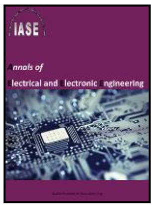
Annals of Electrical and Electronic Engineering, 2(7) 2019, Pages: 7-10

Published by IASE

Annals of Electrical and Electronic Engineering

Journal homepage: www.aeeej.org



Optimization of geometric parameters of power transformer using bee's algorithm

S. Rodríguez *, N. Sánchez, D. Gómez

Faculty of Engineering and Design and Innovation, Politécnico Grancolombiano, Bogotá, Colombia

A R T I C L E I N F O

Article history:
Received 20 February 2019
Received in revised form
6 June 2019
Accepted 11 June 2019

Keywords:
Bee's algorithm
Transformer
Convergence
Optimization
Geometric

A B S T R A C T

In the last decades, nature-based optimization algorithms had many applications in many areas such as nonlinear problem solution, optimization problems, power device placement, control applications, and other cases. In each optimization algorithm, two features are important. The first one is an exploration feature and the second one is an extraction feature. Bee's algorithm is one of the most effective and powerful nature-based optimization algorithms that has introduced in recent years. In this paper, we proposed the application of bee's algorithm to the optimal design of three-phase power transformers. The three-phase power transformers have a vital role in power networks. In the proposed method, geometric parameters of three-phase power transformers have been optimized by the bee's algorithm. The finding of the relation between the geometric parameters and transformer formulation is the main step in the proposed method. More details about the proposed method are described in the body of the paper. For simulating the proposed method, MATLAB software is used. Simulation results show that the proposed optimization technique has excellent performance.

1. Introduction

The new power networks are very complicated systems and have many sections. This system has many generators, distributed generators, power transformers, rectifiers, synchronous motors, compensators, nonlinear loads and other many devices. In this nonlinear and complicated system, the value of power loss is very high. In last decades, researchers attempt to reduce the amount of power loss. One of the most popular and efficient of these techniques is FACTS devices. These devices have good features in power loss reduction and reactive power management. But these devices need to accurate controller. In most cases, the design of proper controller for these devices is very hard problem. Also the application of these devices have high financial load. Therefore in application of these devices, all aspects must be considered (Sreejith et al., 2015; Esmaili et al., 2014; Srithorn and Theejanthuek, 2014). The other technique for power loss reduction is capacitor placement. Similar to FACTS devices, the application of compensate capacitors have financial load. Therefore all aspects in usage of this technique must be carefully considered (Raju et al., 2012; El-Fergany and Abdelaziz, 2014a; 2014b; Shuaib et al., 2015; Aman et al., 2014).

Newly some techniques have been proposed that have no financial loads. One of these methods is power network reconfiguration. In last decade, many researchers studied about this issue (Souza et al., 2015; Zhang et al., 2014; Henriquez and Barrero-Gil, 2014; Prasad et al., 2005). The other methods are optimal design of power network devices, such as generators, transformers and motors. In this study the optimal design of three phase transformers in power networks is investigated. In the propose method, the geometric parameters of three phase transformers is considered as optimization variables. The studied problem is multi objective optimization problem that has many terms and limits.

The three phase transformer is power tool that can change the level of voltage from one value to other value. The three phase transformer has some types. But in all of types of three phase transformer, the voltage is reduced or enhanced from one level to other level. The three phase transformer has big core that is the main section. The three phase transformer is work on electromagnetic induction rule. By varying the voltage level, the current level changed. The changes in current value induce magnetic flux transformer magnetic circuit. This induced magnetic flux; create voltage in secondary circuit in transformer.

