EXPLORATION OF DISTRIBUTED GENERATION FOR FUTURE DISTRIBUTION NETWORKS

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ABSTRACT: 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. In this article the concept of distributed generation is analyzed for future distribution networks. Distributed Generation is a concept of small-scale electric power generation that is operated and installed near to the customer's site.

Keywords: - Distributed Generation, Renewable energy, micro-turbine

1. INTRODUCTION

Independence in electrical power and energy started in early 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 [1]. To utilize the available resources at various regions of the country optimally created 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].

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 to 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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Usually, it is connected via power electronic converter or other power electronic devices to the distribution system. Most distributed generation systems are currently powered by renewable energy, including photovoltaic, wind turbines, fuel cells and micro turbines [4]. These environmentally friendly technologies are more effective in utilizing renewable energy sources (RES), which is abundantly available in nature, pollution-free and a sustainable form of energy.

Distributed Generation is also known as 'embedded generation' in South America, whereas 'dispersed generation' is used in North America, and Asian countries and Europe use the term 'decentralized generation'. Driesen and Belmans define distributed generation as a small-scale electric power generation, which is located near the consumer load, typically having a rating of less than 10 MW [5]. 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.

Increasing power system reliability expectations have evolved into the growth of distributed generation. The main drivers of that growth can be divided into three categories, which are environmental concerns, commercial policies and energy policies. These factors have been contributing to the high interest and penetration of distributed generation utilization. Issues related to the operation and interconnection of distributed generation into power system networks, such as power quality, reliability, stability and protections have been the focus of stakeholders, including power operators, designers, policy makers, engineers and consumers [6]. However, in spite of triggering these issues, distributed generation also offers several advantages.

The major benefits of distributed generation can be divided into two categories: economic and operational [7]. From an economic point of view, distributed generation provides power support when load increases during peak demand periods, thus reducing interruption that may lead to system outages. Distributed generation cuts operational costs when installed close to the customer load because it avoids upgrading or setting up a new transmission and distribution network, thereby providing a cost saving. From the operational point of view, distributed generation warranties the reliability and stability of supply and reduces power losses. The use of local RES will help to reduce dependence on imported fossil fuels and decrease internationally escalating energy prices.

The paper is organized as follows: in section 2, we present an overview of liberalization of electricity. Integration of distributed generation is discussed in section 3. Finally, section 4 concludes this article.

2. LIBERALIZATION OF ELECTRICITY

The liberalization of electricity markets and environmental policy has increased the use of distributed generation units for a range of applications, such as stand alone, peak load sharing and remote applications [8]. These units can be classified into two different categories:

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

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ii. 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. Some of the different types of distributed generation are discussed in the subsequent section.

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.

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.

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.

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,

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FC efficiency is higher than 60 per cent, which is considered to be double that of conventional power generations [12].

3. INTEGRATION OF DISTRIBUTED GENERATION

The integration of distributed generation to electricity networks always has technical issues in power system operation. Therefore, analyzing and determining the impact of distributed generation into power systems during interconnection and operation is a critical issue. It also involves intensive research, depending on the parameters that are required to be evaluated. In operational level for instance, the effect can be analyzed on generation, transmission and distribution perspectives, whereas on the system operation level the impact evaluation can be done in the areas of steady-state analysis, dynamic analysis, power quality, reliability and protection [13].

The term power quality can be associated with the reliability of power supply. However, engineers and power providers define it differently according to the parameter characteristic being measured, such as voltage, current or frequency. Adding distributed generation to power systems generally increases system reliability

And power quality, for instance as a voltage support [14]. Power quality related issues are very important and should not become a major obstacle against distributed generation deployment and RES utilization.

DG affects Power Quality in the two main ways:

1) Voltage flicker. The factors caused voltage flicker by DG include: a large-scale distributed units start-up, the drastic change of the distributed unit output, as well as adverse effects brought by the interplay of the DC unit output and voltage feedback control equipment in system.

2) The introduction of a large number of harmonics. A large number of power electronic devices used in DG will inevitably bring a large number of harmonics to the system; the magnitude and order of harmonics are affected by the way, as well as power converters work mode [15]. Although the introduction of DG can cause voltage flicker and the introduction of a large number of harmonics, DG also has the potential to improve power quality.

Technical assessment of the impact of distributed generation technologies on the power quality of the power distribution system is demonstrated in [16]. Power quality is a broad term covering a wide range of operating parameters including both steady state and dynamic conditions.

The basic understanding of power quality in relation to the distributed generation is given in [17]. Due to considerable overlap between two technologies, disturbances affecting the power quality, which are mainly cause by the addition of Distributed Generation (DG) on the existing power system network. Injection of the DG into an electric power grid can affect the voltage quality. Distributed generation of different voltage levels when connected to the power system network could influence the voltage regulation, sustained interruptions, harmonics, sags, swells, etc.

