Assessment of Two Load Flow Methods in Distribution Network with Optimal Reactive Compensation

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***Abstract*—The electrical distribution system is the interface between the power system and customers. Because of its compact architecture and low expense, the radial configuration is favored for distribution systems. Reactive Power Compensation (RPC) that is dependent on the optimal option of location and capacitor size in the network is one of the essential settlements for reducing network losses and adjusting the device voltage profile. Various load models, including constants of impedance (Z), current (I), power (P), and composite (ZIP), are used with contrasts between them to define the highest productive kind of load, which provides the optimum settlement for loss minimization, improving cost and voltage profile reductions. In this paper, a study of optimal Reactive Compensation (RC) with a comparison and assessment between two load flow methods Newton Raphson and Backward-Forward load flow methods (DBFSM), considering miscellaneous models of the load, is present for a distribution power system. The optimization algorithm based on Teaching-Learning (TLBO) is applied to refine the voltage values of buses and losses reduction. This algorithm has been tested for the IEEE-33 standard distribution power system. Comprehensive comparison and assessment have been accomplished among the optimization performances for four diverse load models in order to decide the model of load that provides the most betterment in the voltage profile and loss detraction using MATLAB program.**

The results demonstrate that ZIP model is the most suitable to generate the optimum settlements for capacitor positions and sizes .

Keywords—Reactive compensation, radial distribution system, DBFSM, TLBO, power loss minimization. voltage profile

I. INTRODUCTION

The Radial distribution system (RDS) structure model is desired due to easy, low cost, more reliable, safety devices, and the lowest values for fault currents. The RDS has several challenges, involving significant system branches, voltage perversion, overload, lopsided load, and several various approaches could be used to overcome these RDS problems [1]. Substitution of Conductors in RDS, Regulator of Voltage for generation unit, Distribution Generation (D.G.), methods for distribution system reconfiguring (DSR), and the optimum capacitor position (OCP) are these approaches utilized to address the RDS issues [2, 3]. In special situations, the R.C. and D.G. strategies are utilized because of the immense procurement and implementation costs, but the profit income does not cover these expenditures [4]. The OCP procedure managed the reactive power (RP) that constituted the most difficult task in control and operation of the (RDS). The OCP is a RP management (absorption or injection) mechanism in the RDS that contributes to an increase in voltage and reductions of losses [5]. The intelligent ant lion optimizer (ALO) method is used to determine the location and size of the capacitors in the distribution network [6]. The candidate buses are selected for capacitor installation using the ALO Based on the power loss sensitivity factor (LSF).The OCP methodology's application requires the estimation of the capacitor numbers, locations, and values required to be located at the nodes of the network. Consequently, capacitors construction at unsuitable positions creates multiple device issues, such as growing the real losses and the decrease in bus voltage [7]. More reduction in the cost from the feature of selecting the OCP to boost the network voltage profile and minimizes the active losses with an improvement of the power factor. The genetic algorithm is used to find the optimal capacitor placement and issue sizing solutions. [8]. Several optimization approaches were utilized for OCP methods, including the Voltage Stability Index (VSI), which offers the optimal buses for capacitor placement. In contrast, the optimization algorithm for a cuckoo search (C.S.) was utilized to find the best capacitor size on two IEEE networks (34 and 69 buses) [9]. In an ulterior analysis, the VSI with loss sensitivity index (LSI) were used to provide optimum capacitor locations while the Bacterial Foraging Algorithm (BFA) calculated the optimal size in the IEEE-33 bus network [10]. Based on the algorithm of an Artificial Bee Colony (ABC), enhancing VSI and optimizing the overall saving cost, LSI and VSI were then utilized to evaluate the position of capacitors [11]. Many academics utilized LSI to evaluate the capacitor bus candidates, and the optimization algorithm of Particle Swarm Optimization (PSO) was implemented to achieve optimal capacitor extent dependent on objective loss reduction with voltage optimization objective for 10, 34, and 85-bus RDS [12]. In this study, the RC strategy was applied using TLBO algorithm to solve all these challenges with multi-objective functions, including reducing the active power losses, increasing cost savings annually, and optimizing voltage profile while maintaining the constraints of (RDS). The TLBO algorithm was utilized to check of optimal capacitor locations and sizes on the power system buses without considering the VSI and LSI indices that defined in published researchers.

