International Journal of Research Studies in Science, Engineering and Technology
Volume 1, Issue 9, December 2014, PP 169-179
ISSN 2349-4751 (Print) & ISSN 2349-476X (Online)

Optimal Placement of Distributed Generation (Dg) Sources in Power Systems for Loss Reduction Using BIBC and Analytical Approach

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Abstract: *Due to the increasing interest on renewable sources in recent times, the studies on integration of distributed generation to the power grid have rapidly increased. In order to minimize line losses of power systems, it is crucially important to define the location of local generation to be placed. Proper location of DGs in power systems is important for obtaining their maximum potential benefits. This paper presents analytical and BIBC approaches to determine the optimal location to place a DG on radial systems to minimize the power loss of the system. The results are presented to verify the proposed analytical and BIBC matrix method approaches.*

Keywords: *Analytical approach, distributed generation, radial systems, optimal placement, power loss.*

1. INTRODUCTION

In recent times, due to the increasing interest on renewable sources such as hydro, wind, solar, geothermal, biomass and ocean energy etc., the number of studies on integration of distributed resources to the grid have rapidly increased. Distributed generation (DG), which consists of distributed resources, can be defined as electric power generation within distribution networks or on the customer side of the network [1].Distributed generation (DG) devices can be strategically placed in a power system for grid reinforcement, reducing power losses and on-peak operating costs, improving voltage profiles and load factors, deferring or eliminating for system upgrades, and improving system integrity, reliability, and efficiency [3]. These DG sources are normally placed close to consumption centers and are added mostly at the distribution level. They are relatively small in size (relative to the power capacity of the system in which they are placed) and modular in structure. A common strategy to find the site of DG is to minimize the power loss of the system [5]. There are methods of loss reduction techniques used like feeder reconfiguration, capacitor placement, high voltage distribution system, conductor grading, and DG unit placement. All these methods except DG unit placement are involved with passive element. Both DG units and capacitors reduce power loss and improve voltage regulation; but with DGs, loss reduction is almost double that of Capacitors [4]. A simple method for placing DG is to apply rules that are often used in deciding location of shunt capacitors in distribution systems. A.2/3 rule. is presented in [6] to place DG on a radial feeder with uniformly distributed load, where it is suggested to install DG of approximately 2/3 capacity of the incoming generation at approximately 2/3 of the length of line from the sending end. This rule is simple and easy to use, but it cannot be applied directly to a feeder with other types of load distribution, or to a networked system. Celli and Pilo propose a method to establish an optimal distributed generation allocation on distribution network based on a Genetic Algorithm considering all the technical constraints, like feeder capacity limits, feeder voltage profile and three-phase short circuit current in the network nodes [7]. Griffin and Tomsovic present an algorithm to determine the near optimal, with respect to system losses, placement of these units on the power grid. Further, the impacts of dispersed generation at the distribution level are performed with an emphasis on resistive losses, and capacity savings[8]. This paper presents analytical approaches for optimal placement of DG with unity power factor in power systems using loss reduction criterion. First, placement of DG on a radial feeder is analyzed and the theoretical optimal site (bus location) for adding DG is obtained for different types of loads such as uniformly, centrally and increasingly distributed loads with DG sources. The proposed method is tested by a series of simulations on subset of it, to show the effectiveness of the proposed methods in determining the optimal bus for placing DG. In practice, there are more constraints on the availability of DG sources, and we may only have one or a few DGs with limited output available to add. Therefore, in this study the DG size is not considered to be optimized. The procedure to determine the optimal bus for placing DG may also need to take into account other factors, such as economic and geographic considerations.

2. THEORETICAL ANALYSIS FOR OPTIMAL PLACEMENT OF DG ON A RADIAL FEEDER

To simplify the analysis, only overhead lines with uniformly distributed parameters are considered, i.e., R and L per unit length are the same along the feeder while C and G per unit length are neglected. The loads along the feeder are assumed to be time-invariant*A.*

