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DEFINITION OF FAULTS AND EFFICIENCY IN POWER TRANSFORMERS USING THE ALGORITHM AND COMPUTER PROGRAM CREATED BY THE HEURISTIC OPTIMIZATION METHODS DEVELOPED[1]

Mehmet Zile

Department of Information Systems, Mersin University Mersin, Turkey
mehmetzile@yahoo.com

Abstract

The real-life optimization problems are too complex to be solved by developing a mathematical formula. Heuristic methods are the methods defined to decide the best of a variety of solution actions to solve a problem. Furthermore, it is preferred that heuristic methods are short in solution time and can be applied to different problems. Heuristic methods were developed while trying to find the best solution. The created algorithm, which was based on herd intelligence, was used to solve optimization problems based on the behaviors of bees moving in nature in the process of finding nutrients. By the studies, transformer failures allow us to know without any measurements and tests. The software was developed in C++ programming language by using the created artificial algorithms. The transformer analyses programs have been created by using Microsoft SQL Server 2017 database.

Keywords: Heuristic algorithms, optimization methods, transformer analyses

1. Introduction

Optimization means finding the best solution point. It is the whole process of finding the best result for a problem, system or design. Problems that involve the calculation of unknown parameter values to provide certain constraints are called optimization problems. Depending on the given parameters, a cost function to be minimized or a profit function to be maximized and constraint functions in which problem boundaries are specified must be defined. Heuristic algorithms are criteria or computer methods defined with the aim of achieving a goal or deciding on the effective alternatives to achieve a goal. They do not develop problem-specific solutions and try to apply predetermined solution techniques on the problem. These algorithms are

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capable of convergence but cannot guarantee the exact solution. But algorithms can guarantee a good solution near the exact solution. Meta-heuristic optimization algorithms are algorithms that stand above the heuristic methods and decide the method to be used for the solution of the problem. It has nature-inspired, intuitive, easy-to-implement operators like heuristic algorithms. These algorithms need to meet certain criteria such as the proximity of the solutions they find to the optimum value, the time taken to find this solution, and the coding that can be understood by everyone. The majority of meta-heuristic algorithms consist of algorithms based on population and using herd intelligence. Algorithms start by creating a random population. This process is to create values that fall within the lower and upper limits given for the variables. In addition, the parameters that the algorithm needs should be determined. Afterwards, the fitness value should be calculated in the light of these values for each individual. It has been inspired by the movements of some animal communities living in herds. In the study, different Hybrid Particle Swarm Optimizations have been developed. By applying these developed hybrid optimizations to Electrical Engineering Problems, solutions are presented.

2. The artificial bee algorithm and the cuckoo/flower pollination hybrid algorithm

The Artificial Bee Colony algorithm is inspired by the intelligent foraging behavior of honey bees. It offers a solution based on herd intelligence in numerical optimization problems. The collective intelligence of honey bee colonies in foraging has three basic components. These are nectar sources, worker bees and scout bees. The quality of a nectar source depends on parameters such as proximity to the hive, richness or density of its content. Worker bees are those who search for nectar sources and carry information about the nectar source. Scout bees are groups of bees that watch the dance of the worker bees to decide which resource to search for. The amount of nectar is the objective function value that represents the quality of that solution. The number of solutions is equal to the number of workers. In the beginning, a random starting position is created. In the next step, worker, scout and scout bees evaluate and update the population. Resources express problem solutions. If bees find a better source than their current source during their research, they will memorize the new source. After all worker bees have finished the search, position information is shared with the scout bees. Scout bees evaluate the information obtained from the worker bees and select sources depending on the amount of nectar. The best source chosen represents the best problem solution. [1-4].

In the cuckoo and flower pollination hybrid algorithm developed, mathematical modeling was performed by mimicking the natural behavior of cuckoo and flower pollination. Cuckoo birds lay their eggs in the nests of some birds [5-7]. These eggs are allowed by the host bird to grow. After becoming a mature bird, they migrate to another living space. Migratory birds begin to breed again. Similarly, they lay their eggs in the nests of other birds. From these eggs baby birds grow and grow. Growing birds are determined in the best group. This group is chosen as the new living space. The new cuckoo population migrates to this area [8]. If the desired result has not occurred at the end of the algorithm, this is repeated. If we get the results we want, the algorithm is stopped and the results are taken. The aim of flower pollination is to provide the optimal viability and optimum biological reproduction stage. Pollination and other factors interact best for the propagation of plants. There are two important forms of pollination, biotic and abiotic. While 90% of the flowering plants perform biotic pollination, they perform abiotic reproduction at 10%. While pollinators such as flies and insects carry pollen in biotic form, no pollinator is available in abiotic form. Global pollination processes are carried out biologically, and pollinators carry pollen according to Lévy flights. Abiotic and self-pollination are considered local pollination. Like insects, pollinators can improve the likelihood of proliferation, which is proportional to the similarity of the two flowers. A key possibility of local and global pollination can be controlled by p ∈ [0, 1] [9]. As in flowers, biotic pollination model to determine the solution points at long distances and abiotic pollination model of the solution points to investigate the neighboring of the algorithm is the logic of optimization [10].

3. Detection of faults by using bee algorithm improved in power transformers

This Nowadays, many methods and devices have been developed for the healthy operation of the transformer. A minor problem to be ignored causes a severe malfunction. Early detection of the problem in the transformer slows the development process of the problem. All components of the transformer need to be examined to the extent required by the fault. The fault analysis is quite complex and comprehensive. In the review phase, the fault includes many details, allowing for a definite definition of the fault. It is necessary to bring together a very comprehensive analysis of the contents of a defect in order to examine and examine all the details.

