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Review on the Technical Challenges of Micro-Grid System

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Abstract

This paper presents many technical issues and shortcomings confronted in micro-grids. The objective of this paper is to presents the current status and state of the art of microgrid system as well as the barriers that are being encountered for their integration to the network. It discusses the technical challenges involved in grid integration of micro-grids and highlights some aspects of stability in microgrids. Microgrids can cause several technical problems in its operation and control when operated as autonomous system. In this paper a review of challenges on microgrid with respect to voltage and frequency control, islanding and protection of microgrids.

IndexTerms - microgrid, frequency control, islanding, distributed generations, voltage control, protection

INTRODUCTION

MICROGRIDS comprise low voltage distribution systems with distributed energy resources, such as photovoltaic power systems and wind turbines, together with storage devices. These systems are interconnected to the medium voltage dis-tribution network, but they can be also operated isolated from the main grid [3]. Microgrids are small power systems capable of island and grid modes of operation. Managing their power balance and stability maybe a difficult task since they depend on quite a number of variables. A microgrid is a controllable component of the smart grid defined as a part of distribution network capable of supplying its own local load even in the case of disconnection from the upstream network. For reasons of reliability, distributed generation resources would be inter-connected to the same transmission grid as central stations. They use renewable energy sources, including, but not limited to wind energy, biomass, biogas, solar energy, fuel cells etc. Various technical and economic issues occur in the integration of these resources into a grid. Technical problems arise in the areas of power quality, voltage stability, harmonics, reliability, protection, and control. Behavior of protective devices on the grid must be examined for all combinations of distributed and central station generation. A large scale deployment of distributed generation may affect grid-wide functions such as frequency control and allocation of reserves.

A microgrid (MG) is a localized grouping of electricity generation, energy storage, and loads that normally operates connected to a traditional centralized grid (macrogrid). This single point of common coupling with the macrogrid can be disconnected. The microgrid can then function autonomously [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 con-nectmicrogrid to the grid , iii) can independently operate with-out 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]. Maintaining a near sinusoidal power distribution bus voltage at rated magnitude and frequency is referred to as electric power quality. Voltage unbalance, harmonic content, increased reactive power demand, and frequency deviation are the foremost power quality hitches which affect the utility grid power quality, Voltage unbalance, harmonic content, increased reactive power demand, and frequency deviation are the foremost power quality hitches which affect the utility grid power quality, voltage stability, harmonics, reliability, protec-tion, and control [19]. 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.

Power electronics devices have to be incorporated in order to maintain the balance between load and generated power, and to guarantee the quality of supply on an acceptable level. Strategies have to be developed in order to improve voltage sags/swells and unbalances. Static synchronous compensators are widely used for this purpose [20]. Enhanced networked-based control structure is needed not only to eliminate the fre-quency deviations, power-sharing errors, and stability concerns associated with conventional droop control in microgrids but also to yield improved microgrid dynamic performance, min-imized active/reactive power-sharing errors under unknown line impedances, and high reliability and robustness against network failures or communication delays.

MICROGRID RESEARCH PROJECTS

The microgrid research based on simulation study and hard-ware 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 installa-tion of distributed generation with plug and play capabilities. EU demonstration sites are taking place in Greece, Nether-lands, Germany, Denmark and Spain.
The R and D activities in the United State on microgrids re-search programme was supported both by the US Department of Energy California Energy Commission. The most well-known US microgrid R and 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 modelingap-proach 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 Devel-opment 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 [6]. The main achievement is the development of an optimum operation and control system. Even though multiple field-test of microgrids are demonstrat-ing the technical feasibility of microgrid, but clear economic and environmental benefits have not yet been demonstrated. Method for economic design and optimal operation of micro-grid with renewable energy sources were proposed.

The microgrid R and 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 RD at the Canadian universities has primary focused on development of control and protec-tion strategies for autonomous microgrid operation, micro-grid 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 mi-crogrid, planned microgrid islanding, and prototype testing and performance evaluation

ISSUES OF MICROGRID

Technical benefits of the microgrid are an islanding imple-mentation of distributed generation to improve the distribu-tion 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.

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 [7].