Theoretical Analysis

(i). A Radial feeder without DG

First consider a radial feeder without DG. The loads are distributed along the radial feeder with the phasor load current density as shown in Fig.1.Hence, the phasor current flowing through the feeder at point *x* (the distance *x* being measured from the receiving end) is

$$I(x) = \int_0^x I_d(x).\,dx \qquad (1)$$

Assuming the impedance per unit length of the line is), the incremental power loss at point *x* is,

$$dP(x) = \left(\left|\int_0^x I_d(x).\,dx\right|\right)^2 .R\,dx \qquad (2)$$

The total power loss along the feeder is,

$$P_{loss} = \int_0^l dP(x) = \int_0^l \left(\left|\int_0^x I_d(x).\,dx\right|\right)^2 .R\,dx \qquad (3)$$

ii.)A Radial feeder with addition of DG at location x

Consider a DG is added into the feeder at the location *x*, as injected current source as shown in Fig.1.The feeder current between the source (at*x*=*1*) and the location of DG (at*x*=*xo*)will also change as result of injected current source

0

The feeder current after adding DG can be written as follows:

$$I(x) = \begin{cases} \int_0^x I_d(x).\,dx; & 0 \le x \le x_0 \\ \int_0^x I_d(x).\,dx - I_{DG}; & x_0 \le x \le l. \end{cases} \qquad (4)$$

The corresponding power loss in the feeder is

$$P_{loss}(x_0) = \int_0^{x0} \left(\left|\int_0^x I_d(x).\,dx\right|\right)^2 + \int_{x0}^{l} \left(\left|\int_0^x I_d(x).\,dx - I_{DG}\right|\right)^2 .R\,dx$$

$$(5)$$

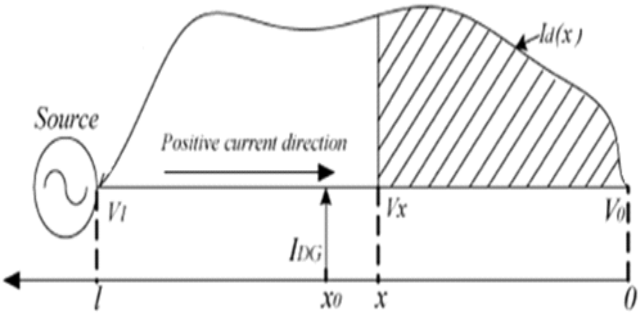

Fig.1. A feeder with distributed loads along the line

(iii).Procedure to find the optimal placement of DG on a Radial Feeder The go a list of add DG at location to minimize the power loss in the feeder .Differentiating the equation(5) with respect to and setting the result to zero ,i.e.,

$$\frac{dP_{loss}}{dx_0} = 0 \qquad (6)$$

The solution of the above equation will give the optimal site for minimizing the powerloss.

3. ANALYTICAL APPROACH FOR OPTIMAL PLACEMENT OF DG UNIT ON A RADIAL FEEDER WITH SOME TYPICAL LOAD DISTRIBUTIONS

We will illustrate the procedure to find the optimal placement of DG on radial feeder with the following three different load distributions:(a)uniformly distributed loads, (b) Centrally distributed loads and (c)Increasingly distributed loads. Thesetypesofloadprofilesareshownin theFig.2 throughFig.4

(a)Uniformly distributed loads:

For uniformly distributed load profile, the phasor load current density is constant and can be used to calculate the total powerloss in feeder as per equation (3).It can be shown that the total powerloss along the feeder without DG is

$$P_{loss} = \frac{I_d^2(x).R.l^3}{3} \qquad (7)$$

After adding DG, using equation (5), it can be shown that total power loss along the feeder with DG is

$$P_{loss} = I_d^2(x).R.l^3 - I_d(x).I_{DG}.R(l^2 - x_0^2)$$
$$+ I_{DG}^2\ (l - x_0) \qquad (8)$$

For optimal location of DG, differentiating equation w.r.to x_0 and equating it to zero, we can evaluate the optimal location of DG unit to be at equation

$$x_0 = \frac{I_{DG}}{2.I_d(x)} \qquad (9)$$

$$x_0 = \frac{I_{DG}}{2 I_{d}(X)} \qquad (9)$$

If the DG unit supplies all the load then substituting value in the equation (9), the optimal location of DG on a feeder is

$$x_0 = \frac{l}{2} \qquad (10)$$

Hence substituting the values of and x_0 in equation (8), the total power loss after adding the DG on feeder is

$$P_{loss} = \frac{I_{d(x)}^2 . R . l^3}{12} \qquad (11)$$

Hence, from equation (7) and (11), the power loss reduction after adding the DG on a feeder is,

$$= \frac{I_d{}^2(x) . R . l^3}{4} \qquad (12)$$

Thus power loss reduction (%) =

$$= \frac{\dfrac{I_d{}^2(x) . R . l^3}{4}}{\dfrac{I_d{}^2(x) . R . l^3}{3}} * 100 = 75\% \qquad (13)$$

