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# Optimum Sizing and Siting for DG Unitsusing Hybrid 2/3 Rule and Harmony Search Algorithm

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*Abstract*—The electrical energy one of most important basics of modern lifeand the demand on this energy increase consciously. Which make some challenges to operators to increase the generation to feed the growing demand. This growth lead to extend the centralized plant to provide distribution network by required energy also lead them to develop transmission system. This method is so costly where it is required money to extend the power system. An appearance of distributed generation DG is considered a solution for these problems and can reduce the cost where it provides the load by electricity in customer side without passing through transmission system. While the aim target from DG is supporting the grid and improve power quality, voltage profile, reduction of power losses and reliability. In this paper will discuss sizing and siting the distributed generation in the grid. In this work introduced hybrid method where it is used 2/3 rule and harmony search algorithm to find optimum location and sizing respectively. This work is done under several loading cases up to 250 % from normal load also compared with other researches in this filed used the same model (IEEE 33 bus redial distribution system ) that used in this paper. MTLAB software used to complete this research.

***Keywords—*** harmony search algorithm, distributed generation and 2/3 rule.

## I. Introduction

Last decades DG becomes more important due to meet the growth demand without needing to upgrade the transmission system (overhead, cables and transformers). Also the centralized power station should be extended to produce enough power meet the demand of load. Recently, using DG as power source in customer side is to feed those increasing demand. Where many researches studied the impact of DG units on distributed system where has positive and negative impact on system performance as voltage profile, losses (active and reactive power) and protective devices. [1.2]

The impact of DG on the system performance is depending on position and size of DG units. Where Authors of [3] speak about that the installation of small DG-PV units near the customer is very attractive to utilities and consumers due to the energy produced close the loads. The distributed generation (DG) always installed at sub transmission network. Where the main aims are to:

- ✓ Reduce transmission lines losses
- ✓ Improve voltage profile on system
- ✓ Reduce the emission from centralized plant
- ✓ Low operating cost due to peak shaving
- ✓ Reduced or deferred investment in generation, transmission, transformers and distribution infrastructure upgrades due to relieve T&D congestion

To get best performance to distributed generation on power system many researchers proposed several studied include a lot of methods to get the optimum place and size of DG to improve the voltage profile and power losses. Some researches assumed the location of DG depend on availability of renewable source (sun, wind seas and Ocean or etc.) in media and it's space [3], also other researchers in by H.L. willis [4]. used simple analytical approach techniques as 2/3 role which is based on installing the DG on 2/3 of feeder by sizing of DG's estimated as 2/3 the value of loads but this techniques not use in uniformly distributive load due to this techniques follow the method of exact loss formula where the size of DG determine by calculate direct equation prevail from the generalized reduced gradient (GRG) method..

In [5], PSO algorithm is used to find the optimum size of DG and the location of DG is limited by Loss Sensitivity Factor LSF and WK bus. Also Zhu and others in [6] are suggested method called Ordinal Optimization to find optimal location and size of DG with keep the balance between loss minimization and capacity maximization. A. Keane et al [7] used linear programing to DG problem.

In [8], A. M. EI. Zonkely proposed Sequential quadratic programming (SQP) to find placement of DG without consideration fault restraints suggested. Also in [9] the authors

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used multi objective function to reduce losses by insertion DG units in optimum allocated. In [10], M. Shaaban and Petinrin proposed method to minimize losses and improve power voltage profile via using combination of sensitivity index, exact loss formula and voltage sensitivity coefficient.

Genetic Algorithm one of oldest search method where based on natural is chosen to get optimum sizing and siting of DG units to minimize losses [11,12]. L. Wang et al. in [13] used Ant Colony optimization to get the optimum location and size of DG units where this search method based on ant behavior to find shortest way from den to food please also search for food.

R.S. Rao et al. [14] used Harmony search to find the optimum site of DG which was depend on the loss sensitivity factor to reduce losses and improve voltage profile in a system. In [15], N.G.A. Hemdan et al. used Particle Heuristic Algorithm to find optimum place of DG where based on the resumption of flow power presented . This technique contains two methods which are clustering techniques and exhaustive search.

