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PALM OIL AS THE COOLING LIQUID IN SINGLE PHASE TRANSFORMER FOR BETTER EFFICIENCY

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Keywords: High voltage, transformer oil, palm oil, insulation oil, vegetable oil

Abstract. The important purpose of mineral oil in transformer is to be insulant and it is role of being a coolant. Petroleum based oil is commonly used because it has a good dielectric strength and cooling performance. However, the application of mineral oil brings negative impact to the environment such as oil spills, leakage, explosion and soon petroleum based oil will be running out for future generation used. Thus, vegetable oil is chosen as an alternative to replace mineral oil for transformer insulation liquid. Formerly, most of Malaysian researches were focusing on the properties of the vegetable oils rather than investigate the effect on the transformer performances after the vegetable oils are applied. Hence, this paper focuses on the performance of the transformer before and after vegetable oils are applied. For this paper, refined palm oil is used as insulation liquid for a single-phase step down transformer which use the 220 V supply and 50 Hz frequency. Transformer is connected to 110V induction motor as load and has been test in two conditions, dry and after palm oil is applied. Comparison is made from both results and clearly shown a good improvement when palm oil is used as insulation oil.

Introduction

Practically, power transformer is one of the main parts of electrical network and power system equipment. It is crucially needed for a stable operation in power system. When a transformer works, normally it will generate plenty of heat. For a normal operating condition, temperature for transformer liquid insulation is around 80^{O}C [1]. Transformer oil acts a cooling mechanism to balance the heating of the transformer. The insulating oil loads up pore in fibrous insulation and also the spaces between the winding in the tank. Then, the heated oil it will flow to the radiator and slowly cooling down which automatically cools the transformer winding as well [2]. There are a few of characteristic of insulating oil which are low viscosity to provide rapid circulation inside the transformer, must be high heat transfer coefficient for the rapid cooling of hot spots inside transformer, low melting point to ensure the liquid is at low temperature, high electrical insulation performance and good thermal stability [3].

The normal transformer insulating oil is mineral oil. It meets all the requirements of insulating oil. Normally, petroleum based oil is used due to its great cooling performance, low dielectric losses, excellent dielectric strength and good long term performance [4]. Despite of all the advantages of petroleum based mineral oil, it gives a very bad impact on the environment because it is non-biodegradable type. When a spill happens because of the equipment failure, it could contaminate the soil and water streams. While if there is a leakage of transformer, an explosion might happen as well and automatically it will affect the nature. Apart from these environmental concerns, we must acknowledge that mineral oil is a non-renewable energy which means in the future there will be no more petroleum based mineral oil and we have been using it for centuries [5]. In 10 or 20 years time, it might be run out. Due to all of these issues, vegetable oil has chosen to be an alternative transformer insulation liquid.

Table 1: Variation of fatty acid and fat content in palm oil [8]

Type of Fatty Acid	Type of Fat	Percentage
Lauric Acid	Saturated	48.2%
Myristic Acid	Saturated	16.2%
Palmitic Acid	Saturated	8.4%
Capric Acid	Saturated	3.4%
Caprylic Acid	Saturated	3.3%
Stearic Acid	Saturated	2.5%
Oleic Acid	Mono unsaturated	15.3%
Linoleic Acid	Poly unsaturated	2.3%
Other Acids	Poly unsaturated	0.4%

Palm oil has an excellent green character and most importantly it is biodegradable. It can simply resolved by microorganism and it has low toxicity to the fish [6]. The reason of choosing palm oil to investigate is because it can easily be obtained all over Malaysia since Malaysia is one of the world biggest producers and exporters of palm oil and palm oil products [7]. Palm oil is mainly used for edible and industry purposes and consists of high saturated fat such as Lauric acid (48%), Myristic acid (8.4%) and Palmitic acid (8.4%). It also has polyunsaturated acid like Linoleic acid (2.3%) [8].

