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Current Situation and Existing Problems of Power Transformer Cooling System

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Abstract

This paper introduces the development history of the transformer cooling method and some existing problems. The transformer is a very important primary equipment in the power system and is responsible for the transmission of electric energy. Especially in long-distance and large-capacity power transmission systems, the situation of transformer heating is more serious. Therefore, the cooling of the transformer is particularly important. If the transformer heats up seriously, it will cause a drop in efficiency and the hidden danger of damage to the insulation. Therefore, the process of the cooling method of the transformer is very important to the development of the power system.

Keywords

Power transformer; cooling; system.

1. Introduction

Power transformer is a very important part of power system, which is mainly used for power conversion. From the power plant to the user's side. Power transformer is responsible for converting electric energy into different voltage levels to realize remote transmission and distribution of electric energy. However, each voltage change process will be accompanied by huge power loss. Increasing the transmission capacity is an effective method to reduce power loss, and it's also the trend of power transformer development in power industry [1].

The development of the cooling technology of power transformer is a key link to accelerate the capacity growth of power transformer[2]. In the operation of power transformer in power system, that is, in the process of power conversion, loss will be generated in the core, oil tank wall and other parts, and these losses are generally distributed in the form of heat energy. Due to the more heat it generates, the operating temperature of the power transformer of large capacity will rise to a certain extent, which will accelerate the aging of the power transformer and shorten its life. Therefore, the cooling technology of power transformer is very important to control the operating temperature of power transformer.

2. Cooling mode of power transformer

Power transformer system has several fixed parts, which constitute the cooling system of power transformer, and the traditional cooling system includes cooling medium and cooling mode. The commonly used media of power transformer are air, power transformer oil, SF_6, etc. Based on these cooling medium, people have produced many cooling methods. For example, people have air-cooled cooling based on air; based on power transformer oil, oil-immersed power transformer was invented, which can be seen everywhere in life; what's more, there's

Air-cooled cooling based on SF_6. The development of cooling medium also indirectly restricts the development of power transformer.

2.1. Air-based cooling method

Due to the low cost and universality of air itself, the power transformer initially used air as the cooling medium. As a result, dry-type transformer appeared. In 1885, the world ' s first power transformer used air cooling. At the beginning of the birth of power transformers, due to the deficient development of insulation, power transformers cannot be developed to high voltage and large capacity. However, dry-type transformer also has its own advantages. For example, dry-type transformer is generally composed of materials that are not prone to combustion, and is safer compared with oil-immersed power transformer. And there is no pollution, no maintenance, and no sealing problems[3].

Dry-type transformer mainly rely on the flow of air for cooling. Generally, there are two types : natural air cooling and forced air cooling. In the peak of electricity consumption, forced air cooling is usually used to promote the heat dissipation of power transformers. In the operation of power transformer, there is very large loss in the winding and iron core, and if the power transformer runs in this case for a long time, overheating will occur, resulting in insulation damage. For small power transformers, heat dissipation can be achieved through thermal radiation and natural convection. Self-cooling is usually used for indoor small power transformers. In order to prevent fire, dry-type transformer are generally used instead of oil-immersed power transformers.

2.2. Cooling Method Based on Power Transformer Oil

As a very excellent medium, power transformer oil is widely used in power system. For example, it is a very important insulating material in high voltage system. In electrical equipment, since the dielectric constant of air is about 1.0 and the dielectric constant of power transformer oil is 2.25, it can be seen that the insulation performance of power transformer oil is far superior to that of air, which means it's not easy to cause arc and breakdown in actual operation. Moreover, power transformer oil is often used in circuit breakers, and when the circuit breaker disconnects the AC circuit, the condition of arc extinction is that the recovery process of dielectric strength is faster than that of arc gap voltage. The role of oil medium is to extinguish the arc by hydrogen and other gases decomposed by insulating oil under the high temperature of the arc. Due to the high temperature and high pressure, this kind of mixed gas is flammable and explosive. Therefore, these factors must be fully considered in the production process, otherwise it will affect the limit parameters of the power transformer.

Viscosity is one of the main physical properties of power transformer oil. It is well known that the smaller the viscosity is, the better the heat dissipation effect of power transformer oil. It is because the smaller the viscosity is, the better the fluidity of power transformer oil is, the faster the heat exchange between power transformer oil and the outside world is, and the better the heat dissipation effect goes. So many countries have certain provisions on the viscosity of power transformers.

Power transformer oil was first used as a cooling medium in the early 20th century. After more than 100 years of development, power transformer oil occupies a dominant position in the cooling medium of power transformer. Oil-immersed power transformer can be seen everywhere in our life. In 1000 kV UHV system, oil-immersed power transformer accounts for 60 % ~ 65 %. The air-based power transformer is only used in some occasions of small capacity. Because all the coils of the power transformer are immersed in the oil of the power transformer, when the current flows through the coil, the coil will generate heat due to the Joule law, which will increase the temperature of the coil, and the increase of the coil temperature will reduce the efficiency of the power transformer and cause harm to the insulation. However, the power

transformer oil will take these heat away through the cooling system, thus keeping the temperature of the power transformer within a certain range and not affecting the normal operation of the power transformer.

The characteristic of oil-immersed power transformer is that the coil and iron core of power transformer are immersed in oil. According to the capacity of oil-immersed power transformer, it is divided into natural oil cooling, oil-immersed air cooling, forced oil circulation air cooling and forced oil circulation water cooling[4].

