Modified Binary Particle Swarm Optimization for Solving Distribution Network Reconfiguration

Ali Nasser Hussain
Department of Electrical Engineering, Electrical Engineering Technical College, Middle Technical University, Baghdad, Iraq
E-mail: alinasser1974@yahoo.com

Abstract: This study utilized Binary Particle Swarm Optimization (BPSO) and Modified BPSO (MBPSO) for solving Distribution Network Reconfiguration (DNR). The search problem space for the presented algorithm is a set of lines (switches) which are normally closed or opened, this search problem may be dissimilar for different dimensions. This paper consists of two parts. First, the reconfiguration with constant load was optimized based on two algorithms BPS and MBPS. The decreasing of real power loss has been invested as an objective function; while node voltage, system radially and line current have been utilized as limits of the system. Second, the reconfiguration with variable load is optimized based on the same two algorithms BPS and MBPS. The proposed methods are applied on IEEE node 33 power system by using MATLAB software to test the effectiveness and efficiency of MBPSO algorithm. The results for the IEEE node 33 power systems indicate that MBPSO algorithm has high ability and effective in reduce power loss and voltage profile enhancing of the system compared to BPSO.

Keywords: BPSO, **MBPSO**, DNR, Reduce power loss, Voltage profile enhancing.

أمثليه حشد جسيمات ثنائي معدلة لحل أعادة تشكيل شبكة التوزيع

علي ناصر حسين

قسم هندسة تقنيات القدرة الكهربائية، الكلية التقنية الهندسية الكهربائية، الجامعة التقنية الوسطى، بغداد، العراق

الخلاصة: يستعرض هذا البحث أمثليه حشد جسيمات ثنائي (BPSO) وأمثليه حشد جسيمات ثنائي معدلة (MBPSO) لحل أعادة تشكيل شبكة التوزيع (DNR). أن فضاء مشكلة البحث للخوارزميات المقدمة هو مجموعة من الخطوط (المفاتيح) التي تفتح عادةً او تغلق، مشكلة البحث هذه قد تكون متباينة لأبعاد مختلفة. هذا البحث يتكون من جزئيين. الأول، اعاده التشكيل مع الحمل الثابت التي أمثلت بالأستناد على الخوارزميتين BPSO و MBPSO . تقليل خسارة القدرة الحقيقية تم أستثمارها كدالة هدف موضوعية، بينما فولتية العقدة، نظام بشكل شعاعي و تيار الخط استعمل كحدود للنظام. الثاني اعادة التشكيل مع الحمل المتغير التي أمثلت بالأستناد على نفس الخوارزميتين BPSO و MBPSO. الطريقتان المقترحة BPSO و MBPSO طبقت على نظام قدرة كهربائي IEEE 33 حافلة باستخدام برنامج الماتلاب. النتائج لنظام قدرة كهربائي IEEE 33 حافلة حددت بان خوارزمية MBPSO لديها قدرة عالية وفعالة في تقليل خسائر القدرة وتحسين ملف الفولتية للنظام مقارنة الى BPSO.

الكلمات المفتاحية : أمثليه حشد جسيمات ثنائي، أمثليه حشد جسيمات ثنائي معدلة، أعادة تشكيل شبكة التوزيع، تقليل خسائر القدرة، تحسين ملف الفولتية

1. Introduction

Loss minimization is used to enhance the flexibility of the system. Distributed generator allocation (DG), conductor grading, capacitor placement and feeder reconfiguration are better approaches for decreasing power loss [1]. On the other hand, adding these methods into the distribution system needs much cost. DNR can be accomplished through the reconfiguration of tie switches and sectionalizing, by this method, the loss system is reduced and voltage level is enhanced by considering the operating limits devoid of costs [2]. By redistributing and arranging the loads from heavy to light, DNR can balance the feeder loads and prevents the overloading [3]. Many techniques have been described in the literature to obtain the optimal DNR. The Artificial neural network technique based on the mapping capability to decide network reconfiguration is presented in [4]. An expert system utilizing heuristic rules to reduce the search problem for decreasing the calculation time has been proposed in paper [5]. The study of load balancing and reducing power loss formulated as integer programming problem was proposed by Baran [6]. Chiang and Jumeau have been proposed a new load balancing index and they utilized it on the test power system for load balancing [7]. A new balance and unbalance load approach in distribution system for decreasing of the power loss was presented in reference [8]. Naveen was presented DNR for reducing loss via modification technique based on the Bacterial Foraging Optimization [9]. Cuckoo Search Approach (CSA) was introduced by Nguyen and Truong; DNR have two objectives, which were to voltage level enhancement and to reduce the loss of the system [10].

In this study, BPSO and Modified BPSO MBPSO approaches are utilized in network reconfiguration to get the better solution with the objective function for decreasing line power loss and enhance voltage profile. The BPSO and MPSO algorithms are applied on 33-node IEEE system with constant loads and variable loads to find the optimal DNR. For variable load (μ multiplied by constant load) where μ represents the ratio value for the load variation. The range of variation for loads is linearly changed between ($\mu = 0.75$) at light load up to ($\mu = 1.250$) at heavy load. The results of DNR problem have been implemented for standard IEEE 33 node power system. From the results, MBPSO algorithm has high ability and effective in reduce the total real power loss and enhancing the minimum and average voltages of the system compared to BPSO and other reported papers.

2. Problem Formulation

A. Load Flow

Load flow in electrical power distribution network can be defined by a number of equations that depends on the active power, reactive power and voltage at the sending end of a line to express the same quantities at receiving end of the line [11]. By utilizing the calculation of power flow, total power loss can be obtained in figure.1.

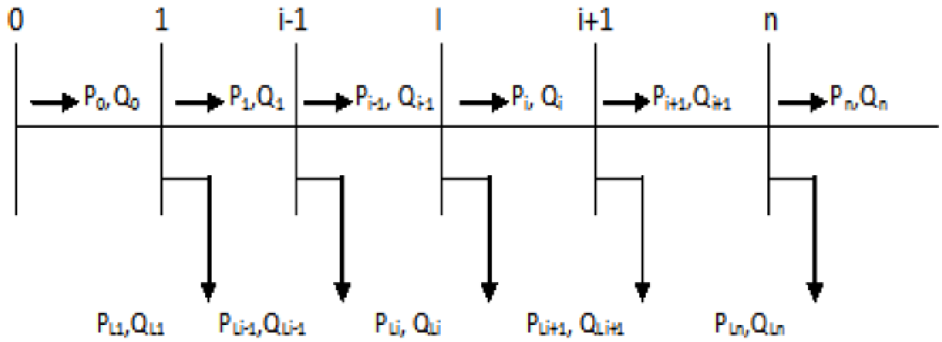

Figure 1: Simple distribution line.