The flocking behavior of the flocks of birds and their flying patterns, the food search behavior of ants, the swimming and grouping of the fish flocks, the communication of honey bees with the dances. These herd behaviors modeling were investigated. Herd intelligence; bees, ants, birds, termites, flocks of fish, such as the interaction of animals in the form of communities that examine the result and as a result of an artificial intelligence technique that aims to find solutions to problems. Intelligent behaviors based on the emergence of herd intelligence that is the ants provide information to the other ants by leaving chemical substances on the paths they have passed. Bird and fish flock moving and adjusting their position and speed relative to each other.

In this study, the analysis of faults in power transformers has been done by artificial bee algorithm. Thus, the faults in the power transformer are known in a short time and allow for immediate intervention. The faults are prevented and the transformer explosions are prevented. Application areas in the bee algorithm for analyzing errors in transformer are core, winding, insulation, tank, bushings, conservator and breather, tapping and tap changing, Buchholz relay, explosion vent and application areas in the bee algorithm for analyzing errors in cooling oil [11-18]. General faults condition of power transformer are given in Figure 1.

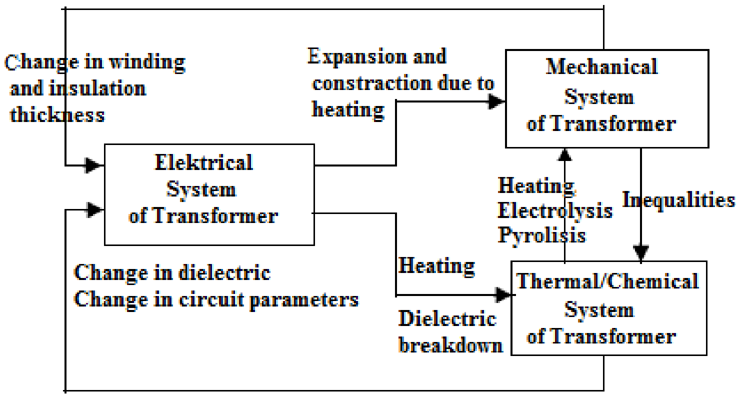

Figure 1. General faults condition of power transformer

In the case of a transformer failure, the operation begins with the suspicion of the operation of the protection relays or the performance of the transformer [19-25]. It is absolutely necessary to collect the explanatory findings carefully and to transfer them to the personnel who will make the fault assessment. In the event of a fault, the teams should be as coordinated as possible and the exchange of information should be transparent. It is clear that, from the lowest to the top management in the right decision for the fault diagnosis, sharing the information with the fault in a healthy way will increase the accuracy in the fault review. The fault analysis consists of four main components; preparation, testing, examination and conclusion of the report. Quickly collect information and documents about the fault in the preparation phase. The findings of the fault are obtained by test studies. The reviews consist of three steps. These are completed by external inspection, internal inspection and, finally, removal of the transformer from its tank, if necessary, by opening. When sufficient data is collected to evaluate the fault and according to the test results, the fault source engineers are identified and the factors that are the source of the fault are determined. Historical records and information of the transformer to be examined must be collected. Application and operation information is obtained by going to the fault area. All personnel who have witnessed the occurrence of the fault or problem are consulted. The transformer is examined and if necessary it can be installed partially or completely [26]. Records and reports of the information obtained and the history of the transformer are analyzed. It is shared with staff that is able to prepare preliminary reports and contribute. Reports are reviewed. With the control, if necessary, additional information or report changes are eliminated. Final report should be prepared. Collecting all information related to the fault is very important in the resolution of the fault. It is decided that the method to be applied against the event encountered in the faulty condition or the transformer. In practice, the isolation of the transformer is done first [27]. The transformer is checked according to the last test results starting from the first operation. After the transformer is energized, it is necessary to record the signals belonging to the relay operating by the protection equipment. In this way, it helps to evaluate faults in the enterprise by collecting information in power transformers. In order to collect the information, employees should cooperate at all levels. The person present to the investigator is informed about the transformer related to the fault quickly and accurately [28]. At the same time, the manufacturer is also informed about the fault. The manufacturer must be informed, in particular, of a transformer failure. Factory tests, the findings of the transformer's history, transformer projects and data outside of the normal data that is considered to benefit the lighting of the fault are obtained from the manufacturer. It is advisable to provide the manufacturer or the repair team together with the information to be used for fault analysis [29]. So things get fast. Accurate decisions are taken for the diagnosis. It is important to obtain and examine the defective transformer file before going to the fault location. With some findings, current information accelerates the analysis. Within the scope of the preparation, the operating instructions of the transformer, information regarding the transformer, transformer pictures, transformer equipment and factory photographs should be obtained [30].

Transformer test reports, factory test reports, field tests, routine test reports, single line diagram of the substation, protection/secondary projects, reports of past studies or fault conditions, settings for protection and measurement systems, camera, tape meter, protective clothing, field goggles, safety glasses, recorder, lens, searchlight, flashlight, magnet, oil sample bottle syringe and oxygen meter must be present.

