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Reconfiguration of Radial Distribution System with Objective of Loss Reduction Using Intelligent Meta Heuristic Algorithm

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Abstract: *In this paper reconfiguration of radial distribution system based on intelligent meta heuristic algorithm titled teaching-learning optimization algorithm (TLBO) with objective of loss reduction is presented. The system optimization variables need to be opened to maintain the radial status of the network. Optimization variables are determined by artificial intelligence algorithm. The reconfiguration has been done in different loading condition. The performance of the proposed method is compared with other methods bacterial forging optimization (BFO), tabu search (TS), simulated annealing (SA) and modified particle swarm optimization (MPSO). The results show the superiority of the proposed method in solving the problem and loss reduction and improving the network voltage profile.*

Keywords: Distribution network; Reconfiguration; Loss; Teaching-Learning-Based Optimization

1. INTRODUCTION

Within a few decades, human societies have always been faced with three major crises which affected the overall policies and technology developments. Three crises are financial crisis, environmental crisis and energy crisis and pollution. Examples of financial crisis that we are seeing it today in the Europe Union, It can make countries facing serious problems and the level of satisfaction of people largely bring down. Environmental crises, in turn, has had a tremendous effect on the planet. Mass production of greenhouse gases has led to threats to the ozone layer and has led or will lead to disastrous consequences such as global warming, Melting glaciers at the poles, drought in some areas and torrential rains in other areas, disturbing the natural ecosystems in many areas and so on. The third crisis, is the energy crisis that in a way can Exacerbate the two first crisis. Major energy consumption in the world is the use of fossil fuels said to them Exhaustible sources of energy and human sees himself at risk of check out these resources [1]. The political crises in the Middle East as the world's richest fossil fuels Increased prices for fuel and exacerbate the financial crisis. This type of fuel are the main source of greenhouse gas emissions therefore should also be examined from the perspective of pollution crisis. The electricity is one of the main energy carriers which in various sectors is considered as the prime mover and the main driver of industrial wheels. The energy consumption is increasing and the need to increase its production units. Given that the approximately 65% of the energy is produced using fossil fuels [2] so the increase of electricity energy generation Will be a factor in the escalation of financial, pollution and energy crisis. The increase in electrical energy consumption is a sign of industrial development and in fact, consumption of this energy is considered in order to advance communities. So the decrease in consumption, is not considered reasonable performance in solving the problems caused by the consumption of electrical energy. A point for debate about electricity energy is the transmission of this energy carrier which must travel long distances of lines and different types of equipment and reach the subscriber.

In this way about 10 to 20 percent of this energy is wasted in equipment resistance which Most of that is related to the distribution networks. Due to the mentioned crisis this is a very impressive amount and therefore a slight reduction in the amount of losses can lead to many benefits. Thus, many methods have been introduced to reduce losses in the industry which most of these methods are in the distribution network.

2. DISTRIBUTION NETWORK RECONFIGURATION

Reconfiguration of distribution network is another approach that is used to reduce distribution network losses. This method does not require additional equipment to install and by opening and closing the distribution network switches and by maintaining constraints of the network, the network configuration and direction of power flow can be changed in a way that path losses reach to its lowest level. There are generally two types of switches in distribution networks: sectionalize switches (normally closed) and tie-switches (normally open). These switches besides the task of circuit breakers, also affect the network configuration and reduce losses and improve voltage profile. In normal working conditions of network by changing the mode of these switches, the network configuration can be changed and the losses can be reduced [3]. Since the number of this switches is many, the problem of determining the best switch to reduce losses grows into an optimization problem and we need to use the optimization method to solve it. It should be noted that because of discrete nature of the problem and its constraints, the use of classical and numerical methods is very difficult and thus solving this problem is very simple using evolutionary techniques [4]. In this paper, reconfiguration of radial distribution network is done using two evolutionary optimization methods under the headings Bacterial Forging optimization and Teaching-Learning-Based Optimization.

3. PROBLEM STATEMENT

Eight-node hexahedral element type is taken, at the same time 2280 elements and 3239 nodes are obtained for the work-piece. The work-piece is assumed to be elasto-plastic and described by updated Lagrange method, i.e., it obeys the Mises yield criterion and Prandtl-Reuss flow rule, and its deformation is simulated in a step-by-step manner, updating the coordinates of material points and the property after each step. The rolls are assumed to be rigid and of heat-transfer, and they were analytically described.