Palm oil can be procured from its flesh or also known as mesocarp layer. Then it will undergo bleaching and deodorizing process and called as Refined Bleaching Deodorized Palm Oil (RBDPO). By undergoing this procedure, the fat content of the palm oil will be decreasing. Fat content of each oil is important to be known because different fat content will result in different dielectric properties of the oil [4]. In other word, the palm oil quality is depending on the fat content the oil.Table 1 presents the variation of fatty acid and fat content in palm oil.

Experiment

Figure 1 Single-phase step down transformer

In this project, refined cooking oil is used as the insulating oil in transformer. It is based from pure palm olein. Palm olein means the oil does not contain Trans Fatty Acid and the proportion of saturated and unsaturated fatty acids are equal [9]. Then, a single-phase step down transformer has been designed for this project as shown in Figure 1. It was designed and manufactured in 2014. It converts high-voltage, low-current power into low-voltage, high-current power. This single-phase transformer can deal up to 7A current input and use 220 V supply and 50 Hz frequency.

During experiment, this transformer is connected to 110 V induction motor as the load and as shown in Figure 2 for the schematic drawing. This experiment consist two (2) conditions of running the transformer to see its performance, condition 1 is when the transformer is operating without any insulation oil (dry condition) and condition 2 is when the transformer isoperating using the palm oil. Transformer is operated for 120 minutes and each 5 minutes power and temperature are measured.

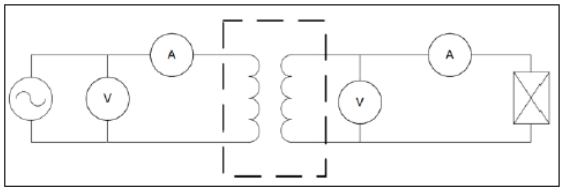


Figure 2 The schematic drawing of single-phase step down transformer together with motor or load

Result

A. Temperature

Figure 3 shows temperature vs time graph for transformer before and after palm oil is applied. During the first condition when transformer is operated without insulation oil (dry), at 120 minutes transformer temperature is at 45.1^{O}C and after transformer is applied with palm oil at 120 minutes temperature showed is only 34.5^{O}C. It can be said that the application of palm oil in transformer has made the temperature decreases for about 76.5%.