(b).Centrally distributed loads:

$$I(x) = \int_0^x I_d(x) . dx \qquad (14)$$

$$= \begin{cases} \int_0^x I_{ld} . x \, dx ; & 0 < x \leq l/2 \\ \int_0^{l/2} I_{ld} . x \, dx + \int_{l/2}^{l} I_{ld} \, (l - x) . dx ; & l/2 < x \leq l . \end{cases} \qquad (15)$$

Using equation (3), the total power loss along the feeder before adding DG

$$P_{loss}(x) = \int_0^{l/2} dP(x) + \int_{l/2}^{l} dP(x)$$

$$P_{loss} = (0.0239) . I_{ld}^2 \, R . l^5 \qquad (16)$$

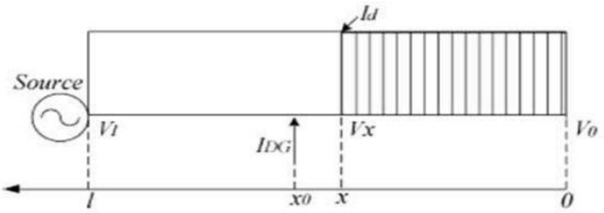

Fig.2 A feeder with uniformly distributed loads

$$I(x) = \begin{cases} \int_0^x I_d(x).dx; & 0 < x \le l/2 \\ \int_0^x I_{ld}(l-x).dx - I_{DG}; & l/2 < x \le l. \end{cases} \quad (17)$$

Using a similar procedure given above, it can be shown that the power loss along the feeder after adding DG is

$$P_{loss} = \int_0^l dP_{loss} = (0.00312).I_{ld}^2.R.l^5 \quad (18)$$

(c) Increasingly distributed loads:

Now for the case of increasingly distributed load as shown in Fig.4, the phasor current density on a feeder is

$$I_d(x) = I_{ld}(l-x) \quad (19)$$

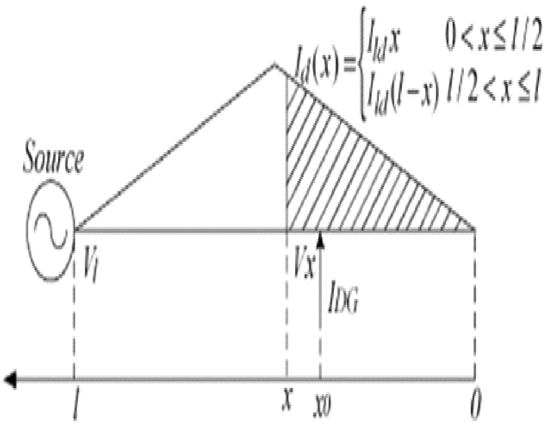

Fig.3 A feeder with centrally distributed loads

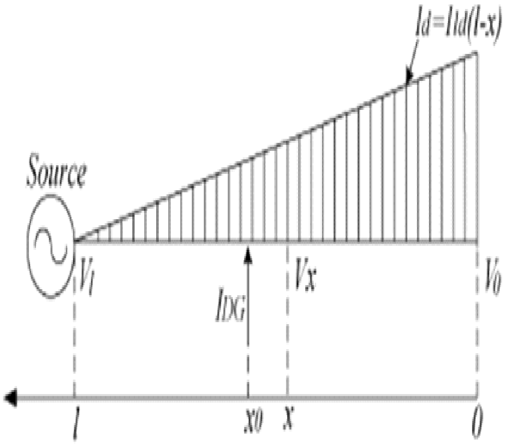

Fig.4 A feeder with increasingly distributed loads

TABLE I
THEROTICAL ANALYSIS RESULTS OF CASE STUDIES WITH DIFFERENT TYPES OF LOADS AND DGs

Load Types	Power loss before adding DG	Power loss after adding DG	Percentage of power loss reduction (%)	Optimal Location ( )
Uniformly distributed load	$\frac{I_d^2(x).R.l^3}{3}$	$\frac{I_{d(x)}^2.R.l^3}{12}$	75	
Centrally distributed load	$(0.0239).I_{ld}^2R.l^5$	$0.00312).I_{ld}^2.R.l^5$	86.9	
Increasingly distributed load	$(0.133)\, I_{ld}^2.R.l^5$	$0.0155\,)\, I_{ld}^2.R.l^5$	88.3	

