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## 2020 12th International Conference on Computational Intelligence and Communication Networks

# CICN 2020

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# Optimal Placement and Sizing of Distributed Generation Using Multi-Verse Optimization

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***Abstract*—In this present situation, power loss minimization in distribution network is one of the challenging area of research. In distribution system losses are more compared to transmission system. High power loss occurs when the connected loads in the distribution network are moved away from distribution substation. Adequate allocation and sizing of distributed generation (DGs) and capacitors are the modern way to minimize the distribution power loss. Improper placement leads to increase in power loss and may affect system performance adversely. Computation intelligence based methods has been used to allocate the DGs in proper location. In this present work a recently developed nature inspired algorithm known as Multi Verse Optimization (MVO) has been implemented for DGs placement problem. The implementation of MVO has been tested on 33 bus radial distribution system. The obtained results have also been compared with the reported results in literature to establish effectiveness of the algorithm.**

***Keywords*—Multi Verse Optimization, Distributed Generation, DTR, WP etc.**

## I. Introduction

The main goal of power system is to deliver the power at each location of the power system network economically and reliably. Previously for generating electrical energy only conventional energy resources were used. These conventional resources are coal, hydro, nuclear. These generators deliver power widely distributed to different types of users are connected through long transmission and distribution networks. In nowadays, the central power plant is becoming weakening. The weakening of the central power plant is due to environmental issues and also due to reduction in conventional resources. As a result transmission and distribution costs are also gradually increasing. Then the distributed generation comes into the existence and it accomplishes a solution the most of these upcoming challenges. DG in simple terms can be defined as small range generation or decentralized generation that is neither centrally planned nor centrally dispatched. DGs are used near to the load side and they use energy sources such as solar PV system, wind generation system, fuel cells, gas micro turbines etc. and its capacity is also less than 100 MW. The reactive power is supplies to the load by the capacitors. By connecting capacitors to the system improvement in the system voltage profile is observed. The capacitor is also comes under $2^{nd}$ type of DGs. When DGs and Capacitors are connected to the system, encouraging effect on the system power losses, system voltage profile is evident. For achieving the encouraging effect on the system after connecting DGs, the optimal size and location of DGs are to be selected in distribution networks. A number of researchers have done the work on this relevant topic for many years for optimal allocation and sizing of DG and capacitors. Several types of research have been done in the past years on optimal allocation problem of DGs and capacitor. For optimally locate the proper size of DGs different methods have been used by the researchers for decades. Some of these are analytical methods, meta-heuristic methods, population based method, computational optimization methods and AI based algorithms etc. In ref. [1] uniformly increasing and distributed type load has been considered. DGs allocation for this type of load has done using combination of sensitivity and analytical method. The authors of this paper had worked on real time system that is Eastern Washington region a small part of large WCSS system. In ref. [2] voltage improving sensitivity and loss minimization sensitivity method are used to calculate best location for DG implementation. In ref. [3] author has done the amalgamation of GA and PSO algorithm for finding optimal location and size of dispersed generation in distribution network. In ref. [4] for determining the optimal location of DG and Capacitor voltage stability index approach has been used by considering both active and reactive power loss minimization as objective function. Voltage Stability Index has been implemented for finding adequate location and size of dispersed generation units [6]. A brief description about DG is also presented in [7]. Modified GA has been implemented for finding adequate location and size of dispersed generation units [9]. In ref. [11] for placing the dispersed generation units at optimal location with optimal size a multi-objective decomposition based evolutionary algorithm (MOEA/D) in distribution network has been applied while considering objectives for the problem as abbreviation system real and reactive power losses. The authors here used multi-objective objective function to optimize total cost per year by reducing real power loss. The Salp Swarm Optimization, Modified GA have been implemented for finding favorable location and size of dispersed generation units [12-13].

## II. PROBLEM FORMULATION

Placement of DGs at favorable location with optimal size is done by minimizing the objective function while satisfying the operational constraints.

