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Distributed Generation System Using Pe Interface

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Abstract - "Distributed generation is an electric power source connected directly to the distribution network or on the customer side of the meter" [1]. Distributed power generation is the future trend due to its ability to accommodate variety of renewable/alternative energy sources, its potential to improve the energy efficiency and power system capability, and its promise for power reliability and security. The smart power grid distributed energy system would provide the platform for the use of renewable sources and adequate emergency power for major metropolitan load centers and would safeguard in preventing the complete blackout of environmental calamity and would provide the ability to break up the interconnected power systems into the cluster smaller regions. This paper describes the integration issues of renewable energy in electric power systems. And the benefits of using PE interface for such applications.

Keywords - Distributed Generation (DG), renewable/alternative energy sources, smart power grid, power electronics (PE), Fuel cell (FC), Micro-turbine generator (MTG), Photovoltaic (PV) arrays, renewable energy sources (RES).

I. INTRODUCTION

Energy technologies have a central role in social and economic development at all scales, from household and community to regional, national, and international. Among its welfare effects, energy is closely linked to environmental pollution and degradation, economic development, and quality of living. Today, we are mostly dependent on nonrenewable fossil fuels that have been and will continue to be a major cause of pollution and climate change. Because of these problems and our dwindling supply of petroleum, finding sustainable alternatives is becoming increasingly urgent. Perhaps the greatest challenge in realizing a sustainable future is to develop technology for integration and control of renewable energy sources in smart grid distributed generation. Distributed Generation (DG), when fully implemented, can Provide reliable, high-quality, and low-cost electric power. As a modular electric power generation close to the end user, it offers savings in the cost of grid expansion and line losses. If connected to the power grid, the bi-directional transactions between the grid and the local generation result in grid capacity enhancement, virtually uninterrupted power supply, and optimum energy cost due to the availability of use/buy/sell options. Distributed power is a concept that covers a wide spectrum of schemes used for local electric power generation from renewable and non-renewable sources of energy in an environmentally responsible way. Main schemes are mainly based on solar energy, wind energy, fuel cells, and micro turbine engines. Twenty years ago, almost all the electric power was generated at large central power stations; twenty years from now, a good part of this power it is expected to be generated by small power units that will be distributed throughout the service grid. Since such units are located close to the customer, they are expected to better meet the customer's needs. In parallel to the introduction of distributed generation, the legislative framework for the electricity sector is undergoing major changes in many industrial countries. These changes are driven by a moving towards more liberalization in order to create a competitive market environment. Within this competitive environment, decentralized power generation has to compete with centralized power generation. It is, however, often argued that electricity market regulations for competitive electricity markets do not provide an equal treatment of centralized and distributed generation. According to new electricity market regulations, distribution network owners/operators use 5 MW as a guideline for determining whether approval should be sought by the distribution network owner/operator from the national grid operator for the generation to be connected to a distribution network. There are a wide variety of potential benefits to DE systems both to the consumer and the electrical supplier that allow for both greater electrical flexibility and energy security [2]. Nowadays fossil fuel is the main energy supplier of the worldwide economy, but the recognition of it as being a major cause of environmental problems makes the mankind to look for alternative resources in power generation. Moreover, the day-by-day increasing demand for energy can create problems for the power distributors, like grid instability and even outages. The necessity of producing more energy combined with the interest in clean technologies yields in an increased development of power distribution systems using renewable energy [3]. In order to increase the usefulness of DG systems and reduce potential impacts, power electronic (PE) interfaces can be used to integrate DG with the existing electrical power system. PE interfaces offer unique capabilities over traditional interconnection technologies. As the price of PE and associated control systems decrease, these types of interconnection interfaces, along with their benefits, will become more prevalent in use with all types of DG systems. In the following sections, this paper examines system integration issues and discusses the benefits of using PE interfaces for a variety of DG applications.

II. DISTRIBUTED GENERATION

Distributed generation (DG) is the term used to describe small-scale power generation, usually in sizes up to around 50 MW, located on the distribution system close to the point of consumption. Such generators may be owned by a utility or, more likely, owned by a customer who may use all of the power on site or who may sell a portion, or perhaps all of it, to the local utility. When there is waste heat available from the generator, the customer may be able to use it for such applications as process heating, space heating, and air conditioning, thereby increasing the overall efficiency from fuel to electricity and useful thermal energy. Now We present distributed generation (DG) architectures. There are two types of architectures:

1) Direct current (DC) architecture
2) Alternating current (AC) architecture

1) Direct current (DC) architecture : The FC and solar power outputs are low-voltage DC that are steps up to a higher-level DC power for processing using DC/DC converters. However, the output power of wind turbines is variable-frequency AC power, and the output power of MTG is high frequency AC power. For these two sources, the AC/DC or AC/Converters are used.