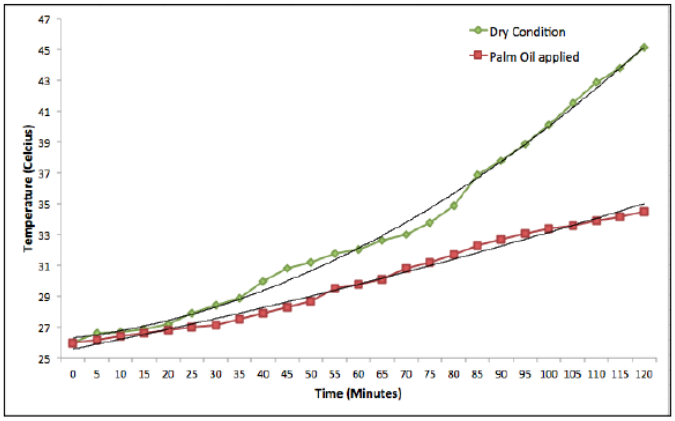


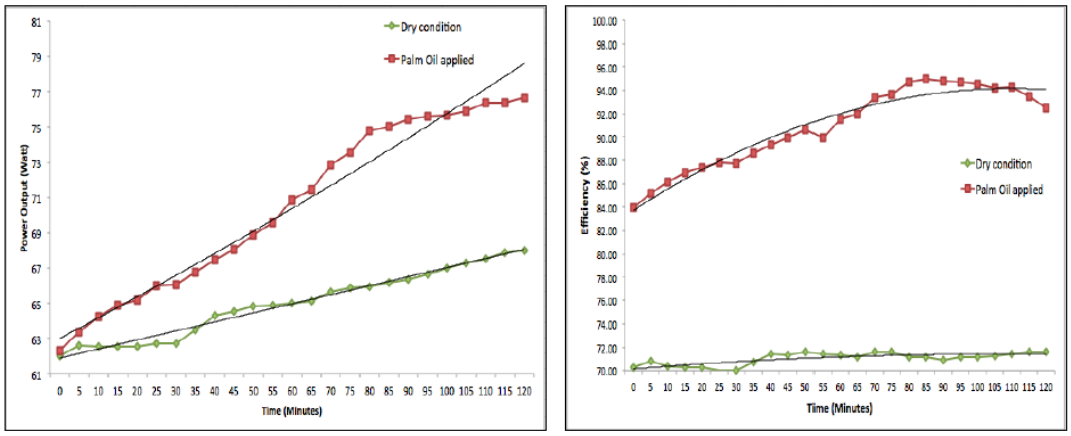
Figure 3 Temperature vs time graph

Based on figure 3, during condition 1, the accretion of the graph is imbalance. From 0 to 60 minutes, the graph slope is 0.108 while from 65 to 120 minutes the slope is 0.239. Therefore, it can be said that when transformer starts to operate, a small rise of temperature is happening however, the longer it is operating without any cooling liquid, its temperature easily get higher. To compare

with condition 2, after palm oil is applied, the accretion of the graph is more balance because the temperature rise is steadier with average 0.078 of its graph slope.

B. Power Output

Figure 4a presents the result of power output vs time graph of transformer. The power output for transformer when it was operated without insulating oil (dry condition) is quite low compared to power output when transformer operated with palm oil as insulating oil. Power output obtained at 120 minutes during condition 1 is only 68.01W meanwhile during condition 2, power output of transformer has increased to 76.65W. The increment per 5 minutes of power output during condition 1 is a bit slow compared to increment per 5 minutes of power output after application of palm oil as insulating oil, the graph shows it steadily increases.



(a) (b)

Figure 4(a) Power outputvs time graph (b) efficiency of transformer performance

In figure 4b also shows the efficiency of transformer performance. Efficiency is counted using efficiency formula, $\eta = \frac{Pout}{Pin} \times 100\%$. The efficiency for transformer during dry condition is very low, the highest efficiency obtained is at 75 minutes and 120 minutes which 71.62% and the lowest efficiency 70.0% at 25 minutes. Meanwhile, during application of palm oil, at 85 minutes the efficiency of transformer reached 94.94%.

Referring to efficiency formula, when power output is increased, efficiency will be increased too. That is why efficiency in condition in 2 is higher than condition 1 (referring to figure 4a and figure 4b). Based from equation $Ploss = K\frac{dT}{dt}$, K is constant, dT is temperature and dt is time (minute), constant K here is 1. Ploss is obtained using Ploss = Pin – Pout formula. Therefore, losses are affected by temperature; when temperature gets higher, losses will be higher too and when losses is high, power output will be low. This explains figure 3 and figure 4a when transformer is operated in dry condition, the temperature is high but power output is very low. While after application of palm oil, the temperature is low and it makes losses is reduced in the transformer and subsequently the power output obtained is high.

Conclusion

It can be conclude that when palm oil is applied as insulating oil in transformer a better power output is obtained and palm oil is can also be used as cooling mechanism in transformer because based from the results obtained comparing two conditions of transformer, one is operated in dry

condition and one is operated with application of palm oil. After transformer is applied with palm oil, the highest temperature stated is only 34.5^{O}C compared to dry condition, the highest temperature is at 45.1^{O}C. During transformer is operating in condition 2, the heat caused by transformer is dissipated through the palm oil, hence a 76% of decrement is obtained after palm oil is applied.Based on the efficiency result of transformer after palm oil is applied, it has proven that palm oil has improved the performance single phase transformer when the efficiency is at 94.94% compared to efficiency of transformer in dry condition is only 71.62%.It has also proven that palm oil can be used as cooling liquid in transformer, however further experiments must be made to ensure the properties of palm oil can be used as insulator in transformer too.

