INTERNATIONAL CONFERENCE ON SCIENCE AND ENGINEERING
1st December 2015 DUBAI - UAE
کنفرانس بین المللی علوم و مهندسی
۱۰ آذرماه ۱۳۹٤ دبی - امارات

Reconfiguration of Distribution Systems for Losses Reducing using Optimal Artificial Bee Colony (OABC) Algorithm

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Abstract

Nowadays, losses reduction in distribution systems is important for utilities. To reach this aim, there are different ways as distribution network reconfiguration is one of the lowest-cost of them. In this paper, this method by optimal artificial bee colony algorithm to optimize the losses of distribution systems is used. For convenience, Comprehensive software is provided and standard distribution systems with 99 and 07 buses have been tested. The results compared with the previous works and proved optimization of the purposed algorithm.

Keywords: reconfiguration, distribution network, optimal artificial bee colony (OABC) algorithm, losses reduction.

Introduction

Distribution systems are constantly exposed to various errors. Some of these errors are: short-circuit in feeders, overload on transformers, natural factors disrupting network stable balance and unbalanced loads. Each of these errors cause an additional losses and cost in the network. For example, when a substation overload is intolerable for transformer, this bus is getting out of the circuit and the power of several customers will be off. Furthermore, additional losses due to the this overload should be considered. To avoid these unexpected situations, different ways were discovered and implemented. In general, these methods are: the capacitor placement on transformers, raise the voltage level of the network, balanced and unbalanced load management, network modernization, replacement of old equipment such as transformers with high life and low efficiency, and small renewable power plants to compensate for the overload losses. In (Masoum et al, 4772) capacitor placement is used to improve the power quality in the presence voltage and current harmonic. Reference (Xu et al, 4709) investigated capacitor placement in distribution transformers and calculated the economic benefit. The size of the capacitors in the placement problem is also particularly important (Baran and Wu, 0393). Placement of capacitors to reduce losses by various methods has been done in (Gallego et al, 4770)– (Sarma and Rafi, 4700). Locate problem of capacitor with respect to a fixed load model is solved in (Mohammadi et al, 4709). Notice to parameters such as an unbalanced system is effective in optimal of capacitor placement final response (Jeihouni et al, 4704). In (Singh and Rao, 4704), the location and size of capacitor were recognized by particles swarm optimization (PSO) algorithm.

The use of small renewable power plants or distributed generation (DG) like wind, solar and hot water power helps to reduce losses and increase network reliability. In (Seker and Hocaoglu, 4709), placement and size of the plants with artificial bee colony algorithm (ABC) is determined. Network optimization with the same time presence distributed generation and capacitor banks with considering to the variable of load by the firefly worm algorithm was carried out in (Shayeghi and Alilou, 4709), and the financial benefit of this work is calculated. References (Dahalan and Mokhlis, 4704) and (Rao et al, 4709) were mixed DG and distribution systems reconfiguration and multiple objective function was solved by PSO and harmony search (HA) algorithms, respectively.

All reviewed procedures have a specific cost where after several year, this cost will be zero. The utilities are always looking for the best solution with possible cost lowest. Currently, the best way to satisfy the demands of the utilities can be distribution networks reconfiguration. This method for execution does not need to install any Extra equipment, which is to attract attention researchers and especially managers of utilities. In (Braz and Souza, 4700), the distribution network was be coding and genetic algorithm (GA) has changed the structure of the system. References (Baran and Wu, 0393) and (Rao and Sivanagaraju, 4707) say that reconfiguration of distribution network is necessary to reduce losses and loads balancing. Network reconfiguration is effective in losses distribution on feeders (Savier and Das, 4770). Using of reliability indices and distribution network reconfiguration based on these indices, creates an objective function that has been investigated in (Paterakis et al, 4702). reconfiguration also includes two-step to load respond: initial network configuration and searching for the best load flow without having knowledge of the load kinds (Lee et al, 4702). Many algorithms can be used to change the structure of distribution networks where in (Mendes et al, 4709)-(Ra et al, 4709) have been studied. In (MuthuKumar and Thanushkodi, 4709) reconfiguration and capacitor placement has been introduced as two important techniques to reduce losses, control voltage profile and increase the reliability and protection. reconfiguration of the distribution networks by ABC algorithm to reduce losses and improve voltage profile is done in (Rao et al, 4779).

The remainder of the paper is organized as follows: In Section II the problem of the distribution network reconfiguration is described. The optimal artificial bee colony (OABC) algorithm is introduced and shown in Section III. In Section IV the reconfiguration of the electricity distribution network is described with proposed. Section V, shows simulation results on 4 examples by designed software and compares these with previous methods results. Section VI is the conclusion.