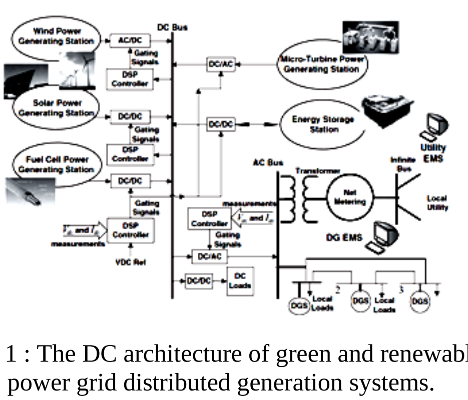

Fig. 1 : The DC architecture of green and renewable power grid distributed generation systems.

In the architecture of Figure 1. the DG sources are connected to a uniform DC bus voltage including the storage system. This will facilitate plug-and-play capability by being able to store the DC power and use DC/AC converters to generate AC power. Today, commercially available storage devices such as flow batteries and battery–flywheel systems can deliver 700 kW for 5 sec to 2 MW for 5 min or 1 MW for up to 30 min, while 28-cell ultra-capacitors can provide up to 12.5 kW for a few seconds. The DG system can be operated as an island system or in parallel with the local utility network. In islanding operation the DG system uses the local utility as backup power. First, depending on the availability of the renewable energy sources, the renewable is used to support all or part of the base load, and the remaining DG sources are used to regulate the system voltage and power. However, the island distribution network and its DG sources not only need to be designed to support its own daily load cycle, but also need to be designed with an assumed reliability criterion such as the loss of the largest DG unit. That is, upon occurrence of a large disturbance, the storage devices in conjunction with regulating units are to control stabilization can be achieved using local frequency droop and providing DC power to the DC bus by controlling DC bus voltage and current and charging the storage devices (e.g., battery, flywheel, etc.) as soon as the disturbance is controlled renewable is used to support all or part of the base load, and the remaining DG sources are used to regulate the system voltage and power. However, the island distribution network and its DG sources not only need to be designed to support its own daily load cycle, but also need to be designed with an assumed reliability criterion such as the loss of the largest DG unit. That is, upon occurrence of a large disturbance, the storage devices in conjunction with regulating units are to control.

2) Alternating current (AC) architecture : Figure 2. Represents AC architecture of DG system. For example, a PV system with 2-MW capacity cannot be economical processed at low-voltage DC due to high power losses. The DC system can be used if the DC converters are used to step up the DC voltage of PV system to higher voltages to reduce the power losses. However, today, it is more economical to step up AC voltage to higher voltages for injection to utility system. As shown in Fig. 1.3, the step-up transformer T1 will step up the voltage from the DC/AC converter to a higher voltage. All PV arrays are connected in parallel to the PV system AC bus. In addition, to provide regulating capability for the PV station, a number of PV arrays and wind power energy are processed in DC and the energy is stored in a flow battery or battery–flywheel system. The DC power of storage system is used for regulating the load voltage and load frequency control. The size of the storage system is specified by the regulating requirements of the PV station when it has to operate as an island. The PV station voltage is stepped up with the transformer T2 for parallel operation of the PV station as part of the utility system.

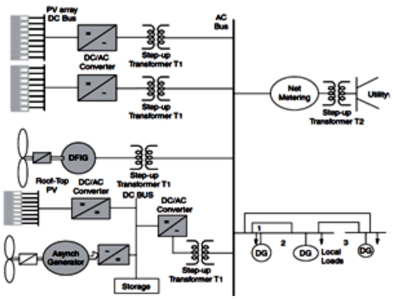

Fig. 2 : The Architecture for design of a 2-MVA PV station.

Disturbance due to sudden outage of utility system can cause severe power system stability of the DG system. Furthermore, upon occurrence of faults, the FC and MTG plants fault current could reach a high level, and hence they must be disconnected. Also, after the FC unit is reconnected, the MTG unit may experience instability. Therefore, appropriate control actions need to be taken to stabilize the DG system. Because of the intermittent nature of renewable energy sources and the slow electrochemical reaction of fuel cells, the need for energy storage devices is inevitable. The energy storage devices will provide operating reserve as fast-acting energy sources when sufficient power cannot be provided during load transients and disturbances.