Impact of distributed generation in voltage regulation

One of the troubles occurs to far-end of redial distribution system or in the rural is dip on voltage. This made some problem to loads and protective device. The voltage profile can be supported and improved by using tab change transformer, shunt capacitor switched on feeder and shifting transformer towards the load center. According for several researches the previous techniques can keep the voltage in the required limit. According to [16] the place and size of DG has important effect in voltage profile. Also when using improved analytical (IA-method) the minimum voltage increase to more acceptable limit. According to American National Standards in voltage fluctuation on distribution systems is within range (+7% to -13%) but in practical many companies keep voltage fluctuation within ±6% which should be considered in any solution suggested to enhance voltage profile . One of the methods used to control on voltage profile in customer side as in [17]. The concept is insertion DG in distribution system as capacitor bank with the DG units inject real power or both active and reactive power where most distributed generation work at between ranges 0.85 lagging to unity power factor. Also the inverter connected to photovoltaic, wind turbine or any DC source to provide the system via leading power factor. All previous cases lead to improve voltage profile when select optimum places and size especially in rural and far-end ofdistribution system. Also reduce all substation capacities from distribution system. Other researches talk about the bad position of DG can be lead to worst system performance [18,19].

### Impact of distributed generation in power losses

One of the important solution can DG introduce in distribution network is to reduce power losses in distribution system. Where several researches appear ability of reduce both active and reactive power losses by inject DG units also increase reliability of system [20].

As appear in [21], the both active and reactive losses in distribution system can be reducing by inserting DG in optimum location and sizing. Several researches apply this concept by injecting both active and reactive power in distribution system which reduce losses and improve ability of system [16,19]. But the most important rule to insert DG units to improve system performance is selection optimum location and sizing to the DG units in distribution system. Authors of [21] considered concept of DG units exactly as capacitor bank but a capacitor bank produce the grid just by reactive power. In [16] Authors used two different methods to select the placement and size of DG units. The active power losses in the system without DG was around 202.677 kW and after use Improved analytical IM-method to find site and size of DG units the losses reduction to 110.1537 kW and by use PSO the losses reduce decrease to 92.4365 kW [16].

In this paper hybrid method is proposed by using both 2/3 rule and harmony search algorithm to find optimum placement and sizing of DG units. 2/3 rule is used to find the location of DGs and harmony search is used to find the optimal sizing of DGs at several loading conditions.

## II. METHODOLOGY

This part of paper will introduce the mechanism to select the location of DGs and DGs sizing. This operation is important to minimize the losses and improve voltage profile to the selection system. In this research the sizing for DG is studied in many cases 100%, 150% 200% and 250% from normal load and the siting will be fixed for all cases. IEEE 33 bus redial distribution system was selected.. The total load of system is (3581KW& 1745KVAr). Fig.1 shows IEEE 33 bus.

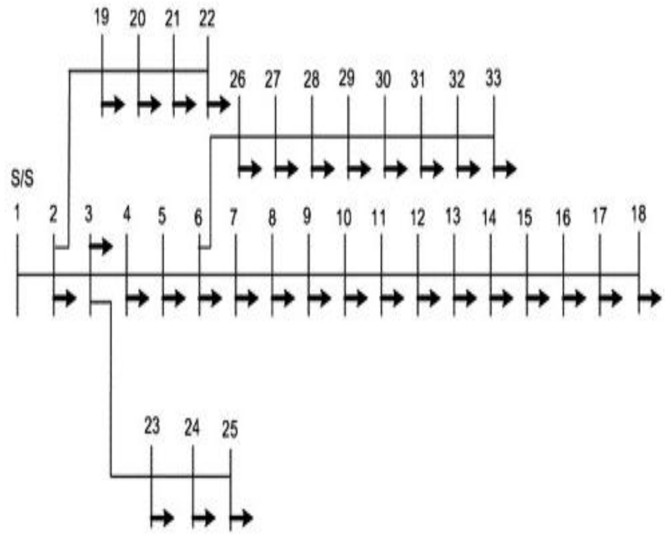


Figure 1. IEEE 33 bus redial distribution system


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Backward/Forward Sweep Method of power flow is used in this paper to obtain the voltage at each bus and the active & reactive power losses in each branch of the system [24]. Table.1 shows the voltage at each bus and power losses at each branch by using Backward/ Forward Sweep Method.

