Research Article

Increasing Efficiency by Applying a New Generation Dual-Core Transformer Design

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Abstract

In this study, in order to reduce the core losses of power transformers, the case of using two cores that can be activated according to the need instead of a single core is discussed. As it is known, in power transformers, the tolerance of core losses in the case of drawing the nominal power from the secondary depends on the materials used. In particular, the flux loss of the soft, siliceous sheet forming the core is tried to be improved by the manufacturing companies. However, if a small amount of the nominal power is drawn from this transformer while using a single core, core losses can be even greater than the power drawn. In the project of this study, a transformer with two different cores will be produced by dividing the core that will provide the total nominal power while manufacturing the transformer instead of a single core. Theoretical studies and simulation results show that this is possible. In the scientific literature, this situation is examined as a parallel study. It is known that transformers that show high variability in the amount of loading throughout the year in the national grid operate at a low occupancy rate. Instead of the single active core, the increase in the occupancy rate will make the second core active and meet the demand *by working in parallel with the cores, which will contribute to the country's economy. Here, the switching on and off of the two cores placed in the same tank will be adapted considering the operating range of the cores with the highest efficiency by selecting the true direction of windings. Transformer prototypes to be produced within the scope of the new generation dual-core transformer project will be selected from among transformers with unbalanced load profiles in YEDAŞ responsibility areas, and transformers with a power of 2x50 kVA will be installed to be applied in pilot areas.*

Keywords: Transformer, Losses, Efficiency, Occupancy, Double secondary

1. Introduction

As a new domestic production, dual-core transformer that will be produced for the first time in our country, the transformers used in the distribution networks will be operated at optimum technical loss, and the core losses will be greatly reduced with the double-core structure in a single tank. As it is known, transformers installed in rural regions, in areas that have just been opened for development and in areas where settlement has not been completed yet, and in areas where summer cottages are dense or where tourism is high, operate at low occupancy rates for 9-10 months of the year, and reach high occupancy rates in the remaining months. This situation causes the transformers to work at low occupancy rate for a long time, but cannot be replaced with small power transformers due to the increasing demand at certain times of the year. With the new design, when the transformer operates at low occupancy rate, only one core will operate and the idle running losses (iron losses in the core) will be reduced.

In addition to the situations mentioned above, new generation dual-core transformer design will play a major role in increasing energy efficiency and gaining operating costs by optimizing the losses in the unbalanced load profile that will be created by distributed power generation facilities and electric vehicle charging stations, which are likely to become widespread in the near future.

An efficient 3D FEM model of power transformers for the leakage field and short-circuit impedance evaluation, suitable for design office use, has been developed and applied in the transformer manufacturing industry [1]. The method is very cost effective, as high accuracy is obtained for low mesh densities, requiring little computational time. This ability, along with the development of an automated, user-oriented, transformer short-circuit impedance calculation program based on the FEM model overcome the main deficiencies of the method and enable its use during the preliminary design process.

2. Material and Methods

The steps to be followed in dual core transformer design and field application are given below.

1. Determination of electrical parameters by magnetic field analysis

2. Bushing and control system design
3. Prototype production
4. Performing standard and type tests
5. Application

Detailed analyzes were made for each transformer power in line with the manufacturer's loss data of the transformers. In the analyzes, well-known loss equations were used in all rate of transformer powers, the curves of these equations were extracted and the analyzes were made [2], [3]. The efficiency curve of the transformers analyzed is shown in Fig. 1.