In last decade some nature based optimization algorithms such as genetic algorithm, artificial bee colony algorithm, ant colony algorithm, simulated annealing, bee's algorithm, honey bee mating algorithm, imperialist competitive algorithm, particle swarm optimization algorithm and its modified versions are emerged. These nature based optimization algorithms are very effective and powerful tool to solve the nonlinear and complicated optimization problems (Mernik et al., 2015; Maeda and Tsuda, 2015; Mansouri et al., 2015; Yu et al., 2015; Gopalakrishnan and Kosanovic, 2015; Chen et al., 2015). In this paper the application of bee's algorithm is proposed to optimal design of three phase power transformers. In the proposed method, the power loss of three phase power transformers is reduced. Also the other aspects of the optimal design such as volume, thermal conditions and cost of building are considered simultaneously. Therefore the investigate optimization problem is multi objective optimization problem. More details regarding the transformers and optimization algorithm is described in next sections.

2. Optimization algorithm

The flowchart of bee's algorithm is shown in Fig. 1. This algorithm is inspired from honey bee manner. The honey bee is

* *Corresponding Author.*
Email Address: rodriguezs@gmx.us *(S. Rodríguez)*
https://doi.org/10.21833/AEEE.2019.07.002

looking for food in nature with special way. In this process, some bee's fly to different areas of nature. These bee's select the best areas that have high amount of honey. From these areas, some have better and higher amount of honey. The related bees are known as elite bees. The elite bees are candidate to local search. This section is illustrated in Fig. 1.

