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Original Research Article

On power transformers energy efficiency based load transfer analysis

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ABSTRACT

Transformers have an important role from the production of electricity energy to consumption. Because they are responsible for ensuring that power transfer is carried out appropriately in many stages. Therefore, power transformers work in many places, from the production phase of electricity to the transmission and distribution phases. If various time periods are taken into consideration for energy using, power transformers can operate at small powers or very small powers. This small-power operation, which can be defined even as minor quantity, is counter-productive as a proportional increase in energy loss. The small working power, because of this loss ratio, is not taken into consideration; but considering large number of power transformers in annual periods, it can cause the serious losses and the costs emerge. In this paper, we propose a dual transformer control model in which apparent time periods with little load are determined by software, and in those periods, the load is fed by power transformers of smaller power or fewer. In this model, we worked for reducing the amount of power loss and energy costs during periods. Reduced load is demonstrated in following parts by statistical results.

Keywords: Power transformers, Load transfer, Energy Efficiency

1. Introduction

In recent years, there are various works on energy efficiency of transformers [1-5]. The subscribers who draw electricity from the grid circuit show changes in their energy usages at various times of the day, weeks, months and years. Public institutions and industrial facilities that do not work at night and on weekends, so the difference in electricity consumption can occur and approach the whole of the power demand. This large change in the power demand leads to different loads of distribution transformers between idle and full loaded operations.

For low-voltage subscriptions, this change has no negative effect. The electricity operations or high voltage subscribers that need to be compatible with this change, assumes the loss caused by the change in the demand for power. In addition to the inefficiency of low-power operation in idle, it is necessary to meet the peak power demands that may occur in some time periods. In other words, the surplus loss incurred by not operating the transformer responsibility in its own power plant without the low power ratio in the empty space will be reflected as a negative effect on the electricity cost of this plant.

In this study, a prototype application is implemented in order to reduce the transformer operation with low or idle power ratio. In this operation, it is aimed to comply with the requested power ratio using more than one transformer. The control layer used for this purpose ensures that the transformer or transformers are switched on or not, without any energy interruption. Thus, the extra electrical energy efficiency is aimed with a control flow that verifies the

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transformer or transformers can provide the required appropriate power when they are in operation.

2. Operating Characteristic of Transformers

All machines that perform energy transfer in transformers don't project all incoming energy to the output, because some of energy appears as loss. The losses in the transformers occur as hysteresis and eddy losses on the core magnetic flux and copper losses on the winding resistances. Because, magnetic-based hysteresis and eddy losses have little relation with the load current, they are usually handled in idle motion power. On the other hand, since copper losses arise from the load current, it is considered in the loaded work power. In these expressions, magnetic losses can be defined as constant losses, and copper losses (1) can be defined as variable losses due to the load current.

$$P_{cu} = I_e^2 \text{ x } R_{e_T} \quad (1)$$

Despite the fact that the loss power increases, operating a transformer on the tag power will reach its maximum efficiency. But in order for this to happen, it is necessary to have a claim to draw this power from the transformer. If power is used unnecessarily from the transformer without power demand, it will be a useless loss of power [6], [7], [9]. When the power is not pulled, the fluctuating losses based current of transformers disappear, however the magnetic power losses keep constant and never change. This leads to inefficiency by increasing the loss ratio, especially in the case of large power transformers that operated in small loads at no load. On the other hand, if the transformer is operated with suitable size for the power demand, the efficiency will also increase because the transformer works close to the tag power. Even if there is an increase in energy efficiency of the transformer with the use of power and energy without any need, the energy efficiency evaluated at the higher stages will be adversely affected [8], [10-12], [14-17].

3. Energy Efficiency Based Dual Transformer Usage

Transformers can be performed as two-stage feeds for high-voltage subscribers who do not work at night and on weekends. The actual power demand is reduced, although it is not possible to ensure maximum efficiency to work close to tag power due to the large variability in load demands. Fig.1 shows high power consumption and two transformer power flows control scheme. Here, TR1 and TR2 can be switched on and off depending on the feedback information obtained from the load.

Transformers TR1 and TR2 should not have any power interruption during their operation. For this purpose, short-term or parallel operation is the subject of the phases of entering and leaving the circuit. Continuous parallel operation is not considered suitable for this operation because of the risk of achieving a minimum power requirement of 1/3 between transformers, which is required by parallel operating conditions.