(ASSUMPTIONS: DG SUPPLIES ALL THE LOADS IN EACH CASE AND IS PLACED AT OPTIMAL LOCATION)

$$P_{loss} = \int_0^l dP_{loss} = 0.133\, I_{ld}^2.R.l^5 \qquad (20)$$

Assuming that DG unit supplies all the feeder load i.e., Consider a DG with is added in to the feeder at the location from end of the feeder current after adding DG is as follows;

$$I(x) = \begin{cases} \int_0^x I_{ld}.(l-x).dx: & 0 < x \le x_0 \\ \int_0^x I_{ld}\,(l-x).dx - I_{DG}: & x_0 < x \le l. \end{cases} \qquad (21)$$

Using equation (5), it can be shown that the total power loss along the feeder.

$$P_{loss} = I_{ld}^2.R\int_0^{x_0}\left(lx - \frac{x^2}{2}\right)^2.dx + \int_{x_0}^{l}(I_{ld}(l.x - x^2/2) - I_{DG})^2.Rdx \qquad (22)$$

The multiplier has been set to the normalize the total load to, then it can be shown that the total power loss along the feeder after adding the DG is

$$P_{loss} = 0.0155\, I_{ld}^2.R.l^5 \qquad (23)$$

and the optimal placement of DG is $x_0 = 0.293l.$

4. ANALYTICAL RESULTS AND DISCUSSIONS

Table I shows the results of analysis, using the foregoing procedure, to find the optimal location for placing DG on a radial feeder with three different load distributions; uniformly distributed load, centrally distributed load and increasingly distributed load and the results shown in Table I, it is assume that the DG supplies all the loads on the feeder in each case, and the distribution system supplies the system power losses significantly when it is located properly.

Several simulation studies with different load distributions were carried out to verify the results obtained analytically for radial systems. A radial feeder with a DG was simulated under uniformly distributed, centrally distributed and increasingly distributed loads. The simulated system for uniformly distributed loads is shown in Fig. 5 .The system architecture is the same when the loads are centrally distributed or increasingly distributed .The line parameters ,DG and load sizes are listed in Table II.

For each type of load configuration, the rating of DG is chosen to be equal to the load on the feeder . The total system power loss is calculated by adding DG at each bus location one-by-one: (i).the proposed analytical method and (ii)BIBC approach. The simulations studies were carried out using SIMULINK tool box in MATLAB.

The figures5.A, 6.A, 7.A ,8.A ,9.A,10.A,11.A,12.A and 13.A , 5.B, 6.B, 7.B, 8.B, 9.B, 10.B, 11.B, 12.B and 13.B show the analytical results for the total system power loss of the radial feeder with three different load distributions (uniformly, centrally and increasingly distributed loads) and different sizes of DG are located at each bus locations. The results obtained using simulation studies are shown in figures 6.B, 7.B and 8.B.The figures shows the results of power losses after adding

DG on a radial feeder having different types of concentrated loads like uniformly, centrally and increasingly distributed loads respectively. The magnitude of power losses decreases to minimum value and again increases with the location of DG source from sending end bus to receiving end bus on feeder. In uniformly distributed radial feeder, 3.5 MW size of DG gives minimum amount of loss at bus no.8 and loss as optimal loss. It is concluding that the bus no.8 is called optimal location or place of DG and 3.50 MW DG is the optimal size. From these figures, it is noted that (i). The values of the system power losses obtained by all these methods are nearly equal. (ii).The system power losses are dependent upon the location of DG.(iii).The optimal location of DG is obtained by selecting a bus at which the system power loss is minimum.(iv). At optimal location of DG, the system power losses are reduced significantly. (v).The optimal location of DG obtained in each method is in agreement with the other methods. In Table II, the optimal bus for placing DG to minimize the total system power loss is given for each load distribution. The total system power losses are given both with and without DG. It is noted that the simulation results agree well with the theoretical results.