TABLE I. IEEE 33 BUS DATA WITHOUT DG UNTI

| Branch | Power Loss (KW) | Reactive loss (KVar) | Bus | Voltage (p.u) |
|---|---|---|---|---|
| 1 | 13.6400 | 6.9531 | 1 | 1.0000 |
| 2 | 56.4646 | 28.7592 | 2 | 0.9964 |
| 3 | 20.6039 | 10.4934 | 3 | 0.9794 |
| 4 | 19.1936 | 9.7756 | 4 | 0.9705 |
| 5 | 39.0578 | 33.7165 | 5 | 0.9618 |
| 6 | 2.1213 | 7.0121 | 6 | 0.9411 |
| 7 | 5.3191 | 1.7578 | 7 | 0.9374 |
| 8 | 4.5562 | 3.2734 | 8 | 0.9315 |
| 9 | 3.8563 | 2.7334 | 9 | 0.9242 |
| 10 | 0.5958 | 0.1970 | 10 | 0.9175 |
| 11 | 0.9502 | 0.3142 | 11 | 0.9164 |
| 12 | 2.8786 | 2.2648 | 12 | 0.9146 |
| 13 | 0.7903 | 1.0403 | 13 | 0.9076 |
| 14 | 0.3964 | 0.3528 | 14 | 0.9051 |
| 15 | 0.3083 | 0.2252 | 15 | 0.9035 |
| 16 | 0.2738 | 0.3656 | 16 | 0.9019 |
| 17 | 0.0571 | 0.0448 | 17 | 0.8997 |
| 18 | 0.2088 | 0.1992 | 18 | 0.8991 |
| 19 | 1.0760 | 0.9696 | 19 | 0.9957 |
| 20 | 0.1302 | 0.1521 | 20 | 0.9910 |
| 21 | 0.0563 | 0.0745 | 21 | 0.9901 |
| 22 | 3.8420 | 2.6252 | 22 | 0.9893 |
| 23 | 6.1978 | 4.8941 | 23 | 0.9749 |
| 24 | 1.5431 | 1.2074 | 24 | 0.9665 |
| 25 | 2.3500 | 1.1970 | 25 | 0.9623 |
| 26 | 2.9464 | 1.5002 | 26 | 0.9388 |
| 27 | 9.7751 | 8.6185 | 27 | 0.9359 |
| 28 | 6.5969 | 5.7471 | 28 | 0.9237 |
| 29 | 3.1339 | 1.5963 | 29 | 0.9149 |
| 30 | 1.8333 | 1.8119 | 30 | 0.9109 |
| 31 | 0.2430 | 0.2833 | 31 | 0.9062 |
| 32 | 0.0140 | 0.0217 | 32 | 0.9052 |
| 33 | zero | zero | 33 | 0.9049 |
| Total Losses | 211.0103 | 140.1770 | Min VOLT | 0.8991 |

## A. *Location of DG*

The location of DG is not less important than sizing of DG where the wrong location for distributed generation lead to increase losses to the system and not support the grid also sometimes caused increasing in the voltage more that demand which produced over voltage. In this paper 2/3 rule is used to find location of DG where this method widely used in several application of power system especially in FACTS where this method so easy to apply in any feeder which based on install DG at 2/3 of feeder by 2/3 of capacity of load but in this research using this method just to location of DG. And by looking to Fig.1 the IEEE 33 BUS and by referring to 2/3 rule the buses selected as location to the distributed generation are (13, 21, 24 and 31) where those sites will be fixed to all cases of loading (100%, 150% 200% and 250% from normal load) and the change will be just in sizing of distributed generation.

## B. *Sizing of DG*

To find optimum size for distributed generation Harmony search algorithm is used in this work. This technique run the power flow program several times and at each process the harmony memory used new data and save the best solution. In this research processed the sizing operation four times at each case use new sizing to the new develop in the grid (100%, 150% 200% and 250% from normal load). The distributed generation produces only active power (unity power factor).

