Optimal Location of DG in Existing Distribution Network

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***Abstract*: The traditional approach in electric power generation is to have centralized plants distributing electricity through an extensive transmission and distribution network. Recently, there has been great interest in the integration of distributed generation units at the distribution level. The foreseeable large use of DG in the future requires the distribution system engineers to properly take into account its impact in the system planning. When considering DG impact the attention should be paid in the siting and sizing of DG units [1]. This paper proposes the use of analytical expressions for finding the optimal size and site of DG in distribution systems. 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 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 analytical approaches [2].**

Keywords: Distribution system, sizing, siting, renewable distributed generation, voltage profile.

I. INTRODUCTION

One of the most important motivation for the studies on integration of distributed resources to the grid is the exploitation of the renewable resources such as; hydro, wind, solar, geothermal, biomass and ocean energy, which are naturally scattered around the country and also smaller in size. Accordingly, these resources can only be tapped through integration to the distribution system by means of Distributed Generation. Distributed Generation (DG), which generally consists of various types of renewable resources, can be defined as electric power generation within distribution networks or on the customer side of the system [1]. DG affects the flow of power and voltage conditions on the system equipment. These impacts may manifest themselves either positively or negatively depending on the distribution system operating conditions and the DG characteristics. Positive impacts are generally called 'system support benefits', and include voltage support and improved power quality; loss reduction; transmission and distribution capacity release; improved utility system reliability. On account of achieving above benefits, the DG must be reliable, dispatch able, of the proper size and at the proper locations [2], [3]. Energy cost of renewable based distributed generation when compared to the conventional generating plants is generally high whereat the factors of social and environmental benefits could not be included in the cost account. Accordingly, most of the studies to determine the optimum location and size of DG could not consider the generation cost, directly. Although one of the most important benefits of the DG is reduction on the line losses, it is crucially important to determine the size and the location of local generation to be placed. For the minimization of system losses, there have been number of studies to define the optimum location of DG. The various approaches on the optimum DG placement for minimum power losses can be listed as the classical approach: second order algorithm method, the meta-heuristics approaches, genetic algorithm and Hereford Ranch algorithm, Fuzzy-GA method and the analytical approaches. In the analytical studies; optimal place of the DGs are determined exclusively for the various distributed load profiles such as uniformly, increasingly, centrally in radial systems to minimize the total losses of the system. Additionally in optimal size of DG is obtained and analyzed by considering the effects of static load models. In the optimal size and location of DG is calculated based on exact loss formula and compared with successive load flows and loss sensitivity methods. The bus impedance matrix; Zbus, the inverse of the bus admittance matrix; Ybus, is used in exact loss formula. Moreover the bus admittance matrix; Ybus in some cases, may be singular, therefore, Zbus may not be readily available. In this study, the optimum size and location of distributed generation will be defined so as to minimize total power loss by an analytical method based on the equivalent current injection technique and without the use of impedance or Jacobean matrices for radial systems[4][5].

II. OPTIMUM SIZE AND LOCATION OF DG

There have been many studies on the reconfiguration of distribution systems for loss reduction. A switch exchange algorithm was proposed in. In an approximate power-flow technique was developed for analyzing loss reduction from network reconfiguration. In Fan et al. formulated the reconfiguration problem as a linear programming problem and applied a single loop optimization method to solve network reconfiguration. Other techniques such as the simulated annealing (SA), genetic algorithm (GA), improved Tabu Search (TS), and ant colony search (ACS) algorithm have been used for the purpose of network reconfiguration for reducing losses [6]. For optimal capacitor placement a well-known "Golden Rule," or "2/3 rule" for loss reduction. This method would yield good solutions in system where the loads are uniformly distributed. In distribution systems, DG can deliver a portion of real and/or reactive power so that the feeder current is reduced and voltage profile can be improved with reduction in losses. However, studies indicate that poor selection of location and size would lead to higher losses than the losses without DGs. Although the 2/3 rule is simple and easy to apply, this technique may not be effective in distribution with not uniformly distributed loads. Besides, if a DG is capable of delivering real and reactive power, applying the method that was developed for capacitor placement may not work. In an analytical approach has been presented to identify appropriate location to place single DG in radial as well as loop systems to minimize losses. But, in this approach, optimal sizing is not considered. In this paper, an analytical expression to calculate optimum size and site for DG placement are proposed. The methodology is computationally less demanding [7]. The DG is considered to be located in the primary distribution system and the objective of DG placement is to reduce the losses. The proposed methodology is suitable for allocation of single DG in a given distribution network.