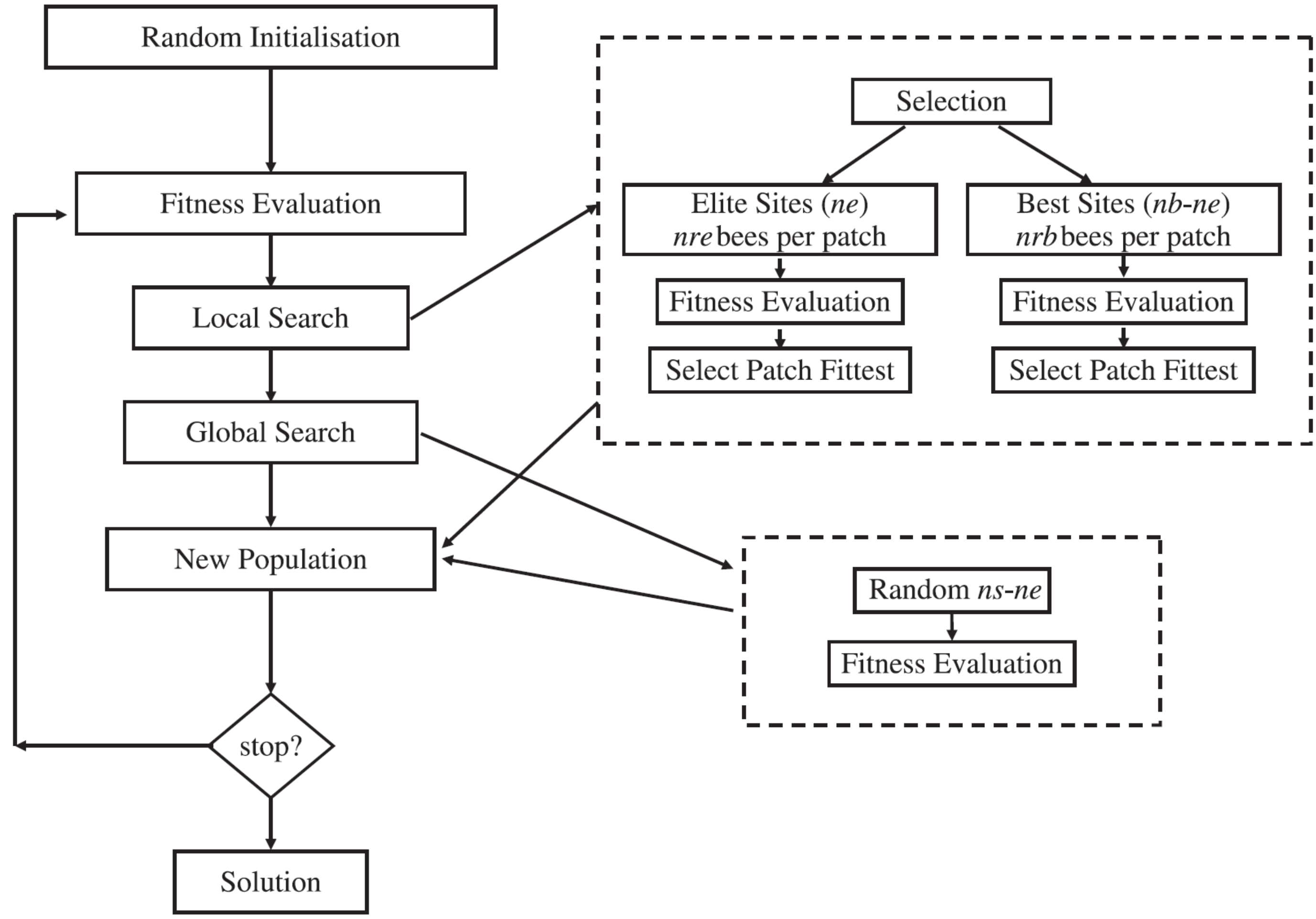


Fig. 1. The flowchart of bee's algorithm (Pham and Castellani, 2009).

The remaining bees are known as global search bees. These remaining bees eliminated and reproduced randomly in search space. In the initial step of bee's algorithm, the boundaries of optimization must be defined. The elite bees and remaining bees must be move in this predetermined boundary. Each elite bee has its soldier bees. These soldier bees aid the elite bee to search the local area.

As mentioned, each optimization algorithm must have to vital features. One of them is exploration feature. This feature aims the optimization algorithm to search all points of search area. In the bee's algorithm, global search bees perform this step. With random producing of these bees, bee's algorithm avoid from trapping in local minima. Some other nature based optimization algorithm such as particle swarm optimization algorithm, imperialist competitive algorithm, artificial bee colony and ant colony optimization algorithm don't have this vital feature. Therefore the mentioned algorithms may trap in local minima.

The extraction feature is the second vital feature in each optimization algorithm. This feature assigns to find the final global answer from the found best area. This feature is satisfied by local search in bee's algorithm. It can be seen that, in the bee's algorithm some soldier bees aim to elite bees to search the best areas. This feature cause to fast convergence speed. Almost all nature based optimization algorithms have this feature. The more details and applications of bee's algorithm can be found in (Castellani et al., 2012; Ruz and Goles, 2013; Kavousi et al., 2011; Pham et al., 2009).

The main steps of bee's algorithm are described as follow:

Step 1) Initialize bee's algorithm parameters, such as boundaries, number of elite bees and other parameters.
Step 2) Produce the initial random population.
Step 3) Evaluate the fitness function for initial random population.
Step 4) Choose the elite bees.
Step 5) Perform the local search by soldier bees.
Step 6) Perform the global search by remaining bees.
Step 7) Check the stop condition. If the stop condition satisfied, go to next step, otherwise go to step 3.
Step 8) the end.

3. Transformer

In the operation of transformer, three main parameters are available that are V_1, V_2 and f. These parameters are selected by user and are related to application. In some cases we used increasing transformers and in some cases we use decreasing transformers. These parameters are selected based on needed power S. In transformers some power loss are available that must be considered and reduced. These power losses are P_{cu} and P_{NL}. In this study a nonlinear schematic of transformer is investigated. The three phase power transformer design parameters are listed in Table 1. In this table the boundaries for each design parameters are determined. Also in Table 2 the terms of optimization problem are listed.

The above mentioned parameters affect the efficiency, power loss, cost and temperature of transformer. The main objective function in this paper is the cost of three phase transformer. But simultaneously other aspects of three phase transformer such as power loss and volume are optimized.

Table 1
Optimization parameters.