II. OPTIMAL PLACEMENT OF CAPACITOR IN THE DISTRIBUTION SYSTEM

Shunt capacitors that used to enhance the voltage and great decrease the losses in power system. The ideal capacitor banks are then integrated into the (RDS) for voltage profile improvement, and loss mitigation and accessibility to this problem include [13]:

- Analytical Techniques.
- To reduce or optimize an objective function utilizing iterative methods, numerical analysis methods.
- The methods of Heuristics .
- The methods of artificial intelligent (AI).

The functional cost is defined as a functional step rather than a constantly differentiable function since essentially capacitors are integrated in regular discrete capacity banks with costs correlated with non-linear capacitor bank size [14].

III. LOADS MODELING IN ANALYSING THE POWER FLOW

The outcomes of research into stability and power flow reflect the options required to improve the device's efficiency. Thus, to reflect the whole power structure, all component models should be combined into a single mathematical model. The simulation of loads will have a huge effect on the outcome of the study. This provides several benefits, such as minimizing errors, optimizing the voltage profile, monitoring the voltage (over/under) of the defined magnitude, and measuring the real demand for active and RP at the separate nodes. There are 2 kinds of load representation models, dynamic and static models, and the static form is split into two kinds: polynomial load and exponential models. [15].

A. The model of Exponential load

As a function of the frequency and voltage of bus bar, this model extracts reactive and active control. The static load design model is expressed as an exponential voltage (V) function.

$$P_d = P_0 (V/V_0)^{np} \quad (1)$$

$$Q_d = Q_0 (V/V_0)^{nq} \quad (2)$$

where (Q_d, P_d) characterizes the aspirations for reactive and real active load power, (Q_0, P_0) defines the load consumption of reactive and active power, (np, nq) represents the exponent of active and RP, the supply voltage is represented by V, and V_0 is the regarded voltage. The usual magnitudes of np and nq are described in [16]. The values are determined based on the numerical simulation technique measurement field.

B. The model of Polynomial load

Several kinds of loads in systems of electrical power, and every node has a certain proportion of those loads, which this varies with time. The ZIP model is one of the most commonly known models, and it is called ZIP, which reflects the convergence of the constants of current load (I), power load (P), and impedance (Z) models. As a context, the model is represented as [17]:

$$P = \alpha P_0 V^2 + \beta P_0 V + \gamma P_0 \quad (3)$$

$$Q = \alpha Q_0 V^2 + \beta Q_0 V + \gamma Q_0 \quad (4)$$

$$\alpha + \beta + \gamma = 1 \quad (5)$$

where (γ, β and α) constitute the relative contribution at any provided device node of constants of impedances (Z), currents (I), and a load of power (*P*). The active and reactive power is exclusively studied based on voltage differences, but the disparity in an intensity-dependent on frequency range is not explored. The following magnitudes are chosen in this paper: α =0.6, β =0.2, and γ =0.2, which lead to better performance for loss minimization and voltage profile enhancement.

C. The methodology of load flow

Traditional load flow techniques like Newton Raphson Method (NRM) are incomplete and can give differ results due to the various electrical distribution systems characteristics including radial and high (R / X) ratio [18]. Other approaches are sophisticated for power flow systems, such as Direct Backward–Forward Sweep Method (DBFSM) used. The reactive compensation (RC) is implemented and compares for two load flow techniques to prove the DBFSM load flow effectiveness. The principal stages of this load flow method are outlined in [19].

D. The Proposed Objective Functions

Employing multi-objective functions is profitable to minimize (P_{loss}) and boost the voltage values for system buses based on the optimization processes. Such objective functions (ob. fun.) are:

i. Power losses reduction (objective function 1):

$$(ob.fun.1) = P_{loss} \quad (6)$$

$$P_{loss} = \sum_{l=1}^{N_{br}} P_{lossl} \text{ kW} \quad (7)$$

$$P_{lossl} = I_l^2 * R_l \text{ kW} \quad (8)$$

where:

P_{loss}: represent the overall losses.

N_{br}: The number of branches that the system has.

R_l: is the branch resistance l

I_l: is the current flow in the branches.

ii. Voltage profile enhancement $(ob.fun.2)$

Buses must have voltages within the appropriate range border (limits) [20].

$$(\text{ob. fun. } 2) = V_C * Re_v + C_C * Re_i \quad (9)$$

where:

V_c: Bus voltages limits.