III. INTERCONNECTION INTERFACES

The electric output of DG systems can be connected to the electrical power system via three basic interconnection interfaces [4], [5].

A. *Synchronous Generator*

Synchronous generators are rotating electric machines that convert mechanical power to electrical power. In a synchronous machine, a prime mover (like a turbine) turns the rotor that induces a voltage on the stator winding. A magnetic field is produced in the rotor by either a dc field current or by a permanent magnet. The electrical frequency of the induced voltage depends on the speed of rotation of the generator. When connected to an electric power system, the synchronous generator must run at a constant speed called “synchronous speed” and generate voltages corresponding to the supply frequency. Synchronous generators are used with most reciprocating engines and most high power turbines (gas, steam, and hydro).

B. *Induction Generator*

Like synchronous generators, an induction generator is a rotating electrical machine that converts mechanical power into electrical power. Both machines have similar stator construction. The rotor in the induction generator, however, is different and no dc field current is needed for operation. There are two types of rotor designs available: cage rotor and wound rotor. Induction generators are typically only used in wind turbines and some low-head hydro applications. The advantage of the cage-rotor induction generator is the lower cost compared to an synchronous generator, but induction generators require a supply of VARs either from capacitors, from the electric power system, or from PE-based VAR generators to operate.

C. *Power Electronics*

The PE interface can be used to connect any type of DG system to an electric power system. PE-based inverters are used in micro turbines, fuel cells, PV systems, some wind turbines, and energy storage systems. The types of PE interface used to connect these DG systems to the electric power system will be described in the following. Because of unique properties of PE interfaces, they can also be used to interconnect reciprocating engines that would normally be interconnected with only a synchronous or induction generator. When used with engines or wind turbines, the output of the electric generators is rectified to dc then converted to ac using an inverter.

IV. PE INTERFACES

The study of PE devices, along with their control systems, is a very dynamic discipline. By taking advantage of technological innovations in semiconductor materials, and microprocessor (or digital-based) control systems, PE is creating devices that enhance energy generation and delivery systems. The versatility and reliability of lower cost devices combined with advances in circuit topologies and controls has resulted in technologies that replaced what has been traditionally done by electromagnetic and electromechanical systems. With the development of solid-state-based packages, PE devices can now convert almost any form of electrical energy to a more desirable and usable form. This is why PE-based systems are ideal for DG systems. Another benefit of PE is their extremely fast-response times. PE interfaces can respond to power quality events or fault conditions within in the sub cycle range. This high-speed response can enable advanced applications, such as the operation of intentional islands (micro grids) for high-reliability applications and reducing fault level currents of DG, features that do not exist today[6].

Benefits of the PE interface:

1) Improved Power Quality.
2) VAR Support and Voltage Regulation.
3) Improved DG-Fault Current Coordination.
4) Interoperability with Other DE Sources.
5) Fast Switches for Micro grids or Intentional Islands.
6) PE Modularity and Standardization.

V. DISTRIBUTED GENERATION ATTRIBUTES

Energy attributes address the investment as well as the sustainability issues for providing electricity. It is difficult to merge RES without defining their attributes against well known sources such as coal. The National Renewable Energy Laboratory, NREL, defines the attributes listed below. NREL is the principal research laboratory for the Department of Energy (DOE) Office of Energy Efficiency and Renewable Energy in the USA. Some of the listed attributes are quantitative in nature, such as capability, capacity and cost, while others can only be considered in a qualitative way, such as indirect benefits and risk diversity. The attributes are:

1) Capability : A measure of the capability of the power plant To deliver its designed full load capacity in a given period Under normal conditions.

2) Availability : A measure of how long power will be Available. Routine maintenance, unplanned maintenance (i.e., breakdowns), refueling, and modifications are prime causes of unavailability in conventional power sources.

3) Dispatch ability : A measure of the degree of control that the power plant/utility could exercise over the hour-by hour And minute-by-minute system output.

4) Modularity : Modularity has implications for installation, increased capacity, availability, and capital investment risk. Using modular generating units allows expansion, when it is required, by adding more units of the same Design and size.

