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Optimal sitting and sizing of Distributed Generation

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Abstract— Matlab is one the important programming stream and consider as hottest research area now a day's, this area has very vast application in real world. Efficient methods and technologies are highly required to this world to reduce the calculations and perform the operation in precise manner. The power system is very abstruse subject so there is a need of optimum solutions with which the system becomes optimized and economical by solving complex problem. There are many benefits to install a DG in system but the problem is there is need to do complex calculation to know the size and the placement of DG. Benefits of employing DG are analysed using Voltage Profile Improvement Index (VPII) and Line Loss Reduction Index (LLRI). The optimal size and location of DG for a distributed system is the basic purpose of this paper.

Keywords— Distributed generation, Benefit Index(BI), Line loss reduction Index(LLRI), Voltage profile Index (VPII)

1. Introduction

Distributed generation can be considered as small scale generation which is not directly connected to bulk transmission and is not centrally dispatched. Distributed power generation is a small-scale power generation technology that provides electric power at a site closer to customers than the central generating stations. Distributed resources are strategically located and operated in the system to defer or eliminate system upgrades, improve voltage profile, reduce system losses, reinforce grid, and to improve system reliability and efficiency. Efficient clean fossil fuels technologies such as micro-turbines, fuelcells, and environmental-friendly renewable energy technologies such as biomass, solar/photovoltaic arrays, small wind turbines and hydro turbines, ranging from sub-kW to multi-MW are growingly used for new distributed generation systems. Distributed generation technologies can enhance the efficiency, reliability, and operational benefits of the distribution system. Its impact on distribution systems may be either positive or negative depending on the system's operating condition DGs characteristics and location.

2. Benefits of The Implementation of DG In Distributed System

- DGs deliver safe, clean, reliable, and efficient electrical energy at low price.
- Provide power in the vicinity of the loads and help in reducing the loadings on feeders.
- Minimization possibilities as well as randomness of faults.
- Achieve reliability, and voltage profile requirements.
- The capital cost of DG is low and also it returns back the benefit with in short period of time.
- Implementing DGs for distribution system planning minimizes the investment risk due to reduced capital cost and less installation time.
- Customer-owned DGs can help customers by providing some portion of their demands during their peak load periods and by feeding the excess power to the grid during their light load periods. This way, they can get some revenue back from the electric utility.

3. Methodology

In order to evaluate and quantify the benefits of distributed generation suitable mathematical models must be employed along with distribution system models and power flow calculations to arrive at indices of benefits.

Among the many benefits three major ones are considered:

- Voltage profile improvement,
- Line loss reduction
- Benefit Index.

Optimal Allocation of Distributed Generation (Effect of Siting and Sizing of DG)

- **Quantification of Technical Benefits**

3.1 Voltage Profile Improvement Index (VPII)

The ratio of the sum of all the voltage at all the buses when DG is connected to the system to the sum of all the voltage at every bus when system is running without DG is defined as VPII.

$$VPII = \frac{\text{Voltage Profile With DG}}{\text{Voltage Profile Without DG}}$$

- VPII < 1, DG has not beneficial,
- VPII = 1, DG has no impact on the system voltage profile,
- VPII > 1 DG has improved the voltage profile of the system.

The general expression for VP is given as,

$$VP = \sum_{I=1}^{N} Vi\ Li\ Ki$$

and

$$\sum_{I=1}^{N} Ki = 1$$

Where,
Vi= voltage magnitude at bus i in per-unit,
Li = load represented as complex bus power at bus i in per-unit,
Ki = weighting factor for bus i,
The weighting factors are chosen based on the importance and criticality of the different loads.
N= total number of buses in the distribution system.

As defined, the expression for VP provides an opportunity to quantify and aggregate the importance, amounts, and the voltage levels at which loads are being supplied at the various load busses in the system. In general, the highest value of VPII implies the best location for installing DG in terms of improving voltage profile.

3.2 Line Loss Reduction Index (LLRI)

During the installation of DG it is necessary to keep the line loss reduction index LLRI in mind because it is the major factor of DG. It represents the line losses so for better result it should be minimum as much as possible. By installing DG, line currents can be reduced, thus helping to reduce electrical line losses.

$$LLRI = \frac{LLW/DG}{LLWO/DG}$$

Where,

LLW/DG =total line losses in the system with the employment of DG and is given as

$$LLW/DG = \sum_{I=1}^{M} Ri\ Ii^{2}\ Di$$

Where Ii=per-unit line current in distribution line i with the employment of DG,
Ri = line resistance for line I (pu/km),
Di = distribution line length (km)
M=number of lines in the distribution system.