C_C: Branch currents limits.

Re_v: Variable of Bus Voltage Retaliation. This parameter is zero if the bus voltage is within appropriate boundaries.

Re_i: The revenge element of branch currents. This parameter is zero if the branch current does not attain the value of the thermal limit. **Buses** must have voltages within the appropriate range (limits).

iii. Increment of annual savings costs $(ob.fun.3)$:

The aim of minimizing losses is to raise the anniversary cost savings associated with P loss of energy and the exploitation costs of the constituted capacitors. Purchase costs, construction, and maintenance costs of capacitors are included in the investment cost of capacitors. The anniversary savings assets are equal to the variance between the losses costs of base case and the losses after implementing the suggested techniques, and the cost of investments are described in [21]:

The capacitor costs and sizes have been given in [22]. Table I, which was used for cost calculations, tabulates the values of the capacitors' cost parameters [23].

TABLE I. STANDARD VALUES FOR EXPENSE PARAMETERS

Parameter	Value
C_{Ic} (\$/Loc_c)	1600
C_{Oc} (\$/Loc_c/Year)	300
C_{En} (\$/kWh)	0.06
$Time$ (h)	8760

The three functional objectives$(ob.fun.1)$,$(ob.fun.2$, and $(ob.fun.3)$ are combined to compose the final functional objective $(ob.fun.f)$.

$$ob.fun.f = ob.fun.1 + ob.fun.2 + ob.fun.3 \quad (10)$$

E. Constraints in General

Regarding technical and operational (constraints), the following are defined as general limitations (restrictions), including advanced RDS performance.

i. The technological limitations

These sorts of limitations are defined as a technical limiting technical and divided into three groups:

a. Proposal Functions of bus voltage

The voltage value should be within the standard range for each of the system buses to conserve power efficiency.

$$|V_{jmin.}| \le |V_j| \le |V_{jmax.}| \quad j \in N_{bus} \quad (11)$$

where: (N_{bus}) is the buses number on the network. The basic normal boundaries of voltage buses are $(0.95 - 1.05)$ p.u [24].

b. Branch Current Limitations

From the safety side, the branch current must not exceed the predefined maximum value while ensuring the continuity of transmission for load power at the same time [25].

$$|I_l| \le |I_{lmax.}| l \in N_{br.} \quad (12)$$

where $(N_{br.})$ is the branches number of the systems.

c. Constraints for total sizing of capacitors

The total sizing of capacitors (Q_{CT}) integrated into the RDS must not overtake the actual total RP of load(Q_{load}) .

$$Q_{CT} \le Q_{load} \quad (13)$$

ii. Limitations of Operation

These kinds of restrictions are referred to as limits of equality are divided into two kinds:

a. Radial limitations are manipulating whole load

The RDS configuration condition is confirmed by exploring the result for a determinant of the [A] bus incidence matrix with rows equal to the branches' number and columns equal to the buses' number, as follows [26]:

$$[A]=\begin{cases} 1 & \text{If the branch i is out from bus j} \\ -1 & \text{if the branch i is inside into bus j} \\ 0 & \text{if the branch i is not linked to bus j} \end{cases} \quad (14)$$

b. Limitation of balancing real power

$$P_{Sup} = P_{Dem} + P_{loss} \quad (15)$$

where P_{sup} is substation power, P_{Dem} is demand power.

IV. TEACHING LEARNING BASED OPTIMIZATION ALGORITHM

The Teaching Learning Based Optimization (TLBO) algorithm is a universal optimization approach specifically advanced in [27]. It is an iterative learning algorithm focused on habitat that displays certain typical data properties with other algorithms of evolutionary computation (E.C.) (Fogel 1995). Instead of learners undertaking genetic operations such as choice, crossover, and mutation, TLBO tests the tutor's knowledge, who is known to be the most learned individual in society, to achieve optimal outcomes. Because of its easy concept and high performance, TLBO has been effectively used for several real-life issues. From the normal distribution between upper and lower limits of awards parameters [28], the leading population is generated with a total population (N.P.) and the amount of design variable (D). There have been two simple learning process modes, instructor phase, and learner phase. The algorithm's performance is calculated in terms of outcomes, the degrees of the students based on the quality of the instructor [29].

A. Teacher Phase

The teaching stage illustrates the learning experience of the pupil by the instructor. Owing to his expertise and information, the superior student in a population topic is the instructor. The discrepancy between the teacher's outcome and the average result of the students for every class could be determined as shown in reference [30].