Changes in the network configuration can move the power flow direction and can affect the losses. Now that, which switches and on what terms they are open or closed to losses reach to its lowest value, is an issue that must be resolved. So the objective function of network reconfiguration problem can be expressed as follows [5]:

$$\min F = \sum_{i=1}^{N_b} r_i \frac{P_i^2 + Q_i^2}{V_i^2} \quad (1)$$

Where N_b is the number of distribution network lines, r_i is the i[th] line resistance, P_i and Q_i are the active and reactive power crossing the ith line and V_i is the voltage of posting bus of [Ith] line. So they need to be as open and closed that the F function is minimized. But there are constraints that must be followed in this equation.

3.1 Constraints

-Power flow equations: Active and reactive power balance equations in the distribution network should be connected to any configuration that is introduced and in the case of convergence, network configuration can be accepted.

- Voltage constraint: Bus voltages with respect to the introduced configuration should be in the acceptable range.

$$V_i^{\min} < V_i < V_i^{\max} \quad (2)$$

V_i is the ith bus voltage and $V_i^{\min}$ and $V_i^{\max}$ are the lower and upper limit of voltage.

- Constraints of Heat limit of lines: the network configuration should not be chosen in such a way that the power crossing the lines is greater than their capacity.

$$I_i < Limit_i \quad (3)$$

I_i is the power crossing the ith line and $Limit_i$ is the thermal limit of this line.

- The constraint of Maintaining the radial mode of distribution network.

The configurations introduced to distribution network must be such that the ring is not formed and maintains the network radial mode. To check the radial network, a matrix is defined entitled incidence. This matrix is a n*m, where m is the number of grid lines and n is the number of network buses. Elements of the matrix are defined as follows.

$a_{ij} = 0$: if the line I have no relation with bus j

$a_{ij} = 1$: if the line I exits from bus j

$a_{ij} = -1$: if the line I enter to bus j

After the formation of the matrix if the determinant of the matrix is zero, network is not radial and if the determinant is 1 or -1 means that the network is a radial network.

4. PROBLEM STATEMENT

The TLBO algorithm is an intelligent optimization approach that is based on the influence of teachers on students to increase academic level classes by Mr. Rowe, was introduced. This method is based on the principle that the teacher tries to make the class level close to his level Students also benefit from the knowledge of the teacher and other classmates regarding their knowledge to increase their level of use. Because the teacher is not able to reach the level of individual students to his level, So he tried it raised the average level of the whole class and class level based on student test scores to evaluate. Mathematical expression of this method is that initially a population of problem variables (students and teacher) are randomly defined. All of these populations are compared using the objective function and a set of variables with best solution is considered as a teacher. This method is divided into two phases, teacher and student phase.

4.1 The teacher phase

In this phase, the teacher tries to reach the class average to his level. But since it is very difficult, the teacher tries to increase the class average from Mi to Mnew. Each set of problem variables are updated based on the difference between the two values. The difference between this values can be saved by the Diff_Mean parameter.

$$Diff\_Mean_i = r_i (M\_new - T_f M_i) \quad (4$$

Which the Tf is the teacher parameter that is selected randomly between 1 and 2. ri is a random number between 0 and 1. By using the follow equation each set of variables are updated.

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(5)

4.2 The student phase

Students use the knowledge of teacher and benefit from each other knowledge. The mathematical expression of this phase is that in this phase and in each iteration, each variable set (i.e. student) randomly selects one of the other students. For example student i chooses student j and this i is against j. If student j has more knowledge than student i, then student i updates his status based on the following equation:

$$X_{new,i} = X_{old,i} + r_i (X_i - X_j) \tag{6}$$

Otherwise, the student's status will be changed as follows:

$$X_{new,i} = X_{old,i} + r_i (X_j - X_i) \tag{7}$$

After all students have their status changed, they are evaluated using the objective function.

