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DETECTION OF FAULTS IN TRANSFORMER WINDINGS BY DEVELOPED ALGORITHM

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Abstract- Using the transformer in overload causes malfunctions in power transformers. At the same time, short circuit, deterioration in insulating materials, manufacturing errors in winding production can cause malfunctions in power transformer windings. In the study, winding faults in the failures at the substations in Erdemli and Silifke Districts have been examined. Ant/firefly hybrid algorithm has been established to determine the fault types in the power transformer windings with the results obtained from these investigations. Heuristic Ant/Firefly Hybrid Algorithm has been developed to identify failures in power transformer windings. Using this algorithm, errors in power transformer windings have been successfully identified. This study allows us to know what malfunctions are present in the power transformer without any measurement and testing.

Keywords: Heuristic Algorithms, Transformer Windings, Winding Failures.

1. INTRODUCTION

Transformers are the most important elements of the electrical system. In order to ensure correct operation of transformers with very high power and dimensions, attention must be paid to fault maintenance and repair activities. It may be the source of the fault and its cause apart from each part that constitutes a transformer. Statistics show that 80% of modern transformer failures have winding faults. Transformer failures are generally due to lack of maintenance and lack of operational controls. A short circuit in the windings is produced by the deterioration of the conductor or coil insulation. With the melting of the copper, the short circuit stops and the fault continue for days. A malfunction of this kind expands gradually for days and ultimately destroys an entire coil. Overheating caused by overload or a short circuit that is opened late may cause winding failure. A defective fatty acid may cause winding failure due to its content. The presence of moisture in the oil or winding can also cause malfunction. High voltage electromagnetic shocks and lightning from nearby lines are a source of malfunction.

Excessive voltages caused by contact of a line to ground or a coupling fault normally do not damage the transformer. If the short circuits recur too much, the insulation of the windings is broken. Good maintenance greatly reduces transformer failures. The over current and cooling devices must be in good condition. Every year, the transformer should be controlled in terms of moisture, color acidity, % pp and sludge formation. In addition, the puncture voltage of the oil must be determined. Low-grade oil must be replaced or disposed of. In dry transformers, the inlet air should be filtered if necessary.

2. FAULT TYPES IN POWER TRANSFORMER WINDINGS

In the fault analysis of power transformers, the electro-mechanical forces cause mechanical deformation. The faults caused by mechanical factors are generally caused by deformation of the windings and the breakdown of cellulose insulation due to the deterioration in the physical appearance of the windings such as wear, swelling and boom [1, 2]. Figure 1 shows the winding failures detected in the breakdowns of the transformer centers in the Erdemli and Silifke districts of Mersin. The winding deformation usually occurs in two ways. These are the effects of electromagnetic forces during the transportation of the transformer. In case of radial effect of the electromagnetic forces in the outward direction, it causes loosening of the conductors.

Figure 1. The winding failures detected in the breakdowns of the transformer centers in the Erdemli and Silifke districts of Mersin.

A small deformation in the transformer creates axial imbalance. This causes the winding to collapse [3, 4]. This also causes rupture or separation of the conductors. This causes the conductors to break with elongation, thus exceeding the elasticity limit of the material. The pressure of the radial forces creates a bend in the innermost winding [5, 6]. In this way, the conductors are bent towards the core. If the gap insulation of this gap is also bended, a defect occurs. With the inward effect of radial forces, it causes mechanical failure in torsion or winding cylinder [7, 8].

In winding transformers, conductors must be transposed at a certain frequency. When the axial forces are exerted more pressure than the pressure to which the transposed bending places will be applied, the conductor bundle is bent. In the winding the paper insulation is torn by bending the conductor. A short circuit fault occurs when the close conductors touch each other. The forces in the axial direction in the opposite direction have a winding effect with the winding center. The forces in the axial direction in the opposite direction cause the holder points to bend or break. It causes the bent part to dislodge and separate. The impedance change in different stages should be checked in amperes winding imbalance. When the independent windings move relative to each other, the outer winding moves up or down according to the inner winding [9, 10].