### *A. Objective function*

Objective of the problem is minimizing the real power loss. The exact real power loss formula is taken from ref [6]. For N bus system the loss formula can be is given as

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$$P_i = \sum_{i=1}^{N}\sum_{j=1}^{N}(e_{ij}(P_iP_j + Q_i\,Q_j) + f_{ij}(Q_iP_j - P_iQ_j)) \quad (1)$$

Where

$$e_{ij} = \frac{r_{ij}}{V_iV_j}\cos(\sigma_i - \sigma_j) \quad (2)$$

$$f_{ij} = \frac{r_{ij}}{V_iV_j}\sin(\sigma_i - \sigma_j) \quad (3)$$

*B. System constraints*

a. Power flow equation need to be satisfied

$$P_{Gi} - P_{Di} = \sum_{i=1}^{N}\sum_{j=1}^{N} V_i\,V_j\,(G_{ij}\cos(\sigma_i - \sigma_j) + B_{ij}\sin(\sigma_i - \sigma_j)) \quad (4)$$

$$Q_{Gi} - Q_{Di} = \sum_{i=1}^{N}\sum_{j=1}^{N} V_i\,V_j\,(G_{ij}\sin(\sigma_i - \sigma_j) - B_{ij}\cos(\sigma_i - \sigma_j)) \quad (5)$$

$$\forall_i = 1,2,3 \ldots\ldots N \quad (6)$$

Where $G_{ij}$ is conductance of the line between bus i and bus j and $B_{ij}$ is susceptance of the line between bus i and bus j.

$$P_i = P_{Gi} - P_{Di} \quad (7)$$

$$Q_i = Q_{Gi} - Q_{Di} \quad (8)$$

b. Voltage at each bus must be within the permissible limit.

$$V_{min} < V_i < V_{max} \quad (9)$$

$$\forall_i = 1,2,3 \ldots\ldots N \quad (10)$$

c. Current at each line connected between two buses must be within permissible limit

$$I_i < I_{rated} \quad (11)$$

$$\forall_i = 1,2,3 \ldots\ldots N \quad (12)$$

## III. Optimization Algorithm

According to big bang theory, universe created by a large explosion. There was nothing before the explosion. Multi verse theory also a new theory in cosmology. It is believed that big bang occurs many times and there are many universes like our own. The three component are chosen of multi-verse theory as main inspiration of MVO algorithm. Black holes, white holes and worm holes are these three components respectively. Black/white holes are used for exploring in the search space to find best fitted solution. Wormholes are used for exploiting in the search space. Object in the universe corresponds to each variable of solution. Solution of the problems is very much similar to universe. Solution fitness function value is similar to inflation rate of the universe. Higher inflation rate of universe represents higher probability of getting white holes whereas lower inflation rate represents higher probability of getting black holes. This optimization algorithm is developed by Alimirjalili in 2015 [14].

Following steps are used to perform MVO algorithm.

a. Black/white hole tunnel

Roulette wheel mechanism is used at every step of solution to choose a universe depending upon their inflation rate. Black/white hole tunnel are used to teleport the object from higher inflation rate universe to lower inflation rate universe.

To mathematically model this phenomenon

$$A = \begin{bmatrix} u_1^1 & u_1^2 & .. & .. & u_1^d \\ u_2^1 & u_2^2 & .. & .. & u_2^d \\ .. & .. & .. & .. & .. \\ .. & .. & .. & .. & .. \\ u_k^1 & u_k^2 & .. & .. & u_k^d \end{bmatrix} \quad (1)$$

$$u_k^i = \begin{cases} u_k^i & if\ p1 \geq N(A_i) \quad (2) \\ u_k^j & if\ p1 < N(A_i) \quad (3) \end{cases}$$

Here $k$ is the number of universe and $d$ is the number of parameters or object (or variables) $u_k^i$ defined $i^{th}$ parameter or object of $k^{th}$ universe. $A_i$ represents $i^{th}$ universe $N(A_i)$ represent $i^{th}$ universe normalize inflation rate. Here $p1$ is a random number between [0,1] interval. $u_k^j$ represents $j^{th}$ parameter of $k^{th}$ universe selected by roulette wheel selection.

b. Transfer of object through wormhole

It is assumed that each universe has a wormhole and the wormhole tunnel connect one universe and the best universe obtained so far. To model this phenomenon mathematically the following equations are used

$$u_k^i = \begin{cases} \begin{bmatrix} U_j + DTR \times ((ub_j - lb_j) \times p4 + lb_j) & p3 < 0.5 \\ U_j + DTR \times ((ub_j - lb_j) \times p4 + lb_j) & p3 \geq 0.5 \end{bmatrix} & p2 < WP \\ u_k^i & p2 \geq WP \end{cases} \quad (4)$$

Where $U_j$ is the jth object of best universe. $u_k^i$ is the $k^{th}$ object of ith universe. WP and DTR are coefficient, which may be constant or may be a function of iteration. WP means wormhole existence probability and DTR means total distance rate.

$$DTR = 1 - \frac{n^{1/6}}{N^{1/6}} \quad (5)$$

$$WP = 0.2 + (n \times \frac{0.8}{N}) \quad (6)$$

Here n represents present iteration and N is maximum iteration. DTR and WP can be taken as constant but these coefficient are used in MVO algorithm to get better results.

