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TECHNICAL CHALLENGES ON MICROGRIDS

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ABSTRACT

Microgrids are becoming increasingly attractive to consumers and as such in the future, a great number of them will be installed at consumer's sites. In this situation, conventional distribution networks that accept distributed generation connections may face serious difficulty when its control and protection functions become more complicated. This incurs a burden to the network operation and some technical limitations will appear when a great number of distributed generations are installed. One way of overcoming such problems, a micro grid system is formed to provide reliable electricity and heat delivering services by connecting distributed generations and loads together within a small area. A microgrid is usually connected to an electrical distribution network in an autonomous way and employs various distributed generation technologies such as micro-turbine, fuel cell, photovoltaic system together with energy storage devices such as battery, condenser and flywheel. Micro grids can cause several technical problems in its operation and control when operated as autonomous systems. This paper is a review of three technical challenges on micro grid with respect to voltage and frequency control, islanding and protection of microgrids.

Keywords: microgrid, frequency control, islanding, distributed generations, voltage control, protection.

1. INTRODUCTION

Recently, microgrid technology in small-scale distributed power generation system combined with power electronic system will produce the concept of the future network technologies. A main function of microgrid is to ensure stable operation during faults and various network disturbances [1,2]. The microgrids advantages are as follows: i) provide good solution to supply power in case of an emergency and power shortage during power interruption in the main grid, ii) plug and play functionality is the features for switching to suitable mode of operation either grid connected or islanded operation, provide voltage and frequency protection during islanded operation and capability to resynchronize safely connect microgrid to the grid , iii) can independently operate without connecting to the main distribution grid during islanding mode, all loads have to be supplied and shared by distributed generations. Microgrid allows integration of renewable energy generation such as photovoltaic, wind and fuel cell generations [3]. Typical microgrid system comprises of distributed generation units with inverters and incorporate control systems that enable flexible operations.

Generally, it connected to the power delivery system at a point of common coupling, thus appearing as a controllable single subsystem to the utility grid.

The microgrid concept enables high penetration of distributed generation without requiring re-design of the distribution system. Distributed generation and corresponding loads can be autonomously separated from the distribution system to isolate the microgrid's load from the disturbance during disturbances. It will intentionally disconnect when the quality of power from the grid falls below certain standard [4].

A microgrid is design to seamlessly separate from the grid when problems in the utility grid arise, reconnecting again once these problems are resolved. Normally, in grid connected mode, the microsources act as constant power sources, which are controlled to inject the demanded power into the network. In autonomous mode, microsources are controlled to supply all the power needed by the local loads while maintaining the voltage and frequency within the acceptable operating limits [5]. Autonomous operation is realized by opening the static switch, which disconnects the microgrid from the main grid as shown in Figure-1. Once the microgrid is isolated from the main grid, the microsources supplies to the system are responsible for maintaining the voltage and frequency while sharing the power.

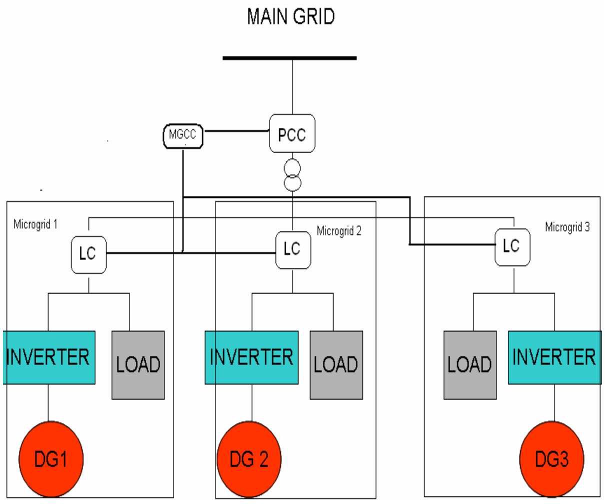

Figure-1. Microgrid architecture.

The bidirectional power flow for both import and export of power is possible during grid-interconnected operation. In event of faults, isolation for microgrid as well as resynchronization is achievable for islanded operation. During islanding, each distributed generation unit is able to balance power and share loads within the microgridid system [4]. The increased penetration of distributed generation in microgrid system may provide several technical problems in the operation of the grid, such as steady state and transient over or under-voltages at the point of connection, protection malfunctions, increase in short circuit levels and power quality problems [6]. The control and protection of the microgrid as an autonomous system will also present challenging problems [25].