Natural oil cooling is a relatively simple form in the cooling system of oil-immersed power transformer. Its cooling system is mainly composed of oil tank and oil pipe. Heat is carried out through the oil in the oil pipe and released to the air. The corresponding oil-immersed air cooling is to install fans on the basis of natural oil cooling to strengthen the heat release. Compared with natural oil cooling, this form of heat release is more effective, which enhances the air flow and makes heat release more quickly. Thus, the capacity of oil-immersed air-cooled power transformer is increased by about 40 %.

Compared with natural air cooling and oil-immersed air cooling, forced oil circulation air cooling and forced oil circulation water cooling only add a pump that can force power transformer oil to pump out. The basic principle of forced oil circulation air cooling and forced oil circulation water cooling is the same as the two air cooling technologies, and the heat is also taken away by air or water. The capacity of this power transformer is also very large.

Although oil-immersed power transformer has many advantages over dry-type power transformer, it is undeniable that it has higher requirements on the production process. Due to the particularity of oil, it cannot be much sealed to avoid dangerous accidents and affect the circulation of power transformer oil. However, dry-type power transformer are more widely used than oil-immersed power transformers in places where fire protection and explosion protection are needed. The safety factor is higher, but the production process requirements are higher, and the cost is higher than the general oil-immersed power transformers. So dry-type power transformer are generally used in distribution lines.

2.3. Cooling method based on SF_6

SF_6 is a very widely used medium in the current power system. For example, in the application of circuit breakers, SF_6 is a electronegative gas, so it has a very excellent ability to absorb electrons, which greatly reduces the number of free electrons in the arc gap and plays a role in rapid arc extinguishing. At the same time, due to the adsorption of electrons, SF_6 becomes negative ions, whose average free travel is reduced, and the collision ionization is suppressed, thereby inhibiting the discharge. The arc extinguishing ability is about 100 times that of air.

Because of its excellent insulation ability, it is applied to the cooling system of power transformer to ensure safety and expand its scope of application.

And the operation of power transformer, maintenance and repair are more simplified. Besides, This kind of power transformer noise is very small, and safer than the oil-immersed power transformer, especially suitable for urban residential areas and some power transformer occasions of higher safety requirements . At the end of the 20th century. This kind of power transformer first appeared in Hong Kong. Since the heat dissipation and heat transfer capability of SF_6 is poorer than that of power transformer oil, it cannot be used in large capacity environments such as high voltage systems[5].

3. Common failures in cooling systems of power transformers

No matter which cooling method is adopted, there will always be some problems in the actual operation. Problems may arise in the production process. Due to the structural defects caused by the negligence of the production personnel, the likelihood of power transformer failure

increases. After the power transformer is put into operation, the negligence or long maintenance cycle of the maintenance personnel of the power company leaves hidden dangers to the fault of the power transformer. Once problems occur in the power transformer cooling system ,it will bring hidden danger. Because the cooling system of power transformer has problems, it will inevitably cause the heat of power transformer can not be effectively distributed, which will lead to temperature rise. If the temperature exceeds a certain safety range, it will cause damage to the wind's insulation of power transformer, and make the core temperature rise so that the performance of power transformer is poor and the efficiency is reduced. Serious situations may also cause serious electrical accidents, resulting in personal safety and property losses.

(1) The problem of cooling function of power transformer may be caused by the outside world. In summer, the power transformer is mostly exposed to strong light outside, resulting in high surface temperature and loose outside insulation. For the oil-immersed power transformer, if loose, it is possible to block the oil pipeline, and affect the oil circulation of the power transformer, so that the heat of the power transformer cannot be fully distributed.

(2) The problems of the cooling function of power transformer may also come from the design of power transformer. Such as the unreasonable design of oil pipeline in oil-immersed power transformer, most of the oil pipeline will have a right angle, and this design will make the flow of power transformer oil is limited. In the power transformer with fan, the fan fails during operation, which makes the heat dissipation function severely limited and the temperature rise. At the same time, in the production of power transformers, it may be due to the reasons of manufacturing process, so that the sealing of power transformers is not guaranteed, resulting temperature rise.

(3) Most of the power system now pursues unmanned and automatic working system, and remote control is carried out through modern communication technology. However, there is still no obvious change in the cooling mode of power transformer, which may cause the power transformer not maintained in time, which cannot meet the requirements of unattended operation[6].

4. The future direction of solving the problem of power transformer cooling system fault

4.1. Improving the temperature system of cooling system

In the improvement of cooling system, the temperature detection of power transformer is very important. Because the rise of temperature will endanger the insulation under certain conditions, the temperature detection module should be further improved. So that the temperature of the power transformer is fully reacted, and improve the design index of the working temperature of the power transformer cooling system, and further protect the hardware composition and insulation performance of the cooling system under the premise of not endangering the work of the power transformer. Based on the principle of energy conservation, when the temperature of the power transformer is lower than a certain range, the working time of the cooling system or the input power should be reduced to save energy to a certain extent, and the service life of the power transformer can be extended and the operation cost can be reduced.

4.2. Improving Design process of internal structure of power transformer

Many oil-immersed power transformer oil pipelines have fluid mechanics' problems. The shape of the pipeline will limit the flow rate of power transformer oil to a certain extent, so that the heat exchange rate between power transformer and external space is limited. The shape and

layout of the pipeline should be optimized according to the chemical and physical properties of power transformer oil to improve the performance of the cooling system.

5. Conclusion

With the continuous development of power system and the increasing capacity, the efficiency and stability of power transformer cooling system are becoming more and more important. In different places, different cooling methods are selected to maximize the economic benefits and ensure the transmission of high-quality electric energy. The problems that may exist in the cooling system of power transformer should be solved according to the specific characteristics and difficulties of different problems. In the future, efficient and green cooling system is the necessary standard to measure a power transformer's performance.

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