INVESTIGATION ON OPTIMAL PLACEMENT AND SIZING OF DISTRIBUTED GENERATION UNITS

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Abstract: *Renewable power generation systems are currently preferred for clean power generation in Distributed Generation (DG) of all the different parts of an electric power system, customers identify closely with the distribution subsystem due to its proximity and visibility on a daily basis. It has a significant impact on the distribution systems. DG plays a significant role in the electric power system of the near future. This paper presents an analysis of DG as a feasible solution. In addition, several compact distributed generation technologies are fast becoming economically viable. This paper also discusses technologies of DG, the technical and potential benefits of DG. Integration of DG into an existing utility can result in several benefits. It also studies the goals and applications of DG.*

Index Terms: Distributed generation (DG), Distribution networks, benefit of distributed generation.

1. INTRODUCTION

Freedom in electrical power and energy was achieved in premature fifties by starting a number of river-valley hydro projects like Bhakra-Beas Management Board, Damodar Valley Corporation etc. Soon after some private sector companies also started contributing towards power generation. In late seventies long distance AC transmission line came into existence. The load demand of states in a region was met by their respective regional Thermal, Hydro and Nuclear generating stations. Thereafter Power Grid Corporation was established with the evolution of regional grids. All regional grids perform in sync with each other. To utilize the available resources at various regions of the country optimally necessitated the need for the formation of national grid.This development enabled the large scale private players and public sector companies to invest and take control of generation, transmission and distribution of electric energy either independently or jointly [1].

At present there is a huge gap between the demand and supply of electrical energy and is still growing at higher rates. This ever increasing demand of electricity supply cannot be fulfilled by existing power generating units. Moreover, large network of single power supply has the disadvantage of high cost and operation difficulty. The division of power system into generation, transmission and distribution as well as the aspiration to reduce green house gas emissions is the major reason to adapt renewable and low carbon based distributed generation (DG).

For the last few years, a number of power customers have been installing stand alone distributed generation for their needs in small units. This trend indicates that distributed generation applications have gained more interest, due to the continued advancement of distributed generation technologies and their effectiveness as a local power source, where generation is in close proximity to the load or consumer. Distributed generation provides power from a few watts (W) to ten megawatts (MW) and offers several benefits compared to conventional power generation [2]. Society‘s awareness of green energy utilization also leads to the increase of distributed generation installation and operation. Moreover, constraints on new construction of bulk power generation and transmission or distribution lines have created the conditions for utilizing this small-scale generation coupled to local transmission or distribution networks [3].

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Distributed Generation is also known as 'embedded generation' in South America, whereas 'dispersed generation' is used in North America, and Asian countries and Europe uses the term 'decentralized generation'. Distributed generation is as a small-scale electric power generation, which is located near the consumer load, typically having a rating of less than 10 MW [5]. The distributed generators are small size generators which come from traditional or other technologies or are electric power sources connected directly to the distribution network. Thus, each country and power-working group has different views on defining distributed generation; some countries describe this technology in terms of voltage level, whilst others base it on the generation capacity, interconnection and location [5]. The main objective of distributed generation is getting the electricity from point of generation close to the point of consumer. DG is a promising solution to many power system problems such as voltage regulation, power loss, etc.

2. CLASSIFICATION OF DISTRIBUTED GENERATION TECHNOLOGIES

Distributed generation based generation, including micro turbines, photovoltaic, fuel cells, wind turbines and biomass.

Distributed generation based storage, including flywheels, battery, super capacitor and superconducting coil system.

All of these technologies are currently being used and are gaining popularity [8]. Some of the different types of distributed generation are discussed in the subsequent section.

2.1 Wind Turbine

In recent years, wind turbine generation has developed rapidly as a competitive and effective source of distributed generation. Wind turbines (WT) use wind energy to generate electricity and have various ratings from a few kW to a few MW [9]. To produce electric power, WT can be operated at variable or constant speeds and is coupled to induction generators. Nowadays, induction generators are widely used in WT and a variable speed generator is the preferred option in newer WT installations. Through rectifier and inverter, a squirrel induction generator could be coupled to the AC grid. In addition, another method of operating induction generators is by connecting the stator directly to the AC grid and connecting the rotor through a power electronic device, thus wound rotor induction machine can be used as a doubly fed induction generator (DFIG). In recent years, doubly fed induction generators seem to be the major option in new wind farm installation, since it supports power system stability and reliability during peak load or disturbances. The WT with DFIG also requires smaller power electronic devices, thus control of the WT by DFIG becomes more flexible, where the active and reactive power can be controlled independently.

2.2 Micro Turbine

A micro-turbine is a mechanism that uses the flow of a gas, to covert thermal energy into mechanical energy. Micro turbine systems are high frequency generators, equipped with air-foil bearings and run at high speeds (50,000–90,000 RPM). They cannot be coupled directly to the power system, thus a power electronics device is used [10]. Before injecting the voltage into the AC grid, the generated voltage must be rectified first using a diode rectifier and linked into a DC-AC inverter to synchronize with the grid.

2.3 Photovoltaic

The Photovoltaic module is an unregulated DC power source that uses semiconductor cells. It generates direct voltage and current from sunlight that falls on the cells. In order to interface the array to the power systems, it has to be conditioned first and a DC/AC inverter has to be used [11]. PV systems have no moving parts, and thus require less maintenance and generate electricity without producing CO_2.

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2.4 Fuel Cells

Fuel cells are electrochemical devices that convert fuel (hydrogen) and air directly to electric power and provide thermal energy through electrochemical processes. FC does not burn hydrogen and there are no moving parts during operations, thus fewer losses and low emissions. Unlike other distributed generation, FC efficiency is higher than 60 per cent, which is considered to be double that of conventional power generations [12].The fuel used is generally natural gas or hydrogen.

