The Feasibility Analysis of Low-temperature Waste Heat Thermoelectric Power Generation, Base on Forced Oil Circulation Cooling Transformer

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Abstract—This paper is intended to propose a way of utilizing low-temperature waste heat what base on forced oil circulation cooling transformer. Cooling of large power transformers affect the normal operation of the power system. Existing techniques simply cool the transformer, but there is not take full advantage of the low-temperature waste heat generated during cooling. This approach resulted in a lot of energy waste. In this paper we present an approach based on the most commonly used power transformer cooling mode forced oil circulation cooling to take advantage of low-temperature waste heat. In this paper, the feasibility of this approach are discussed mainly from the transformer temperature, plant transformation, temperature conditions, economy,etc. You can say that this method provides a new way of thinking and methods for energy recycling power system. This technology will help improve the efficiency of the transformer, to achieve the purpose of energy saving. It has a strong promotional value in improving aspects of large power transformers.

Keywords- power transformer; forced oil circulation; thermoelectric power generation; low-temperature waste heat; energy conservation

I. INTRODUCTION

Oil-filled transformers are the most common power transformer in China. With the improvement of electricity demand In the national production and life, transformer voltage level and capacity has been increasing. Because of this reason causing the transformer load is growing, leading to localized overheating transformer、internal heat transformers and other centralized heat problem. According to a circular manner oil-immersed transformer can be divided into three kinds, namely, natural convection circulation, forced oil circulation and forced oil circulation guide. In these three methods, the mode that forced oil convection circulating pump, whose power is greater than the natural oil circulation, and oil cooling effect is better than the natural circulation. Forced oil circulation guide, which forces oil circuitous guide in the winding,so that the cooling efficiency can be further improved. Large power transformers currently widespread use of forced oil circulation guide approach to cooling in China[1]. Low-temperature waste heat of power transformer comes from the power grid,which is an important part of the power grid in the energy loss at this stage. So far, this part of the thermal energy resources have not been untapped. If we can find a way to take advantage of low-temperature waste heat transformer cooling oil, which would greatly reduce the energy consumption of power transformers,and improve the efficiency of the transformer.

Thermoelectric power generation technology, as a new generation technology, because of its low power requirements of the temperature, which can use low-temperature waste heat and has been widely utilized in many areas of production and life. Considering the forced oil circulation is aimed as much as possible to reduce the temperature of transformer oil, and thermoelectric power generation technology can take advantage of this part of low-temperature waste heat. The combination of the two techniques can improve the cooling effect of transformer oil.At the same time it collects the low-temperature waste heat from the transformer oil, and thus play a fully staffed effect. This paper discusses the feasibility of utilization of these two technologies in power transformersand proves its scientific and can be realized.

II. ANALYSIS OF TRANSFORMER TEMPERATURE RISE

Temperature rise specifically refers to that the temperature difference between the part that we analyze from external cooling medium. In terms of oil-immersed power transformers is the difference between the temperature measuring portion of the cooling air temperature. Under normal circumstances, in order to ensure the normal operation of the transformer, the transformer’s temperature rise limit is: coil temperature 65K,and oil temperature 55K. Typically refers to the average annual temperature of 20 degrees Celsius, and the height is no more than 1000 meters above sea level. the transformer’s temperature rise limit is the maximum temperature difference when oil-immersed transformers on work. Typically, the temperature of the transformer is not greater than this value, but it will not much smaller than it[2].

In order to better illustrate the load and the temperature rise of large power transformers under normal operating conditions, we have access to the relevant data to investigate the 220kV substation in Shanghai Gubei representative transformer 2010 annual operating data (Figure 1 shown).