**Harmony Search algorithm (HS)**: Recently proposed a new heuristic optimization technique inspired from music phenomenon. The procedures of solution. by HS algorithm are to. Initialize the design parameters at first, then harmony. memory (HM) is initialized. After that a New Harmony improvisation is created from the HM, then. Harmony memory is. Updated. Finally, the procedure is repeated starting from harmony memory improvisation until the criteria. of termination is satisfied [25, 26]. The flowchart of the HS algorithm is shown in Fig. 2

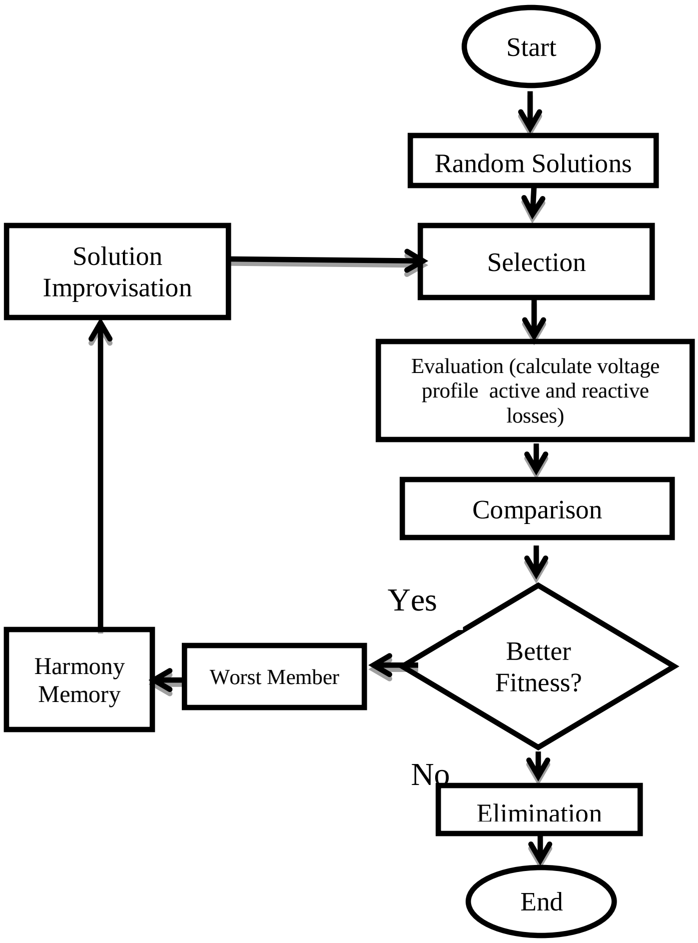


Figure 2. Flow Chart of Harmony Search algorithm


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### III. RESULT

In first case at 100% loading the DG installed at (13, 21, 24 and31) where the harmony search select rating for each bus around (595, 200,285 and 599) KW present around % 45 from load. The voltage in system is reached to 0.9526 pu from 0.8991 and the losses are reduced to 72.27KW which present 2.01% from load and the reactive losses are reduced to 47.71KVAr that present around 2.73%. Where the losses before insert the DG were 211KW (5.89%) and 140.17KVAr present 8.03%. Also can see clear different on voltage at each bus as shown in Fig.3.

TABLE II. SYSTEM AT 100% LOADING

| Case of system | Minimum voltage pu | Maxmum voltage pu | Active power losses | | Reactive power losses | |
|---|---|---|---|---|---|---|
| Without DG | 0.8991 | 1 | 211.013 kW | 5.89% | 140.1770 KVAr | 8.03% |
| With DG (1680 kW) 45% of loading | 0.9526 | 1 | 72.273 kW | 2.01% | 47.7134 KVAr | 2.73% |