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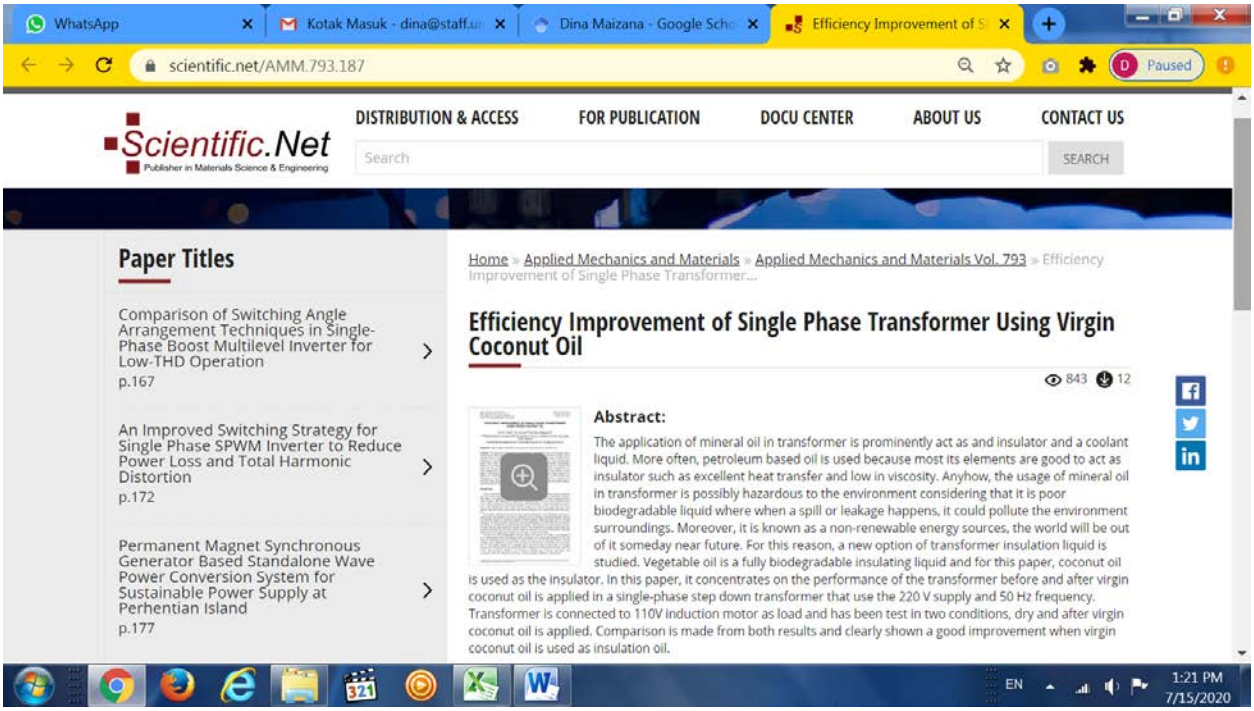