Transformer general inspection cases;
F1:Surge arrester operation status
F2:Physical state of surge arrester
F3:Electrical status of surge arrester

F4:Surge arrester connection status
F5:Any sign of a lightning strike status
F6:Lightning to the zone of the transformer status
F7:Unexpected sounds, situations status
F8:Debris on transformer or accessory status
F9:Redness, skipping trail status
F10:Radiation status
F11:Transformer water system status
F12: Witness information
F13:Overload of transformer in case of malfunction
F14:Collecting information about events in the system
F15:Operation status of fans and pumps
F16:Radiator valves to be open
F17:Residual or corrosion in the cooling system
F18:Inflatable in the cauldron, boom, protruding
F19:Crack status in the tank
F20:Leakage status in the tank
F21:Trace of overheating
F22:Oil level status in the conservatory
F23:Gasket, bushing and cover condition
F24:Gas pressure status
F25:Negligence in the control panel
F26:Leakage status
F27:Porcelain fracture status
F28:Having holes in tapes
F29:Having a jump track
F30:Oil level status
F31:Tap changer position
F32:Maximum tap change position
F33:Minimum tap change position
F34:Unloader tap changer position
F35:Tap changer oil level
F36:Tap-change counter registration
F37:Differential operation status
F38:Overcurrent relay operation status
F39:Overload relay operation status
F40:Earth fault relay operation status
F41:Directional earth relay operation status
F42:Excessive warning relay operation status
F43:Measurement indicators work
F44:Pressure relay operation status
F45:Liquid or oil temperature status
F46:Winding or hot spot trace
F47:Status of oil level in main tank
F48:Status of oil level in tap changer
F49:Oil level status at conservatory
F50:Gas detection relay status
F51:Oil movement relay status
F52:Announcers signals status
F53:Insurance status

F54:Status of fault recordings
F55:Oscillograph records status
F56:Winding-winding resistance status
F57:Winding-earth resistance status
F58:All winding-earth resistance status
F59:Polarisation index status
F60:Total combustible gas level status

In order to determine the main isolation and damage point, winding-winding, winding-earth and all winding- earth tests are performed. Polarization index is checked for the main isolation. The auxiliary isolation and damage point are determined from the winding ratio and winding DC resistance test [31]. The main insulation is controlled from the power factor test. Only the damage point is determined from the dielectric strength test of the oil. Auxiliary isolation is determined by the test of detection of mechanical damage and damage location [32]. Mechanical damage, damage detection, auxiliary isolation control, low voltage impulse, impedance and frequency response analysis is determined from the test. Only the auxiliary isolation control is made from the induction voltage test. The purpose of the polarization index tests is to determine whether the equipment is resistant to normal or overvoltage. Polarization index is the measurement of mega ohm resistance measured at the end of 10 min. When the Polarization Index is less than 1, the Insulation Condition is dangerous. It is weak between 1 and 1.1. It is doubtful between 1.1 and 1.25. It is good between 1.25 and 2. It is very good when it is greater than 2. When Total Combustible Gas level is between 0 and 500 ppm, there is no problem in the operation of the transformer unless a guide gas exceeds the normal limit value [33]. There has been some deterioration in the insulation of the transformer in the 500-1500 range. Necessary precautions should be taken against the possibility of a fault. In the 1500-2500 range the transformer insulation has been damaged. There may be a fault in the transformer. If the situation is in a bad way, the necessary actions are made immediately. Total flammable when the gas level exceeds 2500 ppm, significant deterioration of the transformer insulation may have occurred. The causes of gas generation and gas generation are investigated. Proper actions are taken by taking necessary measures [34].

Basic bee algorithm parameter is shown in Table 1

Table 1. Bee algorithm parameters

Bee Algorithm Parameters	Explanation
n	Number of solution
f	Number of wrong zones selected from problematic
b	Selected ‘f’ is the best number of zones in the wrong region
nbp	Number of solutions applied to the best solution b zone faulty region
nrp	Remaining number of solutions (f-b)
nss	Neighbor solution search size
itn	Stop criterion (number of iterations)

'n' solution research space is shown in Figure 2.

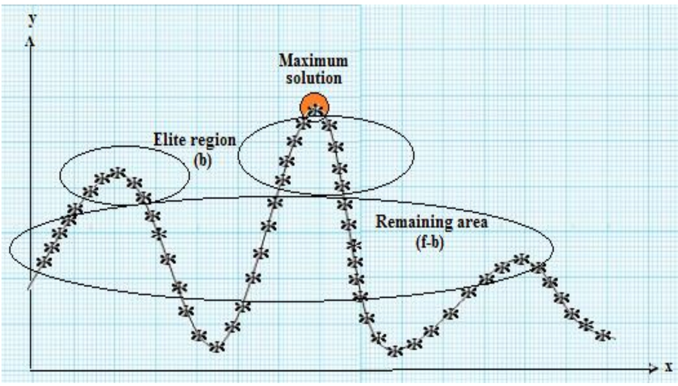

Figure 2. 'n' solution research space

The Created Bee Algorithm for finding and analyzing the transformer errors are given in Figure 3. In the study, the soft ware has been developed in which transformer units and possible transformer failures can be identified. The flow chart of the program is given in Figure 4. Hardware of the program of fault analysis is given in Figure 5. The interface of the program of fault analysis in transformers is shown in Figure 6.