All grid-connected of microsources are required to have protection methods that cause the microsource to stop supplying power to the utility grid if the frequency or amplitude of the voltage at the point of common coupling between the customer and the utility within specified limits.

These protection methods protect consumers' equipment but also serve as anti-islanding detection methods. Consider the configuration shown in Figure-2, in which power flows the point of common coupling (PCC) between the utility and microsource. When the static switch is closed and the utility is connected, real and reactive power Pmic+ jQmic flows from the microsource to PCC, and power Pload + jQload flows from PCC to the load. Summing power flows at PCC, Pgrid = Pload- Pmic and Qgrid = Qload-Qmic is the real and reactive power flowing into PCC from the utility. If the microsource operates with a unity power factor that is, the microsource output current is in phase with the voltage at PCC, then Qmic= 0 and Qgrid = Qload. The behavior of the microgrid system at the time of utility disconnection will depend on Pgrid and Qgrid at the instant before the switch opens to form the island operation.

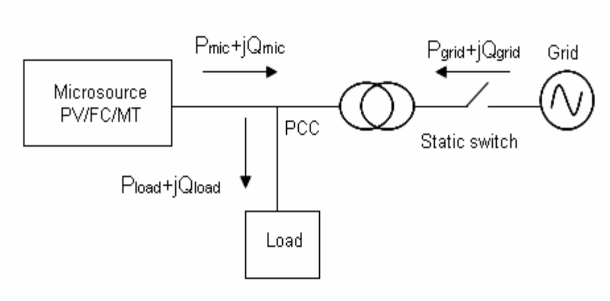

Figure-2. Microgrid power flow to utility grid.

Microgrids have been studied in several research projects. The technical challenge on microgrid is the control of the power flow and the network voltage by the power electronic converter. Most controllers that have been proposed are based on droop lines [2,6]. During the transition from grid connected to islanded operation will cause large mismatches between microsource and loads, posing a frequency and voltage control problem [6]. Several protection techniques and control strategies have been proposed to ensure a stable operation and to protect the microsource [15,17]. Section II briefly introduces the current activities microgrid research project, Section III present the key issues of microgrid, Section IV present the future direction on microgrid research and followed by the conclusion is presented in Section IV.

2. MICROGRID RESEARCH PROJECTS

The microgrid research based on simulation study and hardware laboratory projects are currently in progress to conduct field tests on microgrid applications such as in Europe, the United State, Japan and Canada.

In the European Union (EU), the project was led by the National Technical University of Athens (NTUA) together with research institutions and universities. The project was involved on simulation and demonstrates microgrid operation on laboratory scales.

The project was successfully completed providing several innovative technical solutions, which include the development of islanded and interconnected operating philosophies, local black-start strategies, and grounding and protection schemes, methods for quantification of reliability benefits.

The other achievements of this project are to standardize the technical and commercial protocols and hardware to allow easy installation of distributed generation with plug and play capabilities. EU demonstration sites are taking place in Greece, Netherlands, Germany, Denmark and Spain.

The R&D activities in the United State on microgrids research programme was supported both by the US Department of Energy & California Energy Commission. The most well-known US microgrid R&D effort has been pursued under the Consortium for Electric Reliability Technology Solution which was established in 1999.

The Certs Microgrid is intended to separate from normal utility service during a disruption and continue to serve its critical internal loads until acceptable utility service is restored. Actually, the function provided by the Certs Microgrid is purposely to save cost and no single device is essential for operation, creating a robust system. The reliability of the Certs Microgrid has been well demonstrated in terms of simulation and the bench testing of a laboratory scale test system at the University of Wisconsin, Madison. Full-scale testing on the Certs Microgrid concept has been installed at the Dolan Technology Center in Columbus Ohio, which is operated by American Electric Power.

The Certs Microgrid has presents unique electrical analysis challenges such as contain three phase, single phase and variety of sources interconnected by power electronic devices employing different control approaches. The modeling approach enables analysis of a variety of issue such as prediction and evaluation of imbalance, asymmetries, generation-load control and dynamic voltage.

