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# A Load Flow based Approach for Optimum Allocation of Distributed Generation Units in the 43-bus Distribution Network of Belin Substation in Myanmar

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## Abstract:

In this paper a load flow based method using MATLAB Software is used to determine the optimum location and optimum size of DG in a 43-bus distribution system for voltage profile improvement and loss reduction. This paper proposes analytical expressions for finding optimal size of three types of distributed generation (DG) units. DG units are sized to achieve the highest loss reduction in distribution networks. Single DG installation case was studied and compared to a case without DG, and 43-bus distribution system is used to demonstrate the effectiveness of the proposed method. The proposed analytical expressions are based on an improvement to the method that was limited to DG type, which is capable of injecting real power only, DG capable of injecting reactive power only and DG capable of injecting both real and reactive power can also be identified with their optimal size and location using the proposed method. This paper has been analysed with varying DG size and complexity and validated using analytical method for Summer case and Winter case in 43-bus distribution system in Myanmar.

**Keywords- analytical method,distributed generation,power loss reduction,voltage profile improvement.**

## I. INTRODUCTION

Distribution systems have been operated in a vertical and centralized manner for many years for best control and coordination of their protective devices. Distribution systems are characterized by high R/X branch ratios with radial or weakly-meshed topological structure.

In fact, the radial topological structure makes distribution systems the most extensive part in the entire power system. The poor voltage regulation and the high line resistance both play a significant role in increasing total power losses of distribution systems.

Minimization of power losses of distribution systems is constantly achieved by feeder reconfiguration techniques. At present, the environmental issues has been the major reasons DG been so popular. Customers want the energy that cleaner and has less impact to the environment. They tend to choose DG as alternative power generating because the DG not only use the fuel

Nowadays, the need for more quality of electric supply has become priority for consumer. They are aware of the value of reliable electric supply. There are several reliability problems that disturbing distribution networks. Apart from the large voltage drops to near zero, consumer can also suffered from smaller voltage deviations. For example in radial networks, bus voltages happens to decrease as the distances from the distribution transformer increases and may become lower than the minimum voltage permitted by the utility. By adding DG, the branches current were reduces which causing the reduction of losses and increasing of voltage through feeder.

## II. PROPOSED METHODOLOGY

In this paper 43-bus distribution system is used to locate the DG in an optimal place with the proper sizing. The proposed technique succeeds in solving single DG installation for distribution system.The proposed approach needs power flow to be run for two times, one for the initial base case and another at the final stage with the DG to obtain the optimal solution.

### A. Sizing at Various Location

Distributed Generation sizing and location at optimal places in radial distribution feeder gathers a great importance in power system area. The installation of DG at non-optimal places leads to higher losses and reduced voltage profile. For that reason, the development of new method called analytical approach is capable of indicating the DG unit allocation and sizing at optimal places which improves the power system operation characteristics. The proposed methodology aims to optimize the better location and sizing of DG unit to reduce the power losses and improves the voltage profile.

Real Power loss in the system can be calculated by Equation (1) given the system operating condition,

$$P_L = \sum_{i=1}^{N}\sum_{j=1}^{N}\left[\alpha_{ij}\left(P_iP_j + Q_iQ_j\right) + \beta_{ij}\left(Q_iP_j - P_iQ_j\right)\right] \quad (1)$$

Where,

$$\alpha_{ij} = \frac{r_{ij}}{|V_i||V_j|}\cos\left(\delta_i - \delta_j\right) \quad (2)$$

$$\beta_{ij} = \frac{r_{ij}}{|V_i||V_j|}\sin\left(\delta_i - \delta_j\right) \quad (3)$$

The minimize reactive power loss will have significant impact on voltage stability of the power system. The reactive power loss formula is given by Equation (4),

$$Q_L = \sum_{j=1}^{N}\sum_{k=1}^{N}\left[\gamma_{jk}\left(P_jP_k + Q_jQ_k\right) + \zeta_{jk}\left(Q_jP_k - P_jQ_k\right)\right] \quad (4)$$

Where,

$$\gamma_{jk} = \frac{X_{jk}}{V_jV_k}\cos\left(\delta_j - \delta_k\right) \quad (5)$$

$$\zeta_{jk} = \frac{X_{jk}}{V_jV_k}\sin\left(\delta_j - \delta_k\right) \quad (6)$$

Where,

n is the number of lines are function of loss coefficient between bus i and j.

$P_i$ is real power flow at bus i in MW.

$Q_i$ is reactive power flow at bus i in MVAR.

$P_j$ is real power flow at bus j in MW.

$Q_j$ is reactive power flow at bus j in MVAR.

$P_{Di}$ and $Q_{Di}$ are the loads.

$R_{ij}$ is Resistance of the line connecting bus i and j in Ohms.

$X_{ij}$ is Reactance of the line connecting bus i and j in Ohms.

$V_i$ and $V_j$ are bus voltage magnitude at bus i and j in PU.