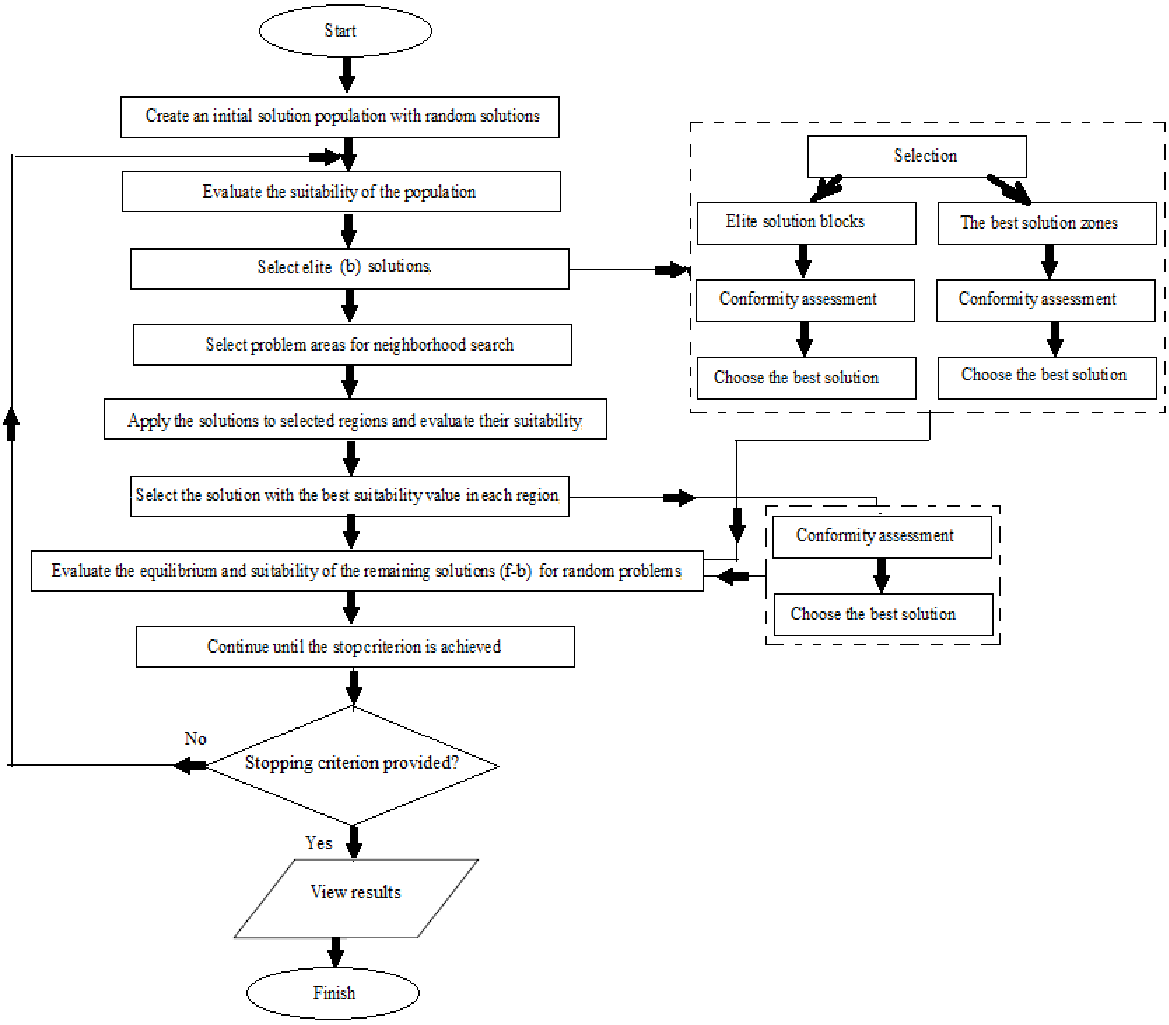

Figure 3. The Transformer Faults Algorithm

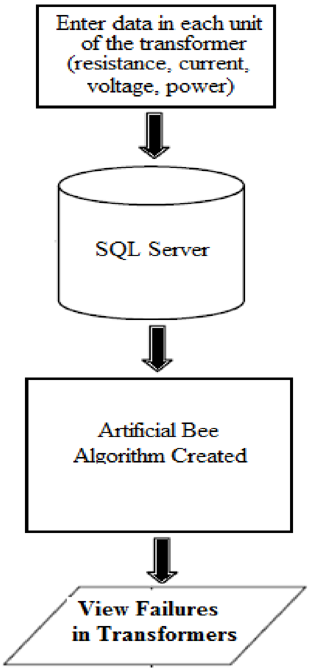

Figure 4. The program of fault analysis

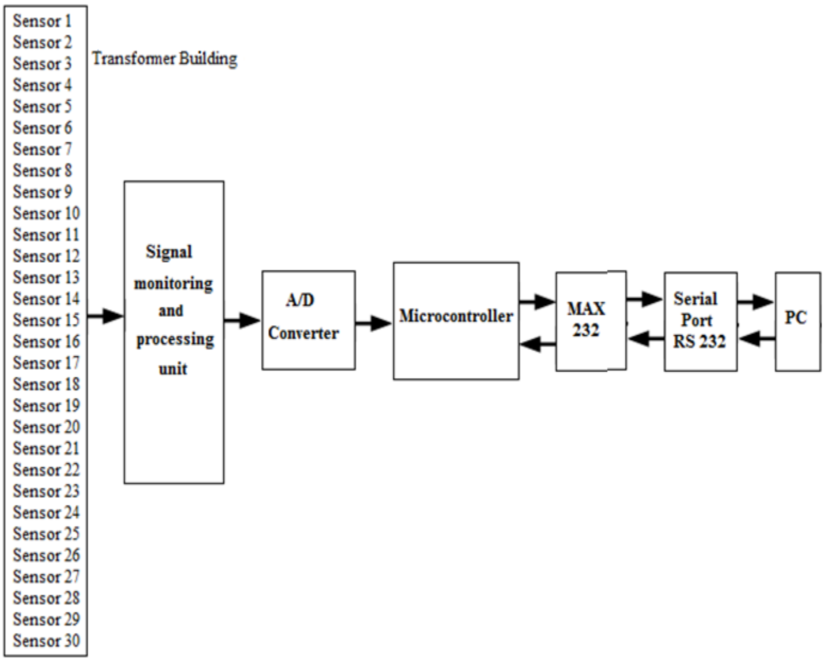

Figure 5. Hardware of the program of fault analysis

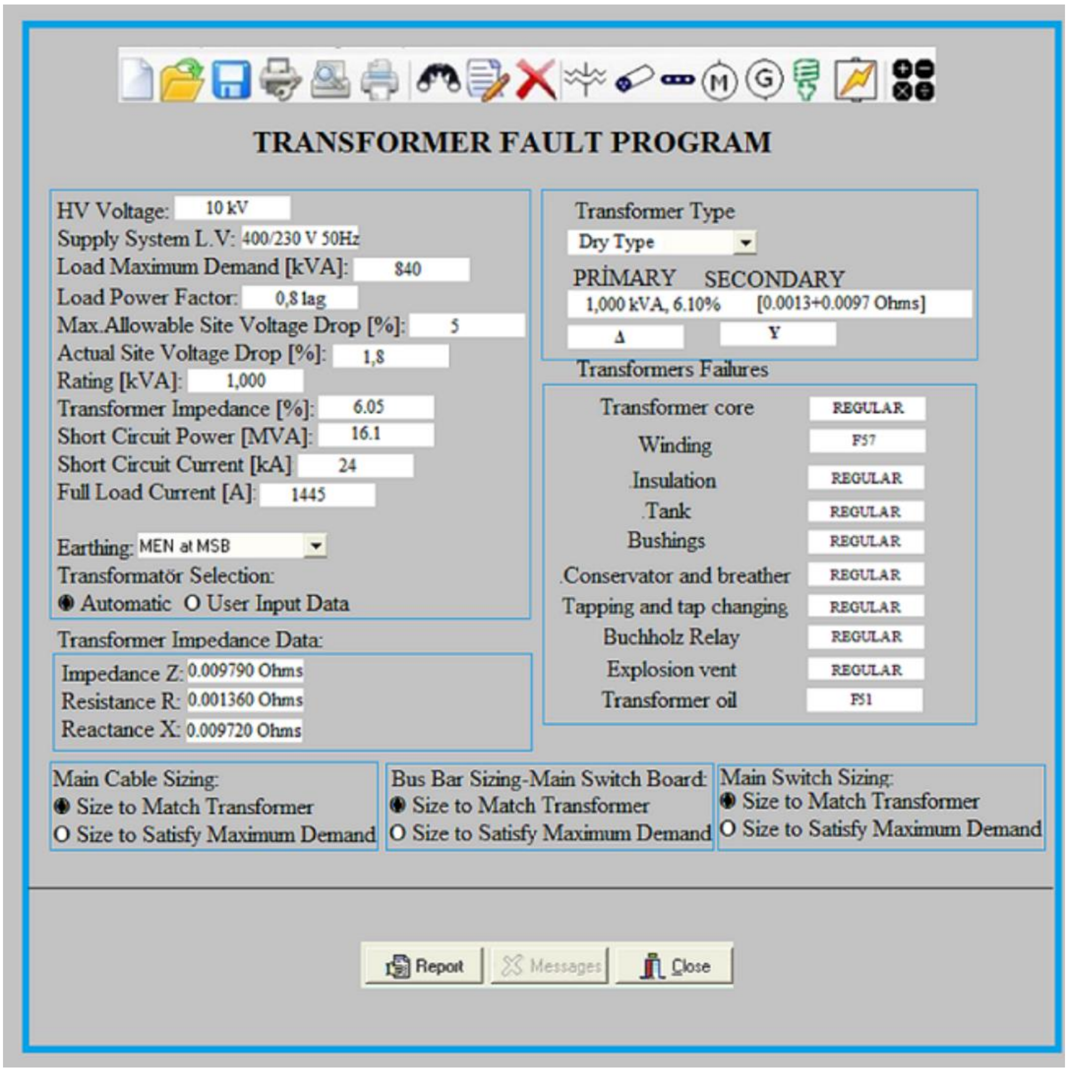

Figure 6. The interface of the program of fault analysis