Reconfiguration of the Distribution Networks

Electrical distribution systems for protection and reliability issues, are produced as circular (screening) and operated in the radial form. In a radial network, there is no loop in the network graph. Therefore, the number of feeders is less one than number of buses. When a bus (or transformer substation) for various reasons, such as overload or transformer failure is disconnected, only the connected loads to this bus, but if this bus is in the course of the next buses circuit, the all of connected loads after this bus will get out of circuit. To solve the problem of overload, the system arrangement should be such that there will be no switched off substation. Rearrangement of power distribution networks, including network reconfiguration so that desired network loads spread between all bus and prevent from feeders current overflow. Limiting terms for reconfiguration,

compliance with the maximum and minimum voltage and the feeders tolerated maximum current (Bahrami et al, 4709), (Rao et al, 4779). In current distribution between the feeders, the network active losses also spread (Savier and Das, 4770) and the best structure is obtained when the losses is possible lowest, according to the method (Rao et al, 4709).
In this paper, the OABC algorithm is used for reconfiguration of electricity distribution networks and achieve the objectives of reducing losses, improving voltage profile and reduce the lines current are created a multi-purpose function. Therefore, with an appropriate and optimal reconfiguration will show that not only the active network losses is reduced, but also as end buses voltage as the voltage drop has increased, and the feeders current are away from the maximum amount.

Optimal Artificial Bee Colony (OABC) Algorithm
Optimize system controllability with mathematical functions, they are always done with different methods. These methods can be included mathematical algorithms (Xu et al, 4709)-(Gallego et al, 4770), (Ng et al, 4777), (Savier and Das, 4770)- (Lee et al, 4702), (Zehra et al, 4707), and (Dolatdar et al, 4773) or taken advantage of Nature (Masoum et al, 4772), (Sarma and Rafi, 4700)- (Braz and Souza, 4700), (Rao and Sivanagaraju, 4707), (Mendes et al, 4709)- (Arandian et al, 4709), (Bahrami et al, 4709), (Ra et al, 4709) and (Rao et al, 4779), or a combination of both (Das, 4779), (Baran and Wu, 0393) and (MuthuKumar and Thanushkodi, 4709). In the inspiration of nature, collective living of animals has particular importance. Birds, ants and bees are such animals that live in group and use collective intelligence to find food. Bees to find food sources used by several indices. The indices are: categorize bees into three groups of employed bees, onlooker bees, and scout bees, rating the quality of food, and distance and range of food sources from the hive with identified quality. To achieve a food source with good quality, all of the stages of a cycle should run by the bees. If the one food by the appropriate employed bee, onlooker bee go to food source to prepare it and finally, scout bee check and reports the quality of all foods of a garden. The number of worker bees and onlooker bees are same, and the parameter space research as a food source (Rao et al, 4779). Quick search due to populous bees is possible, and makes the final answer is obtained in the minimum time.
In this paper, the proper change on probability functions in onlooker bees step, make a stringent selection for observer bees. Thus, final selection in this algorithm is much more efficient selection than selection of the optimal solution would be in a typical ABC algorithm. For claim proof, distribution systems in (Rao et al, 4779) is simulated with the proposed algorithm and the results were compared.

Distribution Networks Reconfiguration with OABC Algorithm
Adjustment of reconfiguration in distribution network with proposed algorithm in this paper to find the best solution consists of several steps. In resumption, introduce and explain each of these steps.

Initial Load-Flow and Produce Food Sources Matrix
In first step, with doing a load flow for the primary structure, feeders current and buses voltages to store as a reference for comparison are obtained. At this stage, no structural change is not carried out by the algorithm.
Then, the algorithm make some food sources as proposed initial structures randomly, and keeps the value of existing food sources using the fitness function. The resulting structures generated from turning off a on feeder of a network graph basic circle, which was created by the corresponding off feeder, and turning on the off feeder and repeat this process number of the all off lines randomly. In the creation of distribution networks with different structures, radial condition is also applied to the network graph don't be in the form of separate and circular. The fitness function for the entire network losses is defined as (0).

$$fit_i = \frac{1}{1 + ploss_i} \tag{0}$$

where fit_i is the total loss fitness value for structure i and $ploss_i$ is value of all loss power.