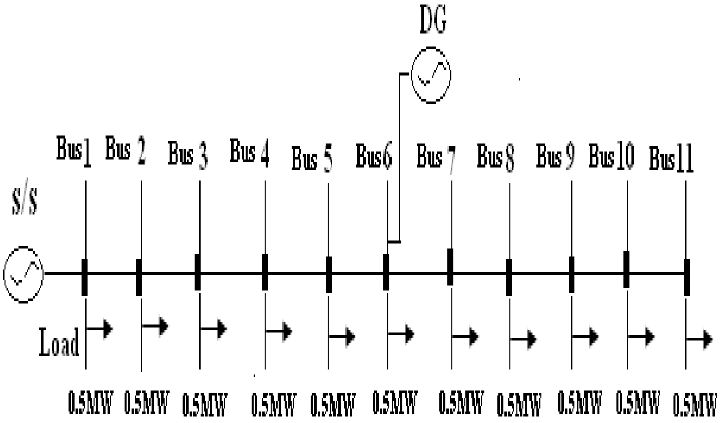

Fig A. *11bus uniform radial feeder system*

Table2. *Parameters of the System in Fig5*

Line parameters (AWG ACSR 1/0)	Line spacing = 1.32m (equal spacing assumed) $R = 0.538\Omega$, $X_L = 0.4626\ \Omega$ Bus Voltage: 12.5kV Line length between two neighboring buses: 2.5km										
Load type	Load at each bus (MW)										
	1	2	3	4	5	6	7	8	9	10	11
Uniformly distributed	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Centrally distributed	0.05	0.1	0.2	0.3	0.4	0.5	0.4	0.3	0.2	0.1	0.05
Increasingly distributed	0.05	0.1	0.15	0.2	0.25	0.3	0.35	0.4	0.45	0.5	0.55
DG size (MW)	Uniformly			Centrally				Increasingly			
	5.5			2.6				3.3			

