Optimal Placement of Distributed Generation (DG) Sources in Power System for Power Loss Reduction

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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 theoretical approaches to determine the optimal location to place a DG on radial systems to minimize the power loss of the system. Simulation results are given to verify the proposed theoretical approaches.

Keywords: Theoretical Approach, Distributed Generation, Radial Systems, Optimal Placement and Power Loss

I. 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 [2]. 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 [3]. 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 approaches 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. The method for allocation of losses in distribution networks with dispersed generation and uses the power summation, and it is based on the branch oriented approach and it establishes direct relationship between losses in each branch of the network and injected active and reactive power in the nodes. Active and reactive power at ending node of each branch of the network is decomposed as a sum of all injected power in nodes plus losses in the branches supplied by the branch [5]. A methodology for determining the optimum size and location for installing the solar photovoltaic (SPY) based DG system for supplying the active power at the node in a radial distribution system for loss reduction [7]. This paper presents analytical approaches for optima 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 Dos 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.

II. THEORETICAL ANALYSIS

A. A Radial feeder without DG

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

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

Assuming the impedance per unit length of the line is z = R + jX(Ω/km). 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,

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

B. A Radial feeder with addition of DG at location Xo

Consider a DG is added into the feeder at the location xo, as injected current source IDG as shown in Fig.l.The feeder current between the source (at x = I) and the location of DG (at x = xo) will also change as result of injected current source JDe .The feeder current after adding DG can be written as follows:

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

The corresponding power loss in the feeder is

$$P_{loss}(x_0) = \int_0^{xo} \left(\left|\int_0^x I_d(x).dx\right|\right)^2 + \int_{x0}^{l} \left(\left|\int_0^x I_d(x).dx - I_{DG}\right|\right)^2 .R\,dx \quad (5)$$

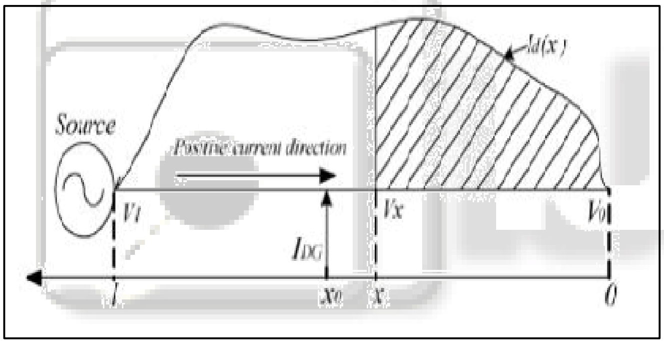


Fig. l: A feeder with distributed loads along the line

1) Procedure to find the optimal placement of DG on a Radial Feeder

The goal is to add DG at location to minimize the power loss in the feeder. Differentiating the equation (5) with respect to Xo and setting the result to zero,i.e.,

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

The solution XO of the above equation will give the optimal site for minimizing the power loss.

III. THEORETICAL 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 Uniformly distributed load distributions: These types of load profiles are shown in the Fig.2

A. Uniformly distributed loads:

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

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

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

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

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

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

If the DG unit supplies all the load (i.e., $I_{DG} = I_d(x)l$), then substituting I_{DG} value in the equation (9), the optimal location of DG on a feeder is

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

Hence substituting the values of I_{DG} and x 0 in equation (8), the total power loss after adding the DG on feeder is

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

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

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

Thus power loss reduction (%) =

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

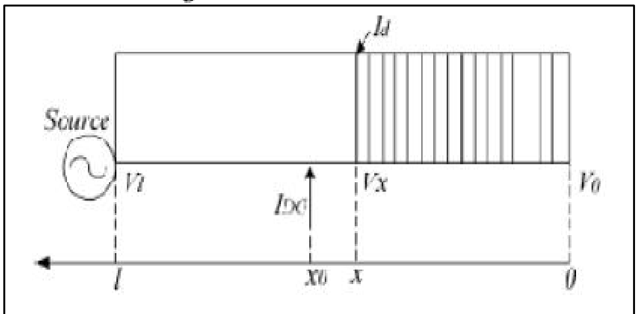


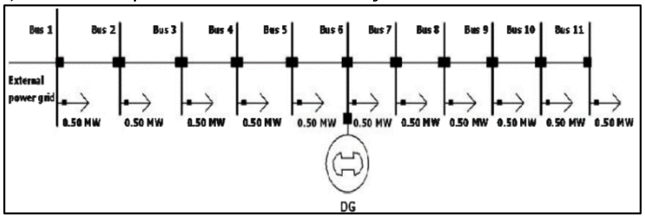
Fig.2 A feeder with uniformly distributed loads

1) Similarly the find out the:

1) Centrally distributed loads and
2) Increasingly distributed loads before adding DG &after adding DG. And the result in given table.