B. Learner phase

A learner interacts randomly with other learners for amending her or his realization. Considering population size of 'n', the learning phenomenon of this phase is evident below:

Randomly select two learners, *P*, and *Q*, such that

$$X'_{total-P,i} \ne X'_{total-Q,i} \quad (16)$$

where $X'_{total-P,i}$ is the updated value of $X_{total-P,i}$ at the end of the teacher phase, $X'_{total-Q,i}$ is the updated value of $X_{total-Q,i}$ at the end of the teacher phase.

$$X''_{j,P,i}=X'_{j,P,i}+r_i(X'_{j,P,i}-X'_{j,Q,i}),\text{if } X'_{total-P,i} < X'_{total-Q,i} \quad (17)$$

$$X''_{j,P,i}=X'_{j,P,i}+r_i(X'_{j,Q,i}-X'_{j,P,i}),\text{if } X'_{total-Q,i} < X'_{total-P,i} \quad (18)$$

Agree $X''_{j,P,i}$ if it gives a better function value. The optimum TLBO parameters are presented in Table II.

TABLE II. OPTIMUM VARIABLES OF TLBO.

Parameter Type	Rate (Magnitude)
Number of Population	30
Predefined Probability	0.1
No. of Iter. = Max. Loop(N. R)	90
No. of Iter. −Max. loop (DBFSM)	90

The proposed algorithm is implemented to find the optimal topology that reduces the real power losses with enhance the voltage profile. The flowchart of this algorithm to OCP problem is shown in Fig. 1.

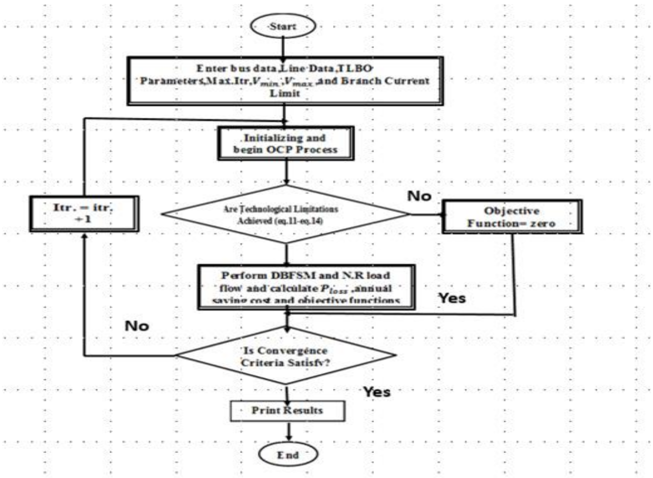

Fig. 1. TLBO algorithm for OCP.

V. SIMULATION AND COMPARISON RESULTS

The optimization process by TLBO has been prepared and implemented in the computer coded by MATLAB program/ m-file code. It is used to minimize the seeking space for the 33 bus standard IEEE RDS for selecting the location of buses and optimal capacitor values. Fig. 2 demonstrates the RDS single line graph case study and includes .The system data are specified in reference [31].

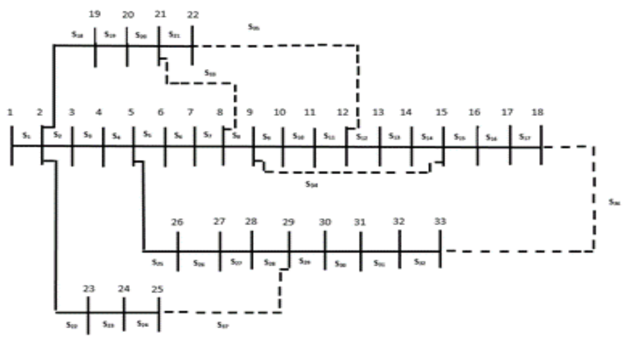

Fig. 2. The RDS single line graph of standard IEEE- 33 bus.

The steps for RC are carried out by selecting 4- buses with counting the models of loads. Table III displays the obtained results and comparison among different load models based on the power flow of the Newton-Raphson method without and with RC for the optimal option of four buses using TLBO. The table results obtained show that the ZIP type represents the best model compared with other models for RC using the N.R. method. . Figs. 3, 4, 5, and 6 show the voltage values of system buses (voltage profile) and the values of power losses for each system branch and indicate the ZIP model is better than other models.