ISLANDING

Islanding is a small-scale representation of the future in-terconnected grid with a high density of distributed gener-ations. 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 [4]. 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

PROTECTION

Microgrid protection is the most important challenges fac-ing 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 [8]. 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 distri-bution 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.
In spite of potential benefits, development of Microgrids suffers from several challenges and potential drawbacks as explained [11-20].

Power Imbalance

A power imbalance occurs in the transition from grid-connected to islanded mode if the microgrid is absorbing or supplying power to the main grid before disconnection. Energy storage units are used to maintain power balance due to the slow dynamic response and low inertia of some micro sources. When a microgrid once again goes from islanded mode to grid connected mode, it is synchronised by ensuring the magnitude and phase of the voltages across thesynchronising device are equal. A high-speed static switch with appropriate sensing capability may be used for disconnection.

Stability Issues in Smart Grids

Lower Angular Stability due to lower overall system inertia: In standard powergrids, the inertial support from the rotating mass of the synchronous genera-tors plays a significant role for maintaining the grid frequency during transient periods. In smart grids, greater part of the DGs and MGs are integrated to the main grid through power-electronic based converters.

Lower Voltage Stability due to lower power distribu-tion support

Since the power electronic converters in DGs and MGs are operated in the current control mode, the power transshipped to the smart grid is limited to preset figures. Therefore, during crisis in the smart grid, the power sharing support from DGs is much less compared to that of regular power plants. Traditional power plants can meet the increased power requirements during various eventualities with the kinetic energy stored in the rotating mass of synchronous generators. As MGs are switched to autonomous mode of functioning during contingencies in the main power grid, the power sharing support from MGs can be considered as zero. Hence, the current controlled functioning of DGs and islanded operation of MGs can deteriorate the total power generation within the smart grid, in turn rejecting the voltage profile. Therefore, high penetration of DGs and MGs can deteriorate the immunity of the voltage profile of the smart grid during various power system outages.

Low-frequency power oscillations

The MPPT al-gorithm in the grid side controller (GSC) of a DG sets the maximum power output value for the DG inverter for that operating condition of renewable source. Depending on the frequency of the MPPT refurbished, the output of the DG inverter will have deviations. These deviations in each DG in the smart grid can sum up to give rise to oscillations in total power generation. These ceaseless changes in the power sharing ratio of DGs can produce rotor oscillations in synchronous generators. These oscillations can be serious when the inception of DGs becomes very high. The influence of these power oscillations on the operation of MGs is of major cause for worry, as MGs are designed to remodel to islanded mode during disturbances in the main grid. The controller at the MG may identify these power oscillations as a disturbance and may drive the MG to islanded mode. This will amplify the power oscillations, leading to aggravation of the transient state of the smart grid. If the rotor oscillations in regular power plants are left unno-ticed, it may lead to serious power fluctuations in the smart grid and can lead to catastrophic failures. Hence, power transients in the smart grid have to be analyzed and damped in real time.

Harmonics in DC Microgrids

The Harmonic currents need to be reduced to reduce harmonic losses. For this harmonic compensation methods have to been proposed. The harmonics result due to operation of power elec-tronic converters. The harmonic voltage and current should be limited to the acceptable level at the point of wind turbine connection to the network. To ensure that harmonic voltage is within acceptable values, each source of harmonic current can allow only a limited contribution, as per the IEC-61400-36 guideline. The brisk switching amounts to large contraction in lower or-der harmonic currents compared to the line commutated converter, but the output current will have increased frequency current and can be comfortably filtered-out.

Inverters for DC-AC Conversion

Microgrids are lo-cal low voltage power systems that offer many ad-vantages over grid power in terms of dependability, power discharge and the ability to incorporate distributed generation, including renewable energy. In low voltage AC microgrids, especially where solar arrays are used, inverters are required to convert DC to AC. With a large number of inverters in a microgrid, there are concerns regarding their ability to support such a small power system when it is under large stress. Such stress can be caused by voltage and frequency deviations arising inside or outside the microgrid, or from faulty situations. Currently, microgrids rely upon accurate design while being manufactured for them to operate steadily. Invert-ers available in the market offer no more than power conversion at unity power factor. However, the newly planned microgrids are likely to be better structured, and inverters will have the capacity to do something more. They may play a role in regulating flow of reactive power and in reducing harmonics, or may offer supplementary services

