International Journal of Enhanced Research in Science, Technology & Engineering
ISSN: 2319-7463, Vol. 13 Issue 1, January-2024, Impact Factor: 8.375

Challenges and Developments in Microgrids

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ABSTRACT

Microgrid is an interconnected network that comprises of several generating sets, the power lines and a number of consuming devices. A microgrid can then be compared to an auxiliary generator in a main grid which easily decouples and runs on a utility grid as soon as it receives a shock with a fault. For example, other important technical design and operational aspects about such systems include control, protection, and infrastructure needs. Microgrid Topology, operation, control, protection and energy management system to look at for its loopholes and developments.

Index Terms – microgrid, control, protection, topology, energy management system.

INTRODUCTION

A microgrid is essentially an electrically constrained section of the distribution system that combines local distributed generating sources, energy storage technologies, and regulated loads to create a self-sufficient energy system. Low-voltage and medium-voltage renewable energy sources with variable generation, can be integrated into distribution networks through the use of microgrids. Although microgrids can provide end users with a variety of advantages, their integration into the current distribution networks is still hampered by a number of problems, most of which are connected to their operation, protection, and control [1]. Presently, majority of microgrids are grid-connected systems. In order to enable the integration of Distributed Generation units, particularly renewable energy sources (RES), in distribution networks, grid-connected microgrids are widely used. Microgrid is the way to support and reduce the load of the main grid that may be AC or DC or both AC and DC i.e., hybrid [2].

The operation and control of AC microgrids have been the subject of substantial research among the several kinds of microgrids, including DC, AC, and hybrid. But, compared to AC microgrids, DC microgrids have a number of advantages, including the ability to provide DC loads more efficiently, the ability to integrate DC Distributed Energy Resources more easily, and the absence of the requirement for synchronizing generators [3]. The research [4] presents an introspective evaluation of available AC and DC Micro Grid systems with renewable-based DG units, energy storage technologies, and loads. In contrast to DC MG systems, the key issues to look for in AC MG systems are DG unit synchronization, in-rush currents from transformers, induction motors, and generators, challenging voltage management, and system stability. The general challenges still revolve around maintaining optimal operating conditions for each component in MG systems, running the power converters while they are integrated with smart grid technologies (like measurements and sensing instruments, etc.), power converters, low short circuit current limitations, and enhancing their fault-riding capabilities during grid disturbances.

STRUCTURE & TOPOLOGY

The microgrid may be radial or loop-shaped, in addition to having renewable or non-renewable energy sources, including solar PV systems, wind energy, and diesel generators. These resources are connected to the DC-DC converters, or choppers, in accordance with the needs. According to the control approach being employed, the solar PV plant, for instance, may be connected to either a buck or a boost converter. After that, the power is sent to the inverter, which converts it to AC power. In wind energy power plant, the unregulated AC electricity is first converted to DC power using a rectifier, and then it is converted back to AC to obtain the desired voltage and frequency. The filter is connected between the converter and the network in order to reduce or suppress any undesirable effects.

The filter's design must be exact in order to ensure that it has adequate attenuation at the inverter's switching frequency and that it does not produce oscillations throughout the entire system. The study [5] discusses the design and simulation of this type of filter. Most distribution systems function in radial mode, which involves radially connecting the majority of loads. Others may have loop closing feeders, but when switches are routinely open, loops remain open and only close when other components of the loops open due to faults. Because the system's protection devices are built for radial operation, the radial structure is preserved.

MICROGRID OPERATION

The micro grid has a limited number of operational modes. Grid connected mode, islanded mode, transfer from on grid to off grid mode (this transition can be non-bump less i.e., emergency islanding or it may be bump less or forced islanding), and resynchronization of microgrid to main grid can all be concluded from this list. If it is needed the microgrid should operate effectively, alert and emergency states may also be present to shield it from any undesirable circumstances. A microgrid can function in one of two modes: islanded mode or grid linked mode. The Point of Common Coupling (PCC), the single place at which the MG is coupled to the main grid, serves as a "switch" that, in the event of distortion, cuts off the MG's connection to the grid. When operating in grid-connected mode, the MG is linked to the main grid and draws electricity from it to supply its customers. It also produces its own electricity from distributed energy sources and stores any extra in storage tanks for later use. Also, it has the ability to sell extra electricity or add it to the main grid.

When operating in islanded mode, the MG is not linked to the main grid and generates all of its own power. In order to keep the microgrid running, we must switch it to an islanded mode of operation while maintaining the DGs' rotation. This is a significant shift since, historically, DG units in a distribution micro-grid should be shut down after an interruption in the upstream network for protection reasons and based on the rules that are now in place. In the study[6], a hybrid ac/dc microgrid is suggested and thoroughly researched, models' coordination control strategies are suggested for all converters in order to maintain stable system performance under a variety of load and resource conditions. By using MATLAB/Simulink, the coordinated control strategies are validated.

MICROGRID CONTROL

To control the grid connected methods there are some schemes [7] like Phase Lock Loop(PLL),current control loop, and the space vector modulation (SVM) lastly the signal is converted to the Gate Pulses of the Inverter. A thorough simulation and implementation of a three-phase grid-connected inverter are studied. Grid-side inverter's control mechanism, space vector modulation SVM and synchronization for inverters connected to the grid are studied in [8]. Voltage, frequency, active power, and reactive power are the variables that need to be controlled for a microgrid, and they mostly depend on the mode of operation. The utility grid maintains the microgrid's voltage and frequency when it is in grid linked mode. So, the micro grid controller's primary duty is to maintain a balance between real and reactive power. Along with actual and reactive power balance during islanded mode, the microgrid controller should also take care of voltage and frequency. Either the local controller (LC) alone manages the power balance or set points provided by the central controller via communication devices can be used, according to the[9].