Created power transformers faults detection panel is given in Figure 7.

Figure 7. Created power transformers faults detection panel

Measured values and obtained values from the algorithm of winding current are given in Figure 8.

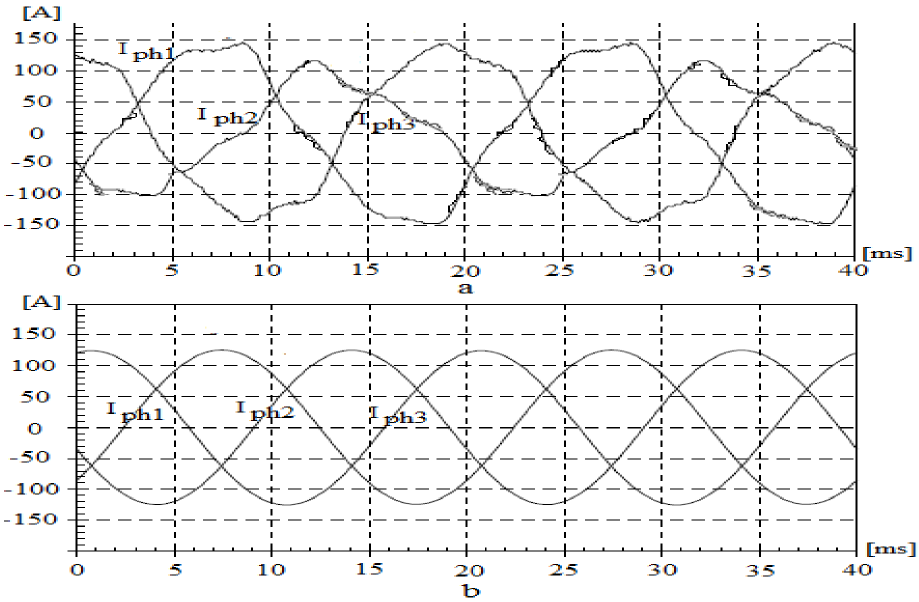

Figure 8. Measured values and obtained values from the algorithm of winding current