## IV. Computational Result

The MVO has been executed on a 33 bus radically connected distribution network as described in Fig. 1. The entire connected load of the test bus system is 3.715 MW and 2.3 MVAr [6]. MATLAB R2013a software is used for execute the program. Fig. 2 illustrates voltage profile that has obtained by running the backward forward sweep load flow method before connecting any DGs and/or capacitors unit.

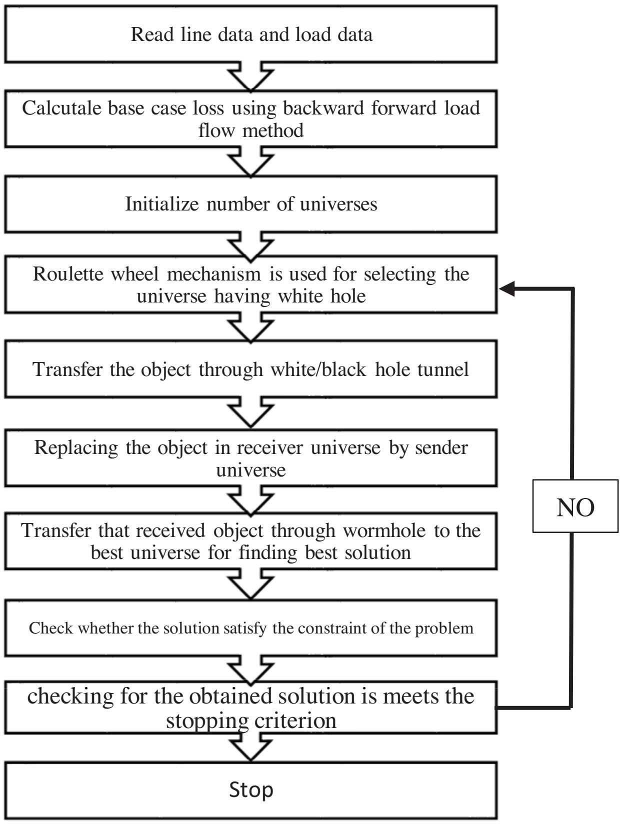



Fig. 1. Flow chart of the problem

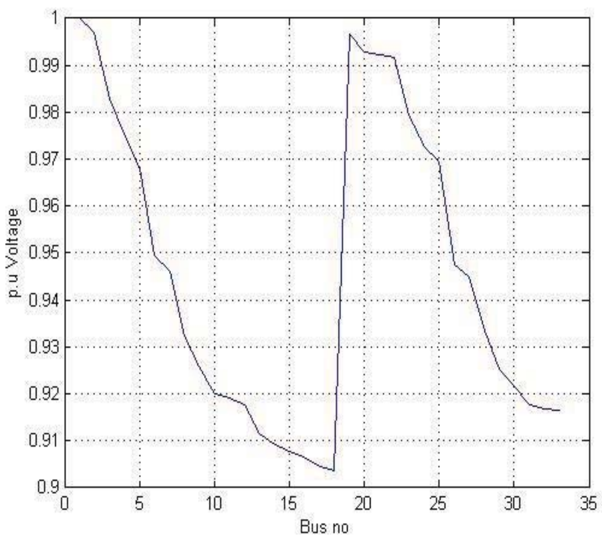



Fig. 2. Voltage layout without DG for 33 bus

This is observed from Fig. 2. which represents voltage profile of 33 buses, the minimum voltage is 0.9038 p.u. at bus number 18. The MVO algorithm has been applied to calculate location and size of DGs. Fig.3. represents the voltage plot of the system when one DG has been installed whereas after installation of two DGs the voltage plot has been shown in Fig.4. Minimum voltage has been increased after DG integration in the system network. Power loss has also been reduced after DG placement.