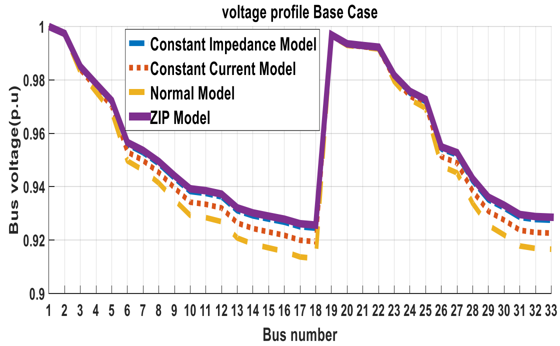

Fig. 3. Voltage profile of standard 33 bus network without RC by using (N.R.).

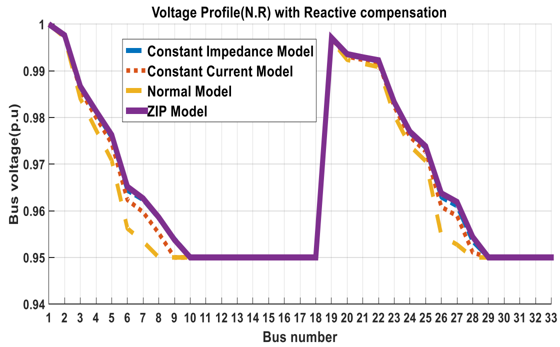

Fig. 4. Voltage profile of standard 33 bus network with RC by using (N.R.).

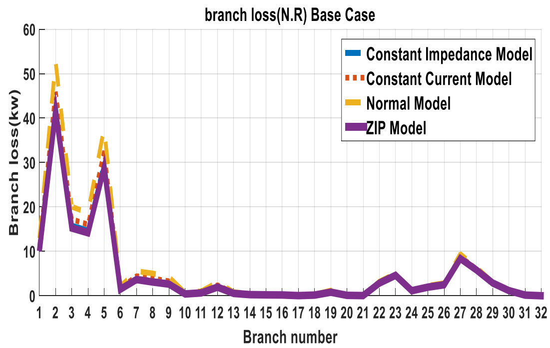

Fig. 5. Branch loss of standard 33 bus network without RC by using (N.R.).

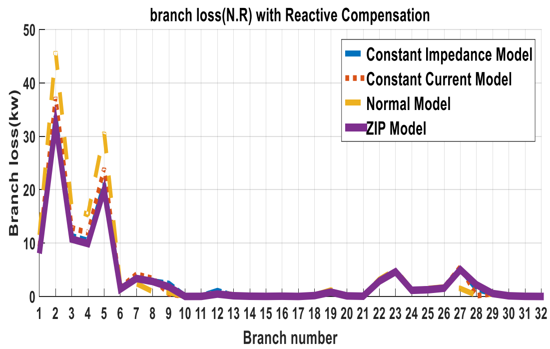

Fig. 6. Branch loss of standard 33 bus network with RC by using (N.R.).

The results are enhanced by using the DBFSM method based on the optimal selection of buses by TLBO as shown in Table IV. The table results show the enhancement in system buses voltage values and the reduction of real losses using the ZIP model with the DBFSM method. Figs. 7, 8, 9, and 10 show the voltage values of system buses and the values of power losses for each system branch and indicate the ZIP model represents the best model.

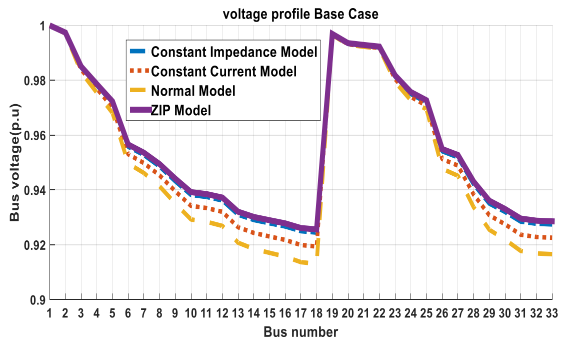

Fig. 7. Voltage profile of standard 33 bus network without RC by using (DBFSM).