Row	Parameters definition	Boundary
1	The value of flux density	[1.5, 1.8]
2	The value of density for current (high voltage)	[3.1, 3.7]
3	The value of density for current (low voltage)	[2.55, 3.33]
4	The value of height in winding	[2.77, 3.55]
5	The magnitude of voltage in each loop	[102, 121]
6	The value of distance in core	[0.81, 1.22]

Table 2
Term of optimization problem.

Row	Limit definition	Terms
1	The amplitude of temperature in winding section	<57.5
2	The amplitude of temperature in oil of transformer oil bank	<49.5
3	The value of current in no load condition	<2.51
4	The value of impedance in no load condition	<11.9
5	The ideal efficiency	>99.1
6	Clearance in each loop	<0.11

The selected objective function is obtained from primary price and core materials. Also the price of winding must be added to this objective function. The following equation shows the objective function:

$$Fitness = w_1 G_i + w_2 G_c + w_3 P_c + w_4 G_i \quad (1)$$

The sample bee is as follows. The target of the optimization algorithm is to find the best parameters that minimize the fitness function.

$$Sample\ bee = [X_1\ X_2\ X_3\ X_4\ X_5\ X_6]$$

4. Simulation results

In this section, the performance of the proposed intelligent technique is evaluated. For this purpose we used one real standard power system and one three phase power transformer. The characters of three phase power transformer are listed in Table 3.

Table 3
The characters of three phase power transformer.

S	65 MVA
Voltage	$33KV/715V$
Frequency	50 Hz
Type	Δ/Y

In each optimization algorithm, the control parameters have high effect on its performance. In bee's algorithm, the number of total bee's, elite bees, soldier bee's and max iteration have vital role in bee's algorithm accuracy and convergence speed. Therefore these parameters must be selected carefully. In this paper, these parameters are chosen based on vast experiments and simulations. For example, the high number of iterations led to better search in search space. But this good search cause to time loss. The high number of elite bees led to good local search, but in contrast led to low global search. For this purpose, the selection of these control parameters must be done cleverly. In Table 4, the selected control parameters are listed.

Table 4
The control parameters of bee's algorithm.

Number of bees	40
Number of elite bees	10
Number of soldier bees	6
Number of iterations	500

In the proposed method, bee's algorithm is proposed to find the optimum parameters of three phase power transformer. The number of optimization parameters is six. The investigated problem is highly nonlinear and there is no linear relation between geometric parameters and objective function. Base on the vast simulations and experiment, we found that the local search is very vital in this optimization problem. For this purpose, we choose the number of elite bees high. In Table 5, the obtained optimum parameters are listed. These optimum parameters are found base on Table 4 control parameters. Also the value of constraints is listed in Table 6. By the obtained optimum parameters in Table 5, the value of objective function is 3.5276×10^6.

Table 5
Optimum parameters.

Parameter	Optimum value
The value of flux density	1.6821
The value of density for current (high voltage)	3.4201
The value of density for current (low voltage)	2.503
The value of height in winding	3.3461
The magnitude of voltage in each loop	111.104
The value of distance in core	1.2043

Table 6
Term of optimization problem.

Limit definition	Terms
The amplitude of temperature in winding section	55.4310
The amplitude of temperature in oil of transformer oil bank	42.6357
The value of current in no load condition	2.0941
The value of impedance in no load condition	11.4205
The ideal efficiency	99.046
Clearance in each loop	0.08304

In Fig. 2, the effect of number of iterations is illustrated. It can be seen that after 500 iterations, there is no improvement in fitness function. Therefore we choose this value for maximum number of iterations.