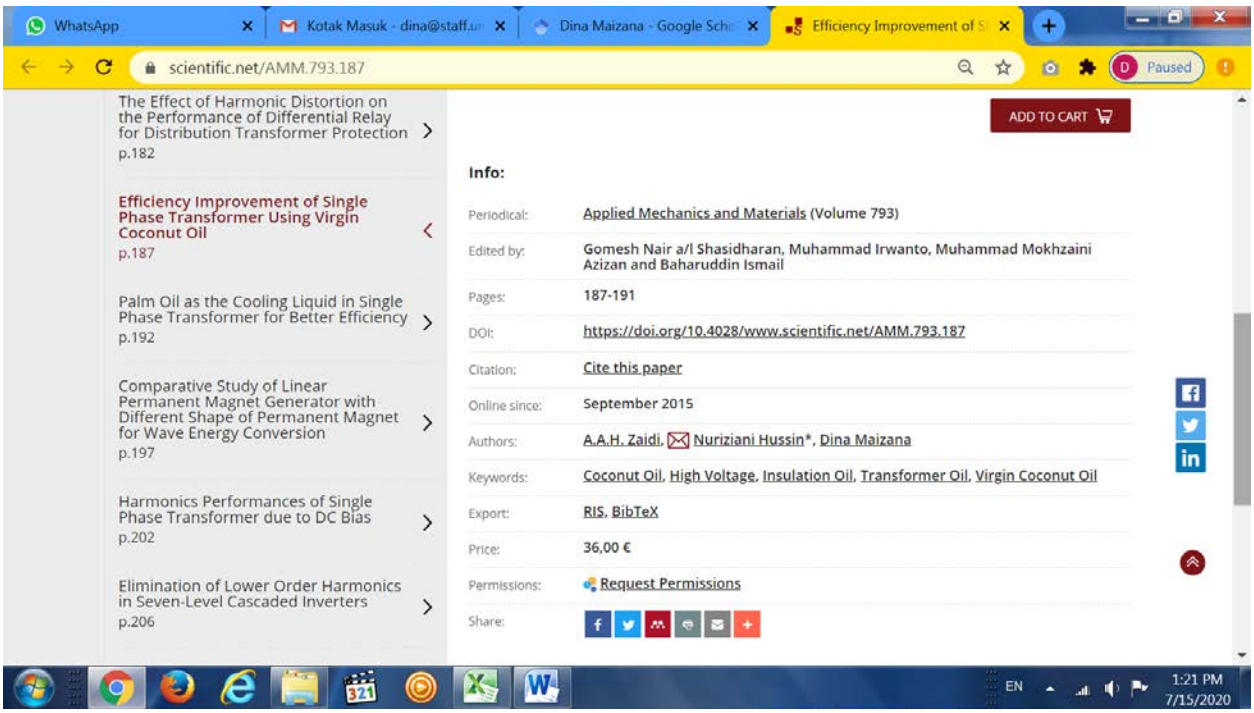

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EFFICIENCY IMPROVEMENT OF SINGLE PHASE TRANSFORMER USING VIRGIN COCONUT OIL

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Keywords: High voltage, transformer oil, coconut oil, virgin coconut oil, insulation oil

Abstract. The application of mineral oil in transformer is prominently act as and insulator and a coolant liquid. More often, petroleum based oil is used because most its elements are good to act as insulator such as excellent heat transfer and low in viscosity. Anyhow, the usage of mineral oil in transformer is possibly hazardous to the environment considering that it is poor biodegradable liquid where when a spill or leakage happens, it could pollute the environment surroundings. Moreover, it is known as a non-renewable energy sources, the world will be out of it someday near future. For this reason, a new option of transformer insulation liquid is studied. Vegetable oil is a fully biodegradable insulating liquid and for this paper, coconut oil is used as the insulator. In this paper, it concentrates on the performance of the transformer before and after virgin coconut oil is applied in a single-phase step down transformer that use the 220 V supply and 50 Hz frequency. Transformer is connected to 110V induction motor as load and has been test in two conditions, dry and after virgin coconut oil is applied. Comparison is made from both results and clearly shown a good improvement when virgin coconut oil is used as insulation oil.

Introduction

Power transformer is an essential component in electrical network and power system equipment and most of the transformers depend on liquid insulation oil. It is because transformer generates heat while it is operating. Transformer needs to operate continuously in order to maintain power system stability and reliability [1]. Transformer insulating liquid not only works insulant but also acts a cooling mechanism to balance the heating of the transformer. A good insulating oil needs to have a few requirements such as high electric strength, low viscosity, low pour point, low water content, high flash point, good electric and thermal properties, low flammability and many more [2].

For decades, petroleum based oil has been used in transformer as its insulating oil because it characteristic and properties are good as insulation such as excellent cooling performance and has low dielectric losses [3]. However, mineral oil will eventually finish and there will be a serious shortage in the future. Besides, mineral oil is poorly biodegradable. It could pollute the environment by leakage of a transformer, explosions and also spillage. Not only the soil would turn into toxicity, if it goes into the water streams all creatures inside it will eventually die because oxygen cannot get through oil spillage onto the water streams. Hence, an alternative sources for transformer insulating liquid needs to be prepared and studied. For this paper, coconut oil is chosen.

