DESIGN, CONTROL AND PROTECTION OF VSC BASED DC MICROGRID

Thesis submitted in partial fulfilment of the requirements for the degree of

Master of Science

by

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under the Supervision of

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This research work is dedicated to my beloved family,

My Parents, Late Shri Ajay Dogra

and Smt. Shashi Dogra

And

My Wife, Nikita Gupta

Declaration by the Research Scholar

I hereby declare that the entire work embodied in this thesis is the result of investigations carried out by me at **School of Computing and Electrical Engineering**, Indian Institute of Technology Mandi, India, under the supervision of **Dr. Bharat Singh Rajpurohit** and **Dr. Narsa Reddy Tummuru**, and that it has not been submitted elsewhere for any Degree or Diploma. In keeping with the general practice, due acknowledgements have been made whenever the work described is based on finding of other investigators.

Place: IIT Mandi
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Declaration by the Research Advisor

I hereby certify that the entire work in this Thesis has been carried out by **Rahul Dogra**, under our supervision at the **School of Computing and Electrical Engineering**, Indian Institute of Technology Mandi, India, and that no part has been submitted elsewhere for any Degree or Diploma.

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Rahul Dogra

ABSTRACT

In recent years, with the exhaustion of fossil fuels and increasing public awareness about the use of green energy, renewable energy has gained popularity and is emerging as an important source of energy. Also, the electrical power grid is on the threshold of a paradigm shift from centralized power generation, transmission and massive electric grids to distributed generation (DG). Renewable energy sources (RES) like photovoltaic (PV) panels, wind turbine, fuel cells, are the important constituents of DG and provide electricity with higher reliability and security and have fewer harmful environmental consequences than traditional power generators.

With increased penetration of DGs into the traditional grid system, it is required to resolve the technical and operational problems viz. power quality, voltage instability, fault identification and clearing, etc. brought by the DG deployment. A microgrid may be one of the solutions to meet these challenges. A microgrid is a group of interconnected loads and distributed generators within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. There can be AC and DC microgrid depending upon the bus type and can be connected and disconnected from the grid to enable it to operate either in grid-tied or standalone mode. Recently, DC microgrid started to attract a lot of attention as they offer a natural interface to generation and consumption units such as renewable sources, energy storage systems and end-user electronic loads.

This research work aims at the design, control and protection of Voltage Source Converter (VSC) based DC microgrid. In order to predict the behaviour of the system under consideration, designing the overall system has been carried out comprising of the governing equations and behaviour is studied for steady-state as well as in the dynamic states. In the present work, PV is used as the distributed generator with two stages of power conversion consisting of the boost converter and grid interfacing inverter. The DC-DC converter is used to boost the output voltage of the PV array to the required DC-link voltage level along with the functionality of tracking the maximum power obtained from the PV array under varying irradiation and temperature.

The DC-AC converter is used to integrate the DC microgrid, formed using DG, loads and DC bus, to the AC grid. The interfacing control algorithms are used to control the DC-AC converter for its efficient utilization and grid synchronization. Conventional control algorithms are not best suited for nonlinear systems like VSC based DC microgrid as the overshoots and long settling time in their response are inevitable. In order to overcome the drawbacks of the conventional algorithms, SRLMS based adaptive control algorithm is proposed for the DC-AC converter. The algorithm also improves the utilization of the system studied by incorporating additional features of active power filter (APF) and VAR generation towards the AC grid.

The grid interconnection of DC microgrid has the advantage of efficient utilization of generated power. However, the power electronic converters are susceptible to huge losses in the case of DC faults, and it is important to protect DC microgrid against such fault scenario. This research work proposes two methods for fault detection based on Fourier analysis and superimposed components of the fault present. A circuit breaker is then used to isolate the faulty section. The proposed detection algorithms work quickly enough to prevent damage to sensitive electronic devices, as per expectations. Further, according to IEEE Std. 1547-2003, one more technical requirement of the grid interconnection is the response of the DC microgrid to islanding. This research work proposes a novel islanding detection algorithm based on the estimation and analysis of superimposed components of Point of Common Coupling (PCC) voltage and VSC current. The proposed algorithm is capable of detecting islanding events even under the worst-case scenario, where the inverter output power is nearly equal to the local load consumption.

The research work presented in the thesis is expected to provide good exposure to the design, control and protection of the VSC based DC microgrid.

Keywords: DC Microgrid, Faults, Islanding, Superimposed components, Protection, VSC control, converters, short circuit faults.

TABLE OF CONTENTS