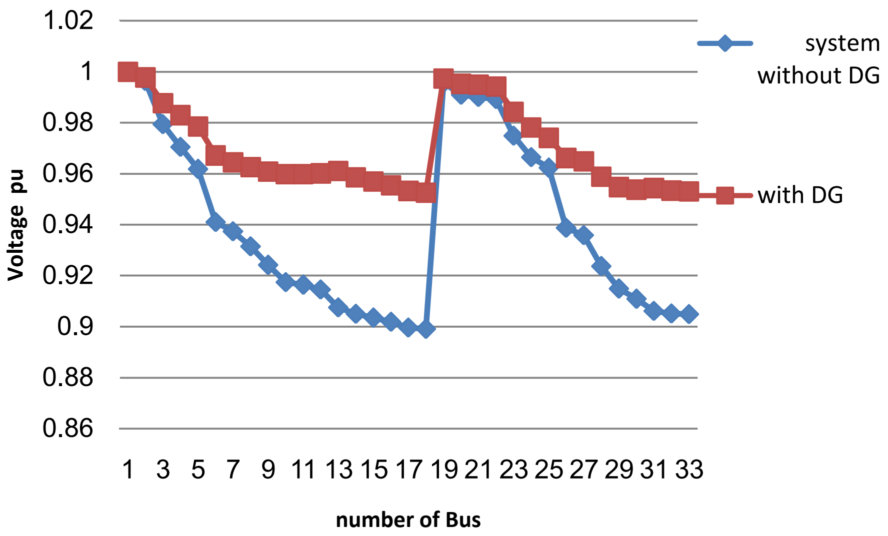


Figure 3. voltages at each bus case 100% from normal load

In second case at 150% loading where the system load is (5371KW &2617.5KVAr) where the value of DG selected by HS are (1000, 500 500 and 1000) KW present around 55 % of loading. And by looking to Table 3 it can be seen that the minimum voltage is increased to 0.9378 pu and the losses in system are reduced to 2.8% & 3.8% of loading for both active and reactive losses. And by increasing the DG rating to (4579KW) 85% the losses are reduced to 2.06 % & 2.9% of loading for active and reactive power and the voltage is reached to 0.9637pu. System result described in Table.3 .Fig.4 show the voltage at each bus at 150% loading.

TABLE III. SYSTEM AT 150% LOADING

| Case of system | Minimum voltage pu | Maximum voltage pu | Active power losses | | Reactive power losses | |
|---|---|---|---|---|---|---|
| Without DG | 0.8412 | 1 | 522.9711 KW | 9.73% | 348.0025 KVAr | 13.2% |
| With DG (3000 kW) 55% of loading | 0.9378 | 1 | 150.4276 KW | 2.8% | 100.0809 KVAr | 3.8% |
| With DG (4579 kW) 85.% of loading | 0.9637 | 1 | 110.7010 KW | 2.06% | 77.6112 KVAr | 2.9 % |

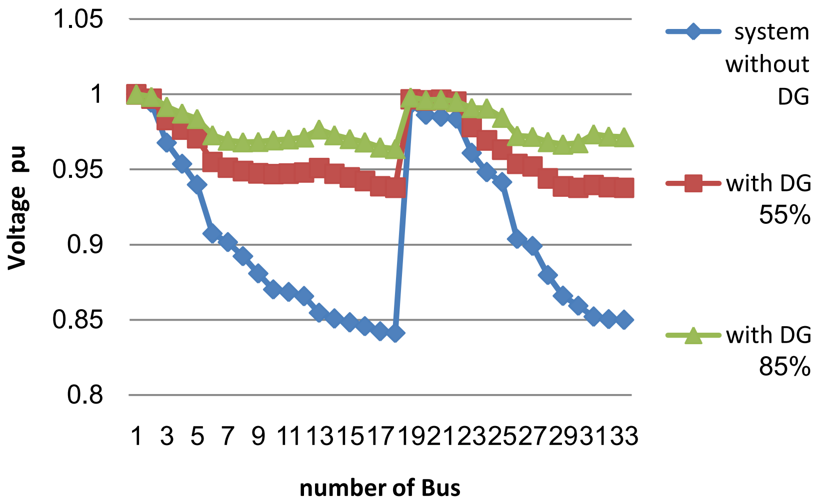


Figure 4. voltage at each bus case 150% from normal load

In third case when using 200% loading (7162KW & 3490 kVAr) the harmony search selected the rating for DG as (802,609,772 and 1900) KW around 56% from load. The DGs are at buses (13, 21 24 and 31) which caused increasing in voltage to reach 0.8918 pu and the losses reduction to 3.91% & 5.54% of loading for both active and reactive power losses from 14.58% &19.95%. When increasing the DG rating to (6170 KW) which present 86% the losses are reduced to 2.7% & 3.99% of loading for both active and reactive power losses and the minimum voltage reach to 0.9546 pu as appear in Tabel.4 . Fig 5 displayed the voltage at each bus.

