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Research Article

OPTIMAL DESIGN OF POWER TRANSFORMER TANK USING ANT/FIREFLY HYBRID HEURISTIC ALGORITHM

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ABSTRACT
Power transformers are one of the most important and expensive components of power transmission lines. Reducing costs in the manufacture of power transformers has always been the subject of science. In this study, an ant/firefly hybrid heuristic algorithm has been developed to optimize the materials used in power transformer tanks and therefore to reduce tank costs. Based on this algorithm, an interface program has been created in Visual Studio Program. Using this power transformer tank design computer program, the materials used in the tanks have been optimized. As a result of the optimization, the materials used in the transformer tank, which is designed as a result, are saved between 5% and 15%. By this study, it has become possible to reduce the manufacturing costs of power transformers.

Keywords: *Power Transformers, Transformers Tanks, Hybrid Heuristic Algorithm, Optimization*

1. INTRODUCTION

Transformers are electrical machines that convert electrical energy into voltages and currents at the same frequency but in one or more circuits with the principle of electromagnetic induction. Since power plants are located close to the source used, they are often located far from consumption centers. For this reason, electrical energy must be able to be transmitted to remote areas from where it is produced. The voltage value of the alternating current produced in the alternators in the power plants is between 0.4 kV and 35 kV. These low voltages must be increased by 15 kV, 34.5 kV, 66 kV, 154 kV and 380 kV in order to transmit them to remote consumption centers. Increasing the voltage value of the alternating current to these values and lowering the operating voltage of 220 and 380 volts in consumption centers are made with expensive transformers. Reducing production costs in these expensive transformers has always been the subject of science. In this study, a computer program has been developed by using hybrid heuristic algorithms in the design of transformer tanks which constitute an important part of transformer. Using this computer program, design optimization of power transformer tanks has been made.

2. POWER TRANSFORMER TANKS

The tank forms the outer frame of the transformer. Oil cooling is used to prevent heating of the core, coil and switch. Hence, it needs to be in a closed environment. A power transformer tank is shown in Fig. 1.

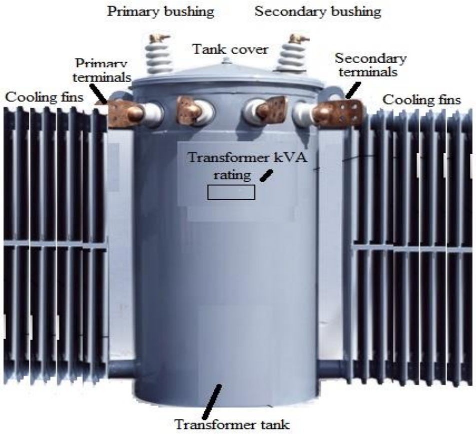

Fig**.** 1. Power transformer tank

This constitutes a closed environment tank. In order to prevent heating of iron sheets from conductive wires passing through the tank, the dimensions are determined by leaving distances between the active part and the sheet. Transformer tank can be of different shapes. It is a gated structure in which the electrical circuits pass through the tank and there is oil for cooling due to this electricity. Due to the presence of oil in the tank, it has a sealing feature. In addition, there are accessories such as bushing, expansion vessel, radiator on the tank. It also carries over supporting structures (Abi-Samra, 2009). In oil transformers, the iron body with the windings is placed in a container called a transformer tank. This container, made of sheet metal, is sealed in an oil-tight state. After the moisture is removed from the active part which is dried in the evacuated ovens, it is placed in the tank (Kothmann**,** 1995). Then, the tank is filled with the oil. Moisture must not get into the oil since the moisture reduces the insulation strength of the oil significantly. When the transformer container is slightly moistened, its puncture resistance value immediately drops to half. The dehumidified oil must be dried. The electrical puncture strength of the oil, ready for boiling according to standards and ready to be re-filled into the tank, shall not fall below 125 kV/cm (Moser, 1986).

The construction of the tank changes according to the size and shape of the transformer. Transformer tanks are manufactured as straight walled, curtain walled, corrugated walled, tubular and radiator from small to big powers (Moser, 1987). Transformer tanks with large forces, which are forced to be cooled, are also constructed as thick-walled, flat-walled. Oil tanks are made of 1 mm to 12 mm thick sheet metal according to the size and cooling type of the transformers. The cover and bottom parts of small and medium power transformers are generally made of 5 mm to 12 mm sheets. In transformers with large powers, the cover and bottom parts are made of 18 mm and 72 mm sheets. The thickness of the tank walls generally depends on the oil height. The flat sheet thickness is 3 mm at one meter height. Tank sheets are supported by various constructions in order not to use very thick sheets in higher walled flat tanks. Various reinforcement constructions are available to support tank sheets. The sheets forming the tank are generally welded together. The base plate is also welded to the side plates of the tank. The cover frame on the upper part of the tank is attached to the front and side wall sheets by making corner welding. The cover plate is either bolted to the cover frame or welded.