The active and reactive load flow equations in the branch among $i+1$ and $n-th$ nodes are:

$$P_{i+1} = \left[(P_i) - (P_{Li+1}) - \left(R_{i,i+1}\right)\right]\left[\frac{(P_i)^2+(PQ_i)^2}{|V_i{}^2|}\right] \quad (1)$$

$$Q_{i+1} = \left[(Q_i) - (Q_{Li+1}) - \left(X_{i,i+1}\right)\right]\left[\frac{(P_i)^2+(Q_i)^2}{|V_i{}^2|}\right] \quad (2)$$

The voltage at nodes i and $i+1$ can be express as follows:

$$|(V_{i+1})^2| = |(V_i)^2| - 2\left[\left(R_{i,i+1}.P_i\right) + \left(X_{i,i+1}\,.Q_i\right)\right] + \left[\left(R^2{}_{i,i+1}\right) + \left(X^2{}_{i,i+1}\right)\right]\left[\frac{P_i{}^2+Q_i{}^2}{|V_i{}^2|}\right] \quad (3)$$

The current equation can be express by the following equation:

$$I_T = \frac{P_i - jQ_i}{|V_i|} \quad (4)$$

The summation of real power loss can be express as shown below:

$$P_{LT} = \sum R_{i,i+1}\, I_T{}^2 \quad (5)$$

from the above equations : (P_i) and (Q_i) are the real and reactive power loss at node i; $\left(R_{i,i+1}\right)$ and $\left(X_{i,i+1}\right)$: are the resistance and reactance of branch section between two nodes i and $i+1$; (V_i) is the voltage at node i; (I_T) is the total current and (P_{LT}) is the total real power losses.

B. Objective Function

The objective function of DNR is applied to decrease the real power loss and it is presented in equation (6):

$$f(x) = min\, P_{LT} \quad (6)$$

where (x) is the control variable and P_{LT} is the total real power loss.

C. Constrains

In any DNR, the load flow calculation can be done by finding the node voltage, line current and active power loss of a system for every line. The necessities of the objective function are shown below:

1. Bus voltage has min and max bounds as shown in equation (7) below.

$$V_i^{min} \leq |V_i| \leq V_i^{max} \quad ; \quad i = 1,2, \ldots . . N_n \quad (7)$$

From equation (6), V_i^{min} and V_i^{max} are the lower (0.9 p.u min) and upper (1.0 p.u max) voltage of node i; N_n represent the number of nodes.

2. Line current values should not overcome constraint of each line as in equation (8).

$$|I_T| \leq I_T^{max} \quad ; \quad T = 1,2, \ldots . . N_b \quad (8)$$

Where I_T^{max} is the max bound of line current T and N_b is the total number of the lines.

3. Always save the power system in radial structure as written in (9).

$$\left.\begin{array}{ll} det(A) = 1 \text{ or } -1 & \text{(Radial System)} \\ det(A) = 0 & \text{(Not Radial System)} \end{array}\right\} \quad (9)$$

D. Average Voltage Index

This index is presented to replace the lower voltage to estimate the quality of power that is a more suitable from the viewpoint of both sides. This index is given in equation (10).

$$V_{av} = \frac{\sum_{i=1}^{N_n} V_i}{N_n} \quad (10)$$

From the above equation, (V_{av}) is the average voltage for a network; (V_i) is the voltage at node i and (N_n) is the number of network nodes.

3. Reconfiguration Approaches

A. (PSO) algorithm

Basic idea of PSO came from the behavior of animals such as fish schooling or bird flocking to search for food. And it is first introduce by Eberhart and Kennedy [12] in year 1995. The basic PSO algorithm is the real valued PSO, whereby each dimension in the space of the problem can take any real valued number. The particles update their speed and position according to the following equations (11) and (12).

$$v_i^{k+1} = (w * v_i^k) + c_1 * [rand_1 * (p_{bi}^k - x_i^k)] + c_2 *[rand_2 * (g_{bi}^k - x_i^k)] \quad (11)$$

$$x_i^{k+1} = x_i^k + v_i^{k+1} \quad (12)$$

where (v_i^{k+1}) is the velocity of particle at $(k+1)$ iteration; (v_i^K) is the velocity of particle at current iteration; (C_1, C_2) are the two positive constants within $[0-2.5]$; $(rand_1, rand_2)$ are the uniformly distributed positive random numbers within limit $[0-1]$; (p_{bi}^k) is the local best value at (k) iteration; (g_{bi}^k) is the global best value at (k) iteration; $\left(x_i^k\right)$ is the position at current iteration; $\left(x_i^{k+1}\right)$ is the position at $(K+1)$ iteration and (w): is the inertia weight and it is reduce linearly from (0.9 to 0.4) at each iteration, and can be express as follows.

$$W = W_{max} - \left(\frac{W_{max} - W_{min}}{max_{iteration}}\right) * iter \quad (13)$$

B. (BPSO) algorithm

The first concept for BPSO algorithm has been presented by Eberhart and Kennedy in year 1997 [13]. The size of searching space is equal to number of tie switches in a system. In order to transform the exploration of PSO in a real space dimensions to binary space dimensions, sigmoid transformation is applied to the velocity element to force the velocities within a range $[0, 1]$, and force the component values of the locations of agents to be (0 s or 1 s). Therefore, equation (12) for changing the position is replaced by Equation (17). Also W is reducing linearly from (0.9 to 0.4) as shown in equation (15).

$$v_i^{k+1} = (w * v_i^k) + [c_1\text{old} * rand_1 * (p_{bi}^k - x_i^k)] + [c_2\text{old} * rand_2 * (g_{bi}^k - x_i^k)] \quad (14)$$

$$W = W_{max} - \left(\frac{W_{max} - W_{min}}{max_{iteration}}\right) * iter \quad (15)$$

$$sigmoid(v_i^{k+1}) = \frac{1}{1+\exp(-v_i^{k+1})} \quad (16)$$

$$\left.\begin{aligned} x_i^{k+1} &= [1, if\ rand < sigmoid(v_i^{k+1})] \\ x_i^{k+1} &= [0, \quad otherwise] \end{aligned}\right\} \quad (17)$$

where old learning factors, $c_1$old = constant and $c_2$old = constant.

