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A Comprehensive Study on Microgrid Technology

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ABSTRACT

A Microgrid comprises distributed generation, energy storage, loads, and a control system that is capable of operating in grid-tied mode and/or islanded mode. As operation modes are shifted, the Microgrid should successfully manage the voltage and frequency adjustment in order to protect the grid and any loads connected to the system. Facilitation of the generation-side and load-side management and the resynchronization process is required. This paper presents an overall description and typically distributed generation technology of a Microgrid. It also adds a comprehensive study on energy storage devices, Microgrid loads, interfaced distributed energy resources (DER), power electronic interface modules and the interconnection of multiple microgrids. Details of stability, control, and communication strategies are also provided in this study. This article describes the existing control techniques of microgrids that are installed all over the world and has tabulated the comparison of various control methods with pros and cons. Moreover, it aids the researcher in envisioning an actual situation using a Microgrid today and provides insight into the possible evolvement of future grids. In conclusion, the study emphasizes the remarkable findings and potential research areas that could enrich future Microgrid facilities.

Keywords: Microgrid; Distributed energy resources; Distributed generation technology; Future grid.

1. INTRODUCTION

A Microgrid is a modern distributed power system using local sustainable power resources designed through various smart-grid initiatives. It also provides energy security for a local community as it can be operated without the presence of wider utility grid. Microgrid technology generally represents three important goals of a society such as reliability (physical, cyber), sustainability (environmental considerations), and economics (cost optimizing, efficiency). The "distributed generation" (DG) term refers to power generation located at or near the consumption sites. By comparison to "central generation", DG can eliminate the generation, transmission, and distribution costs while increasing efficiency by removing elements of complexity and interdependency. In many cases, distributed generators can provide lower generation costs, higher reliability, and increased security not realized via traditional generators. For instance, Pike Research has identified 3.2 gigawatts (GW) of globally existing Microgrid capacity. The North America leads to global Microgrid generation with 2,088 MW operating capacity according to the report. On the other hand, Europe holds the second rank with 384 MW installed Microgrid capacity while Asia Pacific follows with 303 MW of operating capacity. The installed Microgrid capacity in the rest of world is around 404 MW. If each power user (building/company/hospital/market) cares about reliable power and keep their desire to back up energy source like generation/battery/diesel engine that would be the most expense power system. In a Microgrid system, backup resources are unnecessary because a single user does not have to supply a general load during critical consumption periods. One billion dollars of energy consumption can be conserved by managing a few hundred summer peak hours by shifting or eliminating loads. Therefore, reliability is a major justification for Microgrid operation. Microgrids could also prove economically viable in the southwestern US. The sustainability is another most important factor for considering this new technology, but less so, in the US; it is more necessary in China where a lot of environment issues is emerging nowadays. The Microgrid could tackle the energy crisis since the transmission losses are greatly reduced. Additionally, a Microgrid provides a significant reduction in generation costs while providing reliable and sustainable energy to loads. The cyber security issue is addressed as well due to the localized nature of the

system. Microgrid technology is suitable for regions with an underdeveloped transmission infrastructure, such as remote villages where an islanded Microgrid would be the most advantageous kind of power network.
Microgrids that are similar to a conventional grid structure in terms of power generation, distribution, transmission, and control features are assumed as a minor model of actual grid form. However, Microgrid technology differs from a conventional grid owing to the distance between power generation and consumption cycles as a Microgrid is installed near the load sites. Microgrids also integrate with distributed generation plants such as combined heat and power (CHP), and renewable energy plants powered by solar energy, wind power, geothermal, biomass, and hydraulic resources. Although the power rate of microgrids is limited to a few MVA, it is relative to its application area and grid type. Power parks refer to the interconnection of several microgrids that are installed to meet higher power demands where increased stability and control opportunities are necessary. Moreover, the interconnection of renewable sources and a Microgrid contributes to decreased environmental emissions.

2. OVERVIEW OF THE MICROGRID

Researchers are extensively studying microgrids in order to construct test beds and demonstration sites; the classification of microgrids and relevant key technologies should, therefore, be addressed. In this paper, we categorize microgrids into three types: facility microgrids, remote microgrids, and utility microgrids. The following characteristics are considered: their respective integration levels into the power utility grid; their impact on main utility providers; their different responsibilities and application areas; and their relevant key technologies. Facility microgrids and utility microgrids have utility connection modes while remote microgrids do not. Remote microgrids are located in highly dispersed consumption areas as compared to facility and utility microgrids. Facility microgrids can keep on operating in an intentional or an unintentional island mode. However, in every type of Microgrid, the micro-sources, loads, network parameters, and control topologies will vary

2.1. Distributed Generators

There are two different types of generation technologies applicable for Microgrid design such as renewable distribution generation (solar thermal, photovoltaic (PV), the wind, fuel cell, CHP, hydro, biomass, biogas, etc.), and non-renewable distribution generation (diesel engine, steam turbine, gas engine, induction and synchronous generators, etc.) . The use of wind energy has rapidly increased all over the world by a rate of around 30% per year and has become a significant resource in microgrids, along with solar energy. These emerging technologies and well-established generation technologies are well known, and a detailed study of those generation systems is beyond the scope of this paper.

2.3. Microgrid Loads

A Microgrid system has various kinds of load and it plays a vital role in its operation, stability, and control. An electrical load can be categorized as a static or motor/electronic load. The Microgrid can supply various kinds of loads (such as household or industrial) which are assumed to be sensitive or critical, and demand high-level reliability. This kind of operation requires several considerations such as priority to critical loads, power quality improvement supplied to specific loads, and enhancement of reliability for pre-specified load categories. Additionally, local generation prevents unexpected disturbances with fast and accurate protection systems.

3. FUTURE OF GRIDS

Today, the power industry faces many problems including the rising cost of energy, power quality and stability, an aging infrastructure, mass electrification, climate dynamics and so on. Those problems can be overcome using low-voltage distribution generation where all sources and loads are collocated. The application market of microgrids in 2022 is predicted where the majority of applications would be for campus-type microgrids. The projected Microgrid market growth and the growth of Microgrid revenue by the region where North America holds the largest share. An estimation of Microgrid growth follows as;

i. The growth of globally-installed Microgrid capacity has increased dramatically since 2011 and is forecasted to reach a total installed capacity of over 15GW by 2022.
ii. The market presents a potential of over $5billion and is likely to reach over $27 billion by 2022, in terms of market value for dealers
iii. At present, campus/institutional microgrids are the largest by application and are forecasted to grow at a compound annual growth rate (CAGR) of 18.83% from 2012-2022.
iv. Military, defense-based and commercial microgrids are forecasted to have a similar installed capacity by 2022.
v. Off-grid microgrids continue to grow at the highest CAGR for next 5-6 years, while the hybrid market is expected to grow at the highest CAGR during 2012-2022.
vi. A longer payback period requires for a completely developed Microgrid.

4. CONCLUSION

This topic is currently being concerned by the alarms on global warming, pollution and carbon footprint emissions. Microgrid systems facilitate remote applications and allow access to pollution-free energy and give impetus to the use of renewable sources of energy. Moreover, in an event of a power grid failure, a microgrid is one of the best alternatives. Renewable energy systems help to generate clean and sustainable energy as the demand for energy continues to rise. Nevertheless, there are several challenges that need to be tackled to facilitate the RES that could be used to complete perspective. Renewable resources are widely distributed and due to the intermittent nature of power, such a new distributed system can be provided by various generation approaches to obtain the maximum potential energy of the sources.

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