All transformer tanks are tested for leaks. Domes on the tank cover or sometimes on the side walls allow the bushings to be attached. Doms are generally circular. The diameters and heights of bushings vary according to the electrical stresses and forces. Dom and bushings are made to be mounted to the boiler. The flange is welded to the hole drilled in the lid to secure the dome to the tank. Radiators, oil-air and oil-water coolers are used for cooling the tanks. In radiator cooling, the radiator is generally mounted on the transformer. In cases where the number of radiators is too high to be placed on the transformer, it is made by placing on cooling benches separately from the transformer. The number of fans is determined according to the heat losses to be disposed of. It provides the circulation of oil in the radiators with pipes. These pipes are connected to the radiators from the top and bottom of the transformer. Here, the oil emerges from the top of the tank and passes through the radiators to cool down, and then the cooled oil re-enters the tank from the bottom. The pipes are placed in the region where the oil is the hottest and the transformer is cooled better. The oil expansion vessel is generally located on the top of the lid. Two pipes go from the expansion vessel to the boiler. One of them allows oil to flow from the tank to the other tank. The other pipe allows air to escape. There is an open hole in this expansion vessel to allow free expansion of the oil in case of sudden heating. This hole is bent downwards to prevent foreign objects from entering the oil.

In large transformers, buoys are placed in the container to prevent oxidation and moisture absorption of the oil in the expansion vessel by contact with air. Moisture absorbers are placed between the vent and the oil expansion vessel. In this way, the contact surface of the oil is reduced and moisture is removed .

3. ANT/FIREFLY HYBRID OPTIMIZATION ALGORITHM

The pheromones, which the ants actually use to find the shortest path, are a kind of chemical secretion that some animals use to influence other animals of their own species. As the ants move, they leave their pheromones that they have stored in the paths they have crossed (Dorigo, 2004). They prefer the path where pheromone is more likely to be the least. Its instinctive behavior explains how they find the shortest path to food, even if a pre-existing path is unavailable (Laptik, 2012). Considering that each ant leaves the same amount of pheromone at the same speed. It may take a little longer than the normal process if the ant recognizes the barrier and chooses the shortest path. Each ant takes a step-by-step decision-making policy starting from the source node and creates a solution to the problem. On each node, the local information is stored in the node itself or the arcs that exit from this node are read by the ant. The next step is to decide which node to use when going randomly (Laptik, 2017). Natural behavior of ants is given in Fig. 2.

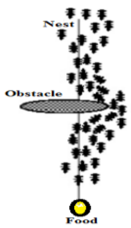

Fig. 2. Natural behavior of ants

An ant hits the node from the node until it reaches the destination node, completes its forward movement and goes back to the motion mode. The optimization potentials through the behavior of ants colony and during the analysis has been realized that the ants are able to find the shortest path to reach the food from the nest that can be used in solving complex problems. Fireflies usually emit a flashing light at short intervals. The flashing rhythm of this light is part of the signaling system that enables fireflies to meet and distinguish fireflies from other light-scattering insects. The speed, frequency and the time before fireflies respond to each other have special meanings. The optimization method developed based on this logic that determines the survival patterns of fireflies is called the firefly algorithm. Population-based heuristic algorithms are selected to optimize multiple model functions. Natural behavior of fireflies is given in Fig. 3.

Fig. 3. Natural behavior of fireflies

Firefly herd optimization method has been developed by observing and imitating the social behaviors of fireflies. The main purpose of using this method is to capture all local maxima. In multi-model function optimization problems, the most important difference between firefly herd optimization and previous approaches is the dynamic decision area used by the individuals in the herd who efficiently place multiple peaks (Yang, 2009). Each individual in the herd uses the decision-making area to select his neighbors and determines his movement through the signal strength he receives from his neighbors (Yang, 2012). Meta heuristics studies have made possible improving of optimization techniques that have the aim of providing top quality solutions to complex systems. In the generated hybrid algorithm, mathematical modeling of ant and firefly colony behavior was performed. This method has been used to solve the continuous and discontinuous problems in the design of power transformer tank, mimicking the natural behavior of ants and fireflies. Hybrid optimization of generated ants and fireflies; It is a hybrid optimization technique which is used as a result of monitoring the paths used by ants and evaluating the light intensity of fireflies.