TABLE IV. SYSTEM AT 200% LOADING

| Case of system | Minimum voltage pu | Maximum voltage pu | Active power losses | | Reactive power losses | |
|---|---|---|---|---|---|---|
| Without DG | 0.7766 | 1 | 1.0446e+3 kW | 14.58% | 696.5683 kVAr | 19.95% |
| With DG (4075 kW) 56% of loading | 0.8918 | 1 | 280.6055 kW | 3.91% | 193.4003 kVAr | 5.54% |
| With DG (6170 kW) 86% of loading | 0.9546 | 1 | 198.3354 kW | 2.7% | 139.4459 kVAr | 3.99% |


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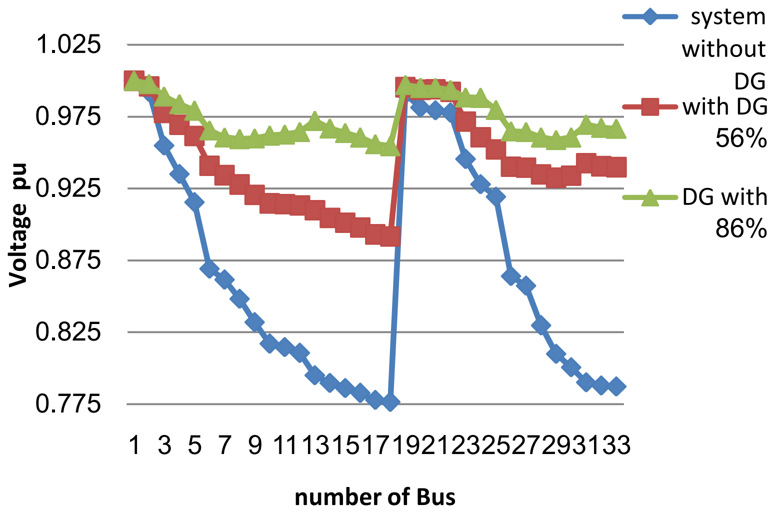


Figure 5. voltages at each bus case 200% from normal load

In last case when using 250% loading (8952KW & 4362KVAr) the harmony search select rating for DGs as (1500,709,892 and 2201) KW present around 59% from load. The DGs are installed at buses (13, 21 24 and 31) which caused increasing in voltage to reach 0.8953 pu and the losses are reduced to 4.50% & 6.29% of loading for both active and reactive power losses from 21.10% & 28.9%. last case when increasing the rating of DG units to (7816 KW) which present 87% of the load, the minimum voltage in the system is reached to 0.9505 pu and the losses are reduced to 3.47% and 5.03% of loading for active and reactive losses. As displayed in Tabel.5. Fig 6 display the voltage at each bus.

TABLE V. SYSTEM AT 250% LOADING

| Case of system | Minimum voltage pu | Maximum voltage pu | Active power losses | | Reactive power losses | |
|---|---|---|---|---|---|---|
| Without DG | 0.7039 | 1 | 1.8893e+3 kW | 21.10% | 1.2632e+3 kVAr | 28.9% |
| With DG (5302 kW) 59% of loading | 0.8953 | 1 | 403.3315 kW | 4.50% | 274.7843 kVAr | 6.29% |
| With DG (7816 kW) 87% of loading | 0.9505 | 1 | 311.7798 kW | 3.47% | 219.4653 kVAr | 5.03% |

