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A literature review on integration of distributed energy resources in the perspective of control, protection and stability of microgrid

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ABSTRACT

The concept of integration of distributed energy resources for formation of microgrid will be most significant in near future. The latest research and development in the field of microgrid as a promising power system through a comprehensive literature review is presented in this paper. It shows a broad overview on the worldwide research trend on microgrid which is most significant topic at present. This literature survey reveals that integration of distributed energy resources, operation, control, power quality issues and stability of microgrid system should be explored to implement microgrid successfully in real power scenario.

Contents

1. Introduction

Integration or interconnection of distributed energy resources is evolving as an emerging power scenario for electric power generation, transmission and distribution infrastructure globally based on the significant issues, such as scarcity of fossil fuel in future, widespread deployment of advanced Distributed Energy

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Resources (DERs) technologies, deregulation of electric utility industries and public awareness on environmental impact of traditional electric power generation. These issues are changing the power generation concept worldwide and opening up new challenges in the generation and distribution markets. Small non-conventional generation combined with Distributed Generation (DG) is rapidly becoming attractive because it produces electrical power with less environmental impacts, easy to install, and highly efficient with increased reliability. As the awareness on environmental issues like global warming is increasing; renewable energy sources are becoming most significant sources of energy in modern power scenario. Geographical, environmental, political and financial factors of different countries lead to increased use of renewable energy resources like wind–electric conversion system, photovoltaic system, biomass resources etc. Also the low power generation capacity of DER has motivated the need for integration of different types of DERs and loads in the form of microgrid to enhance the power generation capacity, reliability and marketability of dispersed type of microsources with a promising approach to reduce the load congestion on the conventional power system or utility grid and facilitating localized generation at customer ends. The effective integration of DERs depends on the versatile nature of DGs such as photovoltaic system, wind power, small hydro turbines, tidal, Combined Heat Power (CHP) based microturbines, biogas, geothermal, fuel cells including battery storage facilities etc. that have the potential to support conventional power system with many issues involved with their interconnections. In this perspective, IEEE P1547- 2003 is a benchmark model for interconnecting DERs with Conventional Electric Power System [1] which provides guidelines to general interconnection requirements, e.g. response to abnormal conditions including operation, power quality, and safety conditions including operation in utility grid connected and islanded mode.

1.1. Motivation

The motivating factors for this review work on integration of distributed energy resources are supported by the issues related with operation and control of microgrid including deployment of power electronic based inverters in the system, protection coordination issues and in addition, stability analysis of microgrid in steady and dynamic states of operation. These are briefly discussed in the following sections (1.1.1 to 1.1.5) as motivating factors to perform this literature survey on integration of DERs.

1.1.1. Integration of distributed energy resources: microgrid

The distributed generation (DG) is gaining immense importance in the present power scenario globally due to reduced green house gas emission, better power system efficiency, reliability and as promising approach to relief existing power system from today's stress on transmission and distribution system [2]. The distributed energy resources (DERs) are changing the manner of transmission of energy through the utility power grid, enabling consumers to have some scale of flexible energy utilizations and the power system has to be converted into small distributed energy integrated system. The integration of distributed generators based on renewable energy resources (RERs) and microsources like photovoltaic system, Wind turbine, microturbine using CHP system, fuel cells, and batteries with storage facilities etc. has initiated more recent concept of microgrid which is considered as a cluster of interconnected distributed generators, loads, and intermediate storage units that cooperate with each other to be collectively treated by the utility grid as a controllable load or generator towards an evolutionary power solution for scarcity of fossil fuel in near future [3]. The microgrid enriched with modern power electronic based technology [2,4,5] can offer higher dependability of service, better quality of power supply, and better efficiency of energy use by utilizing the available waste heat. The capacity to make use of renewable energy with modest pollution and potentially lesser cost is attractive and gains gradually more interests in many countries. Additionally, distributed generation can benefit the electric utility by decreasing overcrowding on the grid, reducing the need for new generation and transmission capacity, and offering supplementary services such as voltage support and demand response. With advancements in power electronics and control technologies, the large-scale, effective integration of a range of distributed generation and energy storage technologies into the existing electric power infrastructure may finally become possible and economically feasible.

The modern concept of microgrid is highly promising as a solution to the problem due to scarcity of fossil fuel in future in conventional power generation. It is also effective against environmental impacts of existing generating system. Operation of microgrid depends on successful integration of DERs which is related with several factors like power quality issues. The power quality issues should be carefully dealt with to achieve satisfactory values of voltage and frequency in grid connected and islanded mode of microgrid in steady state and as well as, during dynamic state i.e. transition from grid connected mode to islanded mode and vice versa. The effect of harmonics on power quality might be quantified by measuring total harmonic distortion at various important points of microgrid such as across the terminals of critical loads, DER and PCC (Point of Common Coupling).

1.1.2. Operation and control of microgrid

The microgrid, an integrated form of DERs, is normally interfaced with load and utility grid by power electronic inverters [6,2]. It can operate in grid-connected mode or in islanded mode. In grid-connected mode, the microgrid either draws or supplies power from or to the main grid, depending on the generation and load with suitable market policies. The microgrid can separate itself from the main grid whenever a power quality event in the main grid occurs [7]. Autonomous control of microsources [2] suggests that the microgrid should follow a peer-to-peer and plug-and-play model avoiding the installation of a single point of failure like microgrid control center (MGCC) and dedicated storage units, so the microsources should have integrated storage unit (Battery bank in the dc bus of the inverter).

The microgrid should disconnect itself from main grid on occurrence of abnormal condition and to be shifted to islanded mode [1,2]. The variation in voltage and frequency becomes more prominent when microgrid is switched over to islanded mode. Under grid connected situation of microgrid, the voltage and frequency are determined by the grid. When the microgrid islands, one or more primary or intermediate energy sources should be controlled by adjusting its voltage and frequency. If the frequency reaches to a very low value, the load may be temporarily shaded. Also a balanced condition is to be maintained between supply and demand applicable to microgrid. If the microgrid is exchanging power with the grid before disconnection, then secondary control actions should be applied to balance generation and consumption in island mode to ensure initial balance after a sudden fluctuation in load or generation. The microgrid is supposed to preserve an adequate power quality while in island operation with sufficient supply of reactive energy to shrink voltage sags. The energy storage device should be capable of reacting rapidly to frequency and voltage change and