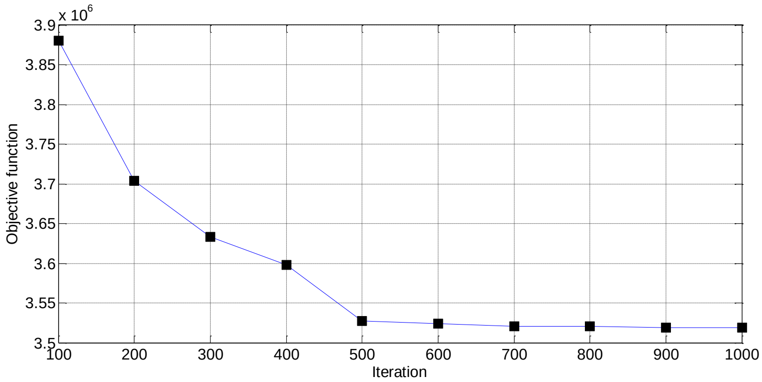


Fig. 2. Investigation of maximum number of iterations.

In order to compare the performance of proposed method, with other optimization algorithms, we used honey bee mating optimization algorithms, artificial bee colony, and ant colony algorithm and simulated annealing algorithms. The obtained results are listed in Table 7. It can be seen that bee's algorithm has much better performance rather than other nature based optimization algorithms.

Table 7
Comparison of optimization algorithm.

Algorithm	Objective function
honey bee mating optimization algorithms	3.5530×10^6
artificial bee colony	3.5753×10^6
ant colony algorithm	3.5310×10^6
simulated annealing algorithm	3.5603×10^6
bee's algorithm	$\mathbf{3.5276 \times 10^6}$

5. Conclusion

In this paper, application of nature based optimization algorithms is investigated. Based on published papers, we used bee's algorithm as optimization algorithm. This type of optimization algorithm has good exploration and extraction capability. The Obtained results show that bee's algorithm can find the optimum parameters of three phase transformer geometric parameters. Also based on simulation results it can be seen that bee's algorithm has better performance rather than other nature based optimization algorithms.

References

Aman MM, Jasmon GB, Bakar AHA, Mokhlis H, and Karimi M (2014). Optimum shunt capacitor placement in distribution system—A review and comparative study. Renewable and Sustainable Energy Reviews, 30: 429-439. https://doi.org/10.1016/j.rser.2013.10.002

Castellani M, Pham QT, and Pham DT (2012). Dynamic optimisation by a modified bees algorithm. Proceedings of the Institution of Mechanical Engineers, Part I: Journal of Systems and Control Engineering, 226(7): 956-971. https://doi.org/10.1177/0959651812443462

Chen CH, Liu TK, Chou JH, Tasi CH, and Wang H (2015). Optimization of teacher volunteer transferring problems using greedy genetic algorithms. Expert Systems with Applications, 42(1): 668-678. https://doi.org/10.1016/j.eswa.2014.08.020

El-Fergany AA and Abdelaziz AY (2014a). Capacitor placement for net saving maximization and system stability enhancement in distribution networks using artificial bee colony-based approach. International Journal of Electrical Power and Energy Systems, 54: 235-243. https://doi.org/10.1016/j.ijepes.2013.07.015

El-Fergany AA and Abdelaziz AY (2014b). Multi-objective capacitor allocations in distribution networks using artificial bee colony algorithm. Journal of Electrical Engineering and Technology, 9(2): 441-451. https://doi.org/10.5370/JEET.2014.9.2.441

Esmaili M, Shayanfar HA, and Moslemi R (2014). Locating series FACTS devices for multi-objective congestion management improving voltage and transient stability. European Journal of Operational Research, 236(2): 763-773. https://doi.org/10.1016/j.ejor.2014.01.017

Gopalakrishnan H and Kosanovic D (2015). Operational planning of combined heat and power plants through genetic algorithms for mixed 0–1 nonlinear programming. Computers and Operations Research, 56: 51-67. https://doi.org/10.1016/j.cor.2014.11.001

Henriquez S and Barrero-Gil A (2014). Reconfiguration of flexible plates in sheared flow. Mechanics Research Communications, 62: 1-4. https://doi.org/10.1016/j.mechrescom.2014.08.001