In this situation the best student is compared with previous step teacher and if it has a better results, is replaced with previous step iteration teacher. This process continues until convergence qualify. To solve the reconfiguration problem, a linear matrix is created with the same number of tie-line. The elements of this matrix are either zero or 1, meaning that a zero means being tie line is open or closed. Another matrix is defined in the same numbers its elements are integers of number of grid lines. Thus, in the first, to the desired number of population, the first matrix elements are randomly selected as zero and 1 and the second matrix elements are selected randomly from among the number of lines. All generated variables are entered into power flow program of distribution network. At first, the condition of radial network is checked. If network keep its radial mode, the power flow is done and the amount of losses come back to optimization program as optimization objective function value for each variable sets. Then the variables are updated based optimization method to move to the optimal response. Given that variables must be integers the variables are rounded to integer after every update.

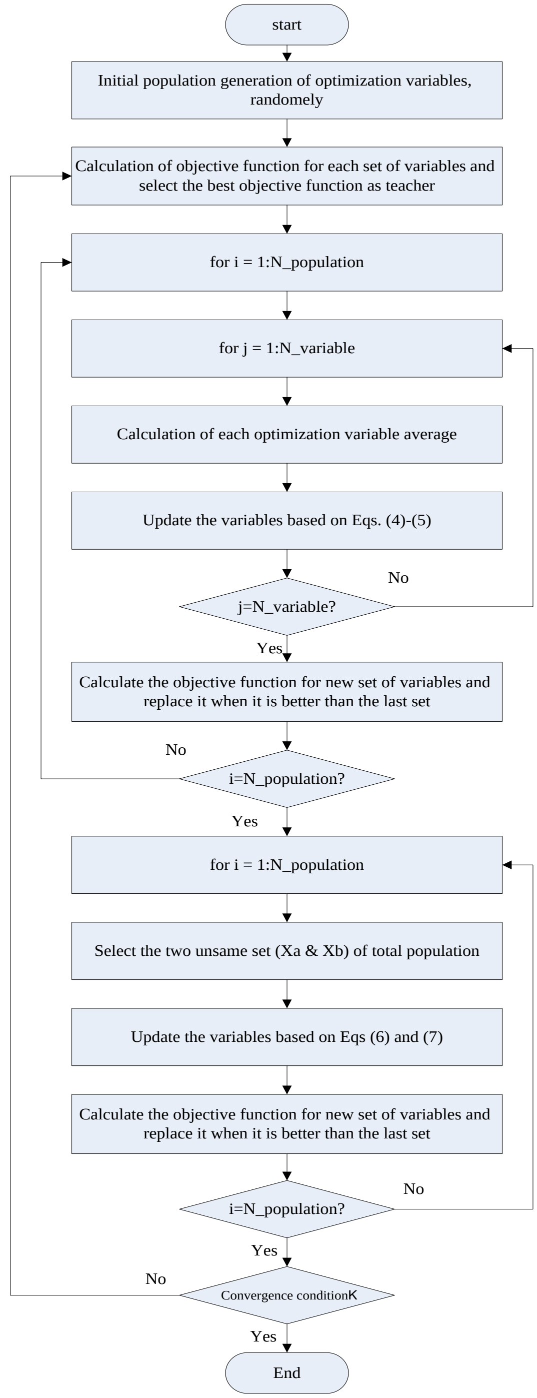

Fig. 1. Optimization flowchart using TLBO method

5. SIMULATION RESULTS

5.1 The system under study

Considering that the aim of this study is the reconfiguration of distribution network to reduce losses, the selected system to investigate the network reconfiguration, is a 69 bus radial system that is used in different references for various tasks such as capacitor placement [3], optimal location of DG [9] or reconfiguration of distribution network and this system scheme with its tie line is shown in Fig. 2. The lines data and load of this network is extracted from [8]. The base voltage is 12.66 kV and the base power is 10 kVA. This network has 3802.2 kW (2694.1 kVAR) load in normal conditions. The losses in this conditions is 20.87 kW and the minimum amplitude of voltage is 0.9725 p.u that correspond precisely with the values presented in [8]. Information on the tie line is given in Table 1. Also 3 level of load is considered. According to [8], the level of full load is 20 % more than normal level and low load level is 50 % below the normal level.