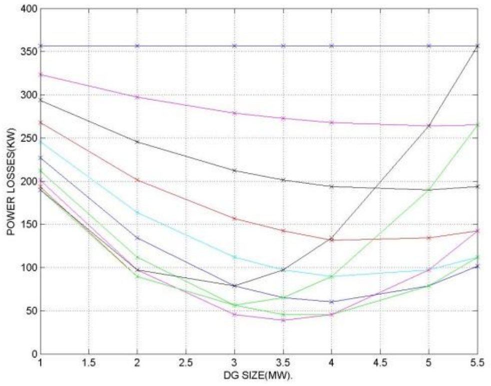

Fig:5A *11bus BIBC uniform distribution load*

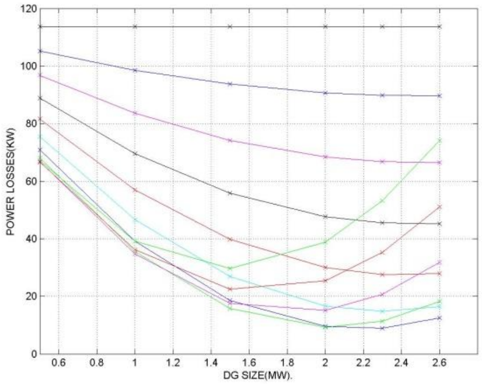

Fig:6A *11bus BIBC centrally increasing load*

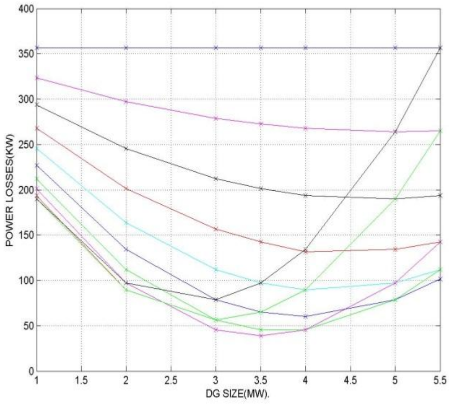

Fig:7A *11bus BIBC uniform increasing load*

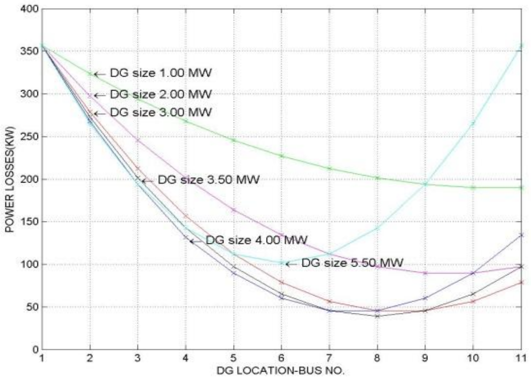

Fig:5B *11bus analytical result uniform load*

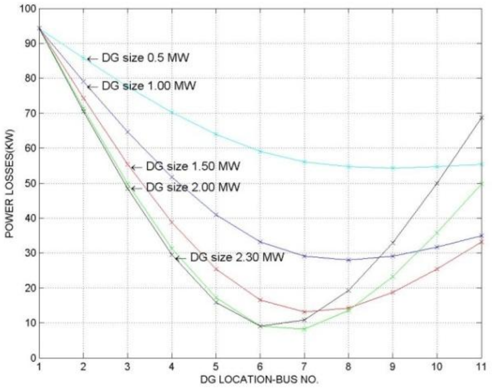

Fig:6B *11 bus analytical results of centrally increasing load*

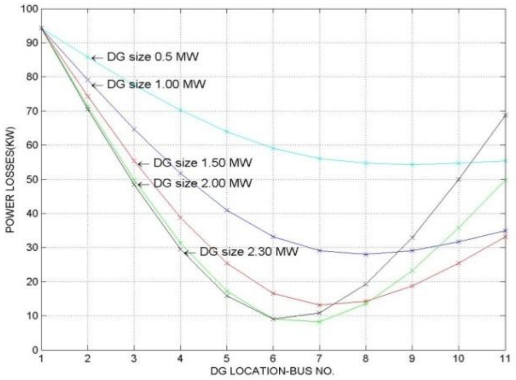

Fig:7B *11 bus analytical uniform increasing load*

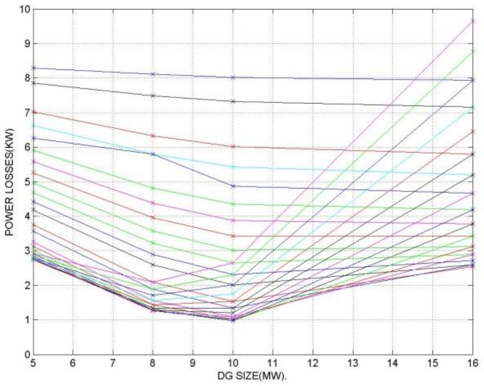

Fig:8A *30bus BIBC uniform distribution loads*

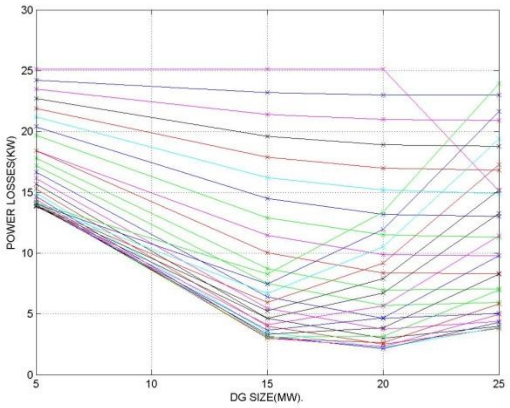

Fig:9A *30bus BIBC centrally increasing load*

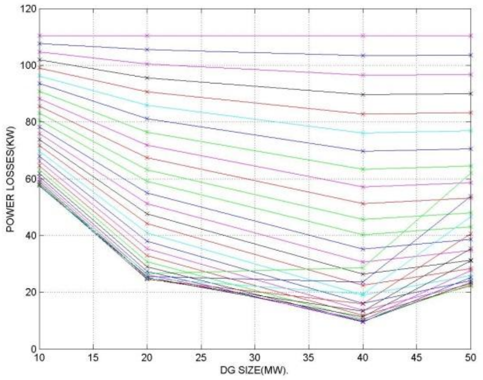

Fig:10A *30bus BIBC uniform increasing load*

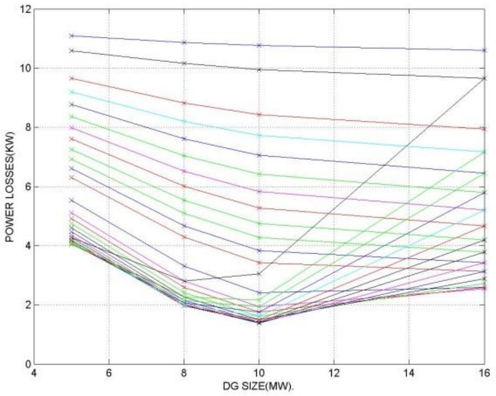

Fig:8B *30 analytical result uniform load*

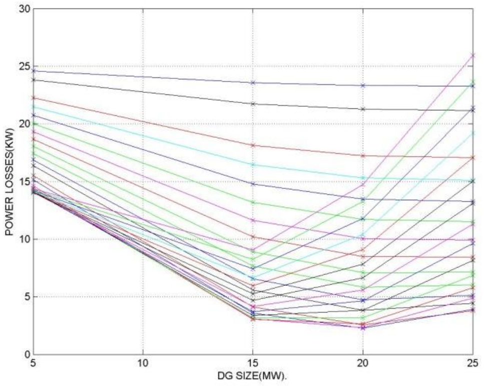

Fig:9B *30 analytical result centrally increasing load*

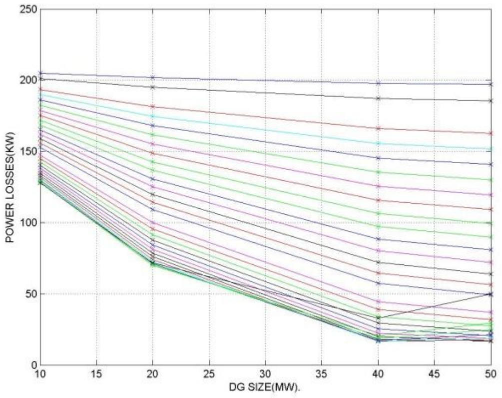

Fig:10B *30 analytical result increasing distributed load*

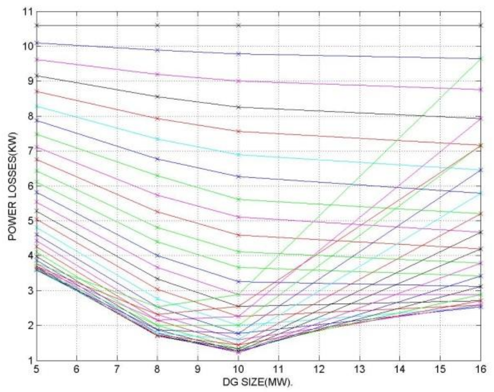

Fig:11A *33 bus BIBC uniform distributed load*

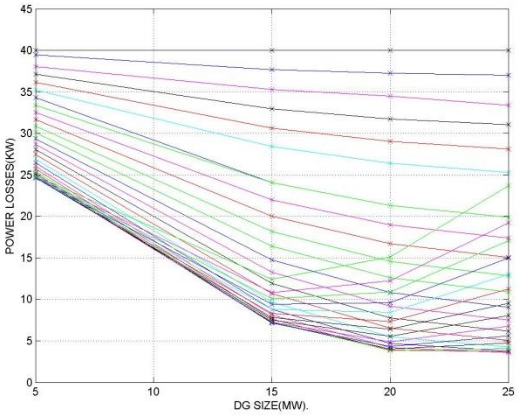

Fig:12A *33 bus BIBC centrally increasing distributed loads*

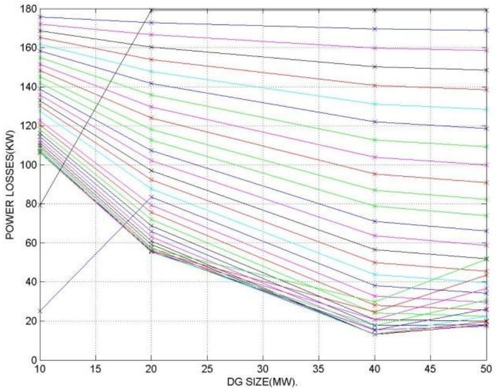

Fig:13A *33 bus BIBC increasing distributed loads*

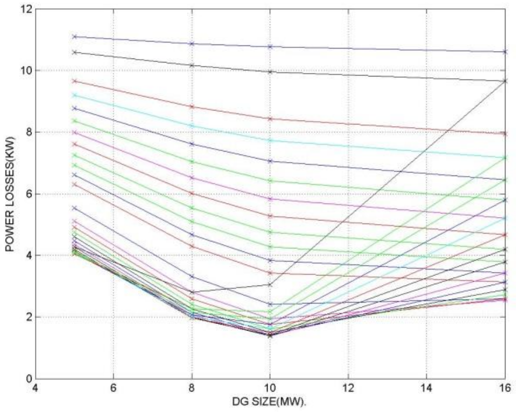

Fig:11B *33 analytical result uniform distributed load*

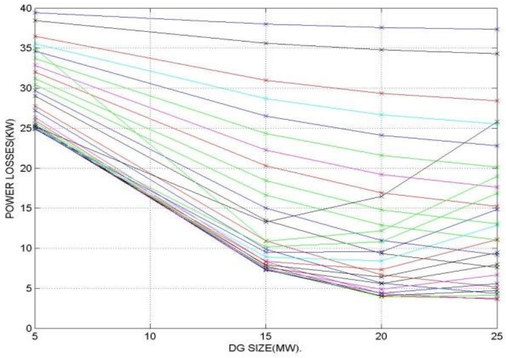

Fig:12B *33 analytical result centrally increasing load*