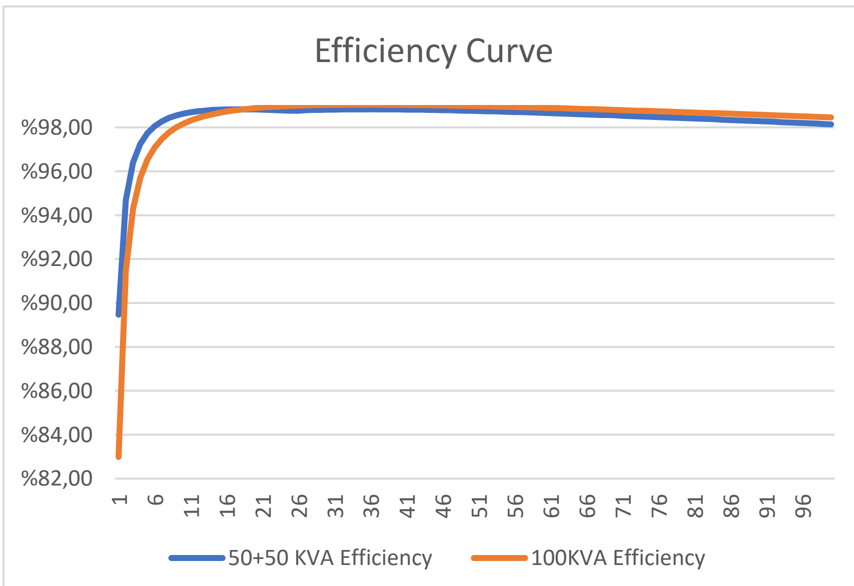
1. 

Figure 1 Efficiency graph according to transformer powers and loads. Theoretically, an increase in efficiency can be achieved with gradual switching on/off in meeting a load

In technical loss analysis, it was determined that the occupancy rate of the dual-core transformer, which operates with a single active core, started to decrease with the increase in the load, and a new generation control/distribution box was designed to automatically switch on and off the second core in order to increase efficiency. A distribution box controls the switch in the top of the designed 50+50 kVA dual-core transformer, enabling the individual cores to work in single or parallel. This specific switch is shown in Fig. 2.

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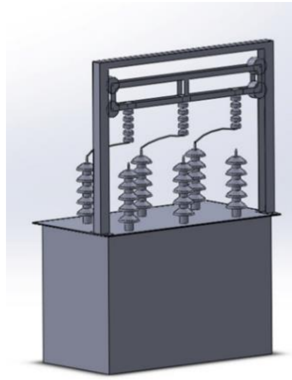


Figure 2 Specially designed switch located in the ceiling part of the transformer. A sliding mechanism will ensure that the transformer core can be changed under load. Thus, there will be no power interruption while changing the core.

While the single core of the transformer is working actively at low load, the Low Voltage (LV) distribution box, which detects the increase in the load, controls the switch and provides parallel connection of the two cores. The LV output of the core number two, which is connected to the first core in parallel, is kept in closed position from the box that will not draw energy during the connection. This novel control box, which detects that the bushings are connected in parallel, opens the contactor to which the LV output of the core number two is connected, and the loads are shared equally from the common busbar in the panel where the AG outputs of both cores are connected.

3D model with cores, tank, and steel parts whose size and distance analyzes were completed by performing laboratory tests (couple thermal tests, eddy loss tests, magnetic field analyzes, etc.). Considering electrical and mechanical connection and placements are as shown in Figs 2, 3, and 4.

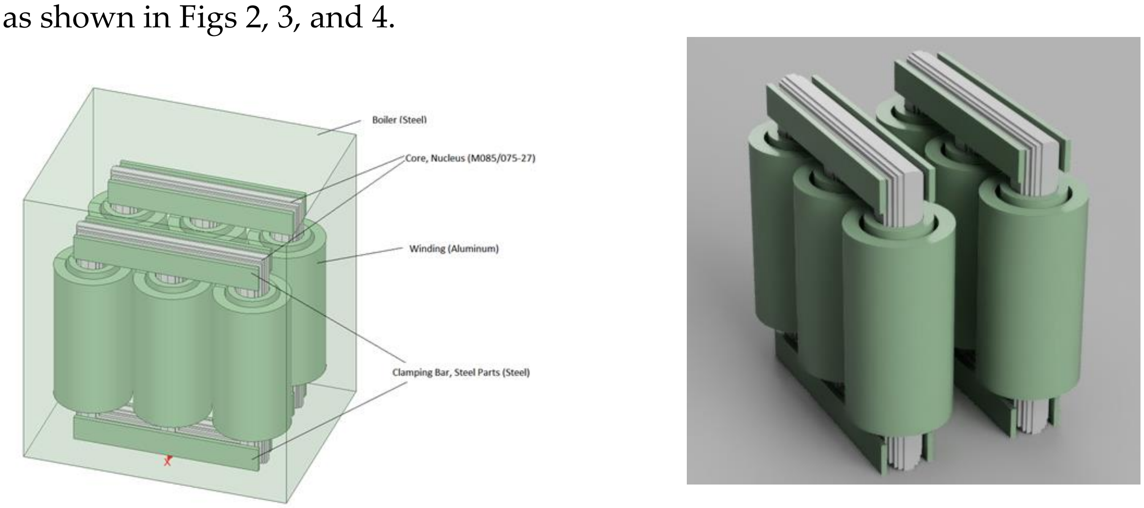


Figure 2 3D model with tank, steel parts and active part. The use of two cores in the same tank creates an electromagnetic design challenge rather than a volumetric and mechanical difficulty