C. (MBPSO) algorithm

In the Modified BPSO (MBPSO) algorithm all agents move to be nearest to the better position based on objective function and discover the global optimum location for minimum point. It is similar to BPSO algorithm but in the MBPSO the old positive constants are modified to a random values in range between $[0-1]$ instead of constant value ($c_1$old and $c_2$old) which are given in equation (14) at BPSO. Also, the size of searching problem space is equal to number of tie switches in a network. This randomly helps to rise the ability of PSO approach in order to reach the optimal solution much faster than ($c_1$old and $c_2$old). The equation of velocity can be written as follows in equation (18).

$$v_i^{k+1} = (w * v_i^k) + [c_1new * rand_1 * (p_{bi}^k - x_i^k)] + [c_2new * rand_2 * (g_{bi}^k - x_i^k)] \quad (18)$$

where c_1new and c_2new are given in equation (19) and (20) are the new learning factors between [0-1] instead of the old learning factors $c_1$old and $c_2$old given in equation (14) in the BPSO algorithm.

$$c_1new = \text{Rand} \quad (19)$$

$$c_2new = \text{Rand} \quad (20)$$

4. Case Study

The efficiency of MBPSO for DNR is tested on IEEE−33 node system. The data details of the network and loads for power system have been given in reference [10]. And the result of the network reconfiguration at BPSO and MPSO are obtained in two cases at constant load and at variable load.

I. Case study (1) with constant load (μ = 1)

In this case DNR is applied to the constant load (μ = 1) demand. IEEE 33−node is presented as test system for both the BPSO and MBPSO approaches. Table 1 describes the comparison among the proposed methods and some other methods reported in the literature [2, 9, 10, 14]. Switches status, real power loss, minimum and average voltage are given in this table.

Table 1: Result of DNR for the IEEE 33−node power system at constant load demands (μ = 1) while using BPSO, MBPSO and some other approaches.

Approach	Open Switches	P_{LT} (KW)	V_{av} $(p.u.)$	$V_{min}(p.u.)$
Initial	sw33, sw34, sw35, sw36, sw37	202.67	0.9485	0.9092
BPSO	sw7, sw9, sw13, sw32, sw37	138.61	0.9657	0.9412
MBPSO	sw7, sw9, sw14, sw32, sw37	135.17	0.9669	0.9431
FWA [2]	sw7, sw9, sw14, sw28, sw32	139.55	0.9674	0.9413
MBFOA [9]	sw7, sw9, sw13, sw32, sw37	141.91	0.9678	0.9378
ITS [10]	sw07, sw09, sw14, sw36, sw37	142.16	0.9653	0.9336
SLR [14]	sw07, sw10, sw14, sw36, sw37	142.67	0.9651	0.9336

It is seen from Table 1, the real power loss (P_{LT}) reduces while using BPSO by 31% from 202.67 kW to 138.61kW and with MBPSO by 33% from 202.67 kW to 135.17kW. The minimum voltage (V_{min}) while using BPSO enhances from 0.9092 p.u. to 0.9412 p.u. and with MBPSO improves from 0.9092 p.u. to 0.9412 p.u., while the average voltage enhances from 0.9485 p. u. to 0.9657p. u. while using BPSO and from 0.9485 p.u. to 0.9669 p.u. with MBPSO.

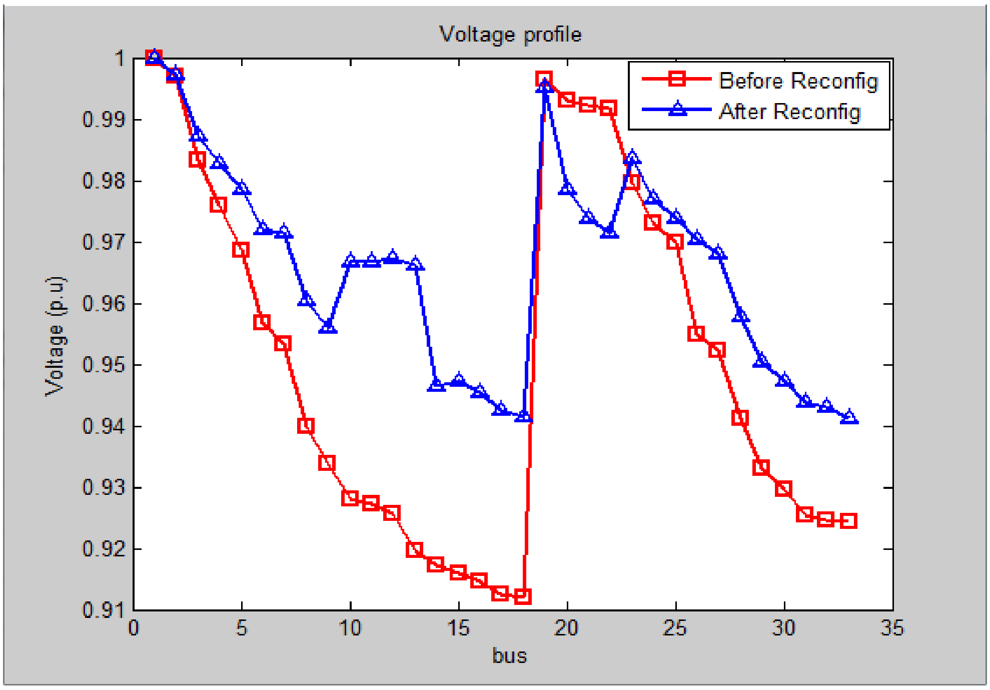

Figure 1: Voltage profile of DNR for the IEEE 33−node power system at constant load demands (μ = 1) while using BPSO.

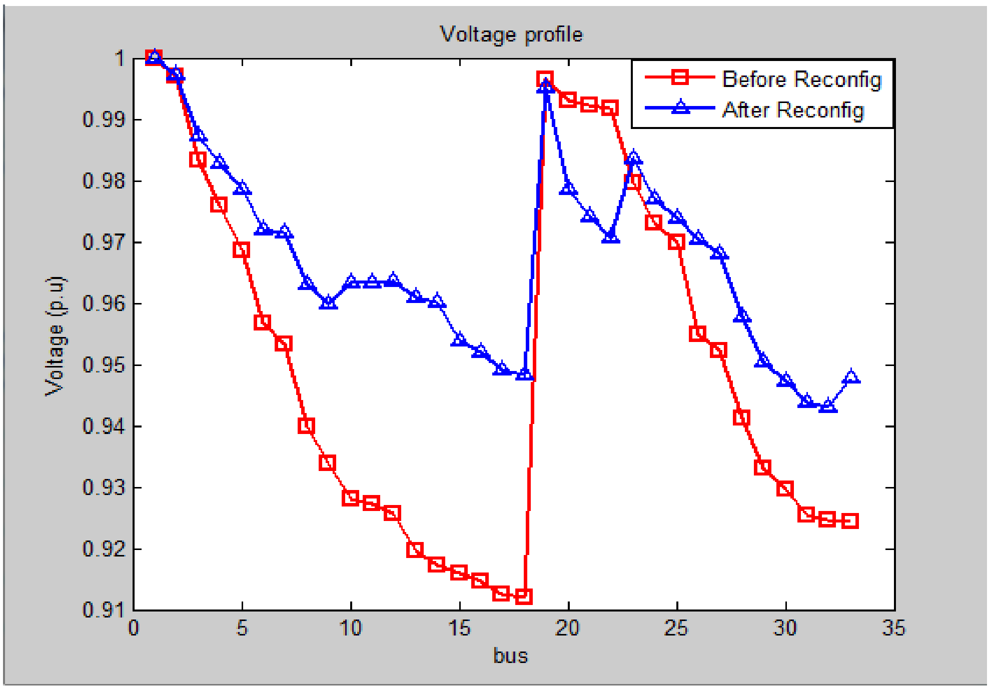

Figure 2: Voltage profile of DNR for the IEEE 33−node power system at constant load demands (μ = 1) while using MBPSO.