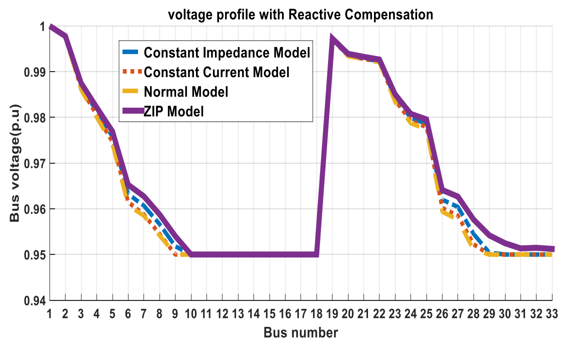

Fig. 8. Voltage profile of standard 33 bus network with RC by using (DBFSM).

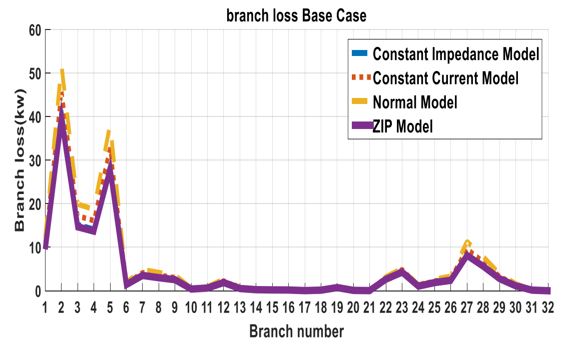

Fig. 9. Branch loss of standard 33 bus network without RC by using (DBFSM).

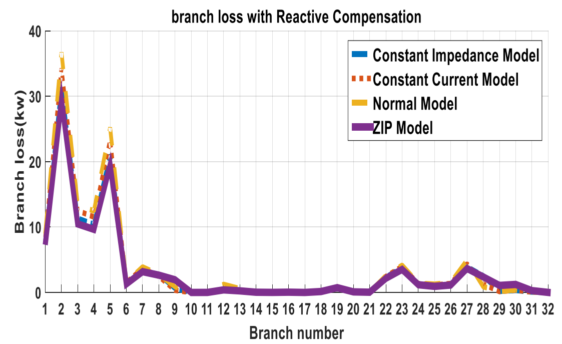

Fig. 10. Branch loss of standard 33 bus network without RC by using (DBFSM).

VI. CONCLUSIONS

Conclusion of this study, the enhancement of the voltage profile, the elimination of further power losses, and the minimization of the radial distribution power system overall expense, taking into account various load models, were presented depending on the RPC methodology. They contrast two load flow techniques, Newton Raphson and Backward-Forward, to identify the kind of load model that produced the most improvement in the loss minimization and voltage profile. The incorrect information for load modeling causes incorrect findings with an investment and cost because of various types of loads. For optimal RC, the TLBO optimization technique is applied by reducing the search space to identify the best capacitors sizes and positions. For the IEEE 33 bus test system, this approach was utilized. The results demonstrate the efficacy of the suggested method for obtaining the optimal capacitor sizes and locations in the distribution systems and its ability for solving multi objective issues.The comparison between the various models of loading verified that the best model is ZIP model to generate the best settlement for capacitor sizes and locations and that the technique of backward-forward load flow is more efficient and useful for RDS.

TABLE III. FINDINGS OF STANDARD 33 BUS WITH AND WITHOUT RC BY USING (N.R.) METHOD.

Item	**Const. P**		**Const. I**		**Const. Z**		**ZIP**	
Action	Without	With	Without	With	Without	With	Without	With
P_{loss} (kw)	202.23	148.31	176.62	127.86	162.92	116.72	157.55	111.57
Q_{loss} (kvar)	134.47	94.26	116.95	82.61	108.24	76.8	104.65	74.55
Location	--	6,28 13, 29	--	6,28 13, 29	--	6,28 13, 29	--	6,28 13, 29
Cap. Size kvar	--	150, 150, 150, 450	--	600, 300, 150, 150	--	450, 300, 300, 150	--	600, 300, 150, 150
Cost ($)	--	338.85	--	387	--	398.85	--	387
C_A^B	106292.08	--	92831.47	--	85630.75	--	82808.28	--
C_A^A	--	83992.001	--	73290.44	--	67446.88		64728.19
Saving%	--	20.98	--	21.05	--	21.23	--	21.83
Loss . Red. %	--	26.66	--	27.6	--	28.35		29.18
Vol. Min.	0.911	0.95	0.918	0.95	0.922	0.95	0.924	0.95
Vol. Max.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

TABLE IV. FINDINGS OF STANDARD 33 BUS WITH AND WITHOUT RC BY USING (DBSM.) METHOD.