$\delta_i$ and $\delta_j$ are bus voltage angles at bus i and j.

### B. Types of DG

DG can be classified into four major types based on their terminal characteristics in terms of real and reactive power delivering capability as follows:

1. DG capable of injecting active power only.
2. DG capable of injecting reactive power only.
3. DG capable of injecting both active an reactive power.
4. DG capable of injecting active power but consuming reactive power.

Photo voltaic, micro turbines, fuel cells which are integrated to main grid with the help of converters/inverters are good examples of type1.

For Type-1 DG, the optimal size of DG at each bus i for minimizing losses is given by Equation (7),

$$P_{DGi} = P_{Di} + \frac{1}{\alpha_{ii}}\left[\beta_{ii}Q_i + \sum_{j=1, j\neq i}^{N}\left(\alpha_{ij}P_j - \beta_{ij}Q_j\right)\right] \quad (7)$$

$$P_i = P_{DGi} - P_{Di} \quad (8)$$

The loss coefficients $\propto$ and $\beta$ are obtained from the base case load flow, and while strictly speaking, they should be updated at every load flow step, the changes in the loss coefficients are small and have a negligible effect on the optimal DG size result.

Real power loss reduction by DG,

$$PLR = \frac{P_{Loss} - P_{Loss}^{DG}}{P_{Loss}} \times 100\ \% \quad (9)$$

$P_{Loss}$ is the real power loss of the system before introducing DG.

$P_{Loss}^{DG}$ is the real power loss of the system after adding DG.

Synchronous motors such as gas turbines are examples for type2.

For type-2 DG, the optimal size of DG at each bus i for minimizing losses is given by Equation (10),

$$Q_{DGi} = Q_{Di} + \frac{1}{\alpha_{ii}}\left[\beta_{ii}P_i - \sum_{j=1, j\neq i}^{N}\left(\alpha_{ij}Q_j + \beta_{ij}P_j\right)\right] \quad (10)$$

$$Q_i = Q_{DGi} - Q_{Di} \quad (11)$$

Reactive power loss reduction by DG,

$$QLR = \frac{Q_{Loss} - Q_{Loss}^{DG}}{Q_{Loss}} \times 100\,\% \quad (12)$$

$Q_{Loss}$ is the reactive power loss of the system before introducing DG.

$Q_{Loss}^{DG}$ is the reactive power loss of the system after adding DG.

DG units that are based on synchronous machine fall in type 3.

$$S_{DGi} = \sqrt{P_{DGi}^2 + Q_{DGi}^2} \quad (13)$$

When power factor of DG is set to be equal to that of combined total loads, computational procedure to find optimal size and location of one of four types of DGs is described in the following**.**

(1) Start the Process.

(2) Run the Base Case without DG using Newton -Raphson load flow using MATLAB software and calculate the bus voltage magnitude, Angle, Real and Reactive Power Loss Respectively.

(3) After Load flow Identify the optimum sizing for each bus using Equation 7 and 10.

(4) By using Equation 7 and 10 find out the approximate losses for each bus by placing DG at the corresponding location with the optimum sizing obtain from the above step. Calculate the approximate loss for each case using Equation 1 and Equation 4with the values α and β of base case.

(5) Check for Constraint Violation after DG placement.

(6) Locate the bus at which the loss is minimum after DG placement and this is the optimum location for DG.

(7) Stop the Process.

## III. DATA ALALYSIS OF DISTRIBUTION NETWORKOF BELIN

At Belin, Yeywa and Shwesaryan are incoming loads which are the total power demand of Belin. And then, Belin substation gives back power to the load sides as outgoing feeders such as MOGE, Kyaukse, Dattaw, Ministry of industry, Sin Min 3 and Sin Min 1 and Sin Min 2. It has two generation sources. Hydro is the main source.

This paper was applied on an existing distribution feeder. The 43-bus distribution system is extracted from 230/33/11kV Belin Substation in Kyaukse area of Myanmar.The capacity of the system is 1270 MW and 698 Mvar. The one line diagram of the 43-bus distribution system under study is shown in Fig. 1.

A computer program has been written in MATLAB to calculate the optimal sizes of DG at various bus and approximate total losses with DG at different locations identify the best location. A Newton-Raphson algorithm based load flow program is used to solve the load flow problem. The proposed optimal DG size and placement in the distribution systems was coded in MATLAB Version 7.10.0.499 (R2010a).

## IV. SIMULATION RESULTS

The proposed methodology was applied on 43-bus distribution system in Belin Substation in Myanmar with different sizes are simulated in MATLAB environment to calculate the optimum DG sizes for various buses and approximate total power losses with DG at various location. To find the proper DG allocation in 43-bus distribution system for voltage profile improvement is the main aim of this procedure. This thesis is proposed an analytical expression to calculate DG optimal size and placement for minimizing the total power losses in primary distribution system.

