Modelling and Control of the Modular Multilevel Matrix Converter and its application to Wind Energy Conversion Systems

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Abstract—In the last past years, some countries are enforcing stringent grid codes to regulate the connection of Wind Energy Conversion Systems (WECSs) to the electrical network, mainly because of the high penetration of electric power from this renewable source. Additionally, the trend of wind turbines has shown an ongoing power rating growth, reaching sizes up to 10 MW. Multilevel converters have appeared as a solution for large WECSs, due to its high reliability, controllability and the capability to reach high power ratings. This paper presents a control strategy for the application of the Modular Multilevel Matrix Converter in Multimegawatts Wind Turbines. Extensive computer simulations and a downscaled laboratory prototype, with twenty-seven power cells, are presented to validate the effectiveness of the proposed control system.

Keywords— *Wind Turbines, Wind Energy Conversion Systems, Fault Ride-Through Capability, Modular Multilevel Matrix Converter.*

I. INTRODUCTION

Wind Energy has become in the industry with greatest and fastest growth among all the renewable energy sources. The wind energy production capacity for the whole world increased exponentially from 17.4 GW in 2000 to 432.4 GW in 2015, positioning wind power as a significant and crucial energy source in areas as China, USA and Europe. Powered 30.5 GW of new installations in China, the global wind power installed in 2015 was 63 GW, representing annual market growth of 22% [1].

A constant increment of wind power capacity is expected in the near future. Truthfully, the European Wind Energy Association (EWEA) plan for the next years is to become wind industry in the most competitive energy source, by 2020 onshore and offshore by 2030. The EWEA has stated that "wind power would be capable of contributing up to 20% of EU electricity by 2020, 30% by 2030 and 50% by 2050".

An important part of the required future installed wind power will be offshore based, because of the higher wind-energy potential and the lower environmental impacts. Going offshore implies several technology challenges, mainly regarding reliability, efficiency and upscaling. Considering that hugely expensive platforms must support the total weight of the WECS, the size and weight of components are critical, and possible weight reductions become crucial. What is more, it has been demonstrated that high power wind turbines could reduce the cost structure of offshore WECS, reason why upscaling has
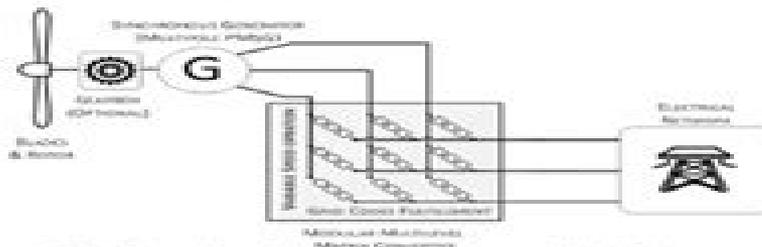
Fig. 1: Proposed topology to drive a High-power Wind Turbine.

become the focus of modern wind energy application and research [2], and why wind turbines manufacturers have been upscaling turbine dimensions.

However, most of the present WECSs are based on low-voltage two-level voltage source power converters (usually based on 1700-V IGBT devices for a 690-V voltage level), which is not the best technology for high power applications due to the high currents required. Consequently, medium or high voltage power electronic converters (e.g. multilevel converters) are well suited for high-power wind turbines. Therefore, Modular Multilevel Converters appears as a suitable technology to reach high power ratings.

The Modular Multilevel Matrix Converter (M³C) is a modular AC/AC converter able to reach medium-voltage levels by the series connection of full-bridge modules. This converter has some advantages compared to traditional two-level converters for high-power applications, fundamentally focused on the full modularity and easy extendibility to reach high voltage and high power levels, redundancy, control flexibility and power quality improvