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Geothermal Heat Pump as a Cooling System to Reduce the Temperature of the Transformer's Oil

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ABSTRACT

The geothermal heat pump is one of the air conditioning systems that can be used to provide indoor cooling and heating inside the building. Of course, this system can also be used in some industrial applications. Power Transformers are used in power transmission network in Iran. In the warm months of the year due to high power consumption, the temperature inside the transformer coil increases, and the high temperature of the oil will reduce the life span of the transformer and reduce it's efficiency and also increase the high power losses. To reduce the temperature inside the transformer, special oil is used to transfer the heat from the inside of transformer into the radiators and the surrounding environment. If geothermal heat pumps have been used as a cooling system for reducing the temperature of the oil in transformer, the electricity power loss and the production cost of transformer will reduced and the efficiency and the life span will increased. In this paper we have attempted to present computational achievements and theoretical research in this regard.

1. INTRODUCTION

Transformer is one of the most important power transmission equipment. This transformer is a device that transfers electrical energy through two or more windings and through electrical induction from one circuit to another. In places where their hot air temperatures are high in the hot months, and people use coolers that work with electricity to reduce the building temperature, power consumption increases, and the coils in the transformer through the flow of electricity It will be very hot. The temperature inside the transformer, and especially these coils, is taken up by the oil in the transformer and the coils are cooled thereby. f the coils and transformer oil do not decrease, the useful life of the transformer will be reduced and if the temperature of the transformer oil is reduced to 10 ° C, the transformer's useful life will double. According to technical standards, if the temperature of the transformer oil is reduced to 10 ° C, the increase in power transmission to the network will increase by 5%.

It should also be noted that if the oil temperature increases and does not decrease by transformer radiators, there will be an explosion or fire of the transformer. Transformers installed in hot areas in Iran use a air cool system that uses radiators and fans to lower oil temperatures, which has low efficiency. For this reason, when purchasing a transformer, it wills double its capacity, which will increase the initial investment.

If you use the geothermal heat pump and heat exchanger system, you can double the lifetime of the transformer by reducing the oil temperature and increasing the power transmission to the power consumption network.

2. TRANSFORMER OIL COOLING PROJECT BY GEOTHERMAL HEAT PUMP IN QESHM ISLAND

Qeshm Island is the largest Persian Gulf Island that is hot and humid in hot months for 6 to 7 months. People use high-energy air-conditioning systems to provide cooler environments. This has caused a lot of problems in the transmission network. One of the most important problems is to increase the temperature of the transformer oil in the power transmission network. For this purpose, the feasibility study of the use of a geothermal heat pump to reduce the temperature of the transformer oil in the power plant of Bsaeido in Qeshm Island (Figure 1) was defined.



Figure 1: Basaeido Substation in Qeshm Island

The regional power company of Hormozgan province was the employer of this project. Hormozgan University and Energy Gostaran Tajdidpazir Company were active as project researcher and consultant. The consultant and researcher of the project carried out studies and calculations on the heat transfer of transformer oil and the initial design of the geothermal heat pump system in a technical and economical manner. The capacity of the transformer in this project is 15KVA, which reduces the voltage level of 63 kV to 20 kV. A view of the transformer is shown in Fig. 2.



Figure 2: project Transformer in Basaeido Substation

3. PERFORM HEAT TRANSFER TRANSFORMER OIL CALCULATIONS

The three-dimensional schematic of the transducer body is shown in Fig 3. To carry out heat transfer calculations, the EES software has been used to model the heat transfer of different parts of the transformer. Based on heat transfer calculations, the heat of the transformer oil is transferred to the environment by the body, floor, ceiling and radiators .

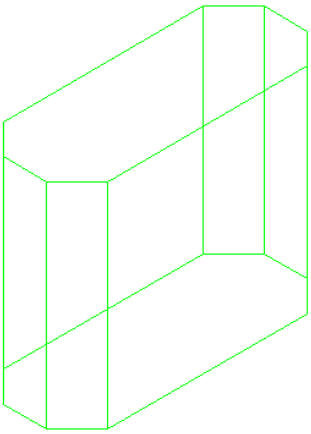

Figure 3: The three-dimensional schematic of the transducer body

Transformer roof is measured according to Fig. 4. Its area is about 3.63 square meters. Also the height of the transformer is two and a half meters. According to the calculations, the heat transfer of the transformer oil from the body of 8.81 kW, the heat transfer from the ceiling of 1.88 kW, the heat transfer of the first radiator of 144.84 kW and the heat transfer from the second radiator is 32.9 kW.

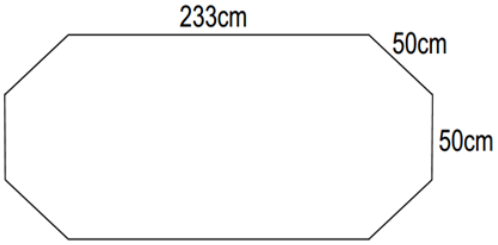

Figure 4: Transformer roof

The software model was implemented in environmental conditions with temperatures of 40, 45 and 50 degrees Celsius for the first and second radiators. Some of the results are presented as a graph in the report.

If the ambient temperature is 50 ° C, the cooling fluctuations of the ceiling are calculated, the results are plotted in figure 5.

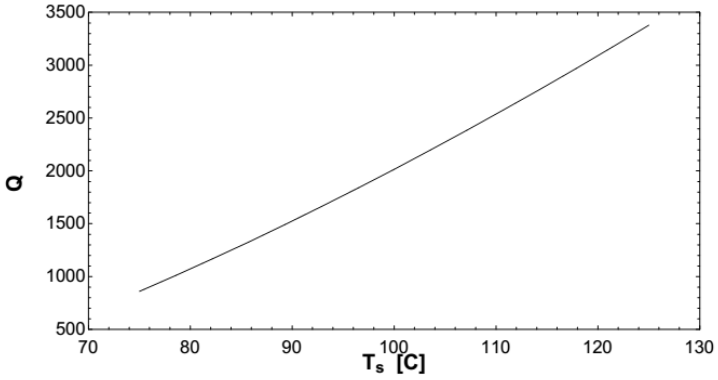

Figure 5: Cooling curve from roof based on ambient temperature 50

If the ambient temperature is 50 ° C, the cooling fluctuations of the 2th radiator are calculated, the results are plotted in figure 6.

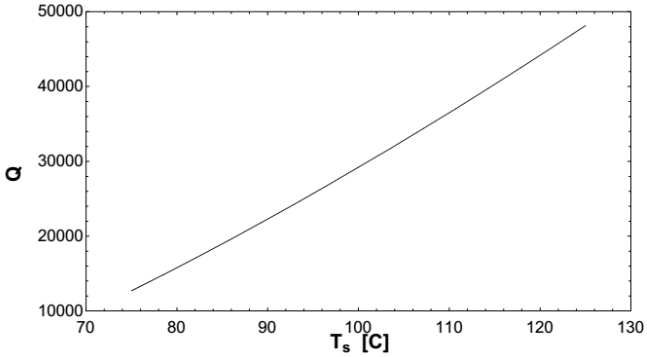

Figure 6: Cooling curve from 2th radiator based on ambient temperature 50

If the ambient temperature is 50 ° C, the cooling fluctuations of the transformer walls are calculated, the results are plotted in figure 7.

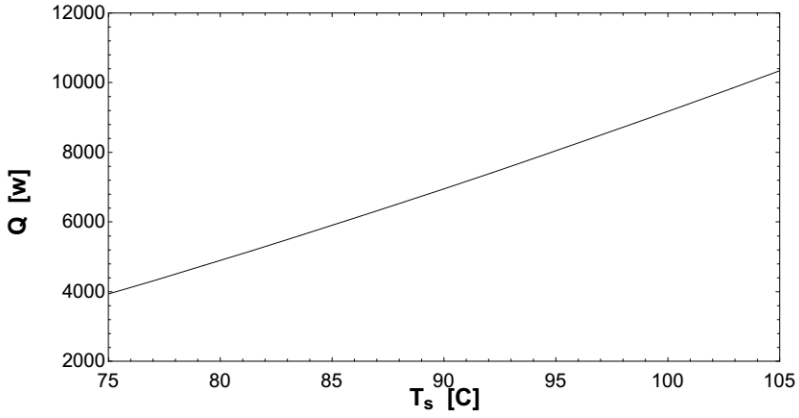

Figure 7: Cooling curve from transformer walls based on ambient temperature 50

Due to the inadequacy of cooling transformer oil with the above mentioned methods, the Transformer Utility Company applied to the installation of a water cooler along with the transformer. Due to the high humidity in hot weather, this cooling device is also not efficient, and practically this system will not reduce the oil temperature of the transformer. In Figure 8, an illustration of the water cooler is shown.



Figure 8: Water cooler image mounted next to the transformer

With all these methods, in order to reduce the temperature of the oil due to the high air temperature and high humidity, this heat transfer rate is not enough to reduce the temperature of the transformer oil and this insufficiency will increase the temperature of the oil during the hot days to more than 120 degrees Celsius, which should not be the same as the temperature of the oil according to the standards of operation of the transformer. For this purpose, the definition of a research project for the geothermal heat pump system was aimed at reducing the temperature of the transformer oil.

5. DESIGN OF GEOTHERMAL HEAT PUMP

Based on the calculations performed in accordance with the EES-based modeling, the capacity of the geothermal heat pump unit, which has the ability to reduce the oil temperature, is estimated to be around 630000 BTU/h. Accordingly, a geothermal heat pump unit with a capacity of 210,000 BTU/h was selected for the early start of the heat cycle and a geothermal heat pump unit with a capacity of 420000 BTU/h for warmer days. Of course, at the peak of the heat and when the temperature of the transformer oil reaches its maximum, both of these devices will be used to reduce the oil temperature.

For the ground coil, the system was selected to choose three coils in the form of vertical closed loop, horizontal close loop and open loop.

5-1- Ground coil vertical closed cycle

According to standards, the design of vertical close loop (Figure 9) was done as follows. In this case, 16 wells with a depth of 200 meters and a diameter of 10 inches are designed to be spaced 20 meters apart. In this case, 6500 meters of polyethylene pipe is considered in diameter of 2 inches. The cost of well drilling and pipe installation in this case was estimated at about $ 0.3 million. Due to the high costs of vertical drilling, the option of the vertical close loop was not economical.

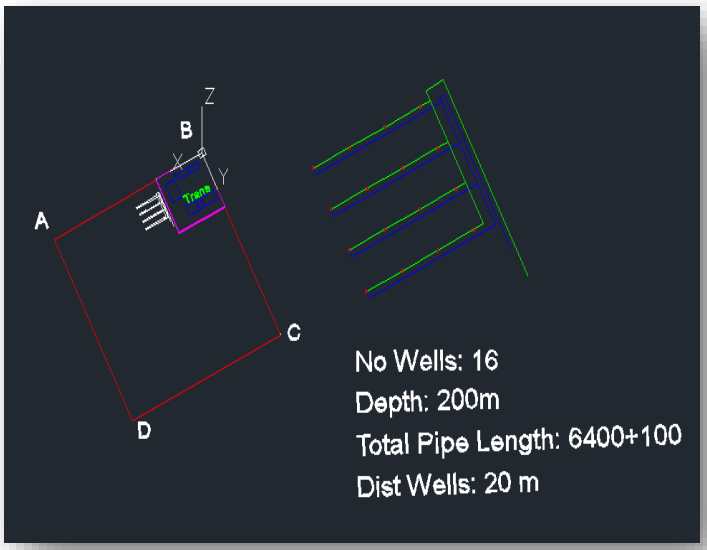

Figure 9: Vertical close loop

5-1- Ground coil horizontal closed cycle

In the design of the ground coil, the horizontal cycle was considered to be installed in a ground spiral coil pipe at a depth of 3 meters. For this purpose, a 1-inch diameter polyethylene tube was considered as a spiral with a diameter of one meter inside channels in width of two meters (Figure 10). In this case, for trenching and installing a polyethylene coil, a ground coil needs to be planted 460 meters long and 145 meters wide, so that the land available on the site does not have this area. Due to the large volume of excavation for the construction of the horizontal coil, this option causes extensive environmental changes in the area. As a result, choosing this type of ground coil for a geothermal heat pump system is not possible.

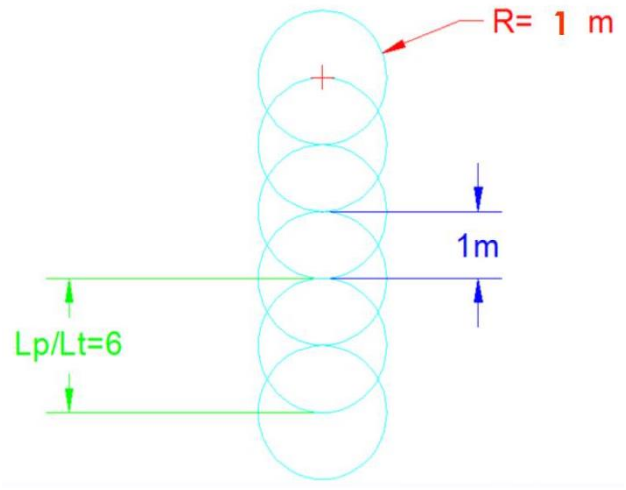

Figure 10: spiral ground coil

5-1- Ground coil open loop

In the design of the ground open loop, two wells with 30 meters depth with 2 meters diameter are intended to be used to allow the water flow rate of approximately 130 gallons per minute to be expected. Of course, these parameters can be changed during excavation of wells and injection of water into the ground depending on the amount of water mass flow from the wells.

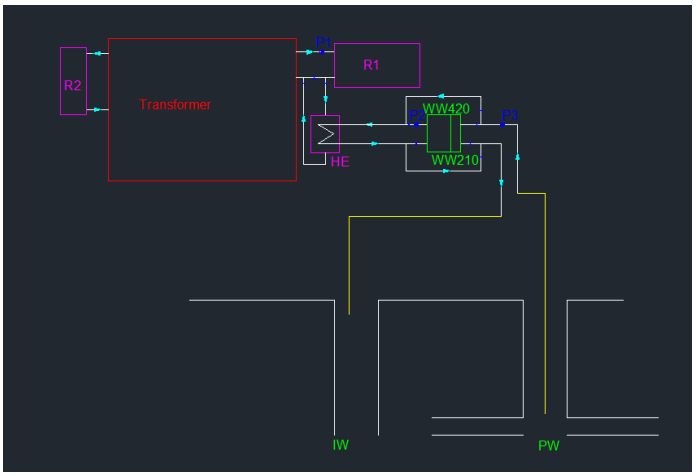

Figure 11: Schematic of open loop coil

As shown in Fig. 11, in the design of the pipelines, the water system is designed to transfer the sea water to a heat exchanger if the sea water temperature is low; it is not need to use the geothermal heat pumps. Of course, if the seawater temperature is not low, the heat pump's heat pump equipment is used in extreme heat conditions and it is required to provide heat exchanger for cold water supply. In this case, the system with supplying cold water for the heat exchanger can reduce the temperature of the transformer oil. In order to install a open loop ground cycle coil, it was necessary to provide credit for about $ 0.1 million.

6. Preliminary economic analysis of the project

According to studies carried out to provide a geothermal heat pump with a capacity of 210,000 BTU per hour, the cost of $ 30,000 and a device with a capacity of 420000 BTU per hour will require about $ 65,000 in capital. Of course, insurance and taxes will be around $ 100,000 .As a result, the whole project will cost about $ 300,000. Considering the lifetime of a transformer is considered to be about 15 years, the lifespan of the geothermal heat pump system includes an open-circuit ground coil and device for about 30 years, as well as the initial cost of purchasing a transformer at around $ 300,000 .It can be said that to increase the lifetime of the transformer more than twice as well as to increase the stability of the power transmission network and not shutdown, paying for the construction of a geothermal heat pump system for $ 300,000 is worth the cost.

7. Conclusion

Power transformers in the tropical regions of Iran are working because of high temperature and humidity in certain environmental conditions. Also, the radiators of the transformer are not able to reduce the temperature of the oil, and in hot days the temperature of the oil will increase sharply. This reduces the lifespan of the transformers and the power transmission network brings less electricity to consumers. For this purpose, a transformer with double capacity is ordered at the time of purchase of the transformer and in high temperature environment, the transformer has the functionality required of the network. If the geothermal heat pump system is used, in order to reduce the temperature of the transformer oil, it is possible to increase the lifetime of the transformer and increasing the network power. According to research, this is technically and economically feasible.

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