III. METHODOLOGY

A. Exact Loss Formula

The real power loss in a system is given (1) which is known as "Exact loss" formula.

$= (+) + \beta\ (-)]$ (1)

where $\alpha =$ cos(-);

$\beta =$ sin(-),

N is number of buses

Is the ijth element of [Zbus] matrix.

is voltage at *i*th bus

and is the injected active power at *i*th and *j*th buses respectively

and is the injected reactive power at *i*th and *j*th buses respectively.

B. Optimal Sizing of DG

The total power loss against injected power is a parabolic function and at minimum losses the rate of change of losses with respect
to injected power becomes zero [8].

= 2 -) = 0 (2)

It follows that,

- + -) = 0

= + -)] (3)

where, is the real power injection at node i, which is the difference between real power generation and the real power demand at that node:

= (4)

where , is the real power injection from DG placed at node i, and is the load demand at node i.

= + + -)] (5)

The above equation gives the optimum size of DG for each bus i, for the loss to be minimum. Any size of DG other than P_{DGi} placed
At bus i, will lead to higher loss.

C. Optimal Location to minimize Loss

After finding optimal size of DG at each bus, next step is to find the optimum location of DG, which will give the lowest possible total losses. The bus having least power loss will be optimal location for the placement of DG [8].

D. Computational Algorithm

Step 1: Run the base case load flow.
Step 2: Find the optimum size of DG for each bus using Eq. (5).
Step 3: Compute loss using Eq. (1) for each bus by placing DG of optimum size obtained in step 2 for that bus. Add the injection from DG for that bus and use base case values for all other variables.
Step 4: Locate the bus at which the loss is minimum after DG placement. This is the optimum location for DG.
Step 5: Run load flow with DG to get the final result.

IV. SIMULATION AND RESULTS

The proposed method of loss reduction by DG unit placement was tested on a distribution system consisting of 33 buses. Optimal sizes of DG units are calculated at each and every bus. Though the proposed methods can handle four different types of DG units, results of type3 DG units are presented. Bus11 is selected as optimal location as the losses are minimum compared to all other buses. Figure1 shows the bar representation of optimal DG sizes at all buses for 33 bus system. From figure 1 it can be observed that the DG size do not follow a regular manner and the size is independent of location of bus.

Fig. 1 OPTIMUM SIZE OF DG AT EACH OF 31 BUS ES OF RADIAL DIST. SYSTEM

The lowest value of Total loss is around 1.3 kW; DG of size 0.7MVA is placed at bus11.

Fig 2. ACTIVE POWER LOSSES WITHOUT DG / WITH DG

Fig 3. REACTIVE POWER LOSSES WITHOUT DG/WITH DG

Fig. 4 COMPARISION OF THE VOLTAGES OF THE BUSES (WITHOUT AND WITH DG INSTALLATION)

V. CONCLUSION

Using exact loss formula the size and location of DG unit is found. The DG unit is placed at optimal location which is reducing power loss as well as reactive power loss. The results are tabulated in Table1, Table2, and Table-3

Table-I
Total active power losses in KW

BUS NO.	WITHOUT DG	WITH DG
1	2.9	0.3
3	2.7	0.3
5	0.8	0.1
6	4.0	0.5

Table-II
Total reactive power losses in KVAR

BUS NO.	WITHOUT DG	WITH DG
1	1.7	0.2
3	1.6	0.2
5	0.5	0.1
6	2.5	0.3

Table-III
Voltages with and without DG in PU

BUS NO.	VOLTAGE IN PU	
	WITHOUT DG	WITH DG
9	0.9837	0.9976
10	0.9836	0.9976
11	0.9833	0.9978
13	0.9827	0.9968
14	0.9824	0.9965
16	0.9824	0.9964
17	0.9823	0.9964
19	0.9820	0.9961
20	0.982	0.9961

22	0.9818	0.9958
24	0.9815	0.9956
25	0.9814	0.995
27	0.9813	0.9954
30	0.9812	0.9953

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