Abstract

Owing to increased penetration of renewable energy resources to the existing grid, the power system today is facing different challenges. This includes reliability issues resulting from uncertainty in generation. Making the power system resilient is an important aspect today. In addition, many of the renewable resources including Solar PVs are dc in nature. Therefore, to avoid multiple stages of power conversion, power distribution through low and medium voltage level dc is showing promising features. Such dc grids are more efficient and absence of a frequency regulation criteria makes dc distribution more attractive than its ac counterpart. This dissertation reports some investigations on dc micro-grid with a motivation to address some of the existing challenges that dc distribution is facing today.

It is quite clear that dc systems have to take care of efficient integration of sources in one side and reliable dispatch of power to the load on the other side. As a first assumption, it is considered that the grid is predominantly fed from renewable energy sources those are intermittent in nature. Therefore, in the source-side it is not only important to extract maximum power but also handle the intermittency of generation either through appropriate storage or through source and/or load curtailment. In the load-side, of course, the load-voltage needs to be regulated and the system must survive in case of a fault. AC circuit breakers are easy to operate having natural zero every half-cycle but dc on the other hand needs some special strategy. DC circuit breakers are thus an emerging research area. This thesis focus on one of the most fundamental and important areas of dc micro-grid. A new series voltage regulator (SVR) is proposed that will keep the load voltage regulated thus making dc grid reliable and useful from practical view-point. The SVR utilizes an input-parallel and output-series topology to optimize the performance of the overall system. It uses a dual active bridge (DAB) at the input side, while a bipolar dc/dc converter that can generate variable dc voltage of either polarity at the output side to keep the load voltage regulated. Performance of the proposed SVR is demonstrated through extensive simulations and prototype experiments in the thesis.

Wide proliferation of dc systems needs a strategy for easy control of power from one grid to the other. Therefore, a power flow controller is required. Having such power flow controller (PFC) will promote receiving and/or sending a controlled amount of power from one grid to the other encouraging business between connecting micro-grids of different zones/region those may be of different ownerships. This thesis proposes a new power flow control architecture. The PFC utilizes the central idea of the SVR but instead of controlling the bus voltage at the consumer end, it controls power delivered/received between the busses or nodes. Simulation and experimental results show the capability of the power flow controller.

All practical systems need to be fault tolerant. Sources of faults in a dc systems can be many. For example, the load terminals can be dead shorted, the converter devices may fail, and the components such as capacitors may also develop failures after prolonged usage. This thesis also attempted to develop a fault tolerant dc systems that when sensing a fault withdraw all the gate pulses of the controlled switches. Proposed fault tolerant systems are investigated through simulations and experimentations. Note that the reliability and resiliency of the dc grid can be improved with energy storage. The thesis goes further to integrate energy-storage while connecting multi terminals. Batteries are connected to the intermediate dc bus in a PFC to regulate power flow

as per the need. A method (using optimization technique) to determine the storage capacity is also discussed. While in the battle of ac vs. dc, the winner is not known, this dissertation takes the current state-of-the-art of dc distribution systems one step ahead expecting widespread use of dc in low/medium voltage applications.

Keywords: Series Voltage Regulator (SVR), Power Flow controller (PFC), dc fault current limitation, energy storage integration, Dual Active Bridge (DAB), dc-dc converters, dc grids, microgrids.