In the analysis made after the model was prepared, the magnetic effects of both active core on each other in the tank were observed. It is inevitable that the transformer, which is under high magnetism, will overheat and have a negative effect on loss optimization. For this reason, the effects of transformer winding directions on magnetism were investigated. Flux distributions were observed in cases where both transformers are loaded and winding directions are the same, active winding directions of both transformers are opposite and only one transformer is loaded. In Table 1, the current and voltage values of each step are given for the single active part with 50 kVA power.

Table 1 HV winding information at different stages

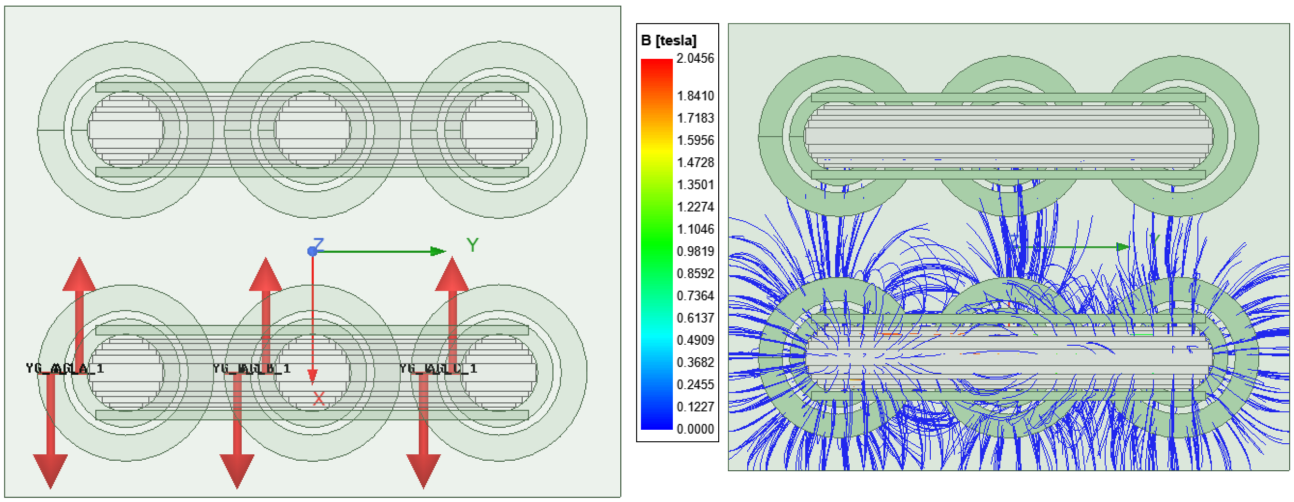
Position	Theoretical Step Voltages (V)	Real Stepped Voltages (V)	Winding Numbers	Number of Turns Between Stages	Current Phase (A)	Current Line (A)	Deflection %
6	36000	35998,78	9041	376	0,80	0,80	-0,003
5	34500	34501,66	8665	377	0,84	0,84	0,005
4	33000	33000,55	8288	377	0,87	0,87	0,002
3	31500	31499,43	7911	377	0,92	0,92	-0,002
2	30000	29998,32	7534	376	0,96	0,96	-0,006
1	28500	28501,19	7158		1,01	1,01	0,004

The analyzes were carried out using Eddy-current solution type. Excitations were made for the 6th Stage, where the worst case occurred and the highest flux occurred. Therefore, the HV Coil is excited with 9041 Coil and 0.80 A. Information of secondary winding is given in Table 2.