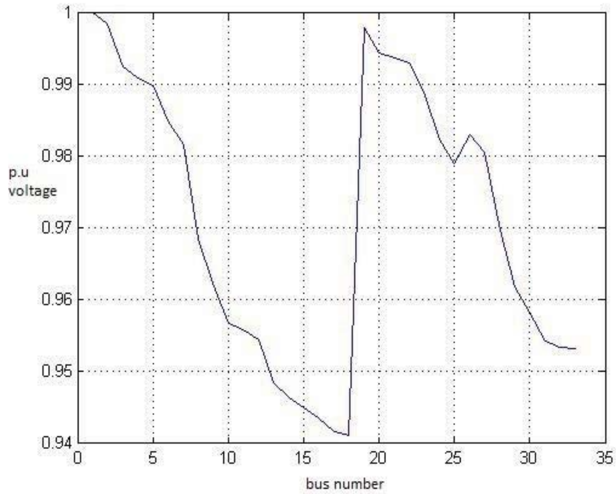



Fig. 3. Voltage layout with one DG for 33 bus

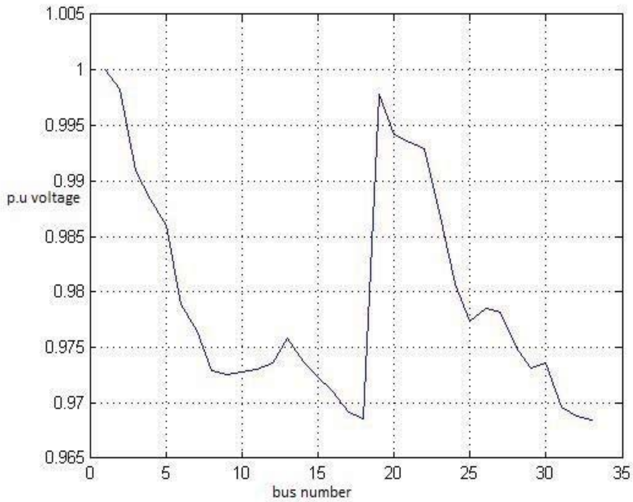
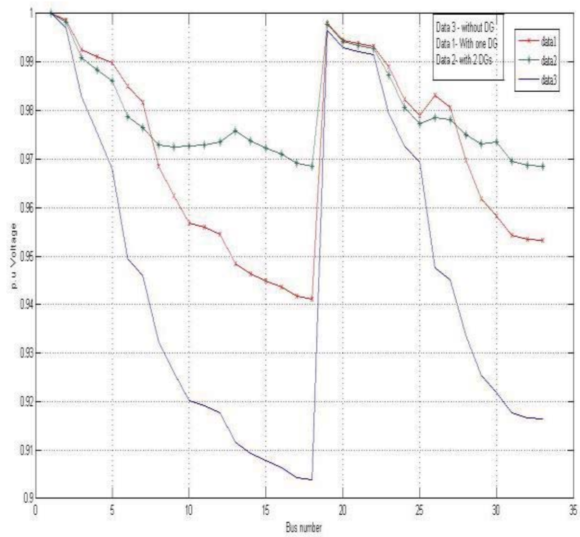



Fig. 4. Voltage layout two DG for 33 bus




. Fig. 5. Voltage comparison with and without DG

The comparison of voltage profile before and after DG placement has been shown in Fig.5. It can be observed clearly shown in this figure that voltage profile of the system has been improved significantly after DG allocation. Minimum value of bus voltage has also been increased.

The results after running the algorithm has been shown in the TABLE I. The active power loss of the system was 210.9856 kW before DG placement. After placement of one DG of 2.5 MW at bus number 6, resulted in reduction of real power loss as 47.315%. The placement of two DGs of 0.852061 MW and 1.15695 MW at bus number 13 and 30 respectively has further resulted in reduction of power loss of 58.67 % that of base case and 21.56 % that of placement after one DG. The convergence characteristics for MVO implementation for one and two DGs have been illustrated in Fig. 6. and Fig.7. respectively. As can be seen from Fig.6 MVO converges in 13 iterations for placement of one DG at the same time it converges in 22 iterations for placement of two DGs as shown in Fig. 7. In TABLE II the detailed comparison summary of implementation of proposed ALO, Hybrid Particle-Swarm optimization [9], Particle- Swarm optimization [6], Moth-Flame optimization [11] has been presented in detailed. This illustrates that MVO provides better solution quality, less computational time and also better accuracy.