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Power Quality in electric networks is one of today's most concerned areas of electric power system. The power quality has serious economic implications for consumers, utilities and electrical equipment manufacturers. The impact of power quality problems is increasingly felt by customers - industrial, commercial and even residential. Some of the main power quality problems are sag, swell, transients, harmonic, and flickers etc [18]. By custom power devices, we refer to power electronic static controllers used for power quality improvement on distribution systems rated from 1 to 38 kV [19], [20]. This interest in the practice of power quality devices (PQDs) arises from the need of growing power quality levels to meet the everyday growing sensitivity of customer needs and expectations [21]. One of those devices is the Dynamic Voltage Restorer (DVR), which is the most efficient and effective modern custom power device used in power distribution networks. Its application includes lower cost, smaller size, and its fast dynamic response to the disturbance [22].

Moreover, the presence of distributed generation can have both positive and negative impacts on power system networks. Previous research shows that the insertion of distributed generation into distribution or transmission systems will change the direction of power flows, which has a serious impact on the operation of the system

[23–25]. Prata [26] presents that coupling distributed generation to distribution networks has a significant contribution to improving system reliability, preventing under voltage drops and maintaining voltage levels in acceptable ranges during peak load periods. However, due to the integration of distributed generation, voltage variation and violation can still happen. Therefore, the limit of power injection to the system must be verified before installing distributed generation on the system.

The value of DG installed as a backup generator is quantified in terms of its contribution to the reliability improvement of a residential distribution network. The value of placing DG at various distances from the substation, as well as the impacts of installing a large-scale DG vs. several small-scale distributed DGs, was discussed [27]. The research findings are expected to be useful to electric utility companies in evaluating the reliability benefits of DG of various sizes and penetration levels installed at various distances from a distribution substation.

Using Monte Carlo time sequential simulation and a simplified equivalent network, a new reliability evaluation method for the distribution system with distributed generation was discussed [28].

Distributed generation will also affect the network transient stability. Kumar *et al.* investigated the positive impact of distributed generation on DS during faults period [29]. The result shows that rotor angle deviation and voltage drop are found to decrease. This means that the transient stability of the system is improved with an increased penetration level of distributed generation.

The impact of distributed generation (DG) penetration on power system stability [30]. It discusses the dynamic impact of stand-alone or grid-connected DG or hybrid power systems on the transient and small signal stability of power systems.

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The impact of distributed generation technology and penetration level on the dynamics of a test system is investigated [31]. It is found that the effects of distributed generation on the dynamics of a power system strongly depend on the technology of the distributed generators.

The impact of DG on the distribution system during service restoration procedure is discussed, and the mathematical model of network reconfiguration with DG is established [32]. The objective function and constraints are modified considering DG and power quality indicators.

An overview of the changes that the power system is undergoing and how these affect the aspects of communication, ancillary services, voltage regulation and losses and harmonics [33].

Modeling and simulation techniques and software required for such studies and applicability of intelligent techniques in assessing transient and small signal stability of power systems with DG penetration are also discussed.

When networks begin to contain large numbers of DG units with higher capacities, the dynamics of the distribution system effect distribution system's stability [34].

(*a*) Transient stability. Transient stability issues, also referred to as the first swing stability, are among the most important practical concerns in power system operation and planning studies. It has been observed [35] that the utilization of DG units reduces the magnitude of the maximum power angle deviation. This indicates that the existence of the DG units improves significantly the transient stability of the system.

(*b*) Oscillatory stability. The oscillatory instability occurs usually due to the insufficient damping of the electromechanical oscillations. Increasing penetration of DG causes lower damping and higher frequency with small numbers of DG units near some of the load nodes, the DG controllers have only local action and the global damping of the controller mode is worsened [36].

(*c*) Frequency stability. Frequency stability refers to the ability of electrical power systems to maintain fixed frequency after being subjected to a severe disturbance [37]. The frequency will not cause a stability problem if the equilibrium between generation and load is restored. This requires sufficient generation reserve and adequate response from the control and protection devices.

(*d*) Voltage stability. It is defined as the ability of a power system to maintain the voltages at all nodes within acceptable limits after being subjected to a disturbance [37]. The analysis of the system performance with regard to voltage stability shows that DG can support and improve the voltage profiles at load terminals. This can extend the stability margin of dynamic loads, *i.e.*, induction motors, which can lose their stabile operating point with large voltage [37].

DG has much potential to improve distribution system performance and it should be encouraged. However, distribution system designs and operating practices are normally based on radial power flows and this creates a special challenge to the successful introduction of distributed generation.

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4. CONCLUSION

It is observed that the work on the investigation on distribution generation is very much diversified. However there is a scope to investigate the effectiveness of distribution generation for increasing reliability and power quality of distribution system. As the distribution system locates the end of power system and is connected to the customer directly, so the reliability of power supply mainly depends on distribution system. In addition, several compact distributed generation technologies are fast becoming economically viable. Integration of DG into an existing utility can result in several benefits. These benefits include line loss reduction, reduced environmental impacts, increased overall energy efficiency, relieved transmission and distribution congestion, voltage support, and deferred investments to upgrade existing generation, transmission, and distribution systems. Benefits are not limited to utility. Consumers also benefit from DG in term of better quality of supply at lower cost.

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