Table 2 LV Winding information

Position	Theoretical Step Voltages (V)	Real Stepped Voltages (V)	Winding Numbers	Number of Turns Between Stages	Current Phase (A)	Current Line (A)	Deflection %
	400	400	116		72,17	72,17	0

Cores in the same tank and their flux distributions can be seen in Fig. 3. In Fig. 4, we can see flux distributions and excitation directions when dual cores are switched on and windings are in the same direction.



2. *Figure 3 Flux distributions in single active circuit (top view)*

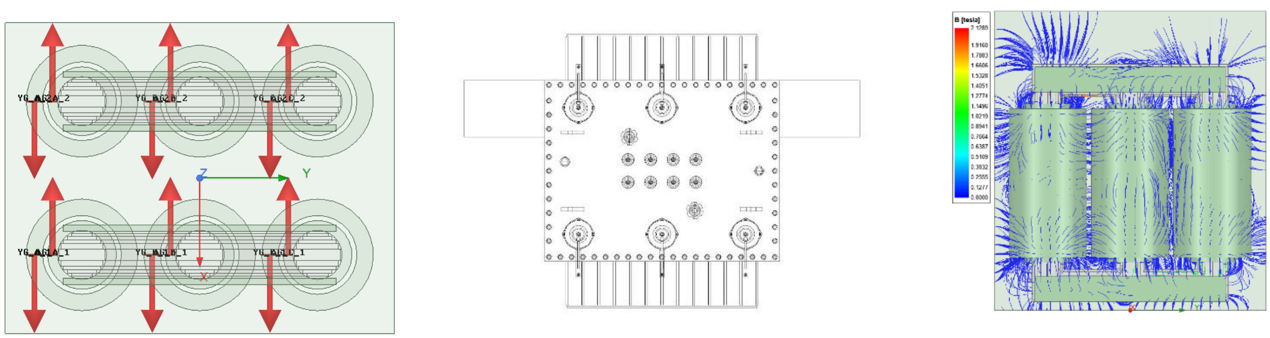


Figure 4 Flux distributions and excitation directions when dual cores are switched on and windings are in the same direction (front view).

3. Results and Discussion

The flux paths showed in the analyzes performed are 0.01% of the amount of flux passing through the core is 1/10000. This corresponds to a very small amount of flux. The maximum value of trace leakage flux is about 119 microTeslas. For this, attention should be paid to the winding direction changings obtained from the simulations, during transformer manufacturing. Thus, the flux values in the simulations given in Fig. 3 and 4 will be obtained. In the analysis studies, it has been determined that conventional single-core transformers with 100 kVA power operating below 20% occupancy rate cause high core losses at low loads and operate more inefficiently compared to double-core transformers with 50+50 kVA power. It has been observed that the magnetic effects of both active cores against each other reduce the total magnetism when the winding directions are the same for the case where the double winding is active. According to our preliminary results of the magnetism analysis, it has been revealed that the new generation dual active core transformer has lower magnetism than conventional transformers. This will play a positive role in reducing total losses. There are some design constraints that need to be considered for the economical operation of multiple windings operating in parallel [4].

With the use of the double core transformer in the distribution system, iron and copper losses will be reduced in the periods when the power demand is low. This decrease will contribute to a more efficient use of energy as well as a reduction in the loss-leakage rate. In addition, it is predicted that the transformer temperature will decrease to a certain extent as the losses in the transformer decrease. The decrease in oil and winding temperature will allow to reduce the thermal stress on the insulation material and thus increase the transformer life. The fact that the transformers can remain in operation even for a few more years will be of great benefit both technically and economically. However, having two cores in the same transformer means that one core can be used as a backup. Therefore, the efficiency in supply continuity will increase utilizing the dual core transformer.

4. Conclusions

As stated in the analysis made, due to the characteristics of transformers operating at low occupancy rates for most of the year, high technical losses are caused when their lifetimes in the network are taken into account. These losses are far above the transformer costs. The table below shows the tables regarding the gain provided to EDAŞ's regions in some transformers with a power of 100 kVA.