Coconut oil is fully biodegradable and have almost low toxicity. So if there is any spillage of oil, it will practically have zero impact to the environment. It is a quite good insulator too [4]. The reason of choosing coconut oil is because coconut tree and its oil can be easily found in tropical countries such as Malaysia. In below 30°C coconut oil it will turn into a solid form and it can melts at 25°C. the normal coconut oil is colorless and it will be in white in solid form. It is largely composed of saturated fatty acids which about 94% including 62% of medium chain fatty acids like Lauric acid ($C_{12}H_{20}O_2$), Myristic acid ($C_{14}H_{28}O_2$), Caprylic acid ($C_8H_{16}O_2$) and Capric acid ($C_{10}H_{20}O_2$) [5][6]. The CH bonds here shows a strong resistance breaking in saturated fats.

Virgin coconut oil has medium-chain fatty acids and it is extracted the meat of mature coconuts. Virgin coconut oil is obtained by mechanical or natural which means without any application of heat process [7]. This method also makes the oil is pure and has no alteration of the oil.

Experiment

In this project, a virgin coconut oil is used as the insulating oil in transformer. A single-phase step down transformer has been designed for this project as shown in Figure 1. It was designed and manufactured in 2014. It converts high-voltage, low-current power into low-voltage, high-current power. This single-phase transformer can deal up to 7A current input and use 220 V supply and 50 Hz frequency.

Figure 1 Single-phase step down transformer

During experiment, this transformer is connected to 110 V induction motor as the load and as shown in Figure 2 for the schematic drawing. This experiment consist two (2) conditions of running the transformer to see its performance, condition 1 is when the transformer is running without any insulation oil (dry condition) and condition 2 is when the transformer is running in the presence of palm oil.

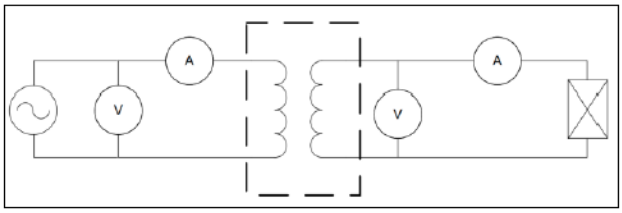


Figure 2 The schematic drawing of single-phase step down transformer together with load

Temperature of the transformer were also taken to ensure the transformer investigation instrument is in good condition and to see either virgin coconut oil can be used as the transformer cooling liquid or not. Transformer is operated for 120 minutes and each 5 minutes power and temperature are measured.

Result

A. Temperature

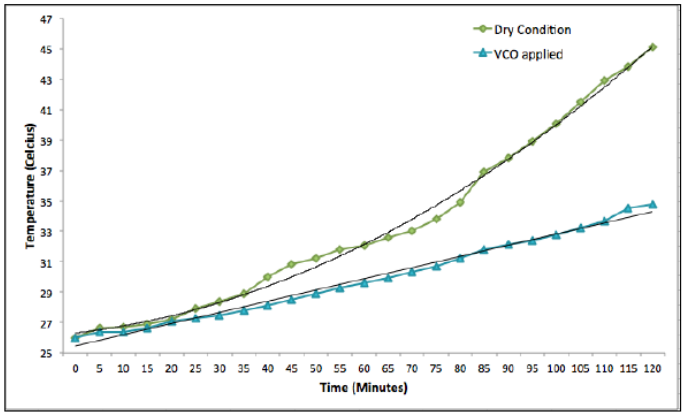


Figure 3 Temperature vs time graph

In figure 3, it presents the temperature vs time graph for transformer before and after virgin coconut oil is applied. When transformer is operated in dry condition,temperature of the transformer has reached up to 45.1^{O}C compared to temperature of transformer when virgin coconut oil is applied, where the highest temperature obtained is 34.8 ^{O}C. A 77.2% decrement of transformer temperature happened when it is applied with virgin coconut oil.