This paper was divided into two main parts. Two different cases for 43-bus distribution system were used to analyse the proposed analytical method in finding the optimal DG size and place. The first case is a 43-bus distribution system for summer and the second case is a 43-bus distribution system for winter. The loads for two cases are constant and the generation sources are variable for two cases in this paper.

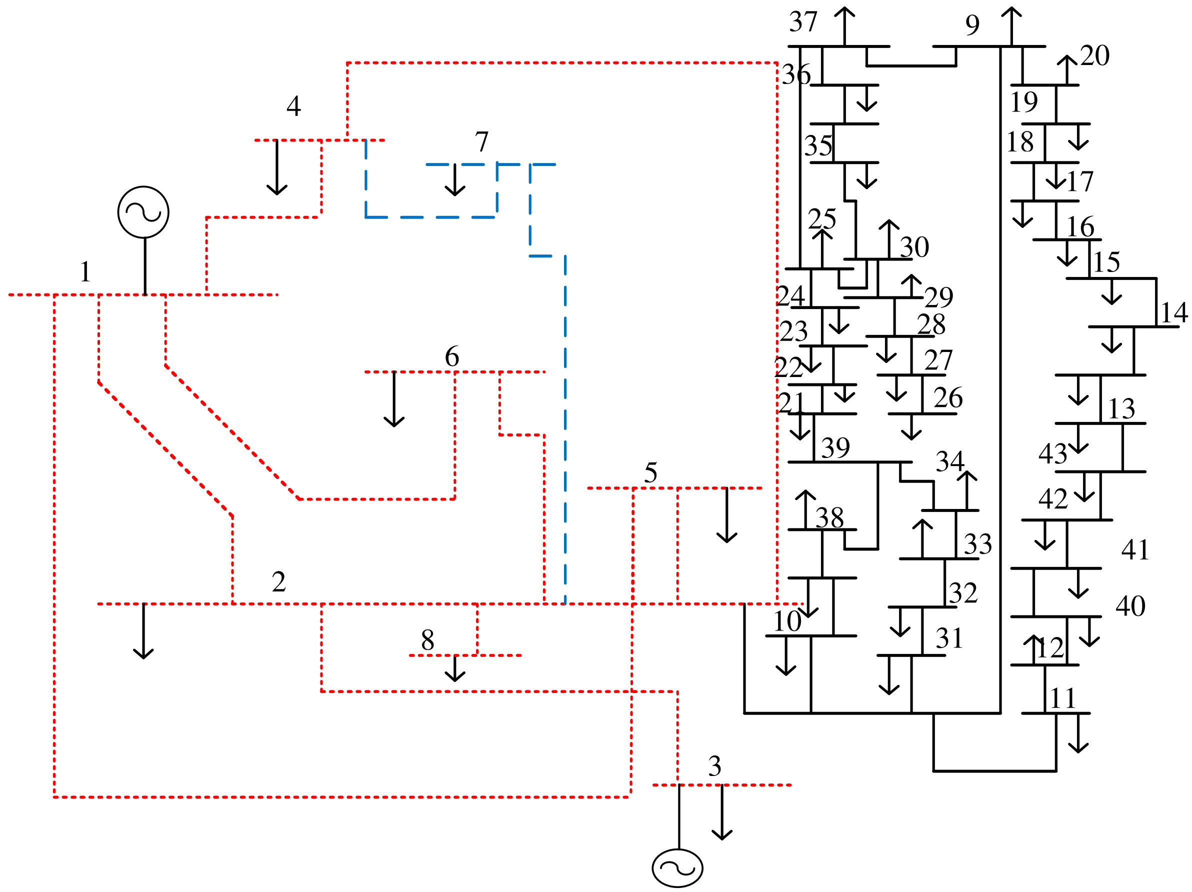


Fig. 1.. One Line Diagram of the 43-bus Distribution System in Myanmar

**A.** ***Case 1: Base Case Study for Summer***

In the first simulation, no DG is connected to the system voltage magnitudes at all buses for summer is recorded. The voltage magnitude of all buses is plotted in Fig. 2.

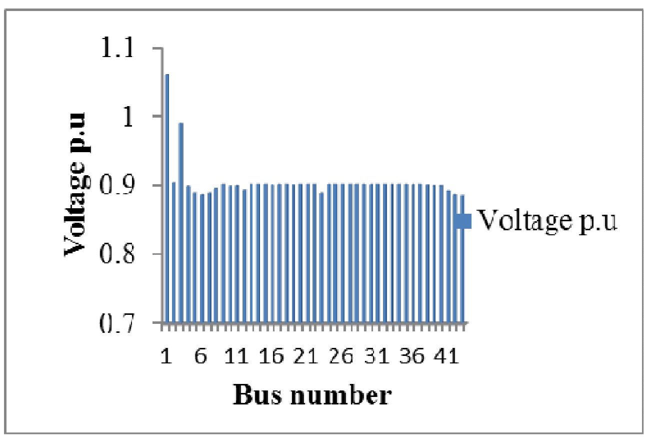


Fig. 2. Voltage Magnitude at Various Buses for Base Case Study for Summer

**B.** ***Optimum Size Allocation of Type-1 DG for Summer***

Based on the proposed analytical expression optimum sizes of DG's are determined using Equation 7 at various nodes for Belin distribution system in Myanmar.