Figure 1 and Figure 2 show voltage profiles of the network while using BPSO and MBPSO. It is clear that the voltage at all nodes (except the nodes 19, 20, 21, 22) were improves after reconfiguration. Finally, it is clear that from Figure 1 and Figure 2 by using MBPSO greatly improves the voltage profile compared to BPSO.

II. *Case study (2) with variable load*

The load demand (real and reactive) at the nodes is changes within the range$(\mu^{min} \leq \mu \leq \mu^{max})$ where $(\mu^{min} = 0.75)$ at light and $(\mu^{max} = 1.25)$ at heavy with the percent of step change $(\Delta\mu)$ equal to12.5%. The load is varied by multiplying μ with load at base case.

$$P_{Li} = \mu P_{Li0} \qquad (21)$$

$$Q_{Li} = \mu Q_{Li0} \qquad (22)$$

From the above equations, μ is the value of the load variation ratio, P_{Li0} and Q_{Li0} are the base constant real and reactive powers of the $i-th$ load. And the results of these cases are shown below.

At loading with variation ratio (μ = 0.75): in this case DNR is applied to the light load (μ = 0.75) demand. IEEE 33−node is presented as test system for both the BPSO and MBPSO approaches. Table 2 describes the comparison among the proposed methods and some other methods reported in the literature [2,9, 10, 14]. Switches status, real power loss, minimum and average voltage are given in this table.

Table 2: Result of DNR for the IEEE 33−node power system at light load demands (μ = 0.75) while using BPSO, MBPSO and some other approaches.

Approach	Open Switches	P_{LT} (KW)	V_{av} $(p.u.)$	$V_{min}(p.u.)$
Initial	sw33, sw34, sw35, sw36, sw37	109.75	0.9621	0.9362
BPSO	sw7, sw9, sw13, sw32, sw37	76.16	0.9746	0.9565
MBPSO	sw7, sw9, sw14, sw32, sw37	74.33	0.9754	0.9579
FWA [2]	sw7, sw9, sw14, sw28, sw32	76.87	0.9758	0.9566
MBFOA [9]	sw7, sw9, sw13, sw32, sw37	77.88	0.9762	0.9540
ITS [10]	sw07, sw09, sw14, sw36, sw37	77.97	0.9743	0.9510
SLR [14]	sw07, sw10, sw14, sw36, sw37	78.25	0.9742	0.9510

It is seen from Table 1, the real power loss (P_{LT}) reduces while using BPSO by 30% from 109.75 kW to 76.16 kW and with MBPSO by 32% from 109.75 kW to 74.33 kW. The minimum voltage (V_{min}) while using BPSO enhances from 0.9362 p.u. to 0.9565 p.u. and with MBPSO improves from 0.9362 p.u. to 0.9579 p.u., while the average voltage enhances from 0.9621 p.u. to 0.9746 p.u. while using BPSO and from 0.9621 p. u. to 0.9754 p. u. with MBPSO.

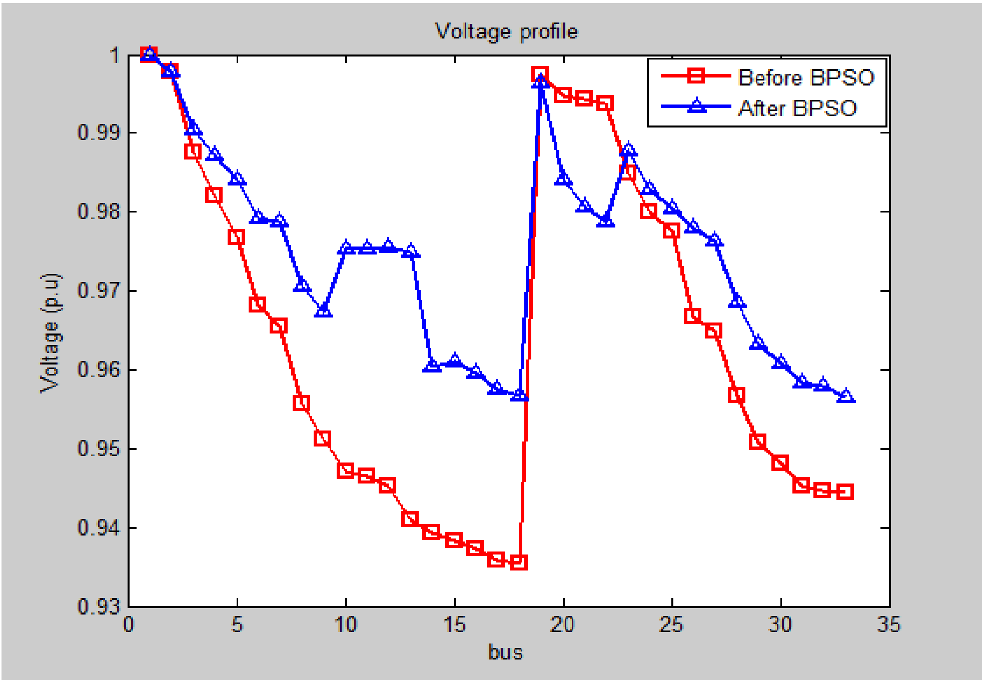

Figure 3: Voltage profile of DNR for the IEEE 33−node power system at light load demands (μ = 0.75) while using BPSO.