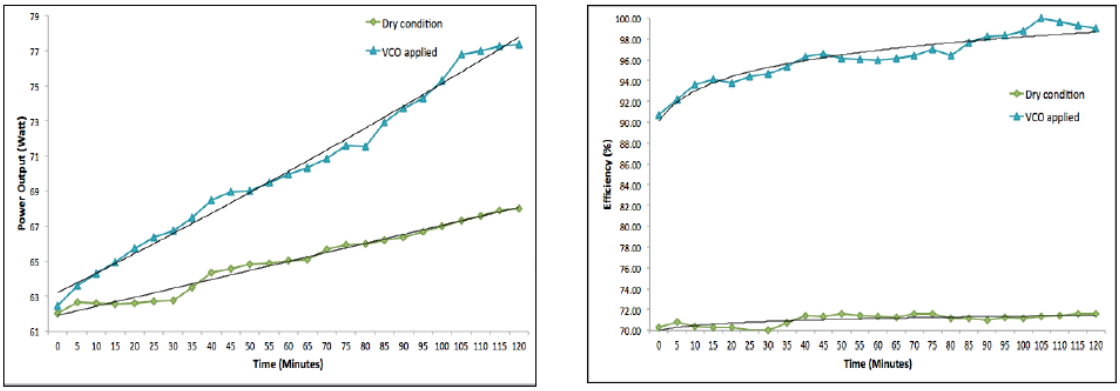
From the graph, when transformer is operated in dry condition, it can be seen that the graph is slightly unstable. From 0 minute to 60 minutes, the slope for it is 0.108 and start from 65minutes till 120 minutes, 0.239. Both slopes are not equivalent and it can be said that from 0 to 60 minutes, temperature increment is slower than temperature increment for 65 minutes to 120 minutes. Meanwhile, during application of virgin coconut oil into transformer, temperature increment is more stable because the slope of the graph is the same, which is 0.073.

B. Power Output

Figure 4a shows power output vs time graph for transformer in dry and after application virgin coconut oil. From the graph, when virgin coconut oil is applied, the power out is gradually increased from 0 minute to 120 minutes. When transformer is stop operating at 120 minutes, its power output is 77.8W compared to dry condition transformer, it only obtained 68.01W.

When transformer is operating, heat will occur and temperature will get higher but when virgin coconut oil is applied, it has reacted as medium to cool down the heat and simultaneously make losses reduced. Therefore, higher power output obtained after the oil is applied. According to $Ploss = K\frac{dT}{dt}$ formula, K is being constant while dT is temperature and dt is time (minute); K is counted and using Ploss = Pin – Pout formula and K is equal to 10.52. Hence, when losses is increased, temperature will increase too but there will be a reduce in power output, as seen in figure 4a.

In the meantime, figure 4b shows the efficiency of transformer performance. Efficiency is counted using efficiency formula, $\eta = \frac{Pout}{Pin} \times 100\%$. When virgin coconut oil is applied, efficiency of transformer has increased drastically compared to dry condition transformer operated. The highest efficiency obtained during dry condition is only 71.62% while efficiency obtained in application of virgin coconut oil after 120 minutes is 99.07%.



(a) (b)

Figure 4 (a) Power output vs time graph (b) efficiency of transformer performance

Conclusion

From the experiments, it can be observed that virgin coconut oil can be used as cooling mechanism for transformer because there was 77.2% decrement of temperature after it is applied in transformer. When temperature is lower, losses is reducing too which makes a higher power output will be obtained.

As for power output, it has shown a better improvement when it obtained 87.4% more after the application of the oil in transformer. The efficiency oftransformer performance is also better after the application of virgin coconut oil. Before application of virgin coconut oil, it is only 71.62% of efficiency obtained from the transformer but after the application the efficiency has reached up till 99.99%. Virgin coconut oil has proven that its application has improved the efficiency of the transformer. However, it is only tested in terms of cooling liquid, more experiments will be done in the future on its properties to suit it as insulation liquid in transformer.

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