Item	**Const. P**		**Const. I**		**Const.Z**		**ZIP**	
Action	Without	With	Without	With	Without	With	Without	With
P_{loss} (kw)	202.67	132.01	176.62	108.92	156.87	93.58	151.14	88.79

Q_{loss} (kvar)	134.47	109.97	116.95	100.53	108.24	97.26	104.65	92.28
Location	--	24 31 13 29	--	24 31 13 29	--	24 31 13 29	--	24 31 13, 29
Cap. Size kvar	--	450, 150, 300 600	--	450, 150 150 600	--	450, 150, 150 600	--	300, 300 300 600
Cost ($)	--	425.85	--	395.85	--	395.85	--	416.55
C_A^B	106523.35	--	92831.47	--	82450.87	--	79439.18	--
C_A^A	--	75514.14	--	63344.2	--	55281.49		52784.57
Saving %	--	29.11	--	31.67	--	32.95	--	33.55
Loss. Red. %	--	34.86	--	38.33	--	40.17		41.25
Vol. Min.	0.913	0.95	0.919	0.95	0.924	0.95	0.9256	0.95
Vol. Max.	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

REFERENCES

[1] F. Saccomono,"Electric power system, analysis and control", IEEE Press Series on Power Engineering, 2003.

[2] S. S. Nuchhi, R. B. Sali, S. G. Ankaliki, "Effect of reactive power compensation in voltage profile", International Journal of Engineering Research7 Technology (IJERT), Vol. 2, Issue 6, 2013.

[3] T. Husain, M. Khan and M. Ansari, "Power flow analysis of distribution system", International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol.5, Issue5, 2016.

[4] D. Das, D. P. Kothari, A. Kalam,"Simple and efficient method for load flow solution of radial distribution networks", Electrical Power &Energy Systems, Vol.17, No.5, pp.335-346, 1995.

[5] J. L. Guardado, F. R. Davalos, J. Torres, S. Maximov and E. Melgoza," An Encoding Technique for Multiobjective Evolutionary Algorithms Applied to Power Distribution System Reconfiguration," The Scientifics World Journal, vol. 2014, Article ID 506769, 2014.

[6] M. Bakhtiari, M. Mallaki, Nima Moaddabi," Optimal Capacitor Placement in Radial Distribution Network Based on Power Loss Sensitivity Index Using Ant Lion Optimizer Considering Different Loading ",Signal Processing and Renewable Energy, June 2020,(pp. 73-85)

[7] Y. Y. Hong, F. J. Lin and F. Y. Hsu, "Enhanced Particle Swarm Optimization-Based Feeder Reconfiguration Considering Uncertain Large Photovoltaic Powers and Demands," International Journal of Photoenergy, vol. 2014, Article ID 704839, 2014.

[8] M. J. Tahir, Badri A. Bakar, M. Alam, M. S. Mazlihum, "Optimal capacitor placement in a distribution system using ETAP software," Indonesian Journal of Electrical Engineering and Computer Science, vol. 15, No.2, August 2019, pp. 650-660.

[9] T. Du, Y. Hu and X. Ke, "Improved Quantum Artificial Fish Algorithm Application to Distributed Network Considering Distributed Generation," Computational Intelligence and Neuroscience, vol. 2015, Article ID 851863, 2015.

[10] T. T. Nguyen, T. T. Nguyen, A. V. Truong, Q. T. Nguyen and T. A. Phung, "Multiobjective Electric Distribution Network Reconfiguration Solution using Runner-Root Algorithm," Applied Soft Computing, vol. 52, pp. 93-108, 2017.

[11] A. Roosta, H. R. Eskandari and M. H. Khooban, "Optimization of Radial Unbalanced Distribution Networks in the Presence of Distribution Generation Units by Network Reconfiguration using Harmony Search Algorithm," Neural Computing and Applications, pp. 1-15, 2018.

[12] S. Nawaz and A. Tandon,"A solution to capacitor placement problem for the minimization of power loss in distribution system", Skite Research Journal, Vol. 4, Issue 2, 2014.

[13] N.I.Voropai and B.B. Undraal," Multicriteria Reconfiguration of Distribution Network with Distributed Generation," Journal of Electrical and Computer Engineering, vol. 2012, Article ID 317315, 2012.