Employed Bees Step
Employed bees at this stage receive to calculated nutritional value of each food. In one cycle, foods be optimized by employed bees once. If a new optimal structure has more fit value than the initial structure, this structure is optimized by neighbor search technique and stored as the best answer. In neighbor search method, each employed bee goes to the food sources as are in the neighborhood of a main food source with particular. Once again, the nutritional value of this food compared with neighbor food to check if its nutritional value is more,

intended structure replaces the original structure. How to obtain a food matrix in the neighborhood of the i[th] food is as follows.

$$v_{i,j} = x_{i,j} + s.(\mathrm{x}_{i,j} - \mathrm{x}_{i,k}) \tag{4}$$

where $v_{i,j}$ is the network structure matrix in the neighborhood of the main structure $x_{i,j}$, s is a real number in the range of [-0, 0], i is optimized structure number, and j and k is the random indexes of rows and columns from matrix of all network structures, respectively that are defined by the following equations.

$$j = fix(rand.D) + 1 \tag{9}$$
$$k = fix(rand.FN) + 1 \tag{2}$$

where *rand* is a real number in the interval [7,0]. D is number of parameters, i.e. network feeders, and FN is number of guessed foods, and both numbers are fixed. Employed bees also calculate the probability of optimal food sources and deliver to observer bees. The used probability function in this article has been changed and obtains from (2).

$$\mathrm{p}_i = (0.9 * \frac{fit_i}{\mathrm{fit}_{\max}}) + 0.1 \tag{2}$$

where fit_{max} is the greatest fitness among the fitness of food resources.

Onlooker Bees Step

At this step, observer bees received the probability of food sources of and employed bees, this time based on maximum probability for a food source, optimization will be done. Improving steps for the food sources follows the pattern described in step employed bees. Equations (4)-(2) is also true for this step. After renewed optimization by observer bees, the best response is obtained in one cycle and currents and voltages are calculated from load flow. Now, approach scout bee step examines the boundary conditions for the desired response.

Scout Bee Step

Finally in the scout bee step, this bee checks ranges and boundary conditions to make sure the food source by observer bees is presented from the boundaries issue, i.e. maximum and minimum of voltage and maximum of current boundaries, are allowed out or are in admissible confine. If the boundary conditions are observed, the next cycle continues and otherwise food source is spoiled and unacceptable. All of these steps are done during a cycle. Also in scout bee step, the search limit is defined as when a food source is too optimized and optimal response is not received, this food has been removed from the list of food sources and a new food is replaced in the matrix.