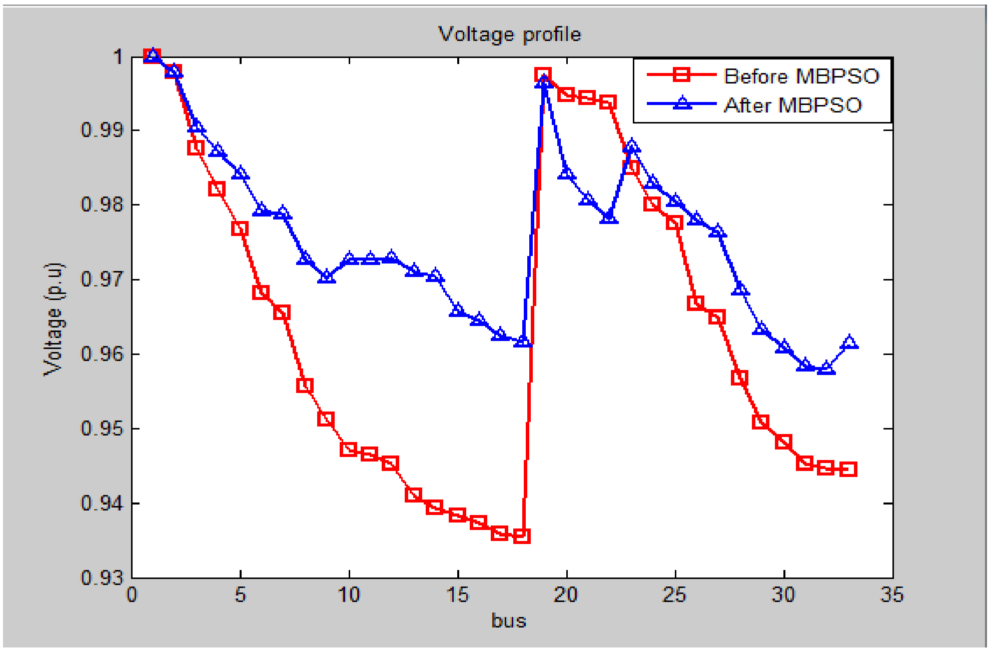

Figure 4: Voltage profile of DNR for the IEEE 33−node power system at light load demands (μ = 0.75) while using MBPSO.

Figure 3 and Figure 4 show voltage profiles of the network while using BPSO and MBPSO. It is clear that the voltage at all nodes (except the nodes

19, 20, 21, 22) were improves after reconfiguration. Finally, it is clear that from Figure 3 and Figure 4 by using MBPSO greatly improves the voltage profile compared to BPSO.

At loading with variation ratio (μ = 0.875): in this case DNR is applied to the load factor (μ = 0.875) demand. IEEE 33−node is presented as test system for both the BPSO and MBPSO approaches. Table 2 describes the comparison among the proposed methods and some other methods reported in the literature [2,9, 10, 14]. Switches status, real power loss, minimum and average voltage are given in this table.

Table 3: Result of DNR for the IEEE 33−node power system at load factor (μ = 0.875) while using BPSO, MBPSO and some other approaches.

Approach	Open Switches	P_{LT} (KW)	V_{av} $(p.u.)$	$V_{min}(p.u.)$
Initial	sw33, sw34, sw35, sw36, sw37	152.20	0.9553	0.9248
BPSO	sw7, sw9, sw13, sw32, sw37	104.87	0.9702	0.9489
MBPSO	sw7, sw9, sw14, sw32, sw37	102.31	0.9712	0.9505
FWA [2]	sw7, sw9, sw14, sw28, sw32	105.88	0.9716	0.9490
MBFOA [9]	sw7, sw9, sw13, sw32, sw37	107.31	0.9720	0.9460
ITS [10]	sw07, sw09, sw14, sw36, sw37	107.46	0.9698	0.9423
SLR [14]	sw07, sw10, sw14, sw36, sw37	107.84	0.9697	0.9423

It is seen from Table 1, the real power loss (P_{LT}) reduces while using BPSO by 31% from 152.20 kW to 104.87kW and with MBPSO by 32% from 152.20 kW to 102.31 kW. The minimum voltage (V_{min}) while using BPSO enhances from 0.9248 p.u. to 0.9489 p.u. and with MBPSO improves from 0.9248 p.u. to 0.9505 p.u., while the average voltage enhances from 0.9553 p.u. to 0.9702 p.u. while using BPSO and from 0.9553 p.u. to 0.9712 p.u. with MBPSO.

Figure 5 and Figure 6 show voltage profiles of the network while using BPSO and MBPSO. It is clear that the voltage at all nodes (except the nodes 19, 20, 21, 22) were improves after reconfiguration. Finally, it is clear that from Figure 5 and Figure 6 by using MBPSO greatly improves the voltage profile compared to BPSO.

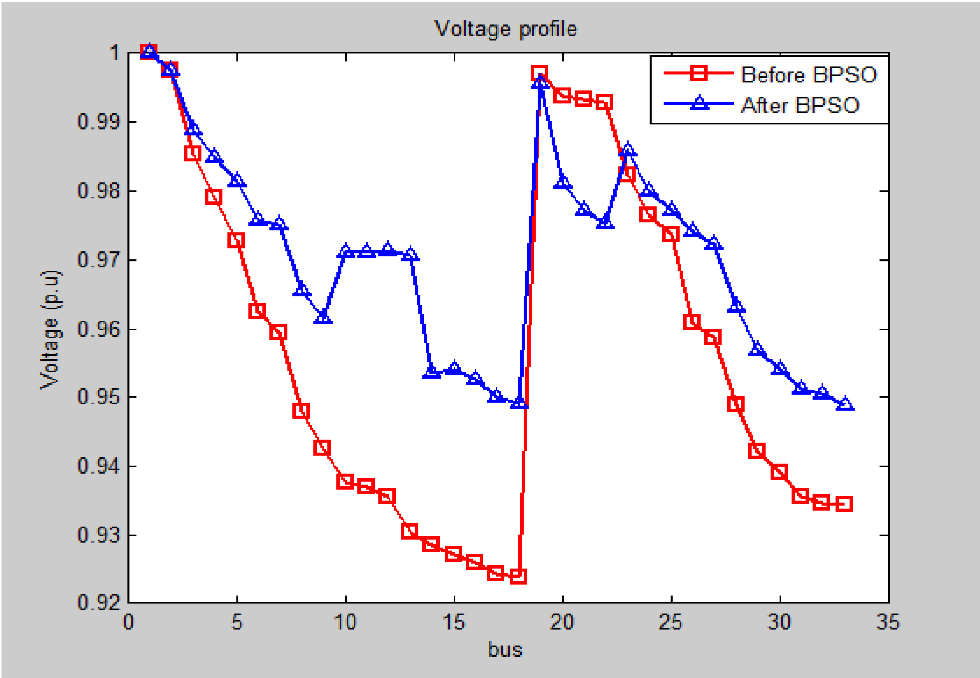

Figure 5: Voltage profile of DNR for the IEEE 33−node power system at load factor ($\mu = 0.875$) while using BPSO.