Load Type	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	$\frac{l}{2}$
Centrally distributed load	$(0.0239).I_{ld}^2R.l^5$	$(0.00312).I_{ld}^2.R.l^5$	86.9	$\frac{l}{2}$
Increasingly distributed load	$0.133\,I_{ld}^2.R.l^5$	$0.0155I_{ld}^2.R.l^5$	88.3	$0.293\,\bar{l}$

2) 11 Bus of Radial Distribution System Network



3) Load Flow Algorithm:

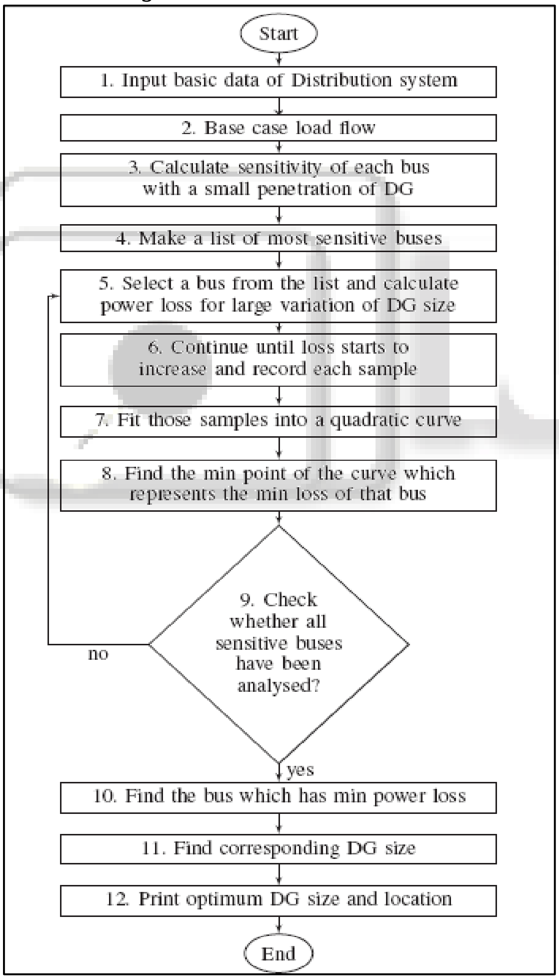


Fig. 2: Flow chart to identify optimum size and location of DG

IV. THEROTICAL AND SIMULATION 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 theoretically 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 theoretica approach and (ii) simulation approach. The simulations studies were carried out using SIMULINK tool box in MATLAB.

Line Loading	Line spacing=132m (Equal spacing assumed) R=0.538?km.X=4626?km Bus voltage : 11kv; Line spacing between two nightbring buses 2.5km										
LoadType	Load at each bus(MW)										
Bus sr no	1	2	3	4	5	6	7	8	9	10	11
Uniformly distributed load	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
Centrally distributed load	0.05	0.1	0.2	0.3	0.4	0.5	0.4	0.3	0.2	0.1	0.05
Increasingly distributed loade	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)	Uniformaly 5.5				Centrally 2.6				Incresingly 3.3		

Table 1: Parameter of the System Fig 5

Line Loading	Rating of DG (MW)	Optimal placement of DG(optimal Bus No)		Total power Losses (KW)	
		Analytical result	Simulated result	Without DG	With DG

Uniformly distributed load	5.5	6	6	356	102
Centrally distributed load	2.6	6	6	95	13
Increasing ly distributed load	3.3	9	9	208	29

Table 2: Result of Case study with Invarien Load and Dg

V. CONCLUSION

This paper presents theoretical 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.

REFERENCES

[1] A.Lakshmi Devi and B. Subramanyam "Optimal DC Unit Placement for Loss Reduction in Radial Distribution system-A case study" (ARPN) Vol 2, no.6,December 2007.
[2] Metodija Atanasovski and Rubin Taleski, "Power Summation Method for Loss Allocation in Radial Distribution Networks With Dispersed Generation" 7th Mediterranean Conference and exhibition on Power Generation, Transmission, Distribution and Energy Conversion 7-10 November 2010.
[3] H. L. Willis, "Analytical methods and rules of thumb for modeling distribution Interaction," in Proc. 2000 [EEE Power Engineering Society Summer Meeting, vol.3, Seattle, A, July 2000.
[4] Sheeraz Kirrnani, Majid Jamil and M. Rizwan. Optimal Placement of SPY based DG System for Loss Reduction in Radial Distribution Network Using Heuristic Search Strategies, 978-1-4673- 0136-7/111 ©2011 IEEE.
[5] Sudipta Ghosh, S.P.Ghoshal Ghosh "Two Analytical approaches for Optimal Placement ofDistributed Generation Unit in Power Systems", 2009 Third International Conference on Power Systems, Kharagpur, INDIA December 27-29.
[6] P. Chiradeja, Member, IEEE "Benefit of Distributed Generation: A Line Loss Reduction Analysis", 2005 IEEEIPES Transmission and Distribution Conference & Exhibition: Asia and Pacific Dalian, China.
[7] Acharya N., Mahat, P. and Mithulananthan N, "An analytical approach for DC allocation in primary distribution nellVor/(', [nternational Journal of Electrical Power & Energy Systems
[8] 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. I,pp. 47- 55, Oct. 1998.
[9] Junfang Zhang and Z Q Bo Research of the Impact of Distribution Generation on Distribution Network Loss, UPEC2010 3 1st Aug - 3rd Sept 2010.