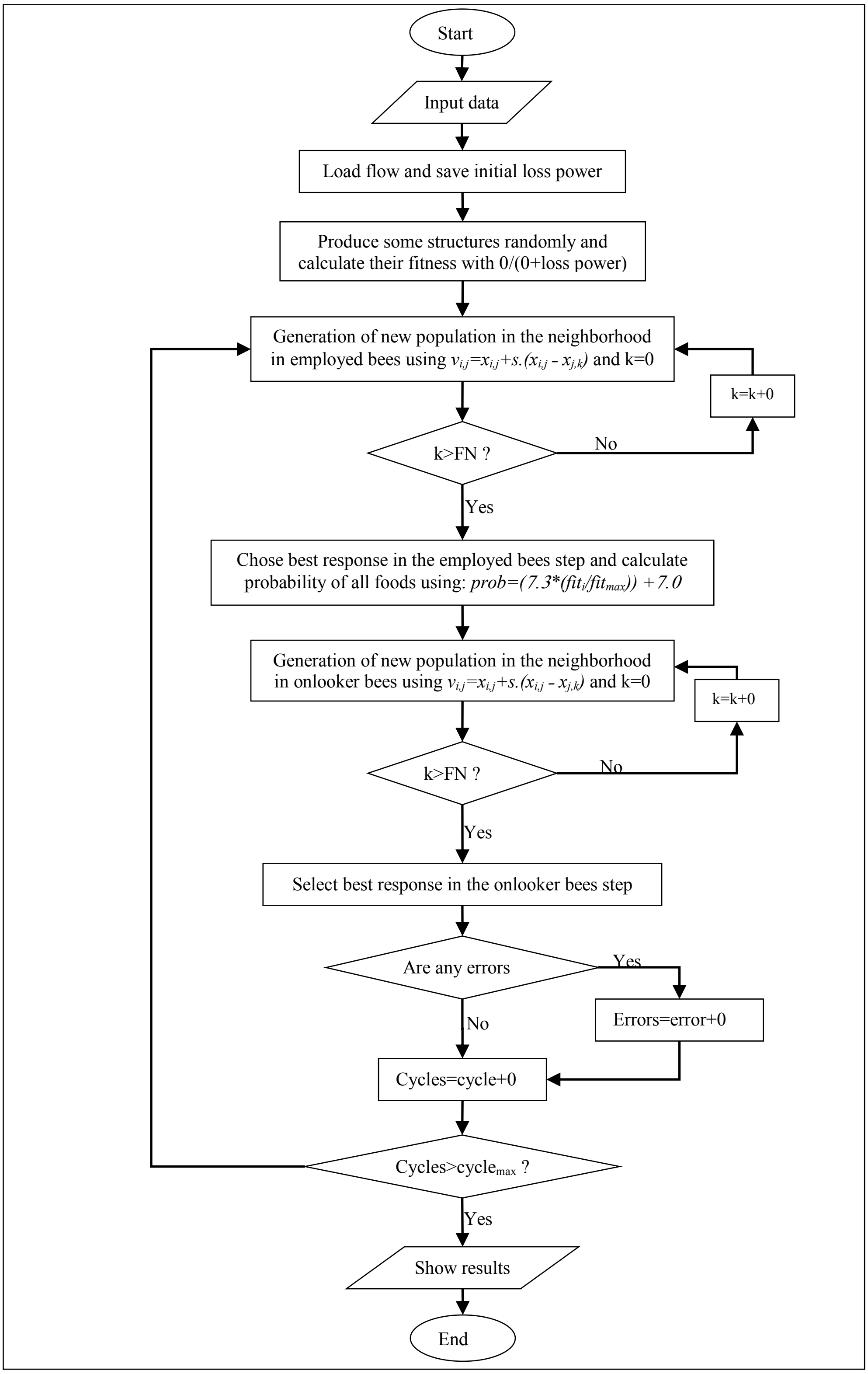

Fig. 1. Flow–Chart for Reconfiguration with OABC Algorithm

Every algorithm running consists of several cycles, and after all cycles, a final answer for this test is obtained. All runs have an optimum solution and finally the best answer among their, i.e. lowest active power loss, is selected and the corresponding network structure is introduced. The flow chart of the proposed method is shown in “Fig. 0”.To show that proposed algorithm is optimal and its performance for multiple object functions, 4 examples of standard distribution systems are discussed and power losses, feeders current and buses voltage will be calculated.

Results of the Simulations

In order to prove the validity of the proposed algorithm in this paper, its effect in reducing losses and improving voltage and current profiles, this way are simulated and implemented on two examples of IEEE standard networking from references. As well as, for user comfort, DLAB software designed and built in MATLAB programming environment. The advantages of this software can be noted such as: easily work with it, its top speed for emergencies and in accordance with all computer operating systems. In this software, the intended distribution network data is in EXCEL format and the his output including display buses voltage and lines current before and after optimization, primary and secondary active losses, the percentage of losses reducing and the issue of open feeders after optimization.

33-Bus Distribution System

Power Distribution System with 99 buses, 94 on feeders, 2 off feeders and voltage level equal to 04.11 kV as single line is shown in “Fig. 4”. Buses loads information and specifications of feeders are available in (Dolatdar et al, 4773). The initial total losses power of network is 472.91 kW and minimum voltage on the bus 09 as 7.329 p.u. The results of simulations for the reconfiguration of this network are compared to algorithms MILP (Paterakis et al, 4702), MSFLA (Arandian et al, 4709), NHA (Dolatdar et al, 4773), and the ABC (Rao et al, 4779) In “Table 0”.

