², Yang Hu¹, Qidong Zhao¹, Chuanzong Zhao¹, Boyu Shi¹

¹Fushun Power Supply Company, Liaoning Electric Power Company Limited, State Grid, China

²Dandong Power Supply Company, Liaoning Electric Power Company Limited, State Grid, China

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Abstract. It puts forwards related test and requirements while analyze harm of outlet short-circuit to power transformer in the state of increasing volume of power system short-circuit. Furthermore it describes process of harm accident when power transformer close range outlet, check test's situation, analyze handling method, introduce judging scene and repair program after damage of transformer outlet short-circuit and puts forward pertinent preventive measures.

Introduction

Power transformer is one of the key equipment of power network, because its stable operation is important for safe of power system. However the limit of design and manufacture technology and operating and maintaining level of transformer, machine error happens occasionally when operating transformer touches low-voltage busbar and power supply circuit. It impacts operation of power system safely and steadily most when happens outlet short-circuit in short range, because they damage transformer lead to quit operation which are mechanical stress by powerful accident short-circuit and high temperature that above allowed operating temperature several times. According to statistics information, more than 80 percent of reasons of damage transformer is outlet short-circuit. Therefore, in order to defend outlet short-circuit happened, it necessarily analyzes reasons of transformer outlet short-circuit's accident, research practical countermeasures, implement targeted preventive measures to ensure the security and stability of transformer has an important significance.

The Harm of Transformer Outlet Short Circuit

Power transformer in export short-circuit electromotive force and mechanical force, the winding of the size or shape of irreversible changes, the winding deformation. Changes of axial and radial size of the winding deformation, the body displacement, twisting, winding drum kits and inter-turn short circuit, is a big hidden trouble for safety operation of electric power system. Transformer winding deformation; some will occur immediately damage accident, more is still can continue to operate for a period of time, running time depends on the severity and location of deformation. Obviously, this transformer with "disease" operation, has hidden trouble.

The harm of electric power to the transformer.

Due to the presence of current and magnetic flux leakage during the operation of the transformer, the transformer winding will generate electric power, the electric power is proportional to the leakage flux density and the current, and also through the current is proportional to the square of the current. The electric power applied to the wire is very small when the normal operation of the transformer, when a sudden short circuit, ten times to several times the short circuit current will generate electric power for hundreds of thousands of times the rated current, it is easy to cause the transformer winding buckling deformation, insulation injured, turn to turn (cake room) short circuit to make the transformer damaged[1].

Damage to the electric power transformer is often expressed as: pressing part of winding deformation, seriously pressing on the steel support plate clamps to be bending, the pressure screw plate falling off, and bending displacement, the end of the paper (wood) wrapped ring crack, breakage and damage of lead frame and so on, as Figure 1 and Figure 2 shown. At the same time it

will cause the winding deformation: the inner winding local bending, the outer winding moving or breaking the marathon; the winding wire deformed along the axial direction. Deformed oil gap between cake line to becomes small, block displacement, failure turns (cake) insulation, insulation breakdown and so on. Transformer withstood the impact of the short circuit many times, even if some switched off when transformer insulation breakdown did not happen, but it has produced multiple winding cumulative deformation, the deformation of the winding made the strength of insulation and mechanical decreased, the internal insulation breakdown may be caused by the impact of the current or over-voltage, even under the action of the normal ferromagnetic resonance over-voltage[2].



Fig. 1 Short circuit of winding

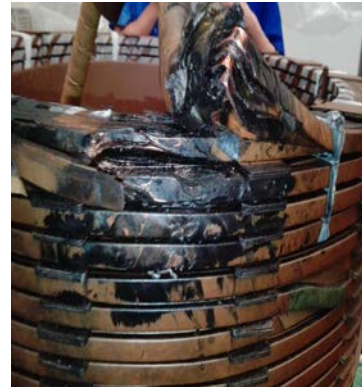


Fig. 2 Winding deformation discharge

Damage of overheating to the transformer.

The resistance loss of the transformer winding is directly proportional to the square of the current and the time through the current, that is $W = I^2 RT$. During the short circuit, the rated short circuit current of several times will increase the resistance loss of the winding by several hundred times, which will be converted into heat energy to increase the temperature of the winding. Due to the short time of short circuit, generally only a few seconds, the heat generated is not too late to spread out to increase the winding temperature. "Fifth parts of the power transformer: capacity to withstand short circuit", during the design of the transformer, the temperature of the winding copper wire allowed is 250°C [2], the design starting temperature is 105°C . Therefore, as long as the protection device and circuit breaker can be reliable and timely action, the duration of the short circuit current thermal stability normally does not exceed the demands of the transformer, the possibility of thermal stability failure of the transformer is also small, it is likely to burn out the transformer in the relay protection tripping, short-circuit current through the winding long time [2].