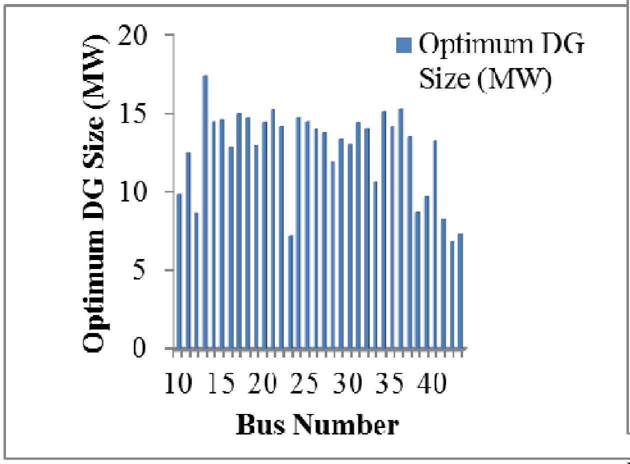


Fig.3. Optimum Real Power Size of Type-1 DG for Summer

In Belin distribution system the optimum sizes of DG ranging from 1.1555 MW to 23.6106 MW for summer. As far as one location is concerned, in a distribution system, corresponding Fig.3.would give the value of DG size to have a ''possible minimum'' total loss.

**C. *Optimum Size Allocation of Type-2 DG for Summer***

In this distribution system, the optimum reactive power sizes of summer ranging from 2.8809 Mvar to 16.842 Mvar as shown in Fig.4.

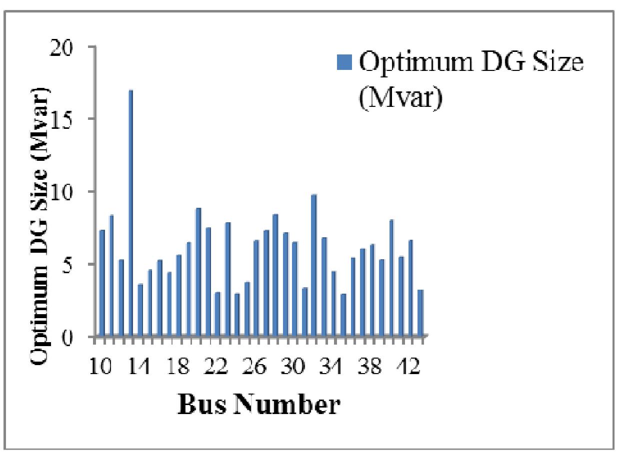


Fig.4.Optimum Reactive Power Size of Type-2 DG for Summer

**D. *Optimum Size Allocation of Type-3 DG for Summer***

The optimum size of type 3 DG at various nodes for 43- bus distribution system is shown in Fig .5.

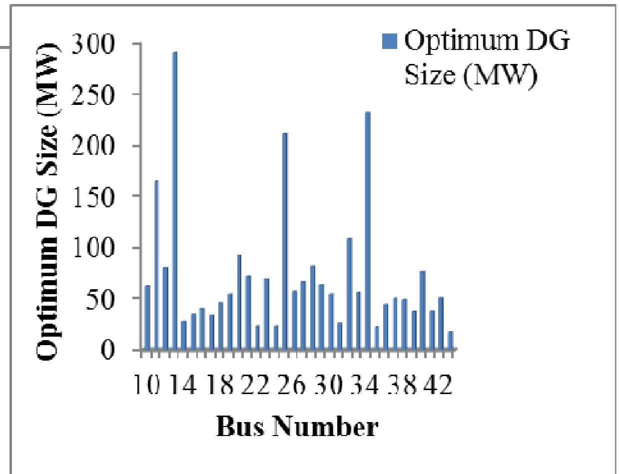


Fig 5.Optimum Size of Type-3 DG at 43-bus Distribution System for Summer

The decrease in total power loss depends on the location and size of DG. The range of optimum sizes of Type-3 DG for summer is from 22.42MW to 295.5 MW.

**E. *Selection of Optimal Location of DG Type-1 for Summer***

The optimal location can be found for the placement of optimal size of DG as shown in Fig.6.as obtained from Equation 6 which will give the lowest possible total loss due to placement of DG at the respective bus is as shown in Fig.6.