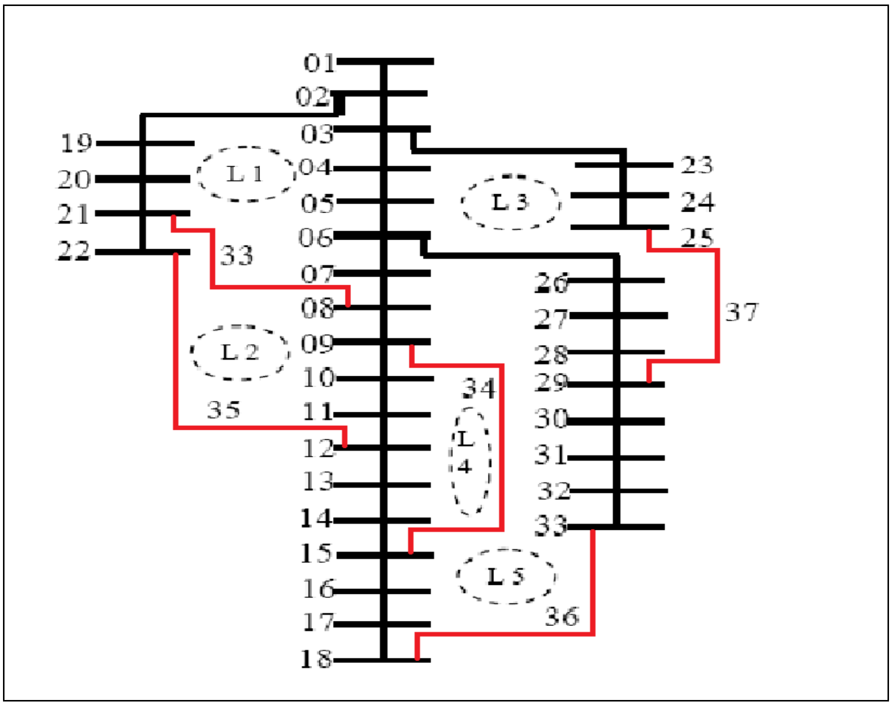

Fig. 2. Single Line Diagram of 33-Bus System

Nodes voltage and the lines current before and after optimization with OABC algorithm by software are shown in “Fig. 9”and “Fig. 2”, respectively. By comparing the results of the proposed method and previous methods can see that the electricity distribution network optimization with proposed algorithms will be more economical than others.

TABLE I. Simulation Results for 33-Bus Network

	Tie switches	Loss power (kw)	Power Loss reduction (%)	Min. Node voltage)p.u(
Initial	9-40, 3-02, 04-44, 09-99, 42-43	472.91	---	7.3290 (node 09)

	Tie switches	Loss power (kw)	Power Loss reduction (%)	Min. Node voltage)p.u(
OABC	0-9, 02-02, 07-00, 94-99, 49-43	043.044	91.9	7.3029 (node 99)
ABC	9-40, 02-02, 9-3, 94-99, 49-43	091.72	99.24	7.3000 (node 99)
MILP	0-9, 3-07, 02-02, 94-99, 42-43	091.22	99.09	7.3010 (node 99)
NHA	0-9, 3-07, 40-44, 1-41, 09-99	020.14	44.90	7.3113 (node 44)
MSFLA	0-9, 3-07, 02-02, 94-99, 42-43	091.22	99.09	7.3010 (node 99)