Test and Requirements after the Transformer Subjected to Short Circuit Faults

Once the transformer short-circuit fault occurred in export, regardless of whether it is caused by tripping, to make Comprehensive analysis and judgments about short circuit fault nature, short-circuit current size, short distance, the distance from the outlet of relay protection and automatic device operation, chromatography analysis and so on. The transformer powered off also measures the transformer winding DC resistance, winding deformation, no-load loss, in order to determine the extent of damage, determine whether to continue to run, to develop a repair plan [3].

Visually Inspected.

To check whether the transformer casing has obvious concave and convex, whether the tank weld is leaking oil, check the pressure release device action, check whether the gas relay action or send a signal, whether the set of combustible gas. Transformer still on the running should pay attention to whether the abnormal sound discrimination, the normal operation of a continuous, uniform, slight buzzing sound, if sound is uneven or special voice, that is regarded as abnormal, such as electric welder, crackling sound discharge sound.

Gas Chromatography Analysis.

The main function of transformer oil is insulation and cooling, when overheating and discharge occurred by the fault inside the transformer, transformer oil and other insulation materials will

occur chemical decomposition to produce specific CH₄, C₂H₆, C₂H₄, C₂H₂, H₂, CO, CO₂ etc.. With the increase of temperature, the maximum gas production is CH₄, C₂H₆, C₂H₄, C₂H₂ in sequence. By measuring the composition and content of the characteristic gas and analyzing the temperature of the internal heating or the discharge point of the transformer, it can determine whether the transformer can be damaged after being subjected to the short circuit of the outlet. Short circuit will cause the winding inter turn short circuit (cake room), continuous flow discharge system of high energy flash frequency, sometimes involving solid insulation, thus the change of C₂H₂ content is larger, if the time how long the short-circuit withstand failure is longer, the content of CO and CO₂ increases [4].

Measurement of DC resistance.

The DC resistance of the transformer winding is basically balanced [4]. The measurement of the DC resistance can be easily and effectively check the connection of the longitudinal insulation and the loop of the winding , it can find the turn(cake) short-circuit and winding faults such as broken strands caused by export short circuit to judge whether the transformer suffered serious impact damage.

Test of winding deformation.

After the local mechanical deformation of the transformer winding, the distribution parameters such as inductance, capacitance and so on are bound to change. Diagnosis of winding deformation, high sensitivity, strong anti-interference ability by frequency response method can use to compare the correlation coefficient of the frequency response curves of the two measured to determine the severity of the winding deformation and deformation. In the absence of original data, it also can compared the difference of the frequency response curve of three-phase winding or the difference between the windings with the same factory and the same type. If the tests found that the correlation coefficient of frequency response curve is less than 0.5, it should be immediately quit running.

Measurement of dielectric loss and capacitance of winding.

When the transformer has local mechanical deformation, the relative position between the winding and the core and the shell will change, and the capacitance will change accordingly. Although the preventive test code for electric power equipment from the angle of the insulated dielectric loss value is provided, but serious winding deformation can cause significant changes in capacitance, so when check whether the transformer winding deformation after short circuit shock, the measured capacitance value is compared with the historical data is also very important, when the change in the value of more than 10% needs pay attention.

Test of no-load loss and no-load current.

Transformer which withstands the impact of short circuit current exports will cause the increase of transformer magnetizing current and no-load loss increases when short circuit between coils or involving core insulation, and comparing with the previous test data , the no-load loss increased by 10% when it should be noticed.

The Example of the Transformer Outlet Short Circuit

Analysis and processing examples.

A main transformer (40000/66/10 - SFSZ7) exploded because of the 10 kV of the outlet cable head three-phase short circuit, transformer differential protection, over current protection acted, transformer three side circuit broke off. Outside cable households (fault) is about 100m far from the transformer outlet, cable fault clearing time is 0.36 s, the maximum short-circuit current through the 10 kV side of the transformer by fault filter is 15 kA. Gas relay oil room has 1/3 gas by field appearance inspection; there is no deformation and other features by appearance inspection.

Test case on site inspection and analysis of cause.

