Micro-grid and Integration of Energy Sources-A Survey

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ABSTRACT

Any research work foundation depends on literature survey. Based on the studies carried out by several researchers and their contribution to research field motivates for further scope of research. In this paper review of several research papers by various authors and technical reports has been discussed. Distributed Generation (DG) and their grid integration issues and later on solutions presented by several authors are presented.

Index Terms:- Microgrid, DG, PCC.

INTRODUCTION

The traditional electrical power grid is unidirectional in nature, where the electricity lows from power generation facilities to end users. This system has served well for the last hundred years. Recently, however, it has been subjected to government deregulation and has suffered from several technical, economic, and environmental issues. Modern society demands this system to be more reliable, scalable, and manageable while also being cost effective, secure, and interoperable [1]. The next-generation electric power system, known as the "smart grid" [2], is a promising solution to the long-term industry evolution. The smart grid is expected to revolutionize electricity generation, transmission, and distribution by allowing two-way lows for both electrical power and information [3]. Moreover, it can complement the current electric grid system by including renewable energy resources, such as wind, solar, and biomass, which is environmentally cleaner as compared to the fossil fuels used in many bulk electric power generation facilities. Furthermore, each of these new power generating systems can be relatively small and can be distributed around the load centers to increase the reliability and reduce the transmission loss, which adds another degree of flexibility while also increase the complexity to the current power system.

The definition and description of the smart grid are not necessarily unique, as its vision to the stakeholders and the technological complexities can be different [4]. For example, the Ontario Smart Grid Forum has defined the smart grid as follows.

"A smart grid is a modern electric system. It uses communications, sensors, automation and computers to improve the flexibility, security, reliability, efficiency, and safety of the electricity system. It offers consumers increased choice by facilitating opportunities to control their electricity use and respond to electricity price changes by adjusting their consumption. A smart grid includes diverse and dispersed energy resources and accommodates electric vehicle charging. It facilitates connection and integrated operation. In short, it brings all elements of the electricity system production, delivery and consumption closer together to improve overall system operation for the benefit of consumers and the environment" [5].

In general, a smart grid is the combination of a traditional distribution network and a two-way communication network for sensing, monitoring, and dispersion of information on energy consumptions. An example of communication architecture in a smart grid is shown in Figure 1. A typical smart grid consists of numerous power generating entities and power consuming entities, all connected through a network. The generators feed the energy into the grid and consumers draw energy from the grid. The ad hoc, dynamic and decentralized energy distribution are hallmarks of the smart grid.

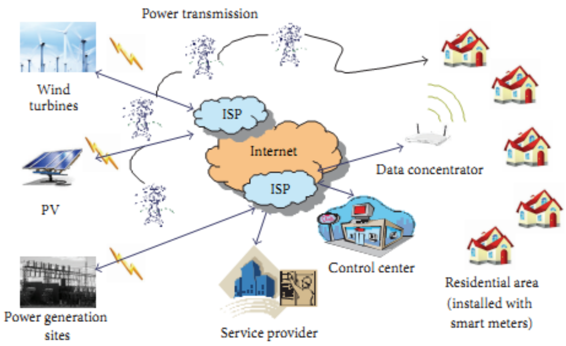

Figure 1. An example of communication architecture in smart grid.

Recent technological advancement on distributed energy resources management helped creating a new grid paradigm, the smart micro-grid distribution network [6]. A micro-grid is an electrical energy distribution network that includes a cluster of loads, distributed generators (e.g., renewable energy sources such as solar panels and wind turbines), transmission, and energy storage systems. A micro-grid can dynamically respond to the changes in energy supply by self-adjusting the demand and generation [7]. Controlled and reliable integrations of distributed energy resources and micro-grids are extremely important to ensure an uninterrupted power supply in the most efficient and economic configuration.