[14] H. Zayandehroodi, M. Amirinegad, H. Afzalynia and A. Noori "Particle swarm optimization algorithm for optimal capacitor placement on electric power distribution networks", International Journal of Scientific &Engineering Research,Vol. 5,Issue 8, 2014.

[15] N. A. Roustami and M. O. Sadegh,"The effect of load modelling on load flow results in distribution systems", American Journal of Electrical and Electronic Engineering, 2018, Vol.6, No.1, pp.16-27.

[16] U. Eminoglu and M. H. Hocaoglu," A new power flow method for radial distribution systems including voltage dependent load models", Electrical Power System Research, Vol.76, pp.106-114, 2005.

[17] S. Mok, S. Elangovan,C. Longiian and M. Salama," A new approach of power flow analysis of balanced radial distribution systems", Electric Machines Power System,Vol.28, pp.325-340, 2000.

[18] F. Teng. "Implementation of a Voltage Sweep Power Flow Method and Comparison with Other Power Flow Techniques," Semester Thesis, Swiss Federal Institute of Technology (ETH), Zurich, 2014

[19] H. K. Verma, and P. Singh, "Optimal Reconfiguration of Distribution Network Using Modified Culture Algorithm," Journal of the Institution of Engineers, vol. 99, no. 6, pp. 613–622, 2018.

[20] C. T. Su, C. F. Chang and J. P. Chiou, "Distribution Network Reconfiguration for Loss Reduction by Ant Colony Search Algorithm", Electric Power Systems Research, Vol.75, No.2-3, pp. 190–199, 2005.

[21] D. Das, "Optimal Placement of Capacitors in Radial Distribution System Using a Fuzzy-GA Method" , International Journal of Electrical Power & Energy Systems, Vol.30, No. 6-7, pp.361–367, 2008.

[22] A. Elsheikh, Y. Helmy,Y. Abouelseoud, A. Elsherif,"Optimal capacitor placement and sizing in radial electric power systems", Alexandria Engineering Journal, (2014) , pp. 809-816.

[23] A. A. El-Fergany and A.Y. Abdelaziz, "Artificial Bee Colony Algorithm to Allocate Fixed and Switched Static Shunt Capacitors in Radial Distribution Networks", Electric Power Components and Systems, Vol.42, No.5, pp.427–438, 2014.

[24] M. R. Haghifam, and O.P. Malik, "Genetic Algorithm-based Approach for Fixed and Switchable Capacitors Placement in Distribution Systems with Uncertainty and Time Varying Loads," IET Generation Transmission & Distribution, vol. 1, no. 2, pp. 244–252, 2007.

[25] R. S. Rao, S. V. L. Narasimham, M. R. Raju, and A. S. Rao, "Optimal Network Reconfiguration of Large-Scale Distribution System Using Harmony Search Algorithm," IEEE Transactions on Power Systems, vol. 26, no. 3, pp. 1080 - 1088, 2011.

[26] M. Sedighizadeh, M. Ghalambor and A. Rezazadeh, "Reconfiguration of Radial Distribution Systems with Fuzzy Multi-Objective Approach Using Modified Big Bang-Big Crunch Algorithm.

[27] S. Chandra S. Anima Naik, and K.Pavrathi,"A teaching learning based optimization based on orthogonal design for solving global optimization problems", Springer Plus, December 2013.

[28] A. Tiwary,"Reliability Enhancement Of Distribution System using Teaching Learning based Optimization Considering Customer and Energy based Indices", International Journal on Future Revolution in Computer Science &Communication Engineering,Volume:3 ,Issue :10,October 2017.

[29] M. El-Arini, A. Fathy,"An Efficient and Reliable method for Optimal Allocation of the Distributed Generation based on Optimal Teaching Learning Algorithm", WSEAS Transactions on Power Systems, Volume 10,2015.

[30] P.J. Pawar, R.Venkata Rao, "Parameter Optimization of Machining Processes using Teaching-Learning based Optimization Algorithm", International Journal of Advanced Manufacturing Technology,Vol. 67,No. 5-8,2013,pages 995- 1006.

[31] Z. Chen," A Study of Power Distribution System Reconfiguration based on Reliability Indices", A Thesis Presented to the Faculty of the Graduate School at the University of Missouri-Columbia, 2016.