TOPOLOGICAL CHANGES

Microgrids operate in two modes: grid connected and stand-alone. Topological changes take place in low voltage networks due to connec-tion/disconnection of generators, storage systems and loads. Also, there is intermittence in the generation of several renewable resources connected in the microgrid. Inception of information and communicationtechnolo-gies to the power grid technologies is changing the architecture and operation of the regular grid. Micro grid topology can be installed in areas such as city buildings, factories, households, villages or rural farms. For different cases, depending on user requirements, strength of the utility grid, and the number of available distributed energy resources (DER), ac, dc or hybrid microgrid can be put up. To improve the dependability of themicrogrid, an energy storage system is established to support the bus voltage when the microgrid goes from the grid connected mode to autonomous mode. This energy storage system can be charged from the main bus voltage through a converter Fig. 3 shows the architecture of a typical microgrid. Microgrids, overall, are controlled by the microgrid control center.

ENERGY STORAGE DEVICES

As diesel generator and renewables are intermittent means of electricity production fluctuations resulting from unstable microgrids and sources. nonlinear loads will execute considerable impacts on normal operation of the MG. Energy storage technology puts forward a preferable solution to the above concern. Energy storage is used to enhance the stability and efficiency of microgrids by disconnecting the generation source from the load. By providing power and lighting during large-scale catastrophical conditions such as rain and storm , energy storage systems of all types reduce the time it takes for first responders to begin recov-ery actions. Energy storage mechanisms and topologies are being developed and the features and benefits of energy storage systems are being reviewed. One such example of an upcoming energy storage technology is the recent introduction of sodium-nickel-based batteries to the marketplace. Other storage methods include:lead acid battery, rechargeable battery, flow battery, super- capacitor, superconducting magnetic energy storage, hy- droelectric or pumped energy storage, flywheel energy storage, compressed air energy storage, thermal energy storage, molten salt, ice storage.

ECONOMIC ASPECTS

Concepts of microgrids are proposed to address primarily various issues related to integration of small scale renewables and increased demand of reliable electricity supply. With an active management control approach and ability to operate in islanding mode, a cluster of micro generators, electricity storage and electrical loads can be operated within the micro-grids framework to provide higher supply reliability to customers. Solutions are required not only to make these concepts technologically feasible and safe to operate but also to be commercially viable and attractive, econom-ically efficient and supported by electricity regulations. Detailed study of investigations on various economic, regulatory and commercial issues faced by the develop-ment of microgrids in projects is need of the hour. The potential economic benefits and contributions to environ-ment from applications of microgrid technologies should be taken into consideration

FUTURE WORK ON MICROGRID RESEARCH

1) Future direction which require further investigation in the context of microgrid research are:
2) Contribute to increase the share of renewables and to reduce GHG emissions;
3) Study the operation of MicroGrids in normal and island-ing conditions;
4) Optimize the operation of local generation sources;
5) Develop and demonstrate control strategies to ensure efficient, reliable and economic operation;
6) Simulate and demonstrate a MicroGrid in lab conditions;
7) To investigate full-scale development, field demonstra-tion, experimental performance evaluation of frequency and voltage control methods under various operation modes;
8) Transition between grid connected and islanded modes on interaction phenomena between distribution genera-tion and high penetration of distributed generation;
9) Analysis the issue of black starting in an unbalanced system on the control, protection and power quality; and

10) Transformation of microgrid system today into the in-telligent, robust energy delivery system in the future by providing significant reliability and security benefits.

CONCLUSION

Small modular generation technologies interconnected to distribution systems can form a new type of power system, the micro-grid. This paper presents a review of the issues in implementation of microgrid technology. It introduces the activities and current progress in microgrid research, especially in various countries of Europe and America. The three key issues of technical challenges that must be overcome for ef-fective implementation of microgrid are voltage and frequency control, islanding and protection.

In upcoming power generation layouts, the microgrid will provide clear ecomonic and environmental benefits as compares to traditional powers system. Efforts for development and application of concepts is required to resolve numerous economic and technical challenges. Combined efforts among researchers on these activities will aid in carrying the microgrid research.

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