The analysis of the related project of transformer electrical test and gas chromatography: all insulation project test qualified, no-load loss of 43.59kW increased to 56.8kW; DC resistance of winding high and medium voltage qualified, the three-phase unbalance factor of the low voltage side reached 26%; it analyzed by gas chromatography of transformer oil that the content of characteristic gases found abnormal, among them, C₂H₂ is up to 50 L/L, chromatogram analysis

data are shown in Table 1.

Table 1 SFSZ7—40 000/66/10 Transformer Oil Chromatogram

Gas content ($\mu\text{L/L}$)							
H ₂	CH ₄	C ₂ H ₆	C ₂ H ₄	C ₂ H ₂	CO	CO ₂	C ₁ +C ₂
350	122.04	17.92	243.22	49.69	385	712	

Checking the transformer substation operation records found it has experienced the 8 close short circuit similar to the impact of export. Because the dissolved gas in oil is mainly C₂H₂, which is far more than the 5 L/L value of the guideline, it concluded that the high energy arc discharge in the transformer can be determined. In addition, the low voltage winding DC Resistance Unbalance, coupled with the low voltage winding of transformer fault transient suffered 15kA short-circuit, combined with the rise of no-load loss of transformer and the previous operation, identification of low voltage winding of the transformer and damage due to the impact of short-circuit current, the transformer can not continue to run back to the factory for repairing

Check back to the factory and repair.

Transformer hung bell cover and check wire after back to the factory, core and external visual components are all normal, the fastener is without loosening, clean appearance, normal insulation; high and medium voltage winding hung out do not have the deformation and damage, and 3 low voltage windings have different degrees of deformation, the A is the most serious, and C is slightly. The shrinkage deformation of the winding of A along the longitudinal 2/3 line is serious, there are 3 winding insulation damages, epoxy lined tube low-voltage of winding is without damage and deformation. Return to factory to take into account the possibility of low-voltage winding damage, which must be replaced by the manufacturer, so advance the production of low-voltage windings with the same structure timely replacement, and dry processing, assembly after the end of back to the transformer substation; after installation test after passing into normal operation.

Measures to Prevent Short Circuit of Transformer

1). Middle and low voltage side of transformer install insulation heat shrinkable sleeve. It can export from the transformer wiring pile head until the bus switch cabinet as long as the outlet is used in hard bus for the middle and low voltage of the transformer 10kV and below, including switch at the bottom of the indoor high voltage switchgear busbar, all install insulation heat shrinkable sleeve. If you use a soft bus, insulation heat shrinkable sleeve is installed on the head and near wall bushing transformer outlet connection pile. This can effectively prevent small animals caused by the short circuit of the transformer.

2). For medium and low voltage side of transformer for 10KV voltage transformers, neutral point is due to its small current grounding system, so we should take effective measures to prevent the single-phase ground resonance overvoltage to cause the insulation breakdown, resulting in transformer short-circuit export.

3). Transformer low voltage side of the pillar porcelain, including high voltage switch cabinet can change the distance antidirt porcelain larger, or brushing room temperature curing silicone rubber coating (RTV), to prevent the transformer insulation breakdown caused by short circuit. Room temperature curable silicone rubber coating shall meet DL/T627 1997 standard.

4). The transformer low-voltage side of the switch replaced by breaking larger capacity switch, to prevent the breaking due to the inadequate capacity of the transformer explosion caused by switching the export short-circuit.

5). On the transformer, busbar and line surge arrester to be replaced by good performance of zinc oxide arrester and improve equipment, over-voltage level.

6). Perfect protection configuration of transformer. Transformer relay protection to take computer, double, as far as possible failure protection, installation of busbar differential protection, improve the protection reliability, sensitivity and speed. The configuration of time-limited quick-break protection should be in the low-voltage side of the transformer, the action time should be < 0.5 seconds. To ensure the transformer short circuit, reliable, rapid removal of transformer fault,

reduce impact outlet short circuit and damage.

7). Strong cable structure plugging, prevent small animal into the switch room, avoid short-circuit grounding caused by single-phase transformer exports caused by the small animal, but also to avoid the damage caused by the over voltage of transformer.

Conclusion

The powerful of short-circuit current causes serious damage when transformer happens error that is outlet short circuit, which impacts safety of power grid. Operation department and manufactures take comprehensive measures to prevent transformer equipment. It should make sure transformer operate safe through decreases rates of outlet short circuit of transformer, reduces short-circuit current by transformer winding, enhance capacity of resistant short-circuit.

Reference

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