4. OPTIMAL DESIGN OF POWER TRANSFORMER TANKS USING HEURİSTİC ALGORITHMS

Power transformer tanks design algorithm improved is shown in Fig. 4. The basic steps of the algorithm are as follows:

Step 1. Enter the number of experiments, the maximum number of generations and the number of the population (N).

Step 2. Enter; tank internal length, tank internal width, surface pressure, cover sheet material type, base sheet material type, active part weight, oil level height, reinforcement sheet length, effective areas, forces, force branches, wall sheet thickness, maximum reinforcement height, boiler vacuum value, reinforcement shape, type of reinforcement material.

Step 3. Determine the tank model.

Step 4. Enter primary voltage, secondary voltage, number of primary winding, number of secondary winding.

Step 5. Generate N chromosomes for the initial population.

Step 6. Set total number of bars, number of rows, number of columns, depth of network embedding.

Step 7. Calculate suitability for each solution.

Step 8. If the maximum number of generations is reached, identify and store the chromosome that is the best fit in the experiment.

Step 9. Increase the number of experiments if maximum number of generations is reached, but maximum number of experiments is not reached.

Step 10. Start the experiment again.

Step 11. If the maximum number of generations is not reached, go to step 5.

Step 12. Go to Step 18 if both the maximum generation number and the maximum number of experiments are reached.

Step 13. Divide the N number of chromosomes into binary groups and cross.

Step 14. Apply mutation to N chromosomes.

Step 15. Select the best N number of chromosomes for the next generation from the chromosomes obtained by N number of chromosomes and N number of mutations.

Step 16. Increase the number of generation by 1 and go to Step 5.

Step 17. Calculate transformer tank parameters of the 3N number of chromosomes.

Step 18. Identify the best chromosome.

Step 19. Calculate the average of the best chromosome of each experiment.

Step 20. View results; cover sheet thickness, cover plate length, cover plate width, base sheet thickness, forcing the base plate, base sheet deflection, bearing forces, wall plate thickness, reinforcement thickness, reinforcement height, reinforcement top sheet thickness, reinforcement top sheet width, strength moments, reinforcement cross section, reinforcement weight.

Power transformer tank design program interface improved is shown in Fig. 5.