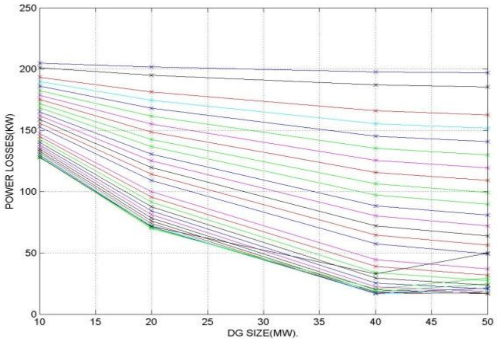

Fig:13B *33 analytical result increasing distributed load*

5. CONCLUSION

This paper presents analytical approaches to determine the optimal location for placing DG on a radial feeder to minimize power losses. The proposed approaches are not iterative algorithms, like power flow programs. Therefore, there is no convergence problems involved, and results could be obtained very quickly. A series of simulation studies have been conducted to verify the validity of the proposed approaches, and results show that the proposed methods work well.

In practice, there are other constraints which may affect the DG placement. Nevertheless, methodologies presented in this paper can be effective, instructive, and helpful to system designers in selecting proper sites to place DGs. system designers in selecting proper sites to place DGs.

REFERENCES

[1] T.Ackermann, G. Anderson, L. Söder, Distributed Generation:a Definition, Electric Power System Research 57, 2013, pp.195-204.

[2] G.Pepermansa, J.Driesenb, D.Haeseldonckxc, R.Belmansc, W.D'haeseleerc Distributed generation: definition, benefits and issues, Energy Policy 33 (2005)787 798.

[3] N. S. Rau and Y.-H.Wan, Optimum location of resources in distributed planning, IEEE Trans. Power Syst., vol. 9, pp. 2014 2020, Nov. 2010.

[4] A.Lakshmi Devi and B. Subramanyam Optimal DG Unit pla -ement for Loss Reduction in Radial Distribution system-A case study (ARPN) Vol 2, no.6,December 2007.