Thus different resources such as reciprocating engines, micro turbines, combustion gas turbines, fuel cells, photovoltaic, & wind turbines, hydroelectric plants, etc can be used in DG. Each of these technologies has its own benefits & characteristics. Also their impact on distribution systems can be either positive or negative depending on the systems operating condition, DG characteristics and location.

3. LITERATURE REVIEW

DG allocation is a critical factor. Optimum DG allocation provides a range of benefits. But inappropriate DG allocation can cause low or over voltage in the network. In a DG connected system the distribution loss depends on the size and location of the DG. As the energy cost is dependent on the distribution loss, in the planning process it becomes crucial to minimize the distribution loss. This needs careful placing of DG in the distribution system with appropriate sizes. Beside this, while placing and sizing the DG other system constraints need to be satisfied. Various system constraints have to be satisfied during the DG placement [13]. Some of them are: voltage limits, feeder capacity limits, maximum DG penetration, substation capacity limit etc. Thus, finding the size and location is an optimization problem (reduction of loss) subjected to various system constraints. Proper location of DGs in power system is important for obtaining the maximum potential benefits. The problem of optimum location and optimum sizing of DGs has been addressed in various references cited. In [14] a successive elimination algorithm is described to place & size the DGs. A new heuristic approach based on cost benefit analysis for determining the optimum DG size & location [15][16] describes a mixed integer programming (MIP) formulation with branch & bound optimization for an industrial power plant. Genetic Algorithm (GA) based optimization for deploying a DG resource in a distribution system is described in [17][18] describes a frame work for embedded generation planning in line with special emphasis on risk & uncertainties. [19] Proposes DG capacity based on risk factor & addresses the reliability issues which arise as a consequence of transmission bottle-necks.

The problem of determining the capacity & location of DG has been formulated to minimize the cost of power, energy loss & the total required reactive power is described in [20].Authors in [21] have presented an approach to determine the proper location for fuelled-gas turbine plants in an electric system. An algorithm has been proposed by Gandomkar et al [22] to determine optimum location & size of DGs, which minimizes the power losses for a fixed number of DGs & a specific total capacity of DGs. Another method for proper location & sizing of DG units in a micro grid has been developed in [23], which is based on stipulated reliability criteria. An approach for the design of grid connected DG systems is used to satisfy on site reliability & environmental requirements are proposed in [24]. A software has been presented in [25] which provides support for decision making concerned the choice of the ratings & proper location of DG based on several objectives & constraints. Ref [26] also targets the problem of DG capacity & allocation in order to achieve a good compromise between the costs of network upgrading, power losses, energy not supplied & power quality.

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Some of the methods are based on numerical approach and some of them are solved analytically [27, 28]. Hereford Ranch algorithm method to find the optimum allocation of DG to minimize the loss has been listed in [29]. Other methods like Fuzzy Logic-Genetic Algorithm [30], Tabu search [31] and 2/3rules [28] are also used for this optimization problem. Dynamic Programming approach is an iterative technique which is applied to find the optimum size of DG. The Genetic Algorithm (GA) based method has already studied to determine the size & location. GA's are suitable for multi objective problems like DG allocation, & can give near optimal results, but they are computationally demanding & slow in convergence [30]. Graffin uses a loss sensitivity factor method [32] & Naresh Acharya proposes an analytical method to determine the optimal size & location of DG in distribution networks [33].

The installation of DG unit at non optimal places can result in an increase in system losses; implying in an increase in costs & resulting low or over voltages in the network, having an effect opposite to the desired. The optimal location of DGs in power systems is very important for obtaining their maximum potential benefits.

DG in a distribution system has several advantages as follows:

- DG can reduce line losses.
- DG is installed for voltage profile improvement.
- DG is used to reduce emissions of pollutants.
- Overall energy efficiency is increased using DG.
- Enhanced system reliability and security.
- Power quality is improved after installing DG in the system.
- Enhanced productivity.
- Relieved transmission and distribution congestion after installation of DG.
- A reduced health care cost due to improved environment is possible through DG installation.
- DG can reduce fuel costs due to increased overall efficiency.
- DG can reduce reserve requirements.
- It provides lower operating costs due to peak shaving.
- DG can increase the system security for critical loads.

4. MOTIVATION AND OBJECTIVE

In this proposed work, investigation on optimum location of DG will be determined for loss reduction and voltage improvement in distribution system. For proper allocation of DG, size of DG also plays an important rule. Size of DG effects losses and voltage profile of the distribution system. The size & location of DGs are crucial factors in the application of DG for loss minimization & voltage improvement respectively.

Also a comparative study will be done between various techniques for finding optimum size and location of DG for loss minimization and voltage improvement in distribution system.

5. METHODOLOGY

The proposed methodology is based on load flow and dynamic programming on 33 kv bus radial distribution system is taken. The main purpose is to find proper place of DG to improve voltage profile and to reduce losses in the distribution system

5. Conclusion

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DG is emerging as a new paradigm to produce on-site highly reliable and good quality electrical power. DG is expected to become more important in the future generation system. Thus, the DG systems are presented as a suitable form to offer highly reliable electrical power supply. The concept is particularly interesting when different kinds of energy resources are available, such as photovoltaic panels, fuel cells or wind turbines. The DG of different kinds of energy systems allows for the integration of renewable and nonconventional energy resources. The benefits obtained by the introduction of DG should be weighed against the costs involved before deciding on the use of DG. As DG technologies improve and cost decrease, their use is expected to rise.

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