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ABSTRACT

The evolution of the traditional electric grid has brought about a dramatic change in the energy industry, with rapid progress towards a modernized grid termed the 'Smart Grid'. To meet this challenge, of rapid depletion of fossil fuels, new developing technologies are focusing on distributed energy resources called dispersed systems. The variable natures of the renewable sources make them intermittent requiring spinning and non-spinning reserve, to compensate for their variable generation. To meet the challenges of integration of distributed resources to the grid, providing grid support and quality of supply, innovative control methods should be developed at the distribution level. This will ensure complete utilization of the available resources thereby decreasing the load on the grid and providing controllability and reliability at the distribution level. An extensive literature survey in this thrust area reveals that, several complexities in terms of energy control and management due to the variable electrical characteristics of these renewable energy sources. Considering these aspects, the significant contributions of this Ph.D. thesis are as follows:

1. Modeling, integration and performance evaluation of Solid Oxide Fuel Cell in a Radial Distribution Network using conventional Control: For investigation of microgrid scenarios, the solid oxide fuel cell has been interconnected to the distribution system which is a 13.8-kV, three-feeder radial distribution system connected to the utility via a 69kV radial line. The performance analysis of the test distribution system using the solid oxide fuel cell as a distributed resource has been carried out with conventional current control strategies, proportional-integral and hysteresis current controls and compared for the same conditions in the radial distribution system. The total harmonic distortion was evaluated and the proportional-integral controller showed better performance, though both controllers show harmonic content as per the prescribed standards.. The intent of this work is to assess whether the controllers have an effect on the quality of energy delivered to the loads and the effectiveness of these control strategies for the solid oxide fuel cell.

2. Development of an Intelligent Interface for Solid Oxide Fuel Cell for Microgrid Operation : The work done in this thesis presents an effective control strategy, which shows improved performance of the solid oxide fuel cell for grid connected and isolated mode. The intelligent strategy based on the Mamdani model, is intended to allow the loads to be supported by the distributed energy

resource under various scenarios for micro-grid operation. The events of grid isolation can be planned or unplanned and this intelligent strategy fulfills the needs of an effective controller by providing reliable support. The intelligent controller compared with the conventional controllers shows better performance in terms of power quality.

3. Modeling and Intelligent interface of a Hybrid system to the distribution system : The strategic yet sporadic location of DERs enables the interconnection at the distribution level. This brings about the hybrid renewable energy source, which uses the advantage of available resources combined with their variable nature. The photovoltaic module along with the solid oxide fuel cell and a battery storage system have been modeled as they hybrid system. The intention of using the battery storage system is to address the variable nature of the photovoltaic system and provide power balance in case of disturbances and/or significant load changes. The performance evaluation of the hybrid system shows effective control and successful MG operation. Under the grid connected scenario, the load demand is met with but raised harmonic levels show compromise in the power quality due to the increased number of power electronic interfaces which could affect the stability of the grid.

4. Design of a Central Voltage Stability Controller for Hybrid DC/AC grid integration for energy flow priority with intelligent Battery Management System: The work done in this thesis presents a central voltage stability controller (CVSC) which has been designed and implemented to give energy flow priority to the consumers by using the hybrid system to support the grid. The DC energy of the renewable sources is collected and used to supply the loads at the feeders of the distribution system by using a single DC/AC converter. The grid supply is converted to DC and the energy mix is done at the DC line. The control strategy of the central controller is based on limiting the voltage level to maintain voltage stability at the DC line. The voltage stability is maintained by using the DG support for any contingency, which may occur at the grid, which in turn affects the consumer. The CVSC is made versatile by implementing an intelligent battery management system to take into account the type and variable nature of the renewable sources of the hybrid system.

Thus, in a nutshell, the objective of this thesis is to investigate and design intelligent strategies for distributed generation interface in a smart grid. The utilization of diverse local renewable sources for grid support as compared to a single distributed energy resource increases the challenges in terms of control, power quality and energy management. With hybrid DC/AC grid integration, the use of a single DC/AC converter helps reduce the number of power electronic devices, which in turn improves the power quality. Transients caused due to faults or using a central voltage stability controller, which ensures voltage stability, eliminates sudden load demands. This can be a step towards helping transform the conventional power systems to several microgrid installations thereby converting the existing grid to a smart grid.