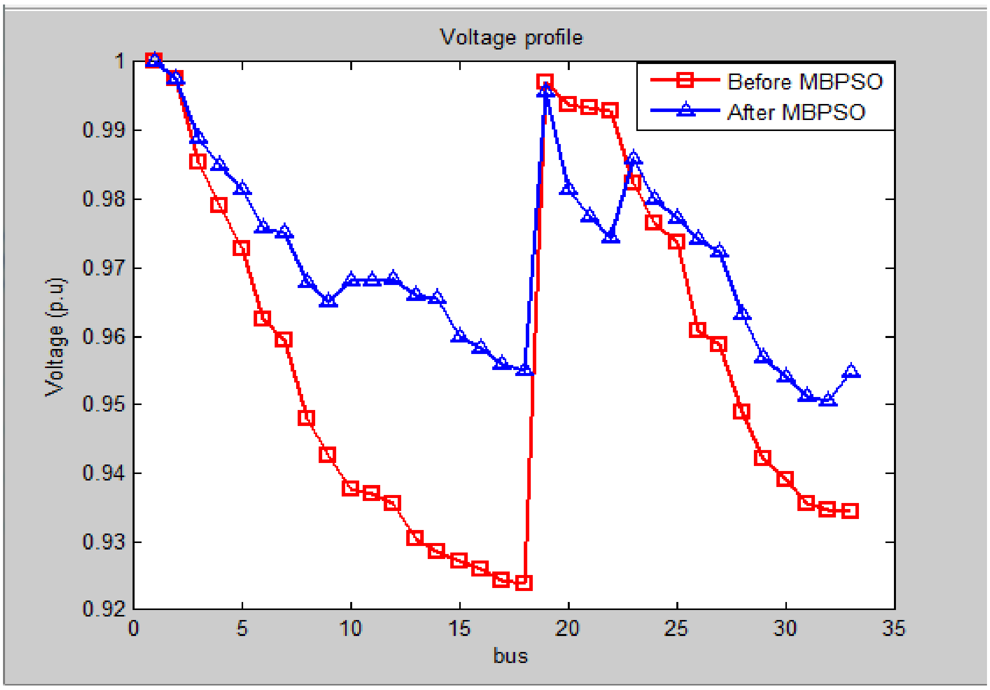

Figure 6: Voltage profile of DNR for the IEEE 33−node power system at load factor (μ = 0.875) while using MBPSO

At loading with variation ratio (μ = 1.125): in this case DNR is applied to load factor (μ = 1.125) demand. IEEE 33−node is presented as test system for both the BPSO and MBPSO approaches. Table 4 describes the comparison among the proposed methods and some other methods reported in the literature [2,9, 10, 14]. Switches status, real power loss, minimum and average voltage are given in this table.

Table 4: Result of DNR for the IEEE 33−node power system at load factor (μ = 1.125) while using BPSO, MBPSO and some other approaches.

Approach	Open Switches	P_{LT} (KW)	V_{av} $(p.u.)$	$V_{min}(p.u.)$
Initial	sw33, sw34, sw35, sw36, sw37	261.69	0.9414	0.9011
BPSO	sw7, sw9, sw13, sw32, sw37	243.63	0.9482	0.9199
MBPSO	sw7, sw9, sw14, sw32, sw37	173.08	0.9754	0.9355
FWA [2]	sw7, sw9, sw14, sw28, sw32	179.63	0.9631	0.9335
MBFOA [9]	sw7, sw9, sw13, sw32, sw37	181.91	0.9636	0.9295
ITS [10]	sw07, sw09, sw14, sw36, sw37	182.29	0.9607	0.9247
SLR [14]	sw07, sw10, sw14, sw36, sw37	182.95	0.9605	0.9247

It is seen from Table 1, the real power loss (P_{LT}) reduces while using BPSO by 6% from 261.69 kW to 243.63 kW and with MBPSO by 33% from 261.69kW to 173.08 kW. The minimum voltage (V_{min}) while using

BPSO enhances from 0.9011 p. u. to 0.9199 p. u. and with MBPSO improves from 0.9011 p. u. to 0.9355 p. u., while the average voltage enhances from 0.9414 p.u. to 0.9482 p.u. while using BPSO and from 0.9414 p.u. to 0.9754 p.u. with MBPSO.

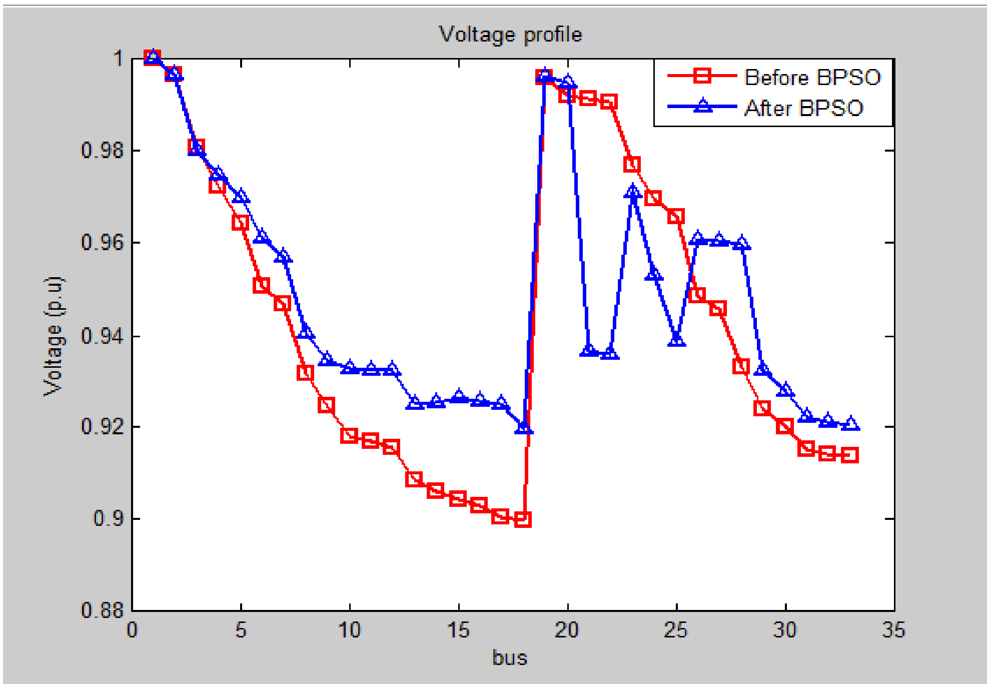

Figure 7: Voltage profile of DNR for the IEEE 33−node power system at load factor ($\mu = 1.125$) while using BPSO.