Measured values and obtained values from the algorithm in power transformer are given in Table 2.

Table 2. Measured values and obtained values from the algorithm in power transformer

Parametre	Measured values	Algorithm values
Free current	1 %	0.95 %
Copper losses	24 kW	22.8 kW
Iron losses	3.8 kW	3.61 kW
Short-circuit voltage	6 %	5.70 %
Full load voltage drop (CosØ=0,8)	4.41 %	3.96 %
Full load efficiency (CosØ=0,8)	98.62 %	93.68 %

The percentage errors of the program of fault analysis are given in Figure 9. Iteration change of the created bee algorithm and other algorithm are shown in Figure 10.

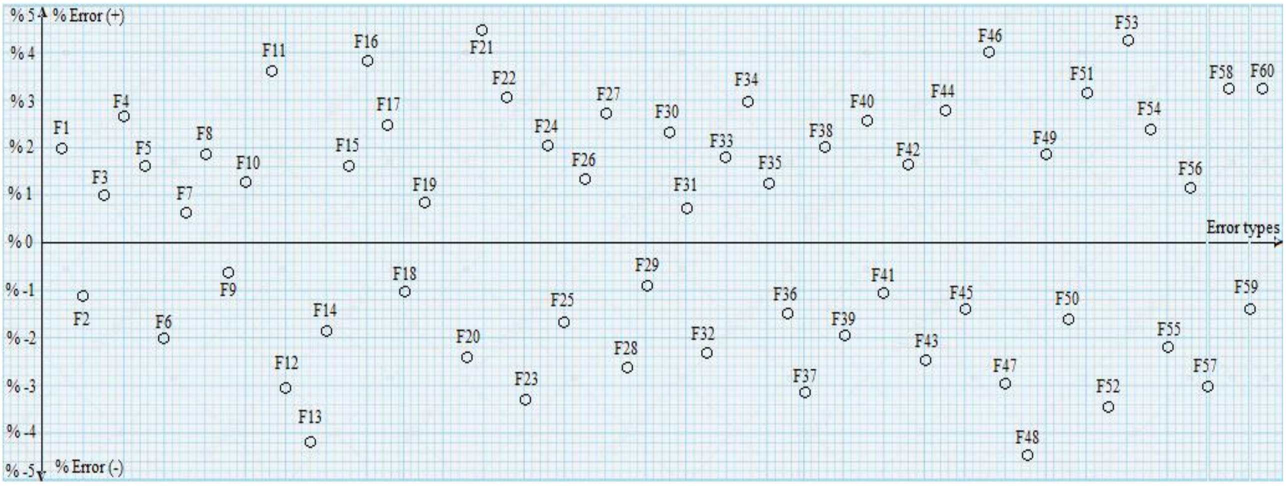

Figure 9. Percentage error of the program of fault analysis

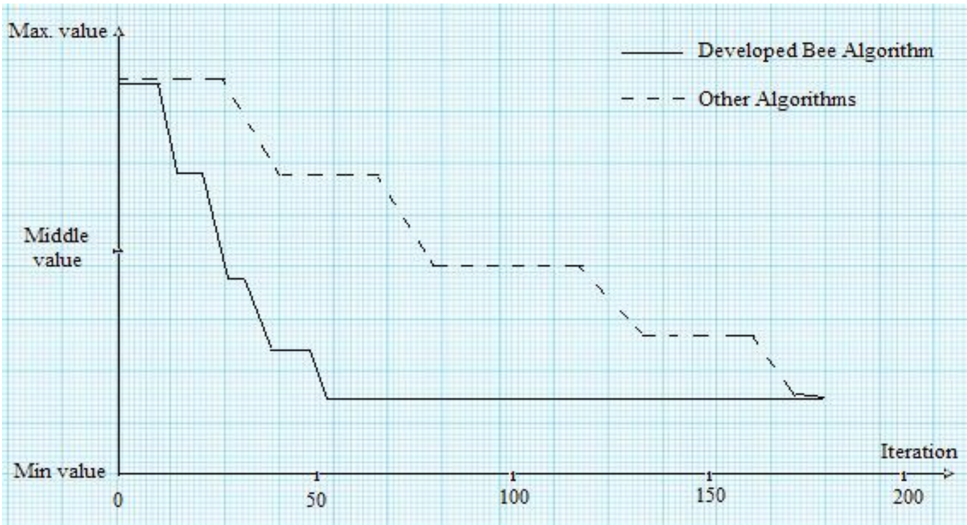

Figure 10. Iteration change of the created bee algorithm and other algorithm

The result was reached in the 170th iteration. Therefore, when compared to the artificial bee algorithm and other algorithms, the improved algorithm is capable of a better search. The increasing need for energy increases the importance of providing uninterrupted electricity supply. In such a case, our task is to diagnose the failures in the energy system that may cause interruption until the end consumer reaches the point where electricity is generated. Even in doing so, it is necessary to be able to diagnose the fault in advance and make these diagnoses without any power failure. The heuristic method has been developed to identify faults in power transformers. Thus, the best result was tried to be reached. An algorithm which automatically identifies the failure in power transformers is created. This algorithm based on herd intelligence is used to describe transformer failures based on the behaviors of bees moving in herd to find food. After the algorithm runs and ends, the transformer failure is automatically displayed. The software was developed in C++ programming language by using Artificial Bee Colony algorithm. Microcontroller and integrated data transfer via serial port. The data obtained from the developed algorithm and the experimental results obtained from the faulty transformer were compared. It is understood that the error in the data obtained from the developed algorithm is between ± 1% and 5% and the results are reached faster. Faults in the power transformer are defined in a short time.

4. Power transformer efficiency optimization using developed hybrid cuckoo and flower pollination algorithm

Developed hybrid algorithm for power transformer efficiency optimization is given Figure 11.

In this study, Hybrid Cuckoo (CA) and Flower Pollination (FPA) algorithm have been developed in order to find the working point in case the transformer efficiency is the best according to different loading conditions of power transformers. The results obtained from the experiments on the transformers in different power and structure in the Transformer Substations in the Erdemli district of Mersin province and the results obtained from the developed algorithms have been compared. The accuracy of the results obtained from the Hybrid Cuckoo (CA) and Flower Pollination (FPA) algorithm developed for efficiency optimization of the power transformer has been found to be appropriate. An alternative method for transformer efficiency optimization has been developed using this hybrid algorithm.