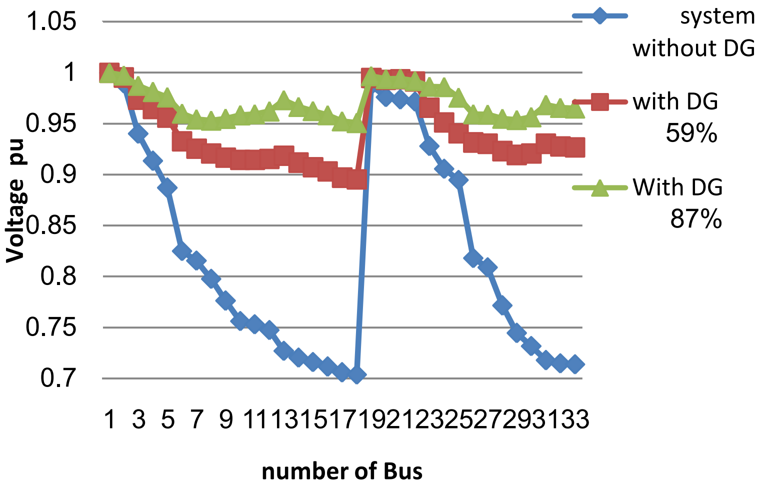


Figure 6. voltages at each bus case 250% from normal load

By looking for Table 7 where Displays the priority in voltage and the losses in system where can see clear advantage on minimum voltage and the total losses in the system in the method used in this paper than others two methods (Improved analytical IA & PSO ) that used in [16] to find optimum sizing and siting. Fig 6 shows the voltage at each bus in those cases.

TABLE VI. COMPARISON BETWEEN IMPROVED ANALYTICAL IA METHOD, PSO METHOD AND(2/3 RULE & HARMONY)

| Method | DG Rating kW | Min voltage pu | Max voltage pu | Active Power losses kW | Reactive power losses kVAr |
|---|---|---|---|---|---|
| AI method[16] | 2560.2300 | 0.957416 | 1 | 110.1537 | non |
| PSO method[16] | 1857.5 | 0.940027 | 1 | 92.4365 | non |
| 2/3& harmony | 1685 | 0.9526 | 1 | 72.2734 | 47.7134 |

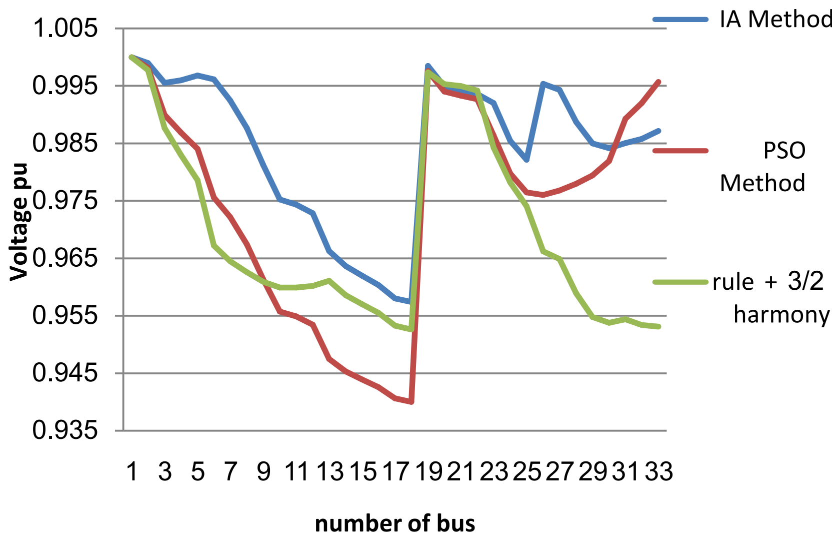


Figure 7. voltage at each Bus 100% loading

## CONCLUSION

In this paper introduced 2/3 rule with harmony method to select the optimum location and sizing for DG units at many several loading conditions. Where in each case the insertion of DGs into the system can reduce the losses in system and improve the voltage profile. Also in case with DGs have high rating; the losses and the voltage profile are better. By looking to the last comparison between the 2/3 rule with harmony showed the priority of this optimization techniques on Improved analytical IA method and PSO where used less rating of DG, improve the voltage profile and reduce the losses better than other cases.

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