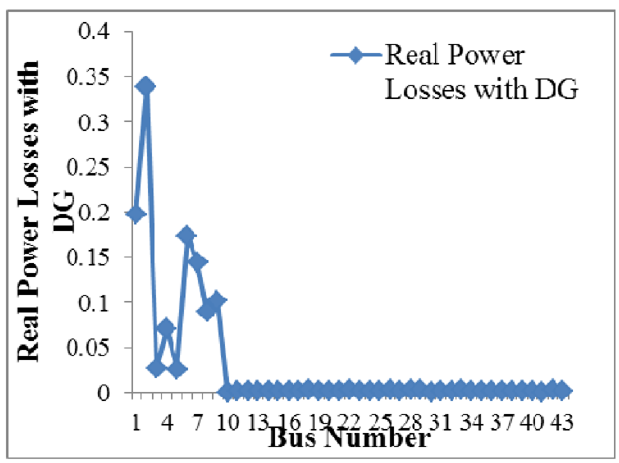


Fig.6. Total Real Power Losses with DG for Summer

**F. *Selection of Optimal Location of DG Type-2 for Summer***

This step is to find the optimum DG location, which will give the lowest possible total losses.

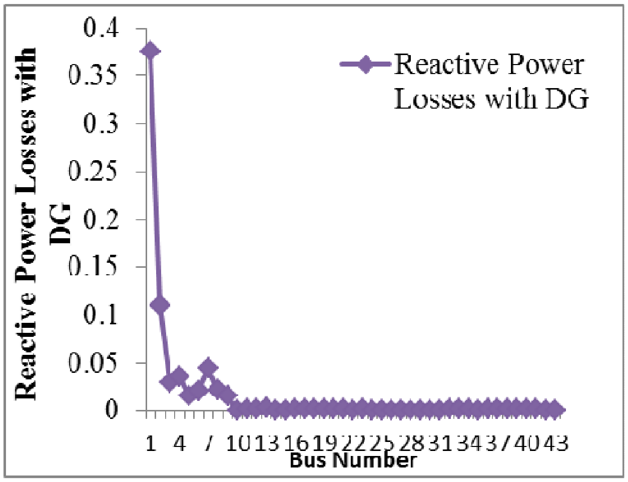


Fig.7.Total Reactive Power Losses with DG for Summer

Fig.7. shows the total reactive power losses for 43-bus distribution system with optimum DG size obtained at various nodes and average reactive power loss is reduced to the range of 0.4763 Mvar to 0.0491 Mvar.

**G. *Selection of Optimal Location of DG Type-3 for Summer***

Fig.8. shows the approximate total power losses for 43-bus distribution systems with optimum DG sizes obtained at various nodes of respective system. The figures also show the accurate loss.

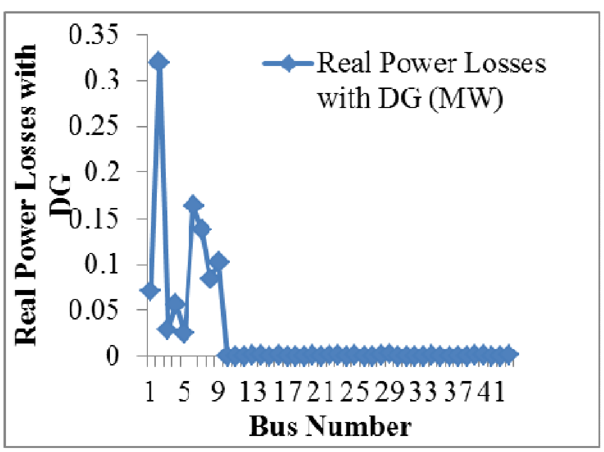


Fig.8.Total Real Power Losses of Type-3 with DG for Summer

The allocating optimal location is find for the placement of accurate size of DG at the respective bus as shown in Fig.9 and which will produce the lowest loss due to the placement of DG at the respective bus is shown Fig.9.

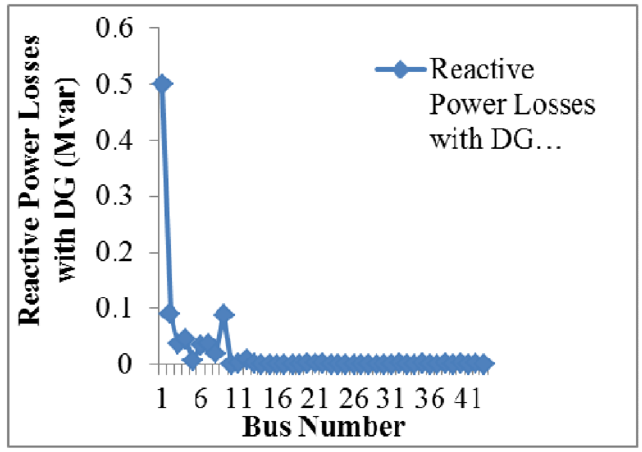


Fig.9. Total Reactive Power Losses of Type-3 with DG for Summer at 43-bus Distribution System

**H. *Optimum Bus Voltage profile for Summer Case***

The voltage at various buses should be maintained within the acceptable limits to meet out the power system demand. But the bus voltage may reach the permissible limit when DG is not connected to the distribution system or the bus voltage may lack due to some disturbances. For this reason Distributed Generation should be placed and sized at the relevant bus location in radial distribution system. The improvement of voltage profile of the DG for summer installed is shown in Fig.10.