Electricity generation is done in three phases at voltages of 13.2 kV or higher. The energy transmission takes place at high voltages of 110, 132, 275, 400 and 750 kV. Therefore, there is a need for transformers which increase the voltage to give the generated voltage to the transmission line. These transmission voltages are reduced to 6600, 4600 and 2300 volts distribution voltages and then to 440, 220 or 120 volts operating voltages. Transformers have an important place in the production, transmission, distribution and consumption phases of electrical energy [35]. Efficiency is an important parameter for all electrical machines. Transformers are expected to be as high as their efficiency [36]. Heuristic algorithms are algorithms capable of providing solutions that are close to the optimum in acceptable time for large-scale optimization problems. The intuitive optimization methods have been developed to find the best, optimum, result under given conditions. Transformer efficiency is to be as high as possible in various load cases. In this study, hybrid cuckoo (CA) and flower pollination (FPA) algorithm has been developed in order to find the working point where the different types of transformers have maximum efficiency compared to different loading conditions. With this developed hybrid algorithm, power transformer efficiency optimization is made. The results obtained from experimental studies were compared with the results obtained from the hybrid optimization method. Some of the power supplied to the transformer is consumed for iron and copper losses. That is, not all of the power given to the transformer can be taken from the secondary. The ratio of the power taken from the transformer to the given power is called yield. There is direct and indirect method yield in transformer. With the direct method, ammeter, voltmeter and wattmeter are connected to the primary and secondary of the transformer. The transformer is gradually loaded from the unloaded to the fully loaded state. Thus, the power delivered to the transformer at various load currents and the power is measured with the help of a wattmeter. The ratio of the received power to the given power and yield is found. The iron loss of the transformer by the indirect method is measured from the blank test and the copper losses from the short circuit test. When these losses are added to the output power, the input power is obtained. Thus, the transformer efficiency is found. As the power of the transformer increases, their efficiency increases. The highest efficiency in power transformers is seen when copper losses are equal to iron losses [37-40]. There are two variables that make up the total loss in transformers. The first one is the iron losses that make up the iron core. The second is the copper losses in the windings. For this, the less the two factors that affect the efficiency, the more total losses will be reduced. The first one of our variables is the iron cross-section.