In Japan the new Energy and Industrial Technology Development Organization and the ministry of Economy, Trade and Industry started three demonstrations under its regional power grid with renewable energy resources project in 2003. Field tests were carried out by integrating new energy sources into a local distribution network.

The microgrid projects were done in Aomori, Aichi and Kyoto [7]. The main achievement is the development of an optimum operation and control system. Even though multiple field-test of microgrids are demonstrating the technical feasibility of microgrid, but clear economic and environmental benefits have not yet been demonstrated. Method for economic design and optimal operation of microgrid with renewable energy sources were proposed.

The microgrid R&D activities in Canada focused on medium voltage and are mostly carried out in collaboration with the electric utility industry, manufacturers and other stakeholders in distributed energy resources integration and utilization. Microgrid related R&D at the Canadian universities has primary focused on development of control and protection strategies for autonomous microgrid operation, microgrid islanding detection methods for parallel micro source in a microgrid and study the impact of high penetration of distributed generation in existing protection strategies. The Natural Resources Canada has also established collaborations with the utility industry to conduct field tests and experiments on applications of autonomous microgrid, grid-interfaced microgrid, planned microgrid islanding, and prototype testing and performance evaluation.

3. KEY ISSUES OF MICROGRID

Technical benefits of the microgrid are an islanding implementation of distributed generation to improve the distribution system service quality and increased the power system reliability [8]. Microgrid can be implemented to meet the increasing growth in demand and distributed generation is used to perform special task for microgrid operation such as reactive and active power control, ability to correct voltage sags and system imbalances [9-10]. This section is a review of three technical challenges on micro grid with respect to voltage and frequency control, islanding and protection of micro grids.

3.1. Voltage and frequency control

In electricity system, active and reactive power generated has to be in balanced condition with the power consumed by the loads including the losses in the lines. The unbalance condition happens from power generated is not equal to the power demanded. The unbalanced between both by the kinetic energy of the rotating generators and motors connected to the system, causing a deviation of the system frequency from its set point value (50/60Hz). The purpose of voltage and frequency control is to ensure that the both voltage and frequency remain within predefined limit around the set point values by adjusting active and reactive power generated or consumed.

In operation of the microgrid, a challenging task is to operate more than one distributed generation on the island; it is no possible to use the active and reactive power control. It is necessary to regulate the voltage during microgrid operation by using a voltage versus reactive power droop controller for local reliability and stability [11]. Each distributed generation is equipped with the power frequency droop characteristic during islanded operation [12]. A dynamic analysis of generation control scheme consisting of active power-frequency and reactive power-voltage controllers for the inverter based distributed generations [13].

These droop-based controllers that allow decentralized operation of the microgrid without communication between the distributed generations. Small-signal models were developed for investigation on dynamic behavior of an n distributed generation chain microgrid. The task is carried out using eigenvalue analysis, sufficient conditions were developed to guaranty their small signal stability, and guidelines are provided for design of controllers to meet the IEEE P1547 performance specifications.

The fast and accurate voltage and frequency control are fundamental requirements for successful island operation of weak low voltage network based microgrid [14]. The control of storage unit in microgrid is not enough to manage/restore voltage and frequency near the set values. Beside that, controllable loads and distributed generations (e.g. PV, fuel cells and microturbines) would take part in voltage and frequency control according to their voltage and frequency droops. This is to enable the plug and play functionality of connection for distributed generations in distribution network.

The master slave approach was conducted to show the performance of a microgrid consisting of two types of distributed generations. The method proposed the output power of inverter based distributed generations are modified to compensate the new change in the microgrid system when the islanding occurs [15]. The microgrid setting is adjusted in order to minimize the transient accruing when switching from grid connected to islanded operation. Inverted based distributed generations can provide the sufficient amount of reactive power to enhance the voltage quality and damping of oscillation occurring in the frequency work effectively.

The small-signal state-space model of autonomous operation of inverter-based microgrid is presented [16]. Each distributed generation inverter have an outer power loop based using droop control to share the real and reactive powers with other distributed generations. Voltage and current controllers is used in inverter internal controls to reject high frequency distrurbances and damp the output filter for prevent any resonance with external network.