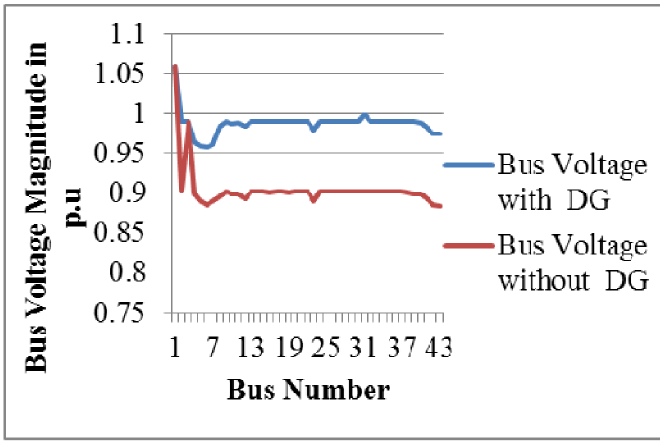


Fig.10. Bus Voltage Profile with and without DG of 43 bus system for Summer

### I. *Case 2: Base Case Study for Winter*

In the second simulation, no DG is connected to the system and power loss and voltage magnitudes at all buses for summer are recorded. The voltage magnitude of all buses is plotted in Fig.11.

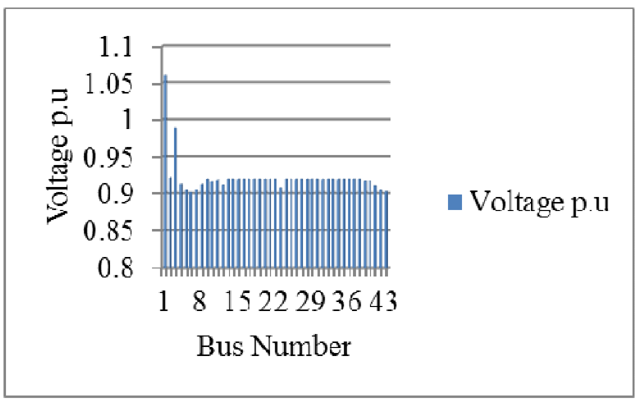


Fig.11. Voltage magnitude at various buses for base case study for Winter

### J. *Sizing at Various Location of DG Type-1 for Winter*

Based on the proposed analytical expression, optimum sizes of DGs are calculated at various nodes for the 43 bus distribution system. Fig.12. show optimum sizes of DG at various nodes for 43 bus distribution test system.

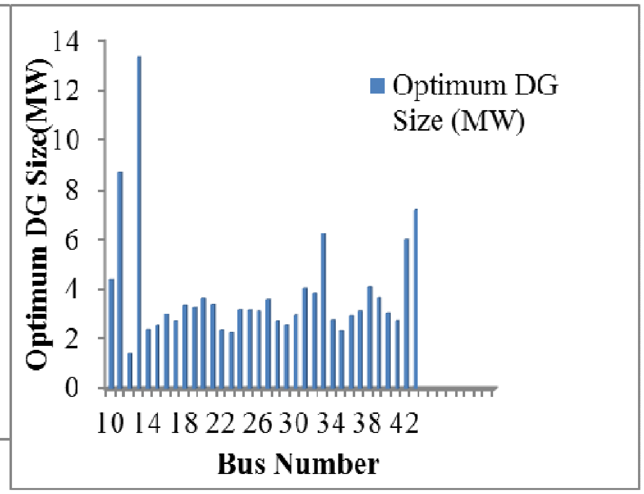


Fig.12 .Optimum Real Power Size of Type-1 DG for Winter at 43-bus Distribution System

### K. *Sizing at Various Location of DG Type-2 for Winter*

Based on the analytical expressions, optimum sizes of DG are calculated using Equation 15 at various nodes for the system. Fig.13. shows optimum sizes of DG at various buses for 43- bus distribution system.

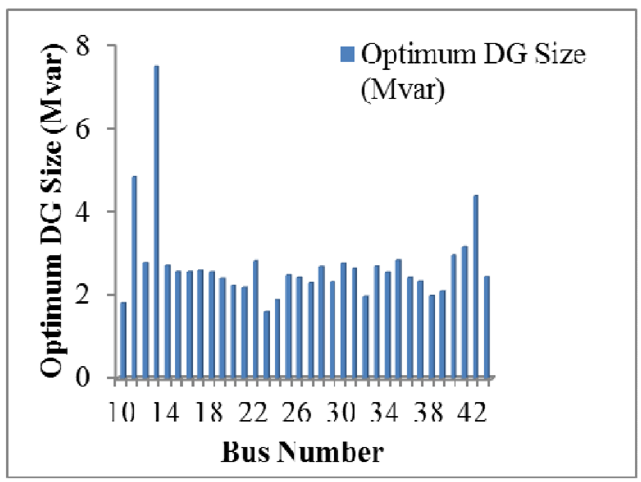


Fig.13. Optimum Reactive Power Size of Type-2 DG for Winter

### L. *Sizing at Various Location of DG Type-3 for Winter*

Analytical expression, the optimum size of Type-3 DG is calculated at each bus for 43-bus distribution system and bus having least total power loss will be the optimal location for the placement of DG; the best location is bus 30 with a total real power loss of 0.000003015 kW as shown in Fig.14.