Axial imbalance causes the windings to move. Movement of the windings moves the outer winding guides up or down according to the inner row. In the case of internal axial failure, the retaining system is transformed into a mechanical failure due to movement relative to each other in the vertical direction in the opposite direction to the winding. In an independent winding, a radial loosening failure occurs as a result of axial instability. These are radial compression failure or axial failure. There is a shift in the conductors downwards and upwards towards each other. An internal axial malfunction occurs with internal failure. The end-of-line failure is caused by the combination of axial and radial forces.

In this type of fault, bending in the outer cavities shows the forces in the form of bending at the end of the winding towards the core legs. Spiral compression failure results from the combining of the axial and radial forces and the covalent compression of the inner windings. The fault occurs when the conductors slide from the center of the winding and are distributed in the radial space. Radial faults generate electromagnetic forces on the elements on the coil edges. If insufficient insulation is provided at the high places of the coil, the radial forces are more severe than the general situation. Radial component forces also show themselves in the tap connections of the winding.

The electromagnetic forces try to extend the conductors in a radial outward direction. The deformation forces present in the high voltage winding group cause axial faults. The insulation space block, where the conductors are placed, remains under pressure. These forces propagate on the conductor in bundles. The axial forces between the different winding coils strike the winding coils towards the cavity of the core layers. This tries to expand the core and winding into the transformer tank, creating pressure on the main insulation. The impact forces, which vary according to the load of the axial forces in the coil groups, are affected in the tank, inside the core and between the coil holder bundles [10].

3. DEVELOPED HEURISTIC ANT/FIREFLY HYBRID 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 store in the paths they cross. Natural behavior of ants is given in Figure 2.

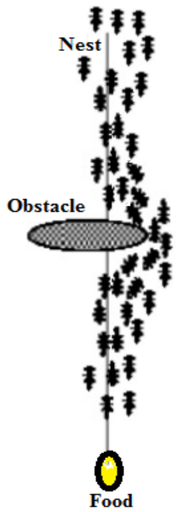

Figure 2. Natural behavior of ants

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. 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. 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. Fireflies usually emit a flashing light at short intervals. Natural behavior of fireflies is given in Figure 3.

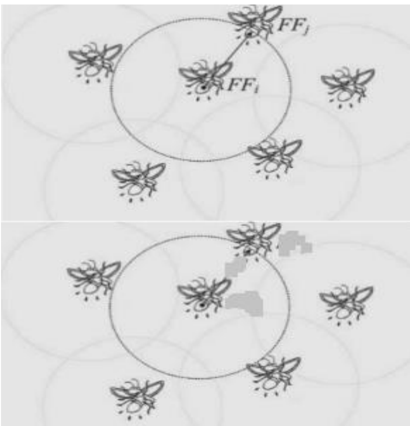

Figure 3. Natural behavior of fireflies

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 base on this logic that determines the survival patterns of fireflies is called the firefly algorithm. The recommended population-based intuitive algorithm for optimizing multi-model functions was conducted.

Firefly herd optimization method was developed by observing and imitating the social behaviors of fireflies. Using this method, all local maxima are captured. It makes it possible to capture multiple peaks effectively in multi-model function optimization problems. It makes it possible to make dynamic decisions by individuals who are placed in many points with the fireflies herd optimization. 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. In the generated hybrid algorithm, mathematical modeling of ant and firefly colony behavior was performed. This method has been used to identify malfunctions in transformer windings by simulating the behavior of ants and fireflies in nature.

Hybrid optimization of produced ants and fireflies; It is a hybrid optimization technique used to monitor the paths of ants between food sources and nests and to assess the light intensity of fireflies [11, 12].

4. DETERMINATION OF FAULT TYPES BY USING HYBRID ALGORITHM

The generated hybrid algorithm for determination of fault types in power transformer windings is shown in Figure 4. The basic steps of the algorithm are as follows:

Step 1. Enter the number of loops, the maximum number of generations and the number of the population (*N*).
Step 2. Enter the information of power transformers
Step 3. Generate *N* chromosomes for the initial population.
Step 4. Set total number of bars, number of rows, number of columns and depth of network embedding.
Step 5. Calculate suitability for each solution.
Step 6. Identify and store the chromosome that is the best fit in the experiment, when the maximum number of loop is reached.
Step 7. Increase the number of experiments if maximum number of generations is reached, but maximum number of experiments is not reached
Step 8. Start the experiment again.
Step 9. If the maximum number of generations is not reached, go to Step 3.
Step 10. Go to Step 15 if both the maximum generation number and the maximum number of experiments are reached.
Step 11. Divide the *N* number of chromosomes into binary groups and cross.
Step 12. Apply mutation to *N* chromosomes.
Step 13. Select the best *N* number of chromosomes for the next generation from the chromosomes obtained by *N* number of chromosomes, *N* number of chromosomes and N number of mutations.
Step 14. Increase the number of generations by 1 and go to Step 3.
Step 15. Calculate the step voltages of the 3*N* number of chromosomes when the eddying condition is not met.
Step16. Identify the best chromosome in all experiments
Step 17. Calculate the average of the best chromosome of each experiment.
Step 18. View results (winding failure, coil failure, number of turns, short circuit failure, winding break, insulation failure, radial draft failure, radial compression failure, axial compression failure, axial pull failure, axial internal failure, end of failure, spiral compression failure, radial fault, axial fault, coil compression failure).

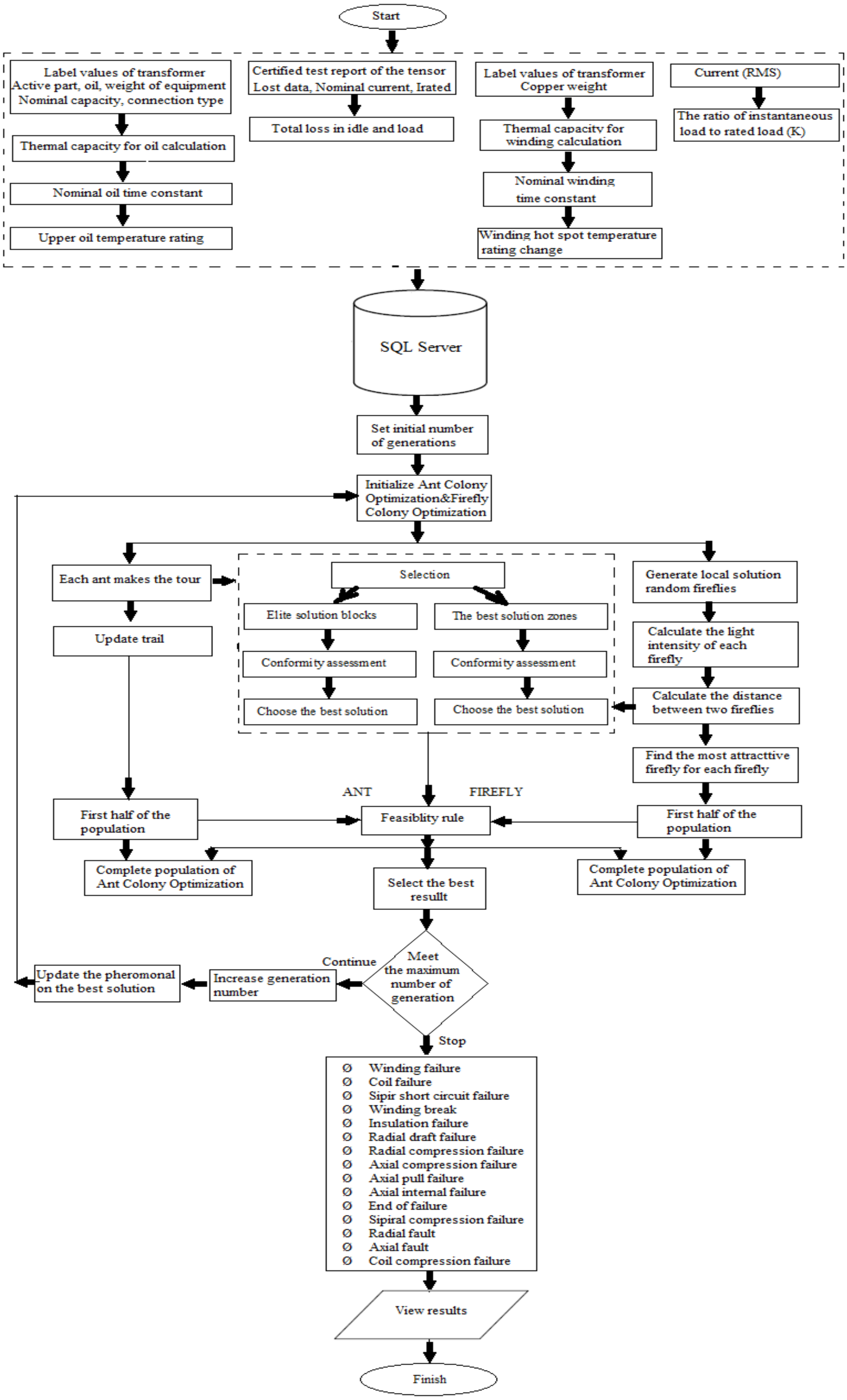

Figure 4. The generated hybrid algorithm for determination of fault types in power transformer windings