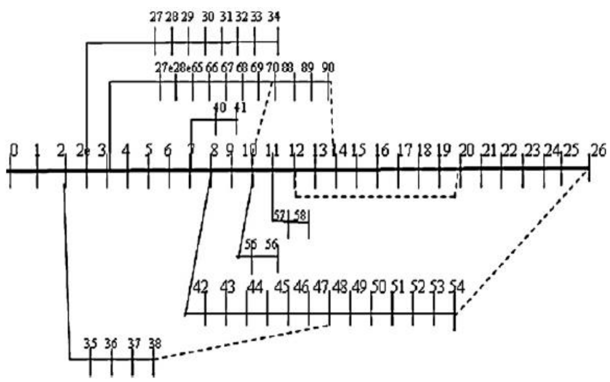

Fig. 2. 69-bus radial network with tie-line [3]

Table 1. the data of tie-lines [8]

Tie line NO.	Sending End	Receiving End	R(Ω)	X(Ω)
1	10	70	0.5	0.5
2	12	20	0.5	0.5
3	14	90	1	1
4	38	47	2	2
5	26	54	1	1

5.2 The simulation results in normal load

The population of each of the algorithms is 20 and maximum number of their iterations is 100 in the process of different scenarios of network load. in this study, convergence curve of optimization methods is drawn just in the case of normal load of the network. Convergence curve of optimization methods is presented in Fig. 3. As shown in Fig. 3 it can be seen that TLBO method earns less than the BFO losses.

In Table 2, first in normal conditions using two methods TLBO and BFO, the reconfiguration program is done and the results are shown. As is clear TLBO is quicker and more powerful way to find the optimum reconfiguration of network and optimal network configuration selected by this method precisely is the same with the tabu search (TS) [5], simulated annealing (SA) [8], modified PSO (MPSO) [9], modified tabu search (MTS) [10] and discrete PSO (DPSO) [11]. While the results of BFO is far from optimal configuration. These results are the best results after the optimization procedure is performed 10 times.

The bus voltage before and after reconfiguration as well as the results of TLBO and BFO have been compared in Fig. 4. As is clear from the figure, the voltage variations from 1 p.u in TLBO based reconfiguration is less from all.

5.3 The simulation results in light load

In this case, according to [8] assumes that the network load is 50% of the load in normal conditions. The amount of losses before the reconfiguration is 5.0938 KW. The results of reconfiguration based on the TLBO and BFO as well as amount of bus voltage is respectively shown in Table 3 and Fig. 4. This results shows that the TLBO has better performance to find the best system configuration. Also as it clear, the obtained results are same with the result of TS, SA and MTS. Moreover the TLBO results are better than others. The voltage profile in the proposed configuration of TLBO is more suitable from two BFO according to Fig. 5.

5.4 The simulation results in heavy load

In this case, according to [8], assumes that the network load is 20% more than the load in normal conditions. The amount of losses in this condition is 30.359 kW. The results of reconfiguration based on the TLBO and BFO is listed in Table 5. The better results of TLBO in this condition is very clear. The voltage profile is shown in Fig. 6. Better voltage profile in the configuration proposed by TLBO is clear.

6. CONCLUSION

In this paper, the network reconfiguration is done using TLBO and BFO to minimize the losses of IEEE 69-bus distribution network with maintaining the network radial mode. Reconfiguration is done for 3 modes of normal load, low load conditions and full load conditions. In the all conditions, the results show that the TLBO method is powerful method in finding the optimal configuration of network and also network voltage profile in the configuration proposed by TLBO is more suitable than the BFO and before reconfiguration.