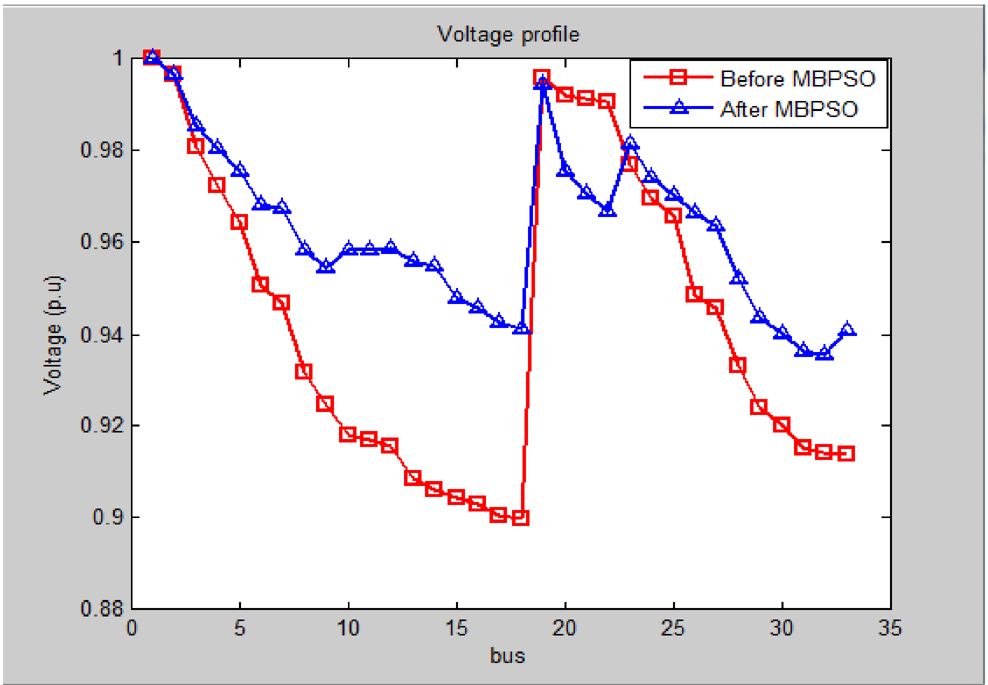

Figure 8: Voltage profile of DNR for the IEEE 33−node power system at load factor ($\mu = 1.125$) while using MBPSO.

Figure 7 and Figure 8 show voltage profiles of the network while using BPSO and MBPSO. It is clear that the voltage at all nodes (except the nodes 19, 20, 21, 22) were improves after reconfiguration. Finally, it is clear that from Figure 7 and Figure 8 by using MBPSO greatly improves the voltage profile compared to BPSO.

At load with variation ratio (μ = 1250): in this case DNR is applied to the heavy load (μ = 1.250) demand. IEEE 33−node is presented as test system for both the BPSO and MBPSO approaches. Table 5 describes the comparison among the proposed methods and some other methods reported in the literature [2,9, 10, 14]. Switches status, real power loss, minimum and average voltage are given in this table.

Table 5: Result of DNR for the IEEE 33−node power system at heavy load demands (μ = 1.250) while using BPSO, MBPSO and some other approaches.

Approach	Open Switches	P_{LT} (KW)	V_{av} $(p.u.)$	$V_{min}(p.u.)$
Initial	sw33, sw34, sw35, sw36, sw37	329.85	0.9342	0.8889
BPSO	sw7, sw9, sw13, sw32, sw37	305.81	0.9420	0.9102
MBPSO	sw7, sw9, sw14, sw32, sw37	216.24	0.9581	0.9279
FWA [2]	sw7, sw9, sw14, sw28, sw32	224.25	0.9587	0.9256
MBFOA [9]	sw7, sw9, sw13, sw32, sw37	227.52	0.9593	0.9211
ITS [10]	sw07, sw09, sw14, sw36, sw37	228.08	0.9561	0.9156
SLR [14]	sw07, sw10, sw14, sw36, sw37	228.92	0.9558	0.9156

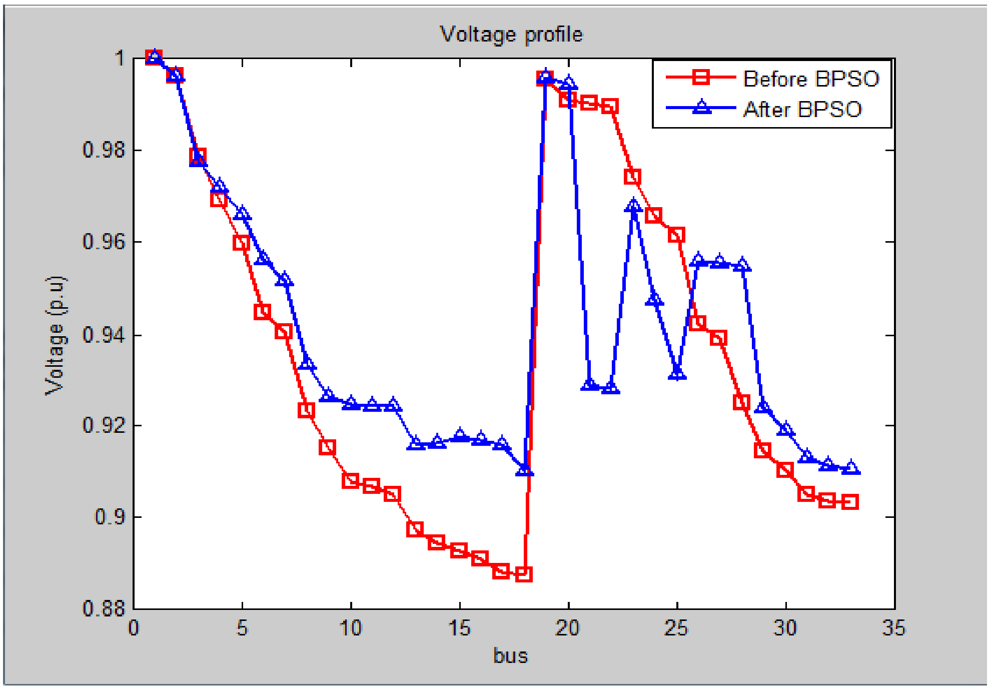

Figure 9: Voltage profile of DNR for the IEEE 33−node power system at heavy load demands (μ 1.250) while using BPSO.