TABLE I. 33 BUS SYSTEM RESULT SUMMARY

| **Parameter** | 33 BUS SYSTEM | | |
|---|---|---|---|
| | ***Without DG*** | ***With one DG*** | ***With two DG*** |
| Real Power loss (kW) | 210.9856 | 111.01446 | 87.1661 |
| Minimum voltgae (p.u) | 0.9038 at bus no. 18 | 0.94109 at bus no. 18 | 0.9684 at bus no. 33 |
| Location( bus no.) and Size(in kW) | -- | 6 & 2500 | 1. 13 and 852.061<br>2. 30 and 1156.956 |

TABLE II COMPARISION OF RESULTS OBTAINED FOR 33 BUS SYSTEM

| Algorithms/ Methods | Power loss Without DG | One DG | | | Two DGs | | |
|---|---|---|---|---|---|---|---|
| | | Location ( Bus no.) | Size (kW) | Power loss (kW) | Locations (Bus no.) | SIZE (kW) | Power loss (kW) |
| Moth- Flame optimization [10] | 210.9862 | 6 | 2590.2 | 111.0187 | 13, 30 | 851.6 and 1157.5 | 87.1666 |
| Particle-Swarm optimization [5] | 211 | 6 | 2590 | 111.03 | 13,30 | 850 and 1160 | 87.17 |
| Hybrid Particle-Swarm optimization [8] | 211 | 6 | 2490 | 111.17 | 13,30 | 830 and 1110 | 87.28 |
| Multi-Verse optimization (Proposed) | 210.9856 | 6 | 2500 | 111.01445044 | 13,30 | 852.061 and 1156.956 | 87.1661 |

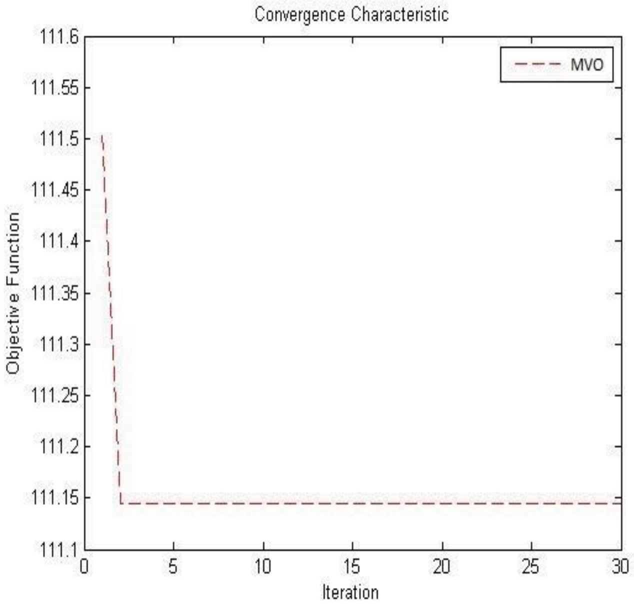



FIG. 6. CONVERGENCE CHARACTERISTICS FOR ONE DG

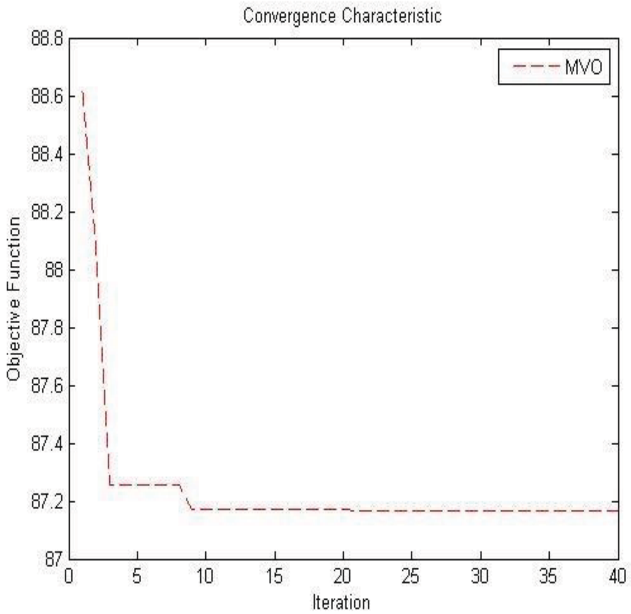



FIG. 7. CONVERGENCE CHARACTERISTICS FOR TWO DG

## V. CONCLUSION

In this paper newly developed multi verse optimization has been used for DGs allocation in distribution system. The sweep power flow method has been used for determination of the base case power loss. After that MVO has applied on the test bus system to obtain the results. Presence of DGs unit in distribution network causes minimization in active power losses and advancement in the voltage profile. Effectiveness of the results are obtained when more than one DG unit has been installed in the system. The paper also compares the effectiveness of results with previously obtained results.

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