The construction of a microgrid is impractical without a reliable and precise control. Although ac microgrid has received a lot of study attention, DC and hybrid AC-DC microgrids are slowly piquing researchers' interest from the perspectives of dependability, minimizing converter losses, and efficiency. The control hierarchy for each of the three types of microgrids follows a similar pattern, with the distinction being in the secondary and tertiary controls used for each category's various operating modes and the droop characteristics included in the primary control. In centralized control, the EMS is at the centre of microgrid control, but the primary controllers are unable to function after the central controller experiences a communication fault and is unable to operate. The command of a centralized controller is not necessary for the operation of main controllers in the case of decentralized secondary control [10].

MICROGRID PROTECTION

Micro-grid protection is one of the issues, and academics have been attempting to create various protection strategies to address this. The studies analyse protection techniques currently being used to handle micro-grid protection challenges in both grid-connected and islanded modes of operation. Most distribution systems function in radial mode with uni-directional power flows. Consequently, most of the protection devices available in the market are designed for uni-directional power flows. [11]. On the other hand, with integration of renewable energy generation in modern MGs, power flow within the micro-grids can also be bidirectional. As a result, the micro-grids would not be adequately protected by the traditional protective measures. The limited fault current capability of the inverter units inside the micro-grid is another issue. The traditional protective devices are no longer sufficient and different solutions for protecting the micro-grids in both grid-connected and islanded modes of operation should be devised.

Choosing appropriate protective devices with higher selectivity, quick operation, simplicity, flexibility, various setup options, and low cost is necessary to ensure the reliable, safe operation of the power system network. Due to bidirectional power flow, the dynamic nature of DGs, their intermittent nature, and variations in fault current, typical protection techniques created for radial flow with high fault current for distribution networks would not operate correctly on a microgrid. According to the [9], one of the biggest obstacles to protecting microgrids are Dynamics of fault current magnitude, Loss of Mains (LOM), Unnecessary disconnections (lack of selectivity), Blinding of protection.

In order to overcome the dramatic variations in microgrid short circuit current characteristics resulting from switching between grid and islanded operational modes,[12] examines the viability of adopting a combined adaptive over current and differential protection strategy. An efficient protection system that mitigates both minor and large disturbances in microgrids has been provided in[13].In study[14],it has been shown that the suggested scheme has the ability to dynamically configure the settings of its relays in response to the shifting network conditions. Grid-connected, islanded, and changeable distributed generation scenarios have all been used to demonstrate how the method works. Moreover, the suggested technique preserves the needed coordination for backup relaying applications. Using programmable numeric relays hardware-in-loop (HIL) platforms, the suggested approach may be further expanded to online/hybrid offline-online adaptation.

In [15], MATLAB was used to create a model of a real-world test system that had the relays set up properly. The selectivity of the upstream relays is impacted by the infeed current of Renewable Energy and a straightforward calculation approach is used in [16]to adjust distance relay settings while taking the infeed current into account. In [17], when a star-connected load is connected downstream of the fault and the low fault resistance arises at the fault point, impedance relays with mho characteristics could cause an unwanted operation, so a directional feature should be included in the distance protection system to address this issue. The interconnection line that connects a Micro Grid to the rest of the grid via a Delta/Wye transformer was protected by a new distance protection algorithm introduced in [18]. This proposed approach may effectively safeguard the interconnection line against all sorts of ground faults and address a number of issues relating to the protection of microgrids.

ENERGY MANAGEMENT SYSTEM

Using the microgrid's backup power necessitates the usage of an energy management system. This energy is primarily stored in the form of batteries and other types of devices. In an island scenario, the microgrid should be able to handle power storage, and in a grid-connected scenario, it should be able to control battery charging [19]. The microgrid's economics are also taken into account in addition to that. Both communication and microgrid management are done using the SCADA system [20]. Lithium batteries have the potential to be a significant replacement for lead-acid batteries in microgrid storage systems in the future. As comparison to lead-acid batteries, Li-ion batteries have the following advantages: extended cycle life, quick charging, high energy density, and low maintenance [21]. The primary goals of the energy management system are to increase the operational efficiency, energy planning, and system dependability in both island-based and grid-connected microgrids for sustainable development. To ensure optimal energy-efficient operation of microgrids, several potential issues must be thoroughly addressed [22].

The study [23] points out issues in Quality of Service, Reliability, Security, Complexity, Standardization and Efficiency. The micro-control grid's systems must deal with a substantial amount of information as a result of the bidirectional communication between agents, which raises the cost of computing. There are many different networking models as discussed in [24], but the Internet model, which is derived from the Open Systems Interconnection (OSI) reference model, is the most widely used benchmark communication architecture. A group of protocols used to provide services over the Internet is known as the Internet Protocol (IP) suite.

The Network Timing Protocol (NTP) for time synchronization, IP, Transmission Control Protocol (TCP), User Datagram Protocol (UDP), File Transfer Protocol, and Simple Mail Transfer Protocol are the protocols that are most frequently used in microgrid applications [25]. The MODBUS protocol, which is originally designed for data exchange between PLCs. MODBUS is capable for routing of different system configurations with not only one master controlling all the slave devices. MODBUS can be deployed over several communication interfaces, like TCP/IP over Ethernet, Serial transmission.

CONCLUSION

The paper presents key design elements of existing microgrids as well as the key control functions needed to assure their economical, dependable, and secure functioning in various operating modes and transitions. These design decisions result in dealing with new technical and operational issues, such as sophisticated control, protection, and infrastructure requirements. The major conclusions of the study presented in the paper highlight the main technical and control issues and the primary solutions that may be used to enable the smooth functioning of the microgrid in all operating modes and transitions. As a result, the solutions found need to be further customized to match the unique requirements of the instance being studied.

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