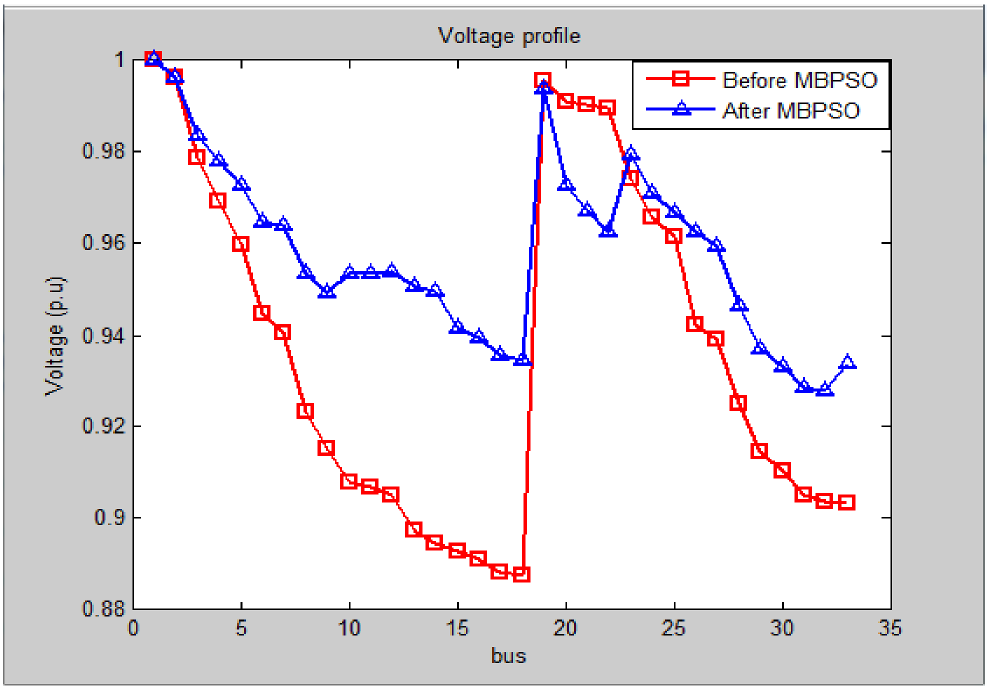

Figure 10: Voltage profile of DNR for the IEEE 33−node power system at heavy load demands (μ 1.250) while using MBPSO.

It is seen from Table 5, the real power loss (P_{LT}) reduces while using BPSO by 6% from 329.85 kW to 305.81 kW and with MBPSO by 34% from 329.85 kW to 216.24 kW. The minimum voltage (V_{min}) while using BPSO enhances from 0.8889 p.u. to 0.9102p.u. and with MBPSO improves from 0.8889 p.u. to 0.9279 p.u., while the average voltage enhances from 0.9342 p. u. to 0.9420 p.u. while using BPSO and from 0.9342 p.u. to 0.9581 p.u. with MBPSO.

Figure 9 and Figure 10 show voltage profiles of the network while using BPSO and MBPSO. It is clear that that the voltage at all nodes (except the nodes 19, 20, 21, 22) were improves after reconfiguration. Finally, it is clear that from Figure 9 and Figure 10 by using MBPSO greatly improves the voltage profile compared to BPSO.

Conclusion

In this study, (BPSO) and Modified BPSO (MBPSO) have been presented as powerful tools to find the optimal DNR. The problem here was formulated as a non−inear problem based on the decreasing of real power loss has been invested as an objective function that is subjected to a set of constraints. The results for the IEEE node 33 power systems demonstrated that MBPSO algorithm has high ability and effective in reduce power loss and voltage profile enhancement of the system compared to BPSO and other results in the papers that reported in the literature.

References

[1] S. Kalambe, and G. Agnihotri, "Loss minimization techniques used in distribution network: Bibliographical survey," *Renewable Sustainable Energy Reviews*, Vol. 29, 2014, PP.184–200.

[2] A. Mohamed Imran, and M. Kowsalya "A new power system reconfiguration scheme for power loss minimization and voltage profile enhancement using fireworks algorithm," *Electrical Power and Energy Systems*, Vol. 62, 2014, pp. 312–322.

[3] E. Carpaneto, G. Chicco, and J. S. Akilimali, "Branch current decomposition method for loss allocation in radial distribution systems with distributed generation," *IEEE Trans. Power Systems*, 2006; 21(3): 1170-79.

[4] H. Kim, Y. ko, and K. H. Jung, "Artificial neural network based feeder reconfiguration for loss reduction in distribution systems," *IEEE Transactions on Power Delivery*, Vol. 8, No. 3, 1993 pp. 1356-1366.

[5] T. Taylor, and D. Lubkeman, "Implementation of

heuristic search strategies for distribution feeder reconfiguration," *IEEE Transactions on Power Delivery*, Vol. 5, No. 1, 1990, pp.239-246.

[6] M. E. Baran, and F. F. Wu, "Network reconfiguration in distribution systems for loss reduction and load balancing," *IEEE Trans. Power Delivery*, vol. 4, No. 2, , 1989, pp. 1401-1407.

[7] H. D. Chiang, and R. J. Jumeau, "Optimal network reconfigurations in distribution systems: Part 1: A new formulation and a solution methodology," *IEEE Transactions on Power Delivery*, Vol. 5, No. 4, , 1990, pp. 1902-1909.

[8] G. K. V. Raju, and P. R. Bijwe, "Efficient reconfiguration of balanced and unbalanced distribution systems for loss minimization," *IEE Proc. Gener. Transm. Distrib.*, 2008; 2(1): 7-12.

[9] S. Naveen, K. Sathish Kumar, and K. Rajalakshmi, "Distribution system reconfiguration for loss minimization using modified bacterial foraging optimization algorithm," *Electrical Power and Energy Systems*, Vol. 69, 2015, 90–97.

[10] T. T. Nguyen, A. V. Truong, "Distribution network reconfiguration for power loss minimization and voltage profile improvement using cuckoo search algorithm," *Electrical Power and Energy Systems*, Vol. 68, 2015, pp. 233–242.

[11] C. T. Su, and C. S. Lee, "Network reconfiguration of distribution systems using improved mixed-integer hybrid differential evolution," *IEEE Transactions on Power Delivery*, 2003; 18(3): 1022-1027.

[12] T. Kennedy, and R. Eberhart, "Particle swarm optimization", In Proc. *of the IEEE international conference on neural networks*, 1995; 1942-48.

[13] R. C. Eberhart, and J. Kennedy, "A discrete binary version of the particle swarm algorithm," *Proc. of IEEE International Conference on Systems*, Man, and Cybernetics, Vol. 5, 1997, pp. 4104-4108.

[14] E. Dall'Anese, and G. B. Giannakis, "Sparsity-Leveraging reconfiguration of smart distribution systems," *IEEE Transactions on Power Delivery*. 2014; 29(3): 1417–1426.