5) Location : Some power plants are built very close to the energy source, which is not necessarily the optimal location for consumers.

6) Cost : Refers to the cost of capital investment, operation and management, and costs incurred or avoided as the Result of employing a technology.

7) Incentives : The subsidies provided by the government to promote the development of a technology.

8) External costs and indirect benefits : The costs and benefits, theoretically borne by others, of operating a technology for which the others receive no compensation or make no payment. For example, there are many property owners who have installed solar thermal and photovoltaic (PV) systems on their property. The installed PV system is in many cases supplying almost 30% of the required energy to that household, which otherwise would be provided by centralized power plants through the grid. The benefits are shared, but not the costs, which are borne directly by the owner and indirectly by the provider. The provider is relieved from his commitment to increasing capacity and the related financial burden. These external factors may also include environmental and regional economic impacts.

9) Risk diversity : Risk describes any unanticipated, unfavourable condition, including unpredicted availability problems with a technology, adverse changes in market conditions, and unexpected changes in legislation.

VI. DG OPPORTUNITIES AND CHALLENGES

Opportunities:

The potential and probable application of interconnecting the dispersed DG “stand-by generating systems”, generating capabilities provide several benefits to both utility and consumers. The consumer will have consumption choices; they can reduce their energy expenditures by incorporating DGs that are powered by cheaper fuel sources, for example, the use of methane gas fueled turbine-generating units. Methane gas can be produced in a nearby landfill. Heat can also be produced through the burning of waste in incinerators; otherwise it will be produced using electricity. Using local or nearby fuel sources that could be generated from large amounts of municipal waste that otherwise need vast landfill sites adds to cities’ energy supply chain. As for the utility, it can use the DG power to enforce its distribution network voltage stability, as well as to increase its peaking capacity without suffering financial costs. By allowing consumers’ own DG units to provide electricity during high electricity rate and short-term supply interruptions, continuous productivity is ensured and the reliability and power quality of the consumed electricity is increased. DG owners or operators could also receive a new source of revenue from electricity sales to the hosting electricity provider. Employing renewable energy sources on a large scale will have a positive impact. For instance, solar power stations are non-polluting and can provide electricity economically in suitable locations. In many large cities, photovoltaic units are incorporated into new buildings, either on the roof or in the cladding, and supply up to 30 percent of the household demand for electricity. Similarly, developing 1 MW of wind energy would, over the 25-year lifetime of wind turbines, save 2300 tones of CO_2, 22 tones of SO_2 and 7 tones of NO_x per year.

Challenges:

For successful integration of DG with Utilities, clear interconnection requirements must be formulated. A broad range of industry representatives have been participating in the development of a new standard for DG/Utility interconnection.

An example of this activity is the undergoing IEEE standard P1547, which is meant to provide a uniform standard for interconnection of distributed resources with electric power systems. Since the introduction of DG provides an unwanted source for re-distribution of both load and fault current, as well as possible source of over voltage and islanded operation [7], the investigated requirements are looking at issues such as performance, operation, testing, safety and maintenance of the interconnection. The current engineering practice for DG/Utility interconnected systems is to revert the utility systems to its original configuration (radial or meshed distribution system) with all interconnected DG units de-energized whenever an unexpected disturbance occurs in the system. Since most distribution systems comprise radial feeders, this practice leads to the discontinuation of the supply for all the downstream customers. Thus, the system reliability stays at the same level as it was before integrating the DG with the system [8]-[9]. At the same time, there exist in the system some unsupplied loads and unutilized DG capacity. If interconnected DGs are permitted to supply loads during utility outages, the system reliability will be much better and the customers will not experience any discontinuity of their supply. This goal can be achieved by simply coordinating intention islanding of DG units [10].

VII. CONCLUSION

This paper describes the basic types and technological aspects of PE for DG systems. Clear benefits in using PE interfaces to interconnect DG systems were discussed . The proper design and use of PE-based systems can be done in a modular approach by targeting the overall system needs. PE interfaces can improve power quality of the customer by improving harmonics and providing extremely fast switching times for sensitive loads. PE can also provide benefits to the connected electric power system by providing reactive power control and voltage regulation at the DG system connection point. A unique property of a PE interface is the ability to reduce or eliminate fault current contributions from DG system, thereby allowing negligible impacts on protection coordination. Finally, PE interfaces provide flexibility in operations with various other DG sources, and can potentially reduce overall interconnection costs through standardization and modularity.

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