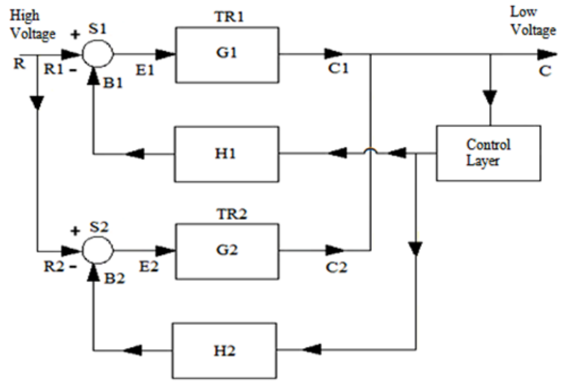

Figure 1. Energy efficiency based dual transformer control

$$TF1 = \frac{C}{R} \quad (2)$$

$$TF2 = \frac{G1}{1+G1H1} + \frac{G2}{1+G2H2} \quad (3)$$

$$TF3 = \frac{G1+G1G2H2}{1+G1H1+G2H2+G1G2H1H2} \quad (4)$$

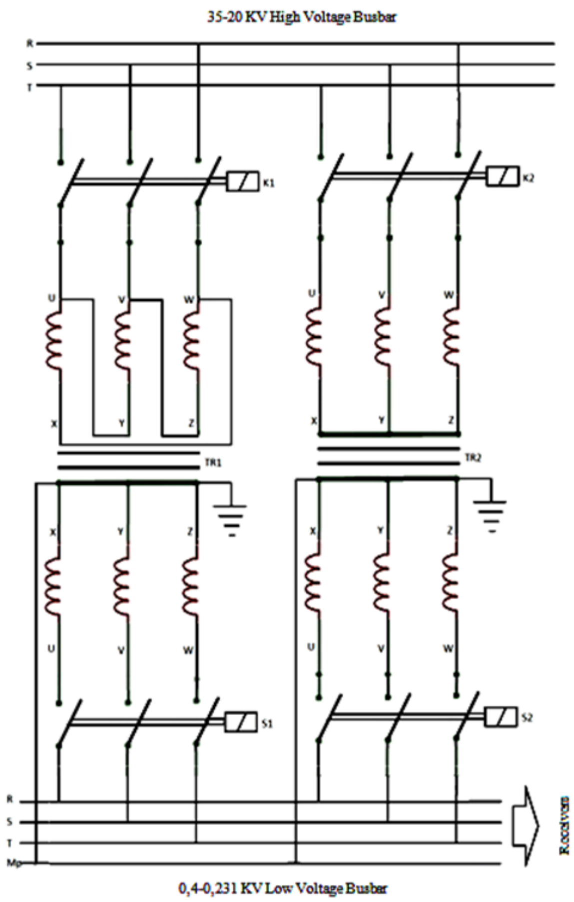

Figure 2. Parallel load transfer of transformers

4. The Effect of Dual Transformer Usage on Energy Efficiency

In Fig. 4, for a load transformer of 500-2000 kVA, a graph of general $\eta = f\ (\%Sy)$ change is given. When looking at the graph, it turns out that if you have a load ratio of 40% or lower for power transformers, there is a drop-in efficiency that must be considered.

When a graph for a 2000 KVA transformer is examined, a loss of 40 KVA is generated when the operation is considered with a yield of 98% at 1/1 power ratio. Considering that it operates at 1/4 power ratio, that is, with an efficiency of 86% for 500 KVA, a loss power of 70 KVA arises. If these power values given in terms of apparent power are considered to have a power coefficient of at least 0.8, they will be reflected as an active loss of a minimum of 80%.

It is recommended to proposed work with a smaller transformer power transfer when a power ratio of 1/4 or less is required. If this power transmission is made with a transformer of 500 KVA operating at 95% efficiency, the loss power at 70 KVA above can be reduced to 25 KVA. If the power coefficient is considered to be at least 0.8, the lost power of 56 KW will be reduced to 20 KW and a loss of 36 KW will be achieved.