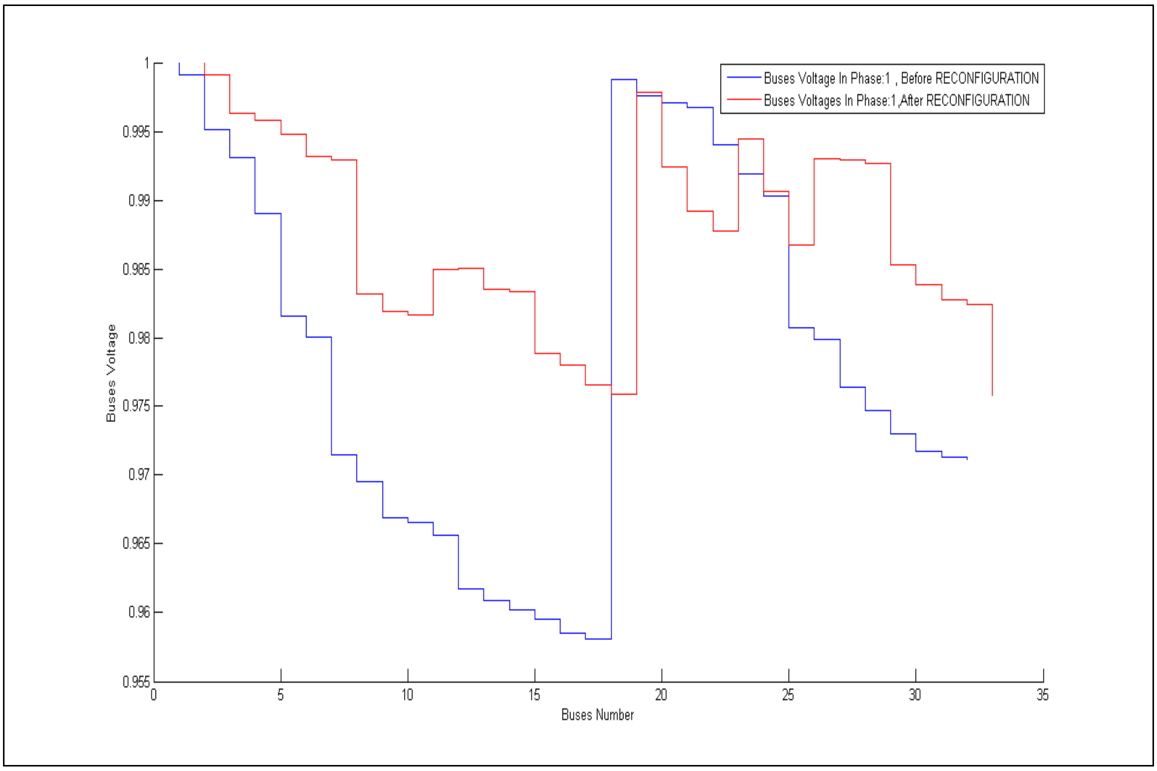

Fig. 3. Bus Voltage Before and After Optimization for 33-Bus System

07-Bus Distribution System

The second tested network has 07 buses. This network has 19 on feeders, 2 off feeder and voltage level is 04.11 kV. Loads and lines impedance data are available on (Ra et al, 4709). Primary losses power is 2.14 kW and minimum bus voltage is on node No. 22. The single phase figure of this network is represented in “Fig. 2”. Comparison the obtained secondary losses power after optimization by the proposed method and ANN-GA (Savier and Das, 4770) algorithm is done in “Table 4” has been conducted to prove the correctness of algorithms with more confidence. Buses voltage and feeders current before and after optimization are shown in “Fig. 1”and “Fig. 0”, respectively.