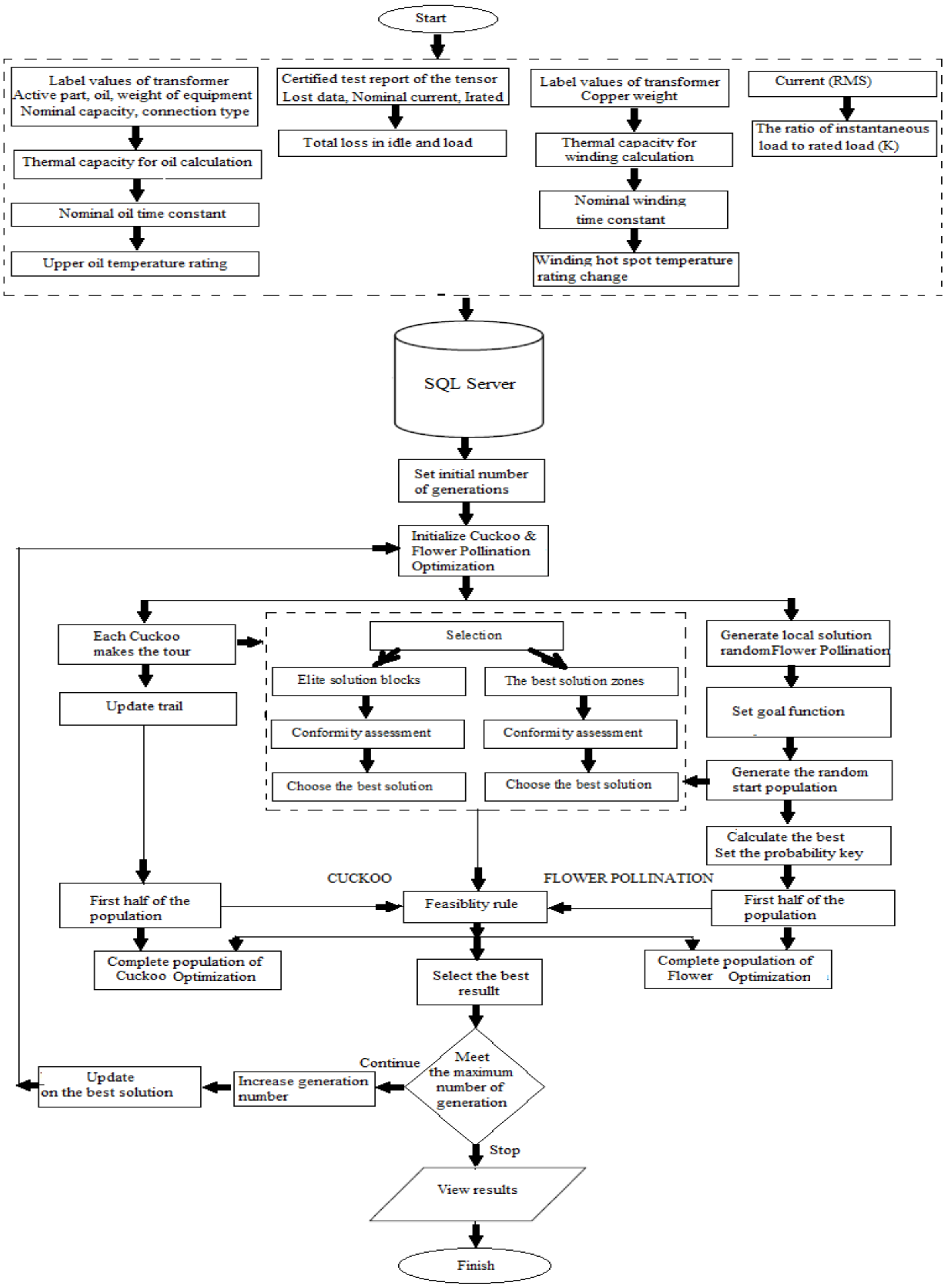

Figure 11. Developed Hybrid Algorithm

This value affects the dimensions of the transformer. The transformer core is thin and long in small values of the iron cross-section conformity factor. The iron core remains thick and flat at the large values of the iron cross-section conformity factor. The iron cross-section conformity factor refers to the amount of energy flowing through the unit area of the iron core. The greater the efficiency of this factor, the greater the efficiency of energy flow. The efficiency of this factor will be low as there will be little energy transition. The primary and secondary conductor cross sections are obtained from current densities and current copper losses are calculated. When the power factor increases, the efficiency of the transformer increases. While the loading is at an optimum point, it is understood that the yield is maximum. Iron and copper losses must be equal to each other in order to ensure maximum efficiency. If the loss of copper, which is variable, is equal to the loss of constant iron at which load rate, the yield will be maximum at that load [41-45].

The algorithm continues until the maximum efficiency parameters of the power transformer are obtained. The algorithm stops when the desired state is achieved. The algorithm has two parallel arms. These, the first branch is flower pollination optimization. The second arm is cuckoo optimization. In the first arm, the objective function is determined. A random start population is generated. The best solution is calculated for the initial population. The probability switch for repeat is determined. The first arm is created in the second arm. Each bird is assigned a random number of eggs. The maximum spawning radius is determined for each bird. Specify the spawning radius of the eggs into the space is released. The eggs recognized by the host birds are destroyed. Chickens are allowed to hatch and grow. The habitat of each growing bird is evaluated. The number of birds that can live in the area is limited. Unwanted areas are destroyed. The best group of birds is identified and the target habitat is selected. New cuckoo population migrates to the target habitat. The optimization is stopped if the required condition is met. If it is not, iterations will continue from the beginning. In the algorithm, two parallel arms are combined below to find the best solution [41-45]. In this study, efficiency optimization in different loading conditions for power transformers was realized with the developed cuckoo and flower pollination hybrid algorithm.

The results obtained with the developed cuckoo and flower pollination hybrid algorithm and the results obtained from the experimental data were compared. It is understood that the results are similar with ± 3% error. This shows that the developed cuckoo and flower pollination hybrid algorithm is an alternative and alternative method for yield optimization. The advantage of this method for designers is to have quick results without having to deal with close-up combinations that are possible to achieve the optimal solution. As the loading rate increased, there was an increase in the yield but this increase did not change after a certain point.

5. The main result

The behaviors of artificial bees, ants, cuckoos, and fireflies have been studied. Ant/Firefly Hybrid Algorithm and Cuckoo/Flower Pollination Hybrid Algorithm have been developed to reach a faster and more accurate solution. Using these hybrid algorithms, interfaces were created in the C++ programming language. By the computer program, errors in the transformer windings were determined. A computer program that determines power transformer failures was created in C++ programming language using the developed bee algorithm. Power transformer efficiency is optimized by using the created cuckoo/flower pollination hybrid algorithm. As can be understood from the data obtained, the error is between ± 1% and 5%. Faults in the power transformer are defined in a short time. Efficiency optimization in different loading conditions for power transformers has been realized with the developed cuckoo and flower pollination hybrid algorithm. This shows that the developed cuckoo and flower pollination hybrid algorithm is an alternative and alternative method for yield optimization. The advantage of this method for designers is to have quick results without having to deal with close-up combinations that are possible to achieve the optimal solution.

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