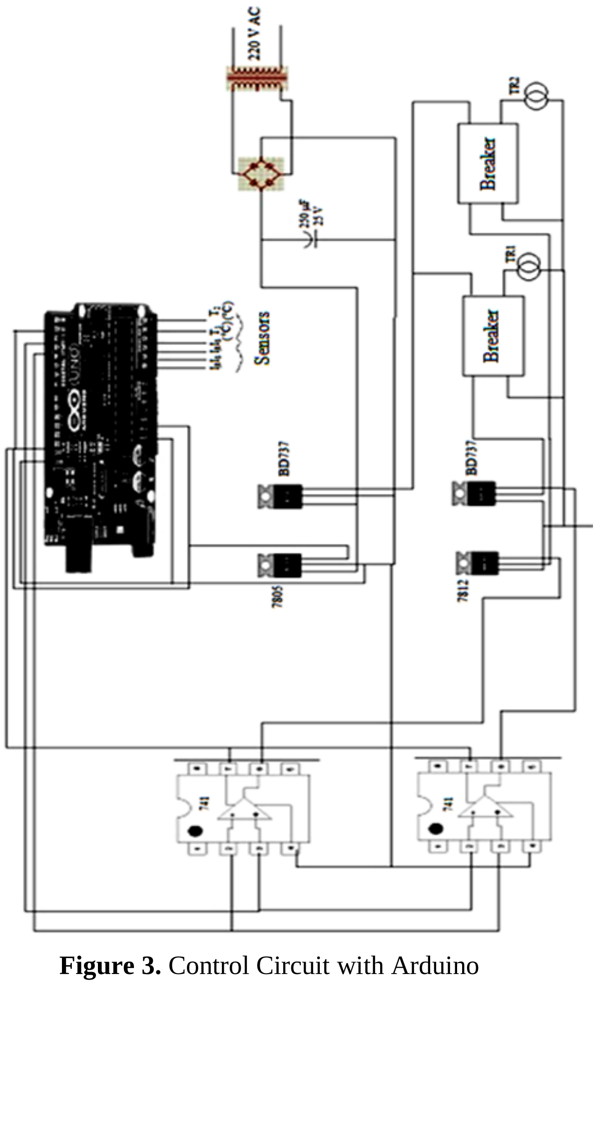

Figure 3. Control Circuit with Arduino

For a workplace that does not work during the weekend or at nights, working is much lower than the 25% power ratio. The monthly passive hour total is 500 for an institution that has 2000 KVA transformer. Monthly, 22 days x 10 hours active, 22 days x 14 hours + 8 days x 24 hours passive. Based on 1/4 power ratio for passive time zones, energy savings of 36 x 500 = 18000 KWH per month and 216000 KWH per year may be the case.

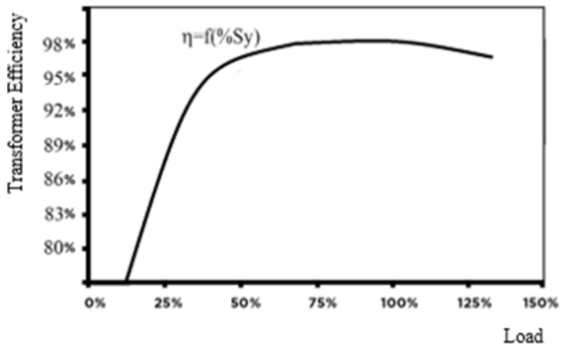

Figure 4. The change of 500-2000 KVA load transformer for η=f(%Sy)

5. Conclusion

The efficiency of power transformers, which are used in many places, from the production stage to the transmission and distribution phases of electric energy, affecting energy efficiency significantly. When different periodic time periods are considered, for different establishments and institutions, it can be seen that while the transformers are operating at small power ratios, the loss ratios increase significantly.

Here, a model which has two transformers is proposed to reduce this loss ratio. When different periodical time periods are taken into consideration for different establishments and institutions, while transformers are working at small power ratios, it can be seen that the loss ratios may increase at important values. Hereby in the event of low power ratio, it is seen that significant power and energy savings can be provided at monthly and annual periods by the transformer usage at low power ratio values.

As an application, the power transmission between two different power transformers and parallel operating conditions are modelled in a control flow diagram, controlled by ardunio processor and power control layers. Besides, the system is modeled as a prototype for the use in real power transformers.

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