Table 3 Table regarding the gain to be provided to YEDAŞ's regions in transformers with a power of 100 kVA

YEDAŞ				
Electric Meter Series Number	Total Losses of New Generation Transformer 50+50 kVA	Total Losses of Standart Transformer 100 kVA	Amortization Life Total Loss Gain (kWh)	Amortization Life Total Losses Gain (TL)
80044728	31.003,08	46.089,37	15.086,29	58.942,13
80055823	32.139,52	46.572,83	14.433,31	56.390,94
80055287	34.403,51	47.521,75	13.118,24	51.252,96
80025215	40.211,91	49.974,34	9.762,43	38.141,81
80056423	43.121,55	51.254,80	8.133,25	31.776,6
80045129	43.239,41	51.373,44	8.134,03	31.779,65
80044728	31.003,08	46.089,37	15.086,29	58.942,13
80082289	29.133,95	45.336,54	16.202,60	63.303,55

By converting the transformer, which is planned in YEDAŞ's region, to dual active core transformer as of 2021, a total gain of 16 202.60 kWh will be achieved with the decrease in technical loss at the end of the 30th year.

In cases of recession in the tourism and production sector from time to time, users with dual core transformer facilities will be able to contribute to energy efficiency by reducing their energy consumption. The necessity of constructing more than one transformer building, which the facilities in the mentioned sectors need in the electrical system installation processes, will be eliminated. Thus, the use of a large number of extra MV cells and buildings will be avoided and great savings will be achieved in installation and operating costs. In addition, the depreciation life of the double-core transformer is longer due to the fact that the oil of the transformer, which will continue the majority of its operating life on only one core, is higher than conventional transformers and it heats up relatively less. The graph showing the benefit-cost relationship of the transformer number 5500585 selected as the first application location under the responsibility of the YEDAŞ distribution region is given in Fig. 5. Our double core losses shows similarity with losses of parallel running transformer connection which is given in scientific literature [5].

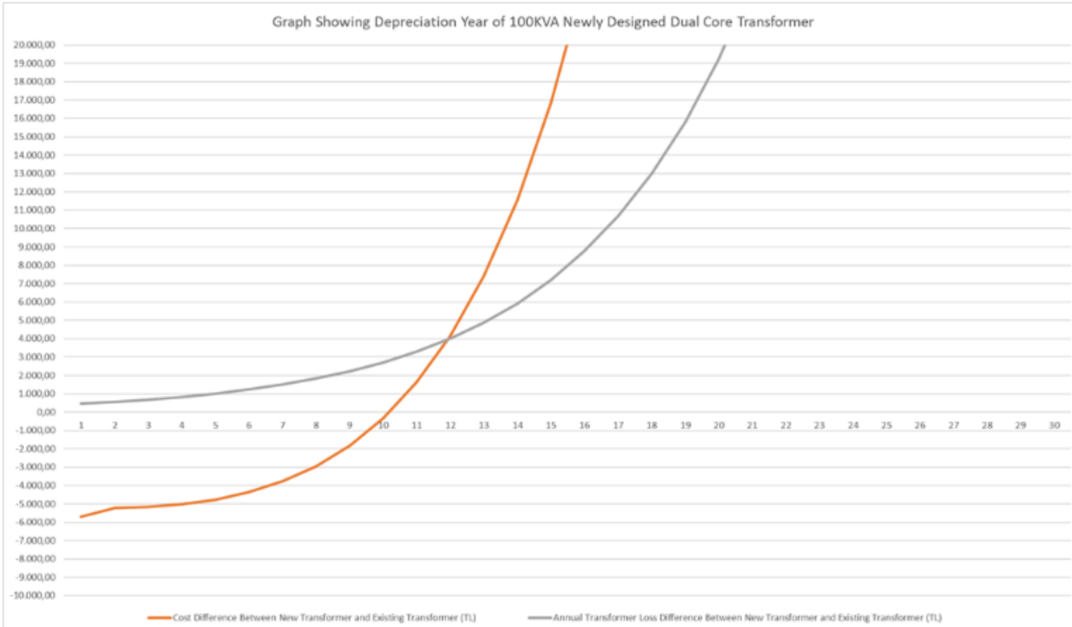


Figure 5 Comparison graphics on depreciation

According to the graphic which is given in Fig. 5, the cost difference between the conventional transformer and the new generation dual core transformer closes within 11 years, and when the 4% annual capacity of the current load profile is evaluated by the consumer, a profitability of 16,202 kWh is achieved at the end of the depreciation life.

5. Acknowledgement

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