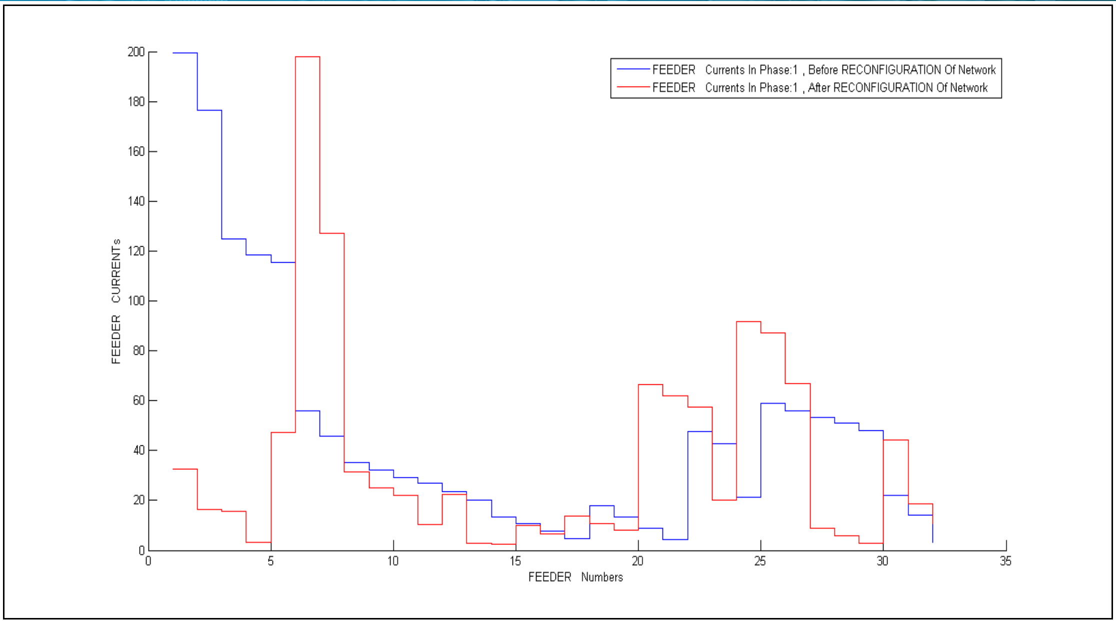

Fig. 4. **Feeders Current Before and After Optimization for 33-Bus System**

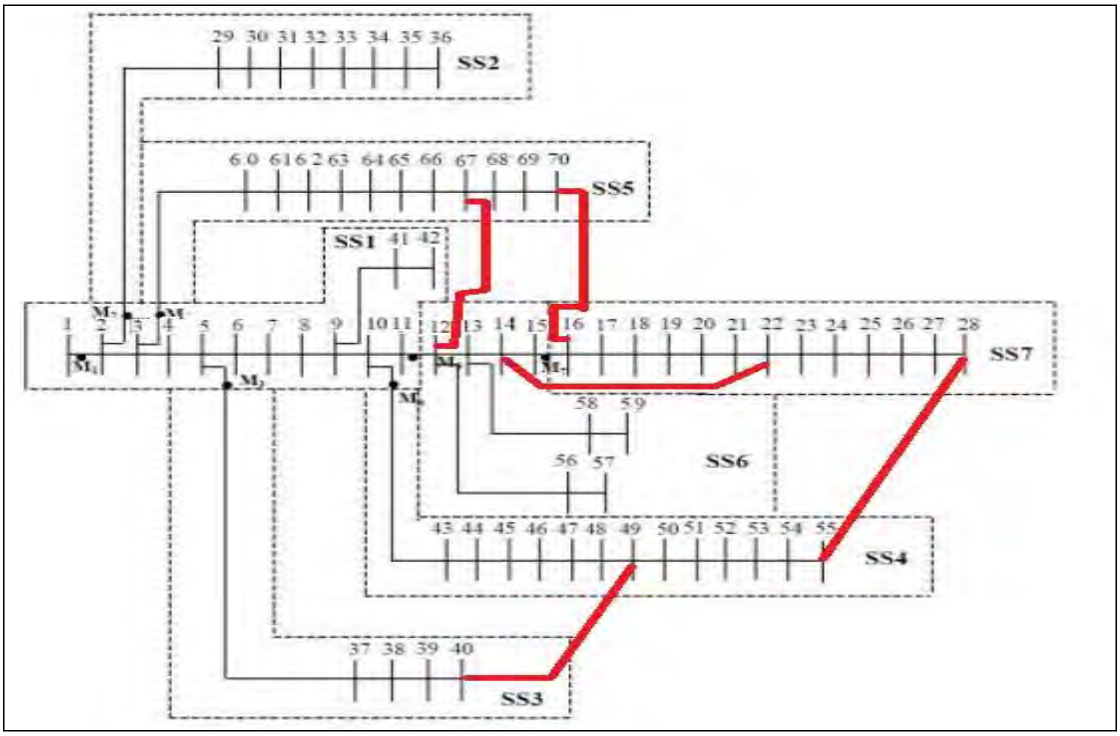

Fig. 5. **Single Phase System with 96 Buses**

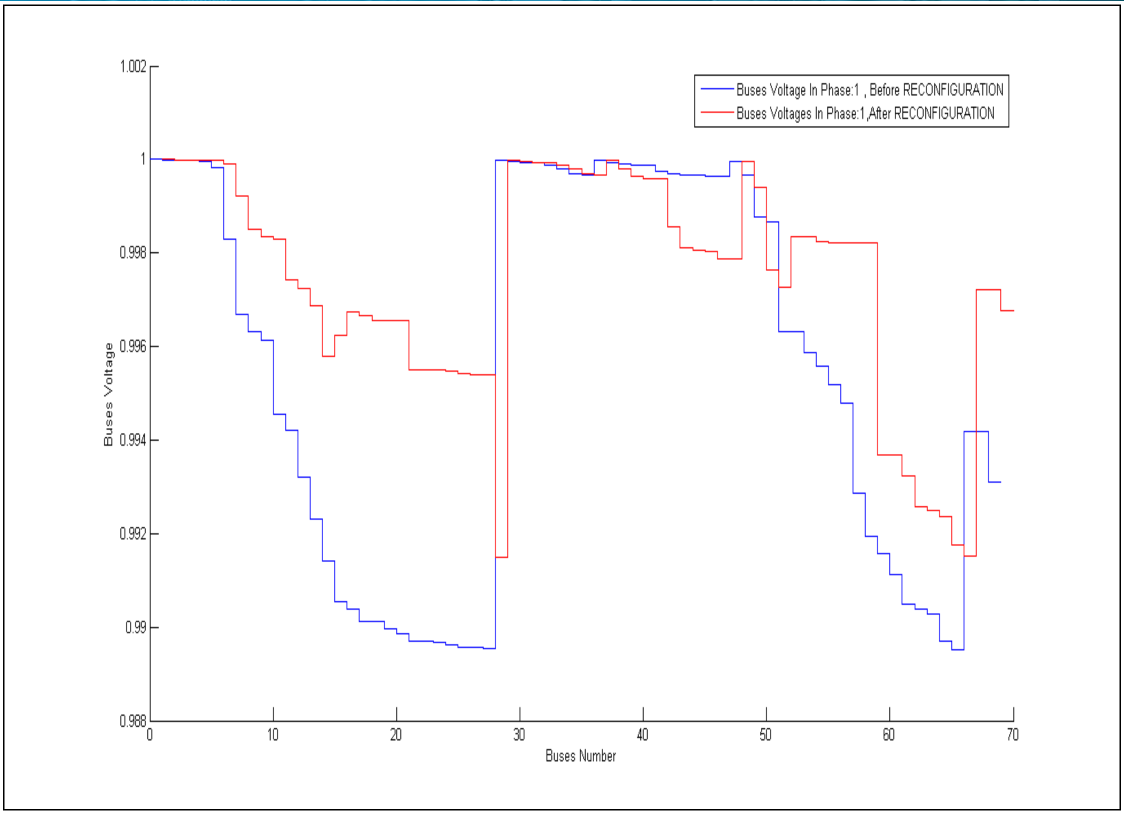

Fig. 9. Buses Voltage Before and After Optimization for 07-bus System

Simulation results for two algorithms represent that the proposed algorithm works better than other algorithms and has satisfactory results in terms of the utility director.

