DESIGN AND PERFORMANCE ANALYSIS OF MULTI-TERMINAL DC MICROGRID

A THESIS

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Declaration by the Research Scholar

This is to certify that the thesis entitled "**DESIGN AND PERFORMANCE ANALYSIS OF MULTI-TERMINAL DC MICROGRID**", submitted by me to the Indian Institute of Technology Mandi for the award of the degree of Doctor of Philosophy is a bonafide record of research work carried out by me under the supervision of **Dr. Bharat Singh Rajpurohit**. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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THESIS CERTIFICATE

This is to certify that the thesis titled **DESIGN AND PERFORMANCE ANALYSIS OF MULTI-TERMINAL DC MICROGRID**, submitted by **Rajeev Kumar Chauhan**, to the Indian Institute of Technology Mandi, for the award of the degree of **Doctor of Philosophy**, is a bonafide record of the research work done by him under my supervision. The contents of this thesis, in full or in parts, have not been submitted to any other Institute or University for the award of any degree or diploma.

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ABSTRACT

The central electricity grid infrastructure is poorly extended to rural areas in India. A promising approach to the challenge of rural electrification is to increase the deployment of decentralized energy generation through the use of microgrids, which refers to a smaller-scale electric grid combined with a local generation source. The DC microgrid provides the opportunity to integrate renewable energy resources (RESs) that are intrinsically DC source (i.e. Solar photovoltaic (PV), small wind turbines, or fuel cells) at higher efficiency. Most of the load in the residential/commercial buildings is DC loads or AC loads that can be easily converted to DC loads. Hence, the DC output of the RESs such as PV system can be directly utilized in the DC microgrid without converting into AC and feeding into the main grid. Therefore, DC microgrid reduces the conversion stages, power loss, demand and improves the reliability of the power systems. Microgrid is component to enable the future smart grid, which can operate either in grid-connected or island mode. The integration of distributed energy resources (DERs) and controllable loads brings tremendous opportunities to increase power system efficiency, sustainability, and reliability. However, the intermittency and variability of renewable DERs and limited supply, especially when the microgrid is operating in island mode introduce significant challenges to maintain the fundamental supply-demand balance for the system stability.

The previous energy management system does not have the ability to accommodate new source or load, since they were centralized control based system. The stochastic nature of PV power and variation in the demand is responsible for voltage fluctuations in the DC microgrids. The voltage stability is a most important issue in case of DC microgrids. The challenging thing is to maintain the microgrid voltage upto a reference value for the variable load. The electricity generation, based on RERs such as PV and wind are uncontrollable because they are depending on environmental conditions. The power fluctuation in DC microgrid due penetration of the RESs imposes the need of integration of the battery bank (BB) and capacitors with the RESs and loads to improve the quality and reliability of the system. The significant development in energy management increased the efficiently utilization of the BB and electric vehicle (EV) as electric energy storage (EES) devices in the DC microgrid. The utilization of such sources improves the system reliability and efficiency as these balances the system power. This requires a proper load or source scheduling. Unlike traditional AC systems, DC systems cannot survive or sustain high

magnitude fault currents. A fault causes the DC bus to de-energize completely; it makes locating faults very difficult. A nodal analysis with over-current (NAOC) and current differential (CD) approaches have been proposed to detect the fault in DC bus and service mains respectively. The demand side management (DSM) promotes distributed generation in order to avoid long-distance transport. The DSM facilitates the consumption of locally generated energy immediately whenever it is available for local loads. The main advantage of DSM's, is that of its less expensive nature to intelligently influence a load, have ability to build a new power plant or install some electrical storage device.

The software part of the thesis work has been done in the MATLAB m-file coding and MATLAB Simulink environment. In the first section of the thesis a comparative analysis of DC distribution system (DCDS) with AC distribution system (ACDS) is done in terms of losses meanwhile a study of basics of the DCDS like its different parts and a configuration has been done. In next second section an intelligent energy management system (IEMS) has been developed to ensure the load sharing (according to the source capacity) among sources and selection of the closest source to load to reduce the power loss in the system, and to enhance the system reliability and power quality. The PID and Fuzzy PID controllers have been designed in the next section of the thesis, for obtaining the voltage stability of the DC microgrid to maintain the microgrid voltage upto a reference value for the variable load and power generation of PV system. In the third section a real time electricity price based energy management (RTEPEM) system has been designed to optimize the energy cost by combined source and load management in a DC microgrid. There is a load shifting from one source to other source and utilization of storage energy in the EES devices, so that the cost of energy is minimized. In the fourth section the designed hardware set up for DC microgrid (includes PV plant and battery banks) is discussed and a DSM scheme has been developed to shift the deferrable load from non-sunny hours to sunny hours and decreases the building demand during non-sunny hours. Additionally, it decreases the charging/discharging cycles of the batteries; which is one of cause to decrease the battery life. The fifth section is related to the development of a protection scheme for fault detection and fault localization in the in DC bus and service mains. The goals of the proposed scheme are to detect the fault in bus segment, service mains of DG and load and then isolate the faulty section without outage of the entire system. Additionally, the power probe unit is used to identify the faulty status, fault location and fault resistance.

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