MICRO-GRID AND INTEGRATION OF ENERGY SOURCES

Recently, distributed generation (DG) has become extremely important due to the growing global interest in reliable and sustainable electric power supply, to incorporate more renewable and alternative energy sources and to reduce the stress and loss in existing transmission system [8]. In DG, different energy resources can be incorporated to form an energy system that can meet the demand of local users. The emphasis in distributed generation is increasing as it can also conveniently support electrical energy needs in remote and rural areas [9], where no main utility power grid exists or is unreliable. A micro-grid, in this context, refers to a controlled system of a cluster of loads and distributed micro-energy sources that can provide electrical power to its neighboring areas [7, 9]. It can effectively coordinate different types of distributed energy resources through local power managements.

The U.S. Department of Energy has defined a micro-grid as "a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid (and can) connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode." A micro-grid is considered to be the building blocks of future smart grids [10] with participation of multiple small-scale renewable energy sources. A conceptual illustration of a micro-grid within the context of a smart grid is shown in Figure 2.

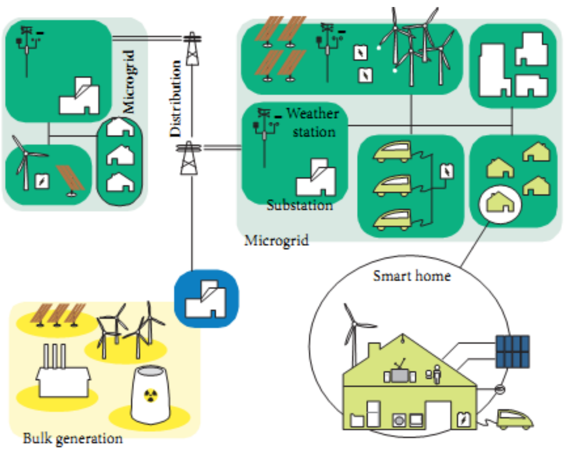

Figure 2: A conceptual illustration of a micro-grid.

Electric power can be generated at a distribution level in a micro-grid. It usually includes a variety of small power generating sources, as well as energy storage systems such as batteries, flywheels, and super capacitors [8, 13]. The power generating sources may include renewable sources such as solar panels and wind turbines, which are typically located close to the consumer sites [8]. A micro-grid can be coupled with the utility power grid through a single connection, known as point of common coupling (PCC). The electrical energy can low in either direction through this coupling, based on the available energy generated within the micro-grid and the demands of the consumers within the micro-grid. A micro-grid, when disconnected from the main grid, is known as an "islanded micro-grid." In an islanded micro-grid operation, DGs continue to power the users of the micro-grid without requiring obtaining electric power from the utility grid [10, 11]. To connect and disconnected processes in a micro-grid are specified by the PCC.

Traditional power system is not designed to incorporate power generation and storage at the distribution level. It is also not designed to allow the distributed energy sources to supply the power to the customers directly [11]. Interconnecting and integrating distributed energy sources to power grid, therefore, is a challenging task. Due to the involvement of significant and critical technical issues associated with such integration, it has attracted significant research attention [11].

Power electronic can play an important role in micro-grid integration. Distributed energy sources can interface with a micro-grid through rotating machines or through electronically coupled units that utilize power electronic converters to provide the coupling media with the host system [12]. The interfaces between the micro-grids and prime movers can be based on power electronic converters acting as voltage sources (or voltage-source inverters in AC micro-grids) [13]. These power electronic converters are connected parallel through a micro-grid. In order to avoid circulating currents among the converters without the use of any critical communication between them, droop control method is generally used; however, it suffers from load-dependent frequency and amplitude deviations, which can be resolved by installing a secondary controller, implemented in the micro-grid central control [13].

The output voltage of distributed energy resources can be DC or AC with a variable frequency. Unregulated output voltage and intermittent nature of renewable energy sources require the use of power converters for integration of the energy sources to the utility grid [14]. Voltages sourced converters (VSC), coupled with isolating transformers, are commonly used for this [14]. Designing grid connected VSC systems may face issues, leading to a distorted line voltage. In [14], modeling and control system design for a three-phase VSC system is investigated. After presenting a model for control system design, simulation, and stability analysis, a control strategy that regulates active/reactive power generation and mitigates the effect of grid voltage distortion on line currents is proposed in [14].