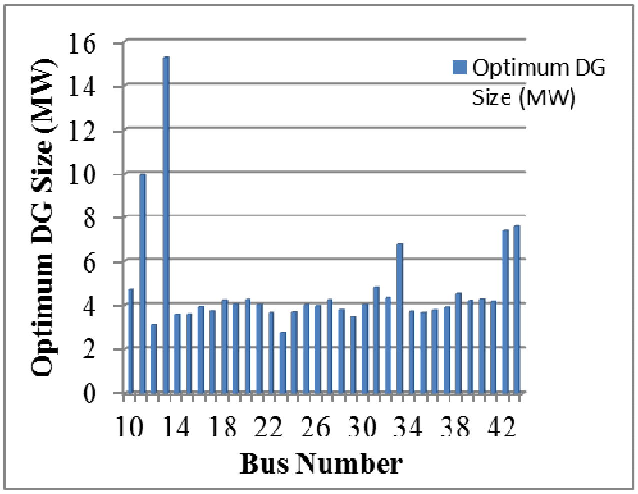


Fig.14. Optimum Reactive Power Size of Type-3 DG for Winter at 43-bus Distribution System

### M. *Location to Minimize Losses of DG Type-1 for Winter*

Based on this result of DG sizing the optimal location of DG is determined where the total real power loss is minimum at the respective buses as shown in Fig.15.

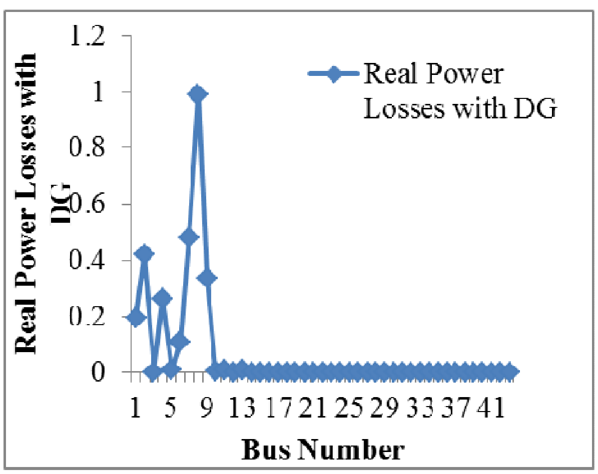


Fig . 15. Total Real Power Losses of Type-1 with DG for Winter at 43-bus Distribution System

### N. *Location to Minimize Losses of DG Type-2 for Winter*

Fig.16. shows the approximate total reactive power losses for 43-bus distribution system with the optimum DG size obtained at various nodes of 43-bus system. This Figure also shows the accurate loss.

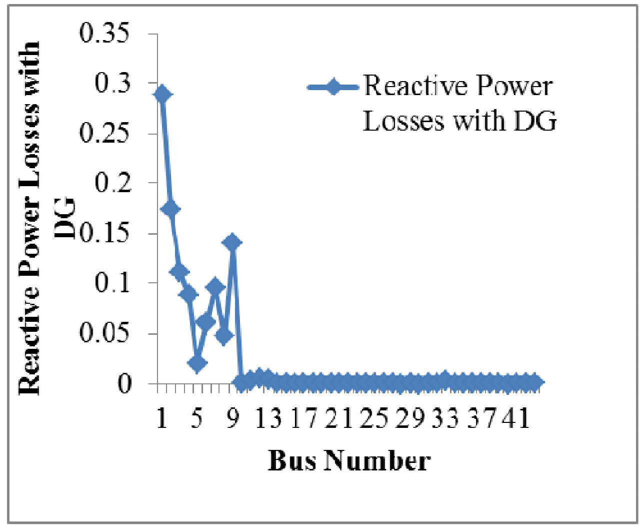


Fig.16. Total Reactive Power Losses of Type-2 with DG for Winter

### O. *Location to Minimize Losses of DG Type-3 for Winter*

Fig.17 demonstrates the total real power losses as a result of Type-3 DG at each bus. Bus 30, the selected location of the DG has a total power loss of 0.000003015 MW as shown in Fig.17, compared with other buses.