Kavousi A, Vahidi B, Salehi R, Bakhshizadeh MK, Farokhnia N, and Fathi SH (2011). Application of the bee algorithm for selective harmonic elimination strategy in multilevel inverters. IEEE Transactions on power electronics, 27(4): 1689-1696. https://doi.org/10.1109/TPEL.2011.2166124

Maeda M and Tsuda S (2015). Reduction of artificial bee colony algorithm for global optimization. Neurocomputing, 148: 70-74. https://doi.org/10.1016/j.neucom.2012.06.066

Mansouri P, Asady B, and Gupta N (2015). The bisection–artificial bee colony algorithm to solve fixed point problems. Applied Soft Computing, 26: 143-148. https://doi.org/10.1016/j.asoc.2014.09.001

Mernik M, Liu SH, Karaboga D, and Črepinšek M (2015). On clarifying misconceptions when comparing variants of the artificial bee colony algorithm by offering a new implementation. Information Sciences, 291: 115-127. https://doi.org/10.1016/j.ins.2014.08.040

Pham DT and Castellani M (2009). The bees algorithm: Modelling foraging behaviour to solve continuous optimization problems. Proceedings of the Institution of Mechanical Engineers, Part C: Journal of Mechanical Engineering Science, 223(12): 2919–2938. https://doi.org/10.1243/09544062JMES1494

Pham DT, Haj Darwish A, and Eldukhri EE. (2009). Optimisation of a fuzzy logic controller using the bees algorithm. International Journal of Computer Aided Engineering and Technology, 1(2): 250-264. https://doi.org/10.1504/IJCAET.2009.022790

Prasad K, Ranjan R, Sahoo NC, and Chaturvedi A (2005). Optimal reconfiguration of radial distribution systems using a fuzzy mutated genetic algorithm. IEEE Transactions on Power Delivery, 20(2): 1211-1213. https://doi.org/10.1109/TPWRD.2005.844245

Raju MR, Murthy KR, and Ravindra K (2012). Direct search algorithm for capacitive compensation in radial distribution systems. International Journal of Electrical Power and Energy Systems, 42(1): 24-30. https://doi.org/10.1016/j.ijepes.2012.03.006

Ruz GA and Goles E (2013). Learning gene regulatory networks using the bees algorithm. Neural Computing and Applications, 22(1): 63-70. https://doi.org/10.1007/s00521-011-0750-z

Shuaib YM, Kalavathi MS, and Rajan CCA (2015). Optimal capacitor placement in radial distribution system using gravitational search algorithm. International Journal of Electrical Power and Energy Systems, 64: 384-397. https://doi.org/10.1016/j.ijepes.2014.07.041

Souza SS, Romero R, and Franco JF (2015). Artificial immune networks Copt-aiNet and Opt-aiNet applied to the reconfiguration problem of radial electrical distribution systems. Electric Power Systems Research, 119: 304-312. https://doi.org/10.1016/j.epsr.2014.10.012

Sreejith S, Simon SP, and Selvan MP (2015). Analysis of FACTS devices on security constrained unit commitment problem. International Journal of Electrical Power and Energy Systems, 66: 280-293. https://doi.org/10.1016/j.ijepes.2014.10.049

Srithorn P and Theejanthuek N (2014). The enhanced performance SVC for transient instability oscillation damping. Energy Procedia, 56, 510-517. https://doi.org/10.1016/j.egypro.2014.07.186

Yu W, L, B, Jia H, Zhang M, and Wang D (2015). Application of multi-objective genetic algorithm to optimize energy efficiency and thermal comfort in building design. Energy and Buildings, 88: 135-143. https://doi.org/10.1016/j.enbuild.2014.11.063

Zhang P, Kawaguchi KI, and Feng J (2014). Prismatic tensegrity structures with additional cables: Integral symmetric states of self-stress and cable-controlled reconfiguration procedure. International Journal of Solids and Structures, 51(25-26): 4294-4306. https://doi.org/10.1016/j.ijsolstr.2014.08.014