A micro-grid is desirable to have a simplified operation capability so that an entity, for example, energy storage system, or a controllable load can be added without requiring a system level reconfiguration. Proper control or energy management system is imperative to ensure system stability, reliability, and deficiency while integrating multiple energy sources, storages, and controllable loads. The measurements taken from different components of micro-grids need to be communicated to the control system that can then decide on optimal operation for each component, based on the available information of the current states and the operating conditions [15].

APPLICATION OF POWER CONVERTER

Power electronic converters are used in microgrids to control the flow of power and convert it into suitable DC or AC form as required. Different types of converter are needed to perform the many functions within a microgrid, which are covered in textbooks and other publications [16]. The paper will primarily focus on converters used to connect DG systems including renewable energy sources to an AC grid or to local loads. They convert DC (photovoltaic, batteries, and fuel cells) or variable frequency AC (wind and marine turbine) into 50/60 Hz AC power that is injected into the grid and/or used to supply local loads. Of these, they have been extensively used for photovoltaic [17], fuel cell [18] and wind based generation systems [19]. Converters are also used to connect to batteries and flywheel energy storage systems or connect high-speed micro turbine generators to the grid.

Normally, converters are used to connect DG systems in parallel with the grid or other sources, but it may be useful for the converters to continue functioning in stand-alone mode, when the other sources become unavailable to supply critical loads. Converters connected to batteries or other storage devices will also need to be bidirectional to charge and discharge these devices.

Grid Connected Mode

In this mode of operation, the converter connects the power source in parallel with other sources to supply local loads and possibly feed power into the main grid. Parallel connection of embedded generators is governed by national standards [20-22]. The standards require that the embedded generator should not regulate or oppose the voltage at the common point of coupling, and that the current fed into the grid should be of high quality with upper limits on current total harmonic distortion THD levels. There is also a limit on the maximum DC component of the current injected into the grid.

The power injected into the grid can be controlled by either direct control of the current fed into the grid [23], or by controlling the power angle [24]. In the latter case, the voltage is controlled to be sinusoidal. Using power angle control however, without directly controlling the output current, may not be effective at reducing the output current THD when the grid voltage is highly distorted, but this will be an issue in the case of electric machine generators, which effectively use power angle control. This raises the question of whether it is reasonable to specify current THD limits, regardless of the quality of the utility voltage.

In practice, the converter output current or voltage needs to be synchronized with the grid, which is achieved by using a phase locked loop or grid voltage zero crossing detection [25]. The standards also require that embedded generators, including power electronic converters, should incorporate an anti-islanding feature, so that they are disconnected from the point of common coupling when the grid power is lost. There are many anti-islanding techniques; the most common of these is the rate of change of frequency (RoCoF) technique [26].

STAND-ALONE MODE

It may be desirable for the converter to continue to supply a critical local load when the main grid is disconnected, e.g. by the anti-islanding protection system. In this stand-alone mode the converter needs to maintain constant voltage and frequency regardless of load imbalance or the quality of the current, which can be highly distorted if the load is non-linear.

A situation may arise in a microgrid, disconnected from the main grid, where two or more power electronic converters switch to stand-alone mode to supply a critical load. In this case, these converters need to share the load equally. The equal sharing of load by parallel connected converter operating in stand-alone mode requires additional control. There are several methods for parallel connection, which can be broadly classified into two categories: 1) Frequency and voltage droop method [27], 2) Master-slave method, whereby one of the converters acts as a master setting the frequency and voltage, and communicating to the other converters their share of the power [28].

BATTERY CHARGING MODE

In a microgrid, due to the large time constants of some microsources, storage batteries should be present to handle disturbances and fast load changes [29]. In other words, energy storage is needed to accommodate the variations of available power generation and demand. The power electronic converter could be used as a battery charger thus improving the reliability of the microgrid

CONCLUSION

After carrying out the literature survey the research work had one orientation towards the importance of renewable DG in the upcoming years and the associated problems when they work on either stand alone or grid integrated system. The solutions suggested by several authors in their research for most of the issues caused by the DG integration. Recent development of power electronics introduces the use of FACTS controllers in power systems. FACTS technologies not only provides solutions for efficiently increasing transmission system capacity but also increases available transfer capability, relieves congestion, improve reliability and enhances operation and control.

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