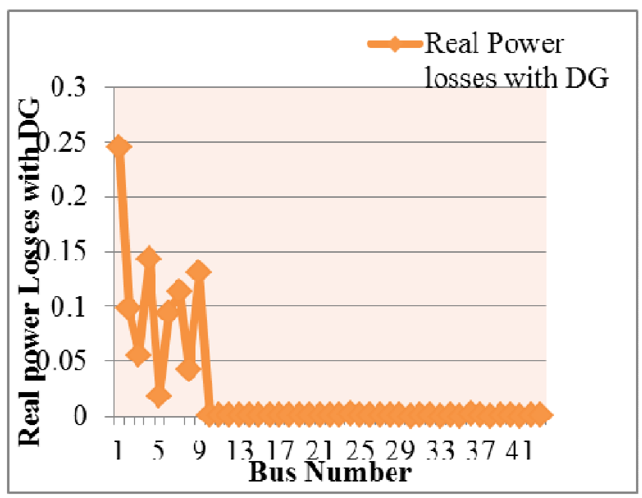


Fig.17.Total Real Power Losses of Type-3 with DG for Winter

The optimal location of Type-3 DG for winter is bus 30. The reduction in reactive power loss for this case is reduced to 0.00001018 Mvar. As can be seen from results of Fig.18, the location and size of DG play an important role in loss reduction of primary distribution system.

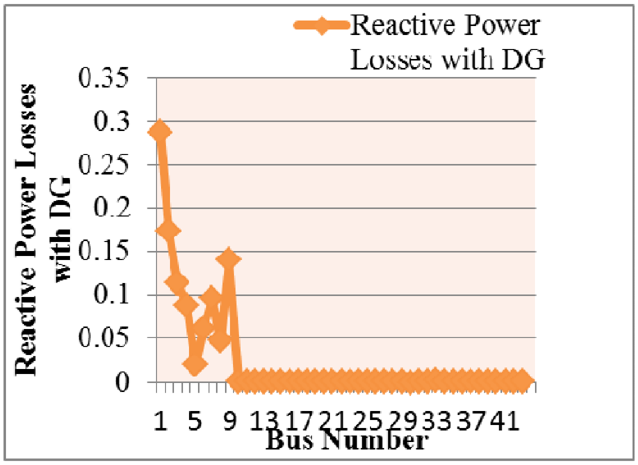


Fig.18.Total Reactive Power Losses of Type-3 with DG for Winter

### P. *Variation of bus voltage with DG for Winter Case*

Fig.19. shows the voltage level comparison for the 43-bus distribution system with and without installation of DG system. In order to have a clear comparison, bus voltages in the base case and also after installation of DG units are illustrated in Fig.19.

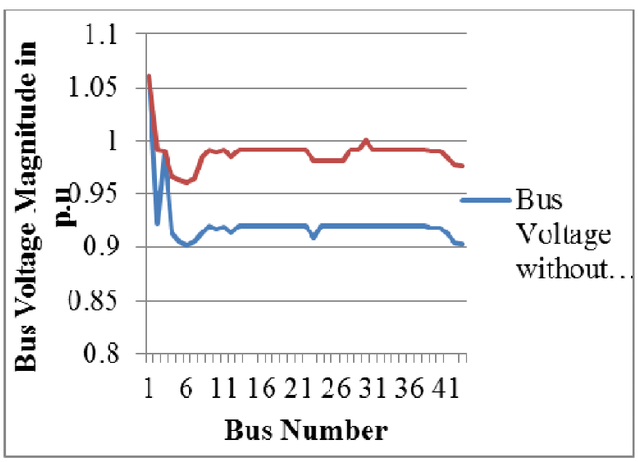


Fig.19. Bus Voltage Profile with and without DG of 43-bus system for Winter

The outcomes represent that installation of DG units considerably improves the voltage profile. Note that installation of DG units give better average voltage levels (1.06 per unit) compared with the original system. In the system without DG units, the lowest voltage level is 0.903 per unit.

## IV. CONCLUSIONS

In this paper a new emerging method called analytical approach is used to identify the optimal placement and optimum sizing of Distributed Generation in 43-buses distribution feeder for Belin Substation in Myanmar. The installation of DG units in power distribution networks is becoming more prominent. These benefits include reducing power losses, improving voltage profiles, reducing emission impacts and improving power quality.

Different types of DG installed in this system have different impacts on real and reactive power loss reduction. Optimal size and location of DG are also changed with different types of DG installed in the system. Analytical method is used to determine optimal size and the location for both type-1, type-2 and type-3.The three types of DG effectively reduced the real power loss, reactive power loss and voltage profile are also improved.

DG type 3 has the most effective way of reducing real and reactive power loss, following by DG type 1 and DG type 2 respectively. It is also interesting to note that DG type 3 has the highest loss reduction since it can generate both real and reactive power and DG type 2 has the lowest loss reduction since it consumes reactive power in the system.

It has been shown that voltage profile is significantly improved by placing DG in distribution system and the losses have been reduced by 96.15 % for summer case and 99.78% for winter case. The results demonstrated and emphasized that DG installation decreased total real and reactive power losses more than without DG installations.

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