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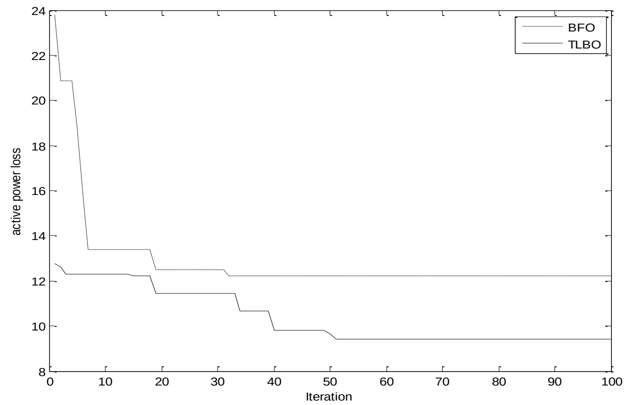

Fig 3. The convergence curve of TLBO and BFO optimization method

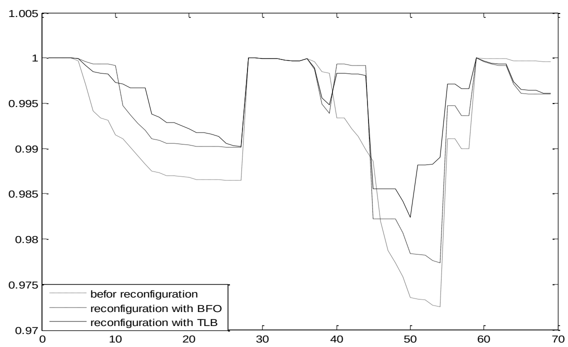

Fig 4. The voltage profile in normal load

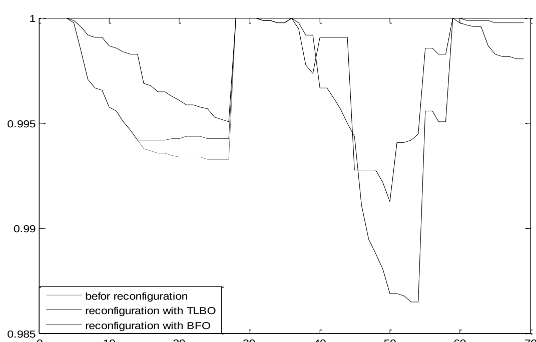

Fig. 5. Voltage profile in normal load

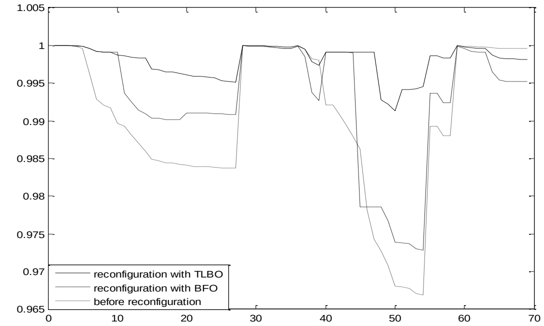

Fig. 6. Voltage profile in heavy load

Table 2. The reconfiguration results using TLBO and BFO in normal load

method	Number of closed tie-lines	closed tie-lines	Opened lines	Loss (kW)	min. voltage
Initial	0	----	----	20.87	0.9725
TLBO	3	3, 4, 5	13, 44, 50	**9.4**	**0.982**
BFO	2	1, 4	10, 44	12.229	0.977
TS [5]	---	---	---	9.4	0.982
SA [8]	---	---	---	9.4	0.982
MPSO [9]	---	---	---	9.4	0.982
MTS [10]	---	---	---	9.4	0.982
DPSO [11]	---	---	---	9.4	0.982

Table 3. The Results of reconfiguration using TLBO and BFO method in the mode of low load

method	Number of closed tie-lines	closed tie-lines	Opened lines	Loss (kW)	min. voltage
Initial	0	----	----	5.0938	0.9863
TLBO	3	3, 4, 5	13, 44, 50	**2.32**	**0.9913**
BFO	1	2	13	5.0346	0.9865
TS [5]	---	---	---	2.32	0.9913
SA [8]	---	---	---	2.61	0.99
MTS [10]	---	---	---	2.32	0.9913

Table 4. The results of reconfiguration using TLBO and BFO method in the mode of heavy load

method	Number of closed	closed tie-lines	Opened lines	Loss (kW)	min. voltage

	tie-lines				
Initial	0	----	----	30.359	0.967
TLBO	3	3, 4, 5	13, 44, 50	**13.657**	**0.9788**
BFO	3	2, 1, 4	19, 10, 44	17.3942	0.9728
TS [5]	---	---	---	13.66	0.978
SA [8]	---	---	---	13.72	0.97
MTS [10]	---	---	---	13.66	0.97

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