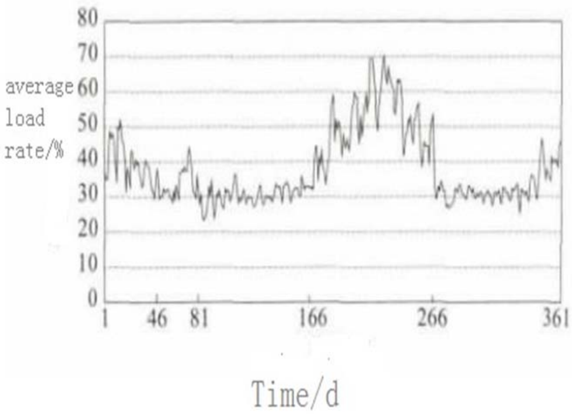

Figure1. Gubei 220kV transformer substation 2010 operating data

The running time of the substation is divided according to the load factor obtained in three stages: The first stage，Summer (June 17 to September 21, a total of 97 days), this season is the year's largest electricity load season. During this time the average daily load was 51.6%. The second stage, winter (January 1 to March 12, December 6 to 31, a total of 96 days), the average load rate of 34.47% during this time. The third stage, spring and autumn (the other time was 172 days in total), the average load was 30.61%, within this time. Meanwhile, according to Figure 1, we can see the daily average of transformer operation: the minimum load was 23.28%, the maximum load was 70.28%; the number of days when the load was less than 30% load factor is 70 days; the number of days when the load was 30% to 40% is 147 days; the number of days when the load was 40% to 50% is 51 days; the number of days when the load was 50% to 60% is 34 days; the number of days when the load was greater than 60% is 19 days.

At the same time, through access to relevant information, we can get the load and temperature curves 220KV transformer (Figure 2). Thus, we can roughly estimate the water temperature.

By analyzing Figure 2, we can see that: When the transformer is loaded runtime (240MVA), the top oil temperature is about 45 K; when running load is 160MVA, the top oil temperature of about 29K; when running load is 150 MVA, top oil temperature of about 25K. Above projections, the average load factor 51.6%, the top oil temperature is about 25K, in the summer; when the average load factor was 33.3%, the top oil temperature of about 19K; average load of 34.47 percent, top oil temperature of about 19K, in the winter.

According to the formula:

oil temperature = temperature rise + ambient temperature (1)

We can estimate the average oil temperature in winter is about 39 °C, and the cooling water outlet temperature is about 39 °C; average summer oil forecast is 61 °C, the cooling water outlet temperature is about 61 °C. Thus, the average annual water temperature is about 50 °C[3].

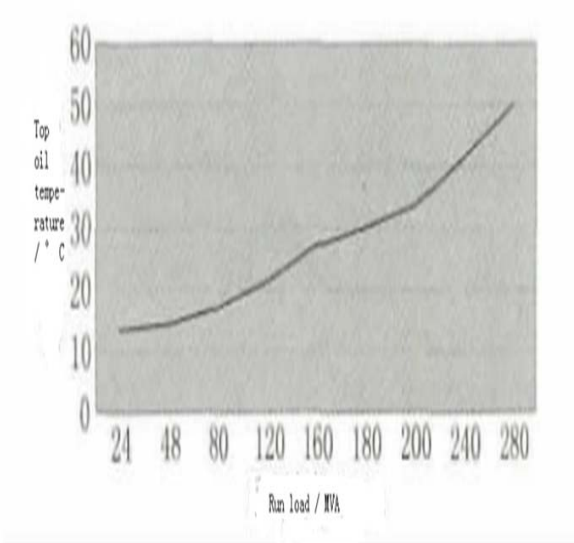

Figure 2. Gubei 220k transformer substation load and top oil temperature curve

III. THE ALTERATION OF FORCED OIL CIRCULATION PATH.

At present, China's large transformer cooling mainly uses oil-immersed self-cooled, oil-immersed forced air cooling and air cooling oil circulation, in which air cooling oil circulation is most widely used. Forced oil circulation is a cooling mode,which uses circulating pumps and other components to ransformer oil by pipeline to the cooler,then use water, wind, and other media to reduce the temperature of transformer oil. Finally, the cold transformer oil is transported through the circulation pump back to the internal transformer, thus completing the entire cooling process. Because of the way the forced oil circulation cooling transformer oil export transformer, it is easy to use other media to reduce the temperature of transformer oil. Thus it greatly improves the cooling effect of transformer oil, and it is more conducive to achieve the purpose that reduce the temperature of large power transformers. Therefore this approach is widely used in the current power system. At the same time, this approach is very similar to forced oil circulating water cooling, the differ only in the cooling medium. Large power transformers are now widely used air cooling, instead of water cooling.The main reason is the cost of air-cooled lower than water cooling, but the disadvantage is difficult to collect air-cooled cryogenic waste heat. Therefore, we can put this cooling device transformed into forced oil circulation cooling water, so as to achieve the purpose of the collection of low-temperature waste heat. Specific transformation diagram shown in Figure 3 [4]:

