ANALYSIS, DESIGN AND CONTROL OF MULTIPULSE VOLTAGE SOURCE CONVERTER BASED HVDC SYSTEM

by

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Submitted
in fulfilment of the requirements of the degree of
DOCTOR OF PHILOSOPHY

to the

INDIAN INSTITUTE OF TECHNOLOGY DELHI

NOVEMBER 2009

CERTIFICATE

This is to certify that the thesis entitled, "**Analysis, Design and Control of Multipulse Voltage Source Converter Based HVDC System**", being submitted by **Mr. D. Madhan Mohan** for the award of the degree of **Doctor of Philosophy** is a record of bonafide research work carried out by him in the Department of Electrical Engineering of the Indian Institute of Technology, Delhi.

Mr. D. Madhan Mohan has worked under our guidance and supervision and has fulfilled the requirements for the submission of this thesis, which to our knowledge has reached the requisite standard. The results obtained here in have not been submitted to any other University or Institute for the award of any degree.

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ACKNOWLEDGEMENTS

I express my deepest gratitude and indebtedness to Prof. Bhim Singh and Dr. B. K. Panigrahi for providing me a life-time opportunity to do the Ph.D work under their supervision. Working with them has opened a new horizon of state-of-the-art knowledge on HVDC technology for controlling and improving the electrical transmission system. Deep insight of Prof. Singh about the subject, ample research ideas, vast resourcefulness in electrical engineering, versatile exposure in international forum and his strong perception has immensely helped me to do their research work. His continuous monitoring, valuable guidance and input, has been always a source of inspiration and courage which are the driving forces to complete my work. It is a life time experience which I am to cherish always.

My heartfelt thanks and deep gratitude to Prof. P. R. Bijwe, Dr. G. Bhuvaneshwari and Prof. T. S. Bhatti all SRC members who have equally given me valuable guidance and advice to improve quality of my work. I am overwhelmed with their immeasurable valuable input received during my research work. I do convey my sincere gratitude and respect to Prof. S. S. Murthy, Prof. R. Balasubramanian, Dr. Sukumar Misra and Dr. M. Veerachary who have taught me all the relevant courses in IITD and helped a great deal to enrich my knowledge bank.

I am grateful to the staffs of PG section, Central library, Electrical Engineering Department Library for their valuable co-operation. I am extremely grateful particular to Shri Gurcharan Singh, Sh. Srichand, Sh. Puran Singh, Sh. Jugbeer Singh and other staff of Electrical Engineering's Drive and Simulation Lab., IIT Delhi for providing the facilities and assistance to carry out my research work. I would like to earnestly extend my sincere thanks to Dr. S. Gopinath, Dr. Parag R. Upadhyay, Dr. R. Saha, Mr. Arun Kumar, Mr. Ravi Kumar Pandi, Mr. P. Packiam, Mr. Ashish Srivatsava, Mr. P. Jayaprakash, Mr. Sanjeev Singh Chauhan, Mr. K.

Srinivas, Mr. Shailendra Sharma, Mr. V. Rajagopal, Dr. Vipin Kumar Garg, Dr. Sanjay Gairola, and Dr. Gaurav Kumar Kasal for their valuable assistance and co-operation. I am also grateful to those who have directly or indirectly helped me to complete my thesis work.

My deepest love, appreciation and indebtedness goes to my parents Mr. M. Duraikannu and Mrs. Kalarani Duraikannu, my wife Smt. Suganya Mohan, my lovable daughter Jaya Priyanka and my in-laws Mr. P. Shanmugam and Mrs. Saraswathy Shanmugam for their wholehearted support, encouragement and valuable time sharing. If I get any success today for the research work, the entire credit and honour should go to my family. It will remain unacknowledged if I don't mention the support of my brother-in-law Mr. M. Senthil and my sister Mrs. Karthiga Senthil and their children S. Kabilan and S. Umaiyal who have always provided the moral supports and enthusiasm in conducting this research work.

I am beholden to almighty for their blessing to help me to raise my academic level to this stage. I pray for their benediction in my future endeavors. From the place of heaven, they have and will give me the light of strength, knowledge, wisdom and determination to achieve what I have achieved so far.

Date :

Place : New Delhi

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ABSTRACT

Continuous growth in power demand increases the necessity of power systems expansion and power stations are being located far away from load centers. The applications of power electronics to power networks, such as High Voltage Direct Current (HVDC) and Flexible AC Transmission Systems (FACTS) enhances the power transmission capacity and efficiency, also improves the system stability. The HVDC technology is a high rating power electronics technology used in the electric power system for such applications as long distance, bulk power, submarine and an asynchronous link between two different frequencies ac grids. For many years, HVDC systems based on the line commutated thyristor converters have been used in these applications. Power semiconductor devices such as Insulated Gate bipolar Transistor (IGBT), Gate Turn off (GTO) thyristor and Insulated Gate-Commutated Thyristors (IGCTs) are commercially available at high voltage and current ratings and are best suited for these power system applications. They offer reliable and continuous operation even during power line disturbances. The HVDC systems with voltage source converters (VSCs) based on IGBT and IGCT are today possible and many commercial projects are already in place. However, it may not be viable for high power applications due to high switching losses.

A detailed investigation is carried out to achieve a cost effective solution with minimum switching losses for high power HVDC systems. This is achieved by operating the VSC converters at Fundamental Frequency Switching (FFS) with self commutating solid state switching devices either IGBT or IGCT or GTO. The problem of harmonics in the HVDC system is minimized due to fundamental frequency switching using multi-pulse VSC topologies.

These investigations are aimed at component level optimization in high power HVDC systems. The FFS gate control is proposed for VSC based HVDC systems in this research work. The multiple units of VSCs are used to have a stair-case waveform of converter AC voltage output close to a sinusoidal waveform. With such a converter configuration, lower order harmonics are mitigated and total harmonic distortion (THD) of current is restrained within the limits of IEEE harmonic standard.

A number of multipulse voltage source converter topologies are proposed for high power HVDC systems. These VSC topologies are (i) Two-level double bridge VSC based HVDC system (ii) Three-level double bridge VSC based HVDC system (iii) Three-level VSC based HVDC sysem with dynamic dead angle control and (iv) two level pulse width modulated VSC based HVDC system. A control algorithm is developed for all these above VSC topologies for HVDC system to provide bidirectional active power flow, an independent reactive power control at the rectifier and an inverter station with the dc bus voltage control. The detailed designs of various multipulse VSC topologies are presented for HVDC system. The performance of the proposed multipulse voltage source converters based HVDC systems are implemented in MATLAB along with Simulink and SPS (Sim Power System) toolboxes.

These four types of VSCs in 12, 18, 24 and 48-pulse VSC configurations are designed and modeled, their performances are studied for HVDC systems for bidirectional active power flow and an independent bidirectional reactive power control at both the converter stations. The performance of these VSC based HVDC systems is found quite encouraging in all four quadrants of active and reactive powers with improved power quality.

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