[5] K.H. Kim, Y.J. Lee, S.B. Rhee, S.K. Lee, and S.K. You,Dispersed generator Placement using fuzzy-GA in distribution systems, in Proc.2002 IEEE Power Engineering Soc. Summer Meeting, vol. 3, Chicago, IL, July 2002, pp. 11481153.

[6] H. L. Willis, Analytical methods and rules of thumb for modeling- distribution Interaction, in Proc. 2000 IEEE Power Engineering Society Summer Meeting, vol.3, Seattle, A, July 2000, pp.1643 1644.

[7] Celli, G and Pilo, F, Optimal distributed generation allocation in MV Distribution Networks, 22nd IEEE Power Engineering Society International Conference on, 2001, PP.81-86.

[8] T.Griffin, K. Tomsovic, D. Secrest, and A. Law, Placement of Dispersed generations Systems for Reduced Losses, in Proc.33rd Annu. Hawaii Int Conf. System Sciences, Maui, HI, 2000.

[9] C. Wang, M. H. Nehrir, Analytical Approaches For Optimal Placement of DG Sources In Power Systems, IEEE Trans. On wer Syst.,Vol. 19, No. 4, November 2004; pp. 20682076.

[10] Acharya N., Mahat, P. and Mithulananthan N, An analytical approach for DG allocation in primary distribution network,International Journal of Electrical Power & Energy Systems

[11] J. O. Kim, S. W. Nam, S. K. Park, and C. Singh, Dispersed generation planning Using improved Hereford ranch algorithm, Elect. Power Syst.Res. , vol. 47, no. 1,pp. 47 55, Oct. 2006.

[12] W. Kellogg, M. H. Nehrir, G.Venkataramanan, and V. Gerez, Generation unit sizing and cost analysis for stand-alone wind,photovoltaic, and hybrid wind/PV systems ,IEEE Trans. Energy Conversion, vol. 13, pp. 7075, Mar. 2000.

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