3.2 Islanding

Islanding is a small-scale representation of the future interconnected grid with a high density of distributed generations. The microgrid provides a benchmark between island and the interconeected grid. It is can be used in the large interconnected grid with the high penetration of distributed generation. The islanding control strategies are very important for the operation of a microgrid in autonomous mode. Two kinds of control strategies of islanding are used to operate an inverter [17]. The PQ inverter control is used to supply a given active and reactive power set point and the voltage source inverter (VSI) control is controlled to feed the load with predefined values for voltage and frequency. The VSI real and active power output is defined by depending on the load conditions. Its act as a voltage source with the magnitude and frequency of the output voltage controlled through droop.

A new control strategy to microgrid in the distribution system. Two interface controls are for normal operation and the other control for islanded operation. An islanding detection algorithm was developed to responsible for switching between the interface controls. The islanding detection algorithm is to be efficient and can detect islanding even under load and DG capacity closely matching conditions.

The proposed control scheme is capable of maintaining both voltage and frequency within the standard permissible levels during islanded operation of the DG. Such control strategy could be used to supply critical loads in the distribution system during utility outage [18]. Two possible control strategies developed in order to operate a microgrid under emergency mode [19]. A sequence of actions for a well-succeeded black start procedure, involving microsource units has been identified for contributing an increase in distribution network reliability.

3.3. Protection

Microgrid protection is the most important challenges facing the implementation of microgrids. Once a microgrid is formed, it is important to assure the loads, lines and the distributed generations on the island are protected [20]. The two alternative current limiting algorithms to prevent the flow of large line currents and protection of microgrid during utility-voltage sags [21]. There are as resistance-inductance feedforward and flux-charge-model feedback algorithms, for use with a voltage-source inverter (VSI) connected in series between the microsource and utility grids.

The resistance-inductance algorithm function which was connected with the microsource and utility grids is to insert large virtual resistance-inductance impedance along the distribution feeder. As a result, the line currents and damp transient oscillations is limited with a finite amount of active power circulating through the series and shunt inverter.

A new protection scheme has been introduced which uses the abc-dq transformation of the system voltage to detect the presence of a short circuit fault and by comparing measurements at different locations provides discrimination between faults in different zones of protection associated with a particular micro-grid network [22]. This scheme avoids the complications caused by the variations in potential fault currents associated with utility connected and isolated operation of the micro-grid. It will provide a complimentary protection to conventional over-current relaying for scenarios, which produce significant fault currents.

A protection scheme based on directional is proposed for micro-grids consisting of overcurrent synchronous based Distributed generations [23]. Directional overcurrent relays are used to protect the lines during both grid connected operation and micro-grid operation. The relay coordination problem is formulated as a Mixed Integer Selective Nonlinear Programming (MINLP) problem and is solved using operation Particle Swarm Optimization (PSO). The directional overcurrent relays are coordinated with each other to assure selectivity and reliability of the protection scheme. In addition, the protection of microgrid is very important to save the power network [24]. The concept of protection is to have the same protection strategies for both grid connected and autonomous operation. Microgrid is interfaced to main power system by a fast static switch to protect a microgrid in both the modes of operation against all types of faults.

4. FUTURE DIRECTION ON MICROGRID RESEARCH

Future direction which require further investigation in the context of microgrid research are:

i) To investigate full-scale development, field demonstration, experimental performance evaluation of frequency and voltage control methods under various operation modes;
ii) Transition between grid connected and islanded modes on interaction phenomena between distribution generation and high penetration of distributed generation;
iii) Analysis the issue of black starting in an unbalanced system on the control, protection and power quality; and
iv) Transformation of microgrid system today into the intelligent, robust energy delivery system in the future by providing significant reliability and security benefits.

5. CONCLUSIONS

This paper presents a review the researches and activities of microgrid technology. It introduces the current microgrid research project, especially in Europe, United State, Japan and Canada. The three key issues of technical challenges on micro grid with respect to voltage and frequency control, islanding and protection is discussed in the last section that must be overcome for implementation microgrid effectively.

In this context, integration of small-scale generation in the form of microgrids, supported by the application of power electronic converter, could potentially contribute to the improvements in service quality seen by end customers. In the future power system configuration, the microgrid will providing clear economic and environmental benefits compared to traditional power system. Development of microgrid concept and technologies requires more effort to resolve numerous economic, commercial and technical challenges by close cooperation and exchange of information among researcher on these activities has highly beneficial for the advancement of the microgrid research.

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