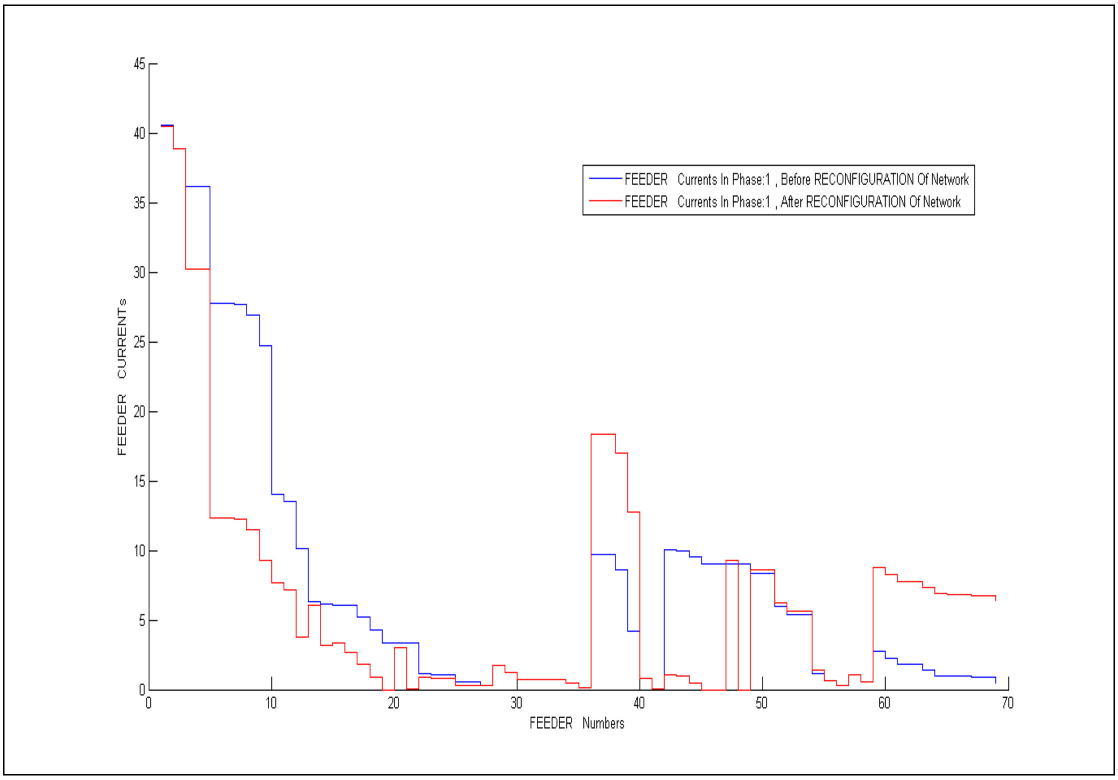

Fig. 0. Feeders Current Before and After Optimization for 07-Bus System

TABLE II. Simulation Results for 96-Bus Network

	Tie switches	power Loss (kw)	Power Loss reduction)%(	Min. Node voltage)p.u(
Initial	04-10, 02-44, 01-07, 27-23, 49-22	2.14	---	7.3932 (node 22)
OABC	04-10, 47-40, 02-09, 20-29, 49-40	4.47	20.30	7.3302 (node 19)
FMO	20-29, 41-40, 02-44, 04-10, 02-02	4.42	20.20	7.3294 (node 19)

Conclusions

Restructuring of the electricity distribution networks is one of the lowest-cost ways for utilities to reduce losses power where in this paper was emphasized. In this paper, the reconfiguration of distribution systems used to reduce losses, improve voltage profile and reduce relative lines current. To do this, we get help from optimal artificial bee colony algorithm (OABC). In this algorithm, how to choose a way to change the structures that the final answer become improved. Using of collective intelligence and bees collaborative also help in the process of problem solving and speed up various selects. Also, to prove article claim, were selected two samples of the IEEE standard networks and analysis results were compared with previous works. Studies have shown that this method alone can optimizes 9 main objective of the distribution network, including reducing losses power and feeders current and increasing buses voltage, in a proper restructuring, so that maintain its radial graph. A software is designed for this work where not only is a confident method to decrease the losses power, but also its graphic structure and easy communication with user causes that to perform the reconfiguration of distribution systems, don't need to additional software.

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