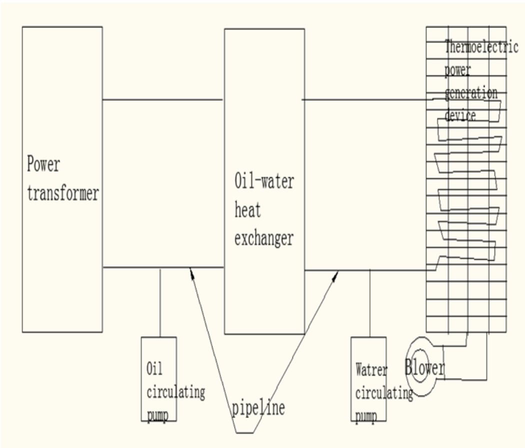

Figure 3. Forced oil circulation path transformation

IV. THE CONDITIONS OF THERMOELECTRIC POWER GENERATION TECHNOLOGY COLLECTING LOW-TEMPERATURE WASTE HEAT

Semiconductor thermoelectric generation technology mainly used the Seebeck principle, which directly converts heat into electricity. And it gets more and more applications in aerospace, electronics, food reserves and other areas. The ends of two different material conductors connected to the loop in this technique. When the temperature of the binding sites, in the loop there will produce thermal electromotive force (also called thermal emf). [5] Figure 4 is thermocouple experimental schematic diagram, the heavy line A and thin line B are different materials of conductor, and the conductor of A and B is called the thermocouple. [6] High temperature side C (temperature record for T1) is working side, which usually be tied together; Low temperature side O (temperature record for T2) is a free end, which would be closed as well. Voltage circuit of temperature difference can be expressed as:

$$\varepsilon_0 = b(T_1 - T_2) \quad (2)$$

In this formula: b is the see beck coefficient.

Thermoelectric potential value is basically constant when the work end and free end of thermocouple under the condition of constant temperature, namely thermocouple work at a constant temperature difference[7],

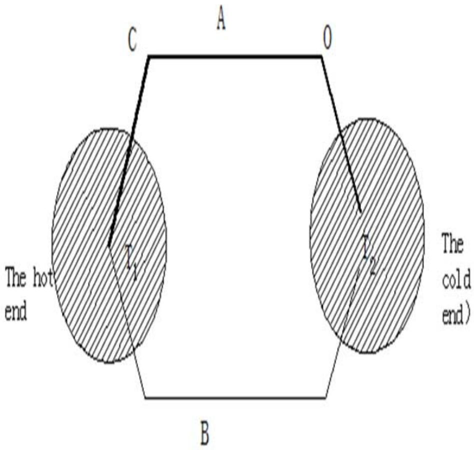

Figure 4. Thermocouple principle diagram

The most suitable temperature difference existing thermocouple power semiconductor thermoelectric power generation piece is about 60K. It can work at a higher efficiency when the temperature difference is 40-90K. Device is given in this paper can provide for the generation component of the difference in temperature is about 50K. Considering the heat diffusion in the transfer process and so on, actually delivered to thermoelectric power generation unit temperature difference of about 45K. The temperature difference conforms to the requirements of Thermoelectric Generator.[8]

V. THE ECONOMY OF THIS TECHNOLOGY

Due to the limitations of existing semiconductor materials technology, and now the price is higher thermocouple thermoelectric power generation semiconductor devices.At the same time the power generation efficiency is low.For example the type of SP1848-27145 thermoelectric power generation chip,whose Market retail price is about 15 yuan / piece. Its generating power of about 0.8W / tablets when the temperature difference is 45K. According to the current market price is estimated that about four years to recover costs.It is a long time so that the technology is hardly to spread. However the price of the raw semiconductor material such as silicon ,which is used to make thermocouples Thermoelectric power generation device is not expensive.The reason why it is expensive is poor manufacturing techniques. However, with the development of materials and technology, in the near future, the production cost of semiconductor materials will be greatly reduced. So that this technology can be obtained in large scale.[9]

VI. CONCLUSIONS

Low-temperature waste heat thermoelectric power generation what base on forced oil circulation cooling transformer. It forced oil circulation cooling pipes and thermoelectric power generation components combine. In the premise of Completing transformer cooling requirements.It put the transformer’s low temperature waste hate resources that into electric energy resources. It can reduce the energy loss of the transformer in a certain extent. Thus, it can improve the efficiency of energy transfer transformer, and play the effect of energy conservation. However, this technique is limited to materials technology,so that the cost of this technique is high and it is difficult to promotion of it. [10] However, with the development of materials and technology, in the near future, the production cost of semiconductor materials will be greatly reduced. So that this technology can be obtained in large scale.

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