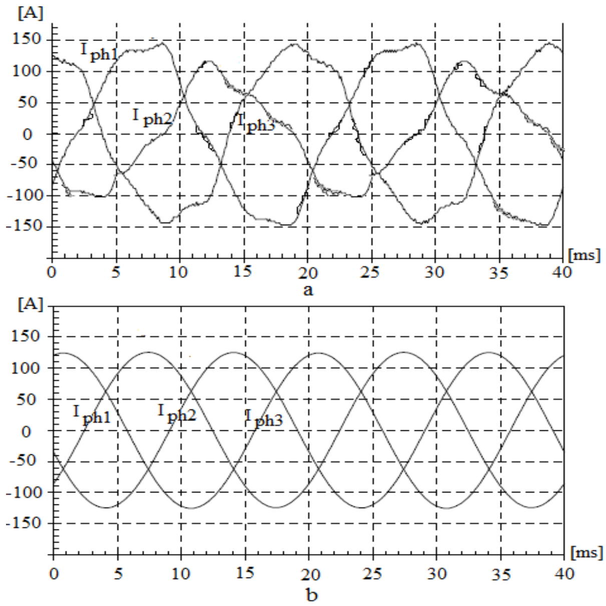

Figure 5. Measured values and obtained values from the algorithm of winding current

Measured values and obtained values from the algorithm in power transformer are given in Table 1.

Table 1. Measured values and obtained values from the algorithm in power transformer

Parameter	Measured values	Algorithm values
Idle current	1 %	0.95 %
Copper loss	24 kW	22.8 kW
Iron loss	3.8 kW	3.1 kW
Short-circuit voltage	6 %	5.70 %
Full load voltage drop (cosφ=0.8)	4.41 %	3.96 %
Full load efficiency (cosφ=0.8)	98,62 %	93.68 %
Full load voltage drop (cosφ=1)	1.14 %	1.08 %
Full load efficiency (cosφ=1)	98.90 %	93.95 %

The error in the optimum data obtained from the developed algorithm is between ±1% and ±5%. Using this developed algorithm, transformer fault data is accessed more quickly.

5. CONCLUSIONS

The way to avoid the major faults in the windings in the power transformers and to protect them from the very serious financial and technical problems caused by these faults depends on providing a working environment with the tools and equipment equipped with the appropriate technical devices. Tests and maintenance must be carried out regularly to prevent problems in power transformer windings and to ensure safe operation of the transformers. In the classification of faults in windings, the scenario should be prepared and preventive measures should be taken.

In the investigation of power transformer winding failures, the methodology of the most probable causes of any transformer failure detected in the system should be established. Fault and event samples should be provided and the procedure should be determined for routine and uniform data collection. In the case of power transformer winding faults, a road map to be followed must be established. In this study, Heuristic Ant/Firefly Hybrid Algorithm has been developed to identify failures in power transformer windings. Using this algorithm, errors in power transformer windings have been successfully identified. This study allows us to know what malfunctions are present in the power transformer without any measurement and testing.

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BIOGRAPHY

Mehmet Zile was born in Ankara, Turkey, 1970. He received the B.Sc. degree from Yildiz Technical University, Istanbul, Turkey, the M.Sc. degree from Gazi University, Ankara, Turkey and the Ph.D. degree from Yildiz Technical University, all in Electrical and Electronic Engineering, in 1992, 1999, and 2004, respectively. Currently, he is an Assistant Professor of UTIYO at University of Mersin, Mersin, Turkey. He is also an academic member of UTIYO Information Systems and Information Technology Department at University of Mersin and teaches information systems and control systems. His research interests are in the area of control systems and electrical machines. He is a member of IEEE.