LLWO/DG is the total line losses in the system with the employment of DG and is given as

$$LLWO/DG = \sum_{I=1}^{M} Ri\ Ii^{2}\ Di$$

Where,
Ii= per-unit line current in distribution line I without DG.
Therefore conclusions made as:

- LLRI < 1 DG has reduced electrical line losses,
- LLRI = 1 DG has no impact on system line losses,
- LLRI > 1 DG has caused more electrical line losses.

This index can be used to identify the best location to install DG to maximize the line loss reduction. The minimum value of LLRI corresponds to the best DG location scenario in terms of line loss reduction.

3.3 Overall Benefit Index (BI)

The BI is a composite index proposed to quantify the overall benefits of DG.There are several benefits offered by DG are explained but only two major ones are considered in this paper:
i.e voltage profile improvement and line-loss reduction index.

BI = (BWVPI) (VPII) + (BWLLR) / (LLRI)

With $0 \le BWVPI \le 1$
and $0 \le BWLLR \le 1$

BWVPI + BWLLR = 1

Where,

BWVPI =weighting factors for voltage profile improvement
BWLLR =weighting factors for line-loss reduction.

In this paper the weight factor is same for each bus and moreover the two indices i.e. VPII and LLRI also have the same weighing factor. However, if DG is installed to mitigate a particular parameter than the corresponding parameter will get higher weight than the other.

4. Problem Formulation

In this paper an algorithm has proposed by maximizing the value of benefit index (BI) to determine the best location and size of DG. Because of the high costs of investment and power production of DG, there is considerable risk in its implementation, therefore the best locating, and proper sizing is very important. DG placement and sizing should be such that the revenue associated with the risk from this investment must be optimized.

Assumptions:-

- Maximum size of the DG which is 10% of the total system load.
- Value of VPII, LLRI and BI is kept 1 for bus number 1 for each and every size of DG with respect to every test systems .
- Classical algorithm is restricted to put DG on bus Number 1 of each and every test system as it is a slack bus.

5. Proposed Algorithm

Computational Procedure for Siting & Sizing of DG Using Classical Algorithm:

Step 1: A IEEE 14 bus system is taken. System model is implemented load flow is performed using MATLAB code using N-R Algorithm.

Step 2: The given data in terms of bus data and branch data of the given test system is prepared and designed in MATLAB code and the basic load flow is executed using MATLAB code. The voltage at each bus and total system losses are calculated and stored.

Step 3: Classical Algorithm is proposed is implemented in MATLAB code. This algorithm connect the DG of various size at each possible location and run the load flow using N-R algorithm for each case and also calculate the objective function i.e. Benefit Index for each case. The optimum location and size is calculated by using this Classical Algorithm approach.

6. Case Study

IEEE 14 bus test system is selected and the above mentioned algorithm is used to calculate for optimum sitting and sizing of DG.

Table 1: Execution Result

VPII	1.0762
LLRI	0.6848
BI	1.1530
DG at Bus No	13
Size of DG(MW)	25.90

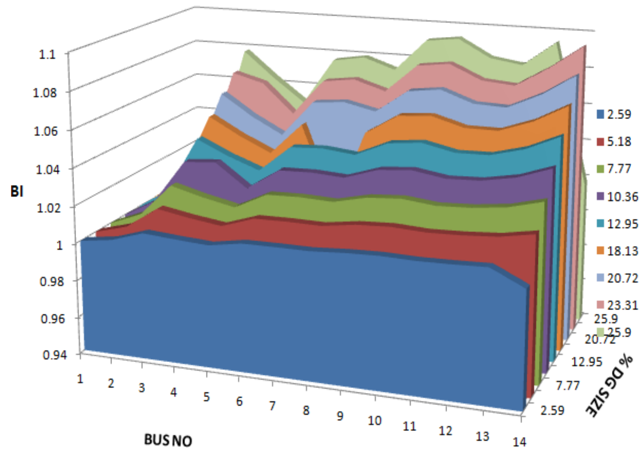

Fig 1: Relation between BI, Bus no, %DG size for 14 bus system.

7. Conclusion

The introduction of DG in a distribution system offers several benefits such as relieved transmission and distribution congestion, voltage profile improvement, line loss reduction, improvement in system, and enhanced utility system reliability. The outcome of classical algorithm approach is used to justify the imp act of DG sizing and allocation on distribution system. This proposed work has presented an approach to quantity some of the benefits of DG namely voltage profile improvement, line loss reduction and improvement of system load ability. The results of the proposed method as applied to IEEE-14 bus System clearly show that DG can improve the voltage profile and reduce electrical line losses and improve voltage stability index. Both ratings and locations of DG have to be considered together very carefully to capture the maximum benefits of DG.

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