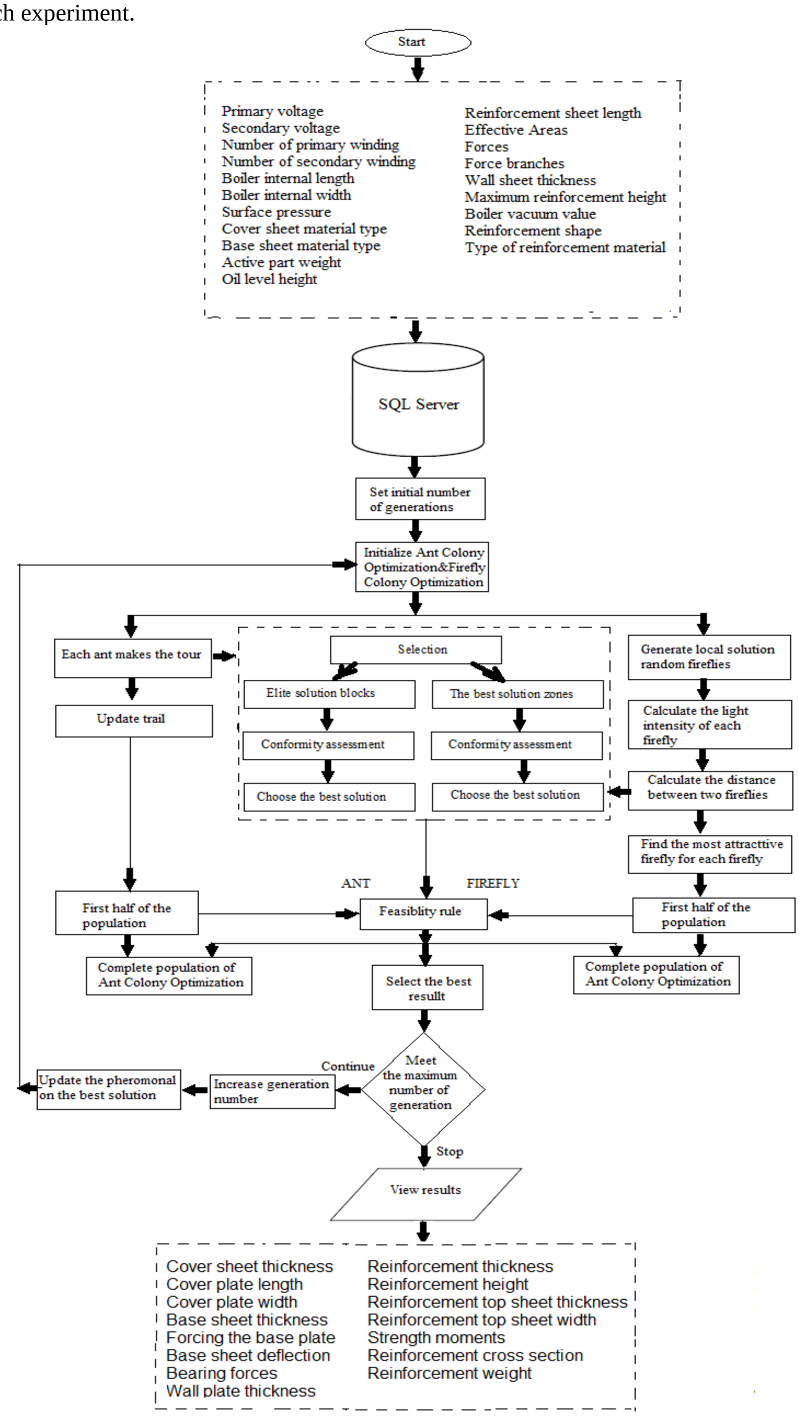

Fig. 4. Power transformer tank design algorithm improved

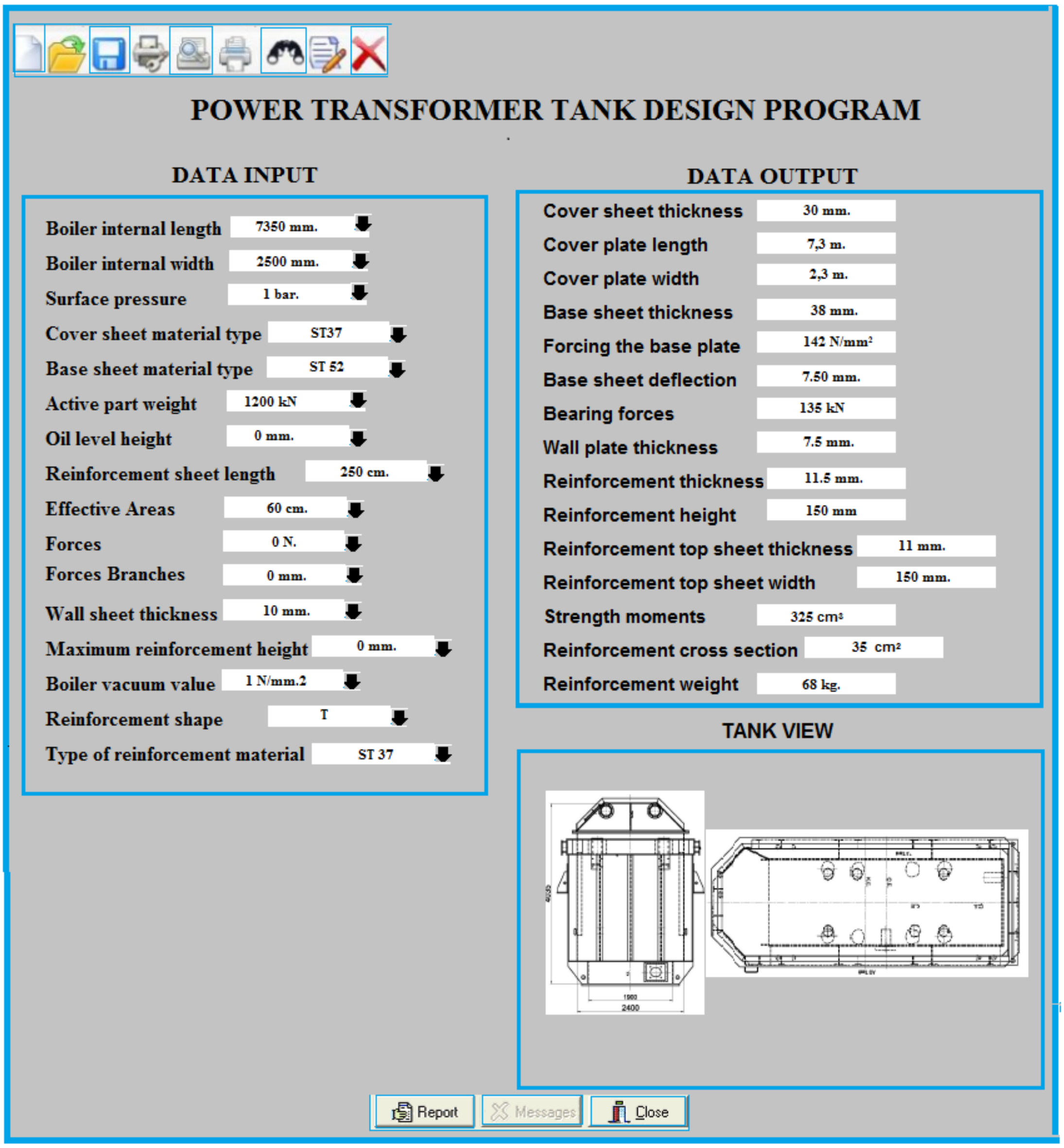

Fig. 5. Power transformer tanks design program interface improved

The variables of power transformer tank design optimization are given in Table 1.

Table 1. Optimization of variables for power transformer tank design

Transformer Tank's Detail	No-opt.	Opt.
Cover sheet thickness (mm.)	32	30
Cover plate length (m.)	7,5	7,3
Cover plate width (m.)	2,5	2,3
Base sheet thickness (mm.)	40	38
Forcing the base plate (N/mm^2)	144	142
Base sheet deflection (mm.)	7.70	7.50
Bearing forces (kN)	140	135
Wall plate thickness (mm.)	9	7.5
Reinforcement thickness (mm.)	13	11.5
Reinforcement height (mm.)	162	150
Reinforce top sheet thickness (mm.)	14	11
Reinforcement top sheet width (mm.)	162	150
Strength moments (cm^3)	340	325
Reinforcement cross section (cm^2)	38	35
Reinforcement weight (kg.)	72	68

In the conventional method design, the thickness of the transformer tank cover is 32 mm. In the generated optimization, it is understood that 2 mm of the cover thickness is unnecessary. In the design, the transformer tank cover plate length is 7.3 m. In the optimization, it is understood that 20 mm of the cover plate length is unnecessary. In the design, the transformer cover plate width tank cover plate length is 2.5 m. In the optimization, it is understood that 20 cm of the cover plate width is unnecessary. In the design, the thickness of the transformer tank base plate is 40 mm. In the optimization, it is understood that 2 mm of the base sheet thickness is unnecessary. In the design, the transformer tank wall plate thickness is 9 mm. In the optimization, it is understood that 1,5 mm of the wall plate thickness is unnecessary. In the design, the thickness of the transformer tank reinforcement is 13 mm. In the optimization, it is understood that 1,5 mm of the reinforcing thickness is unnecessary. In the design, the transformer tank reinforcement height is 162 mm. In the optimization, it is understood that 12 mm of the reinforcement height is unnecessary. In the design, the thickness of the top layer of the transformer tank reinforcement is 14 mm. In the optimization, it is understood that 3 mm of the reinforcing top layer thickness is unnecessary. In the design, the top layer width of the transformer tank reinforcement is 162 mm. In the optimization, it is understood that 12 mm of the width of the reinforcing top sheet is unnecessary. In the design, the transformer tank reinforcement weight is 72 kg. In the optimization, it is understood that 4 kg of the tank reinforcement weight is unnecessary. By this study, it has been possible to optimize the material used in the production of transformer tanks.

5. CONCLUSION

There is no power transformer boiler design by using hybrid heuristic algorithms in the literature. In this study, it is aimed to present a conscious engineering approach to transformer boiler production which is designed and manufactured according to the experiences accumulated over the years. For this purpose, extensive material analyzes have been performed to identify the materials used in boiler manufacturing. The structure of the power transformer tank has been examined in detail. A firefly/firefly heuristic algorithm has been developed to optimize the materials used here. Power transformer tank design program interface has been created in Visual Studio by using this improved algorithm. In this optimization, wall sheet thickness, reinforcement thickness, base plate thickness, base plate strength, base plate deflection, bearing forces, wall plate thickness, reinforcement height, reinforcement top layer width, strength moments, reinforcement section and reinforcement weight have been changed. The best optimum design has been made considering the tensile and yield strength of the materials used in the analysis of power transformer tanks. As it is understood from the values obtained, the materials used in transformer tank are saved from 5% to 15%. By this study, it has become possible to provide a reduction in the cost of transformer tank production. Thus, manufacturing documentation of the power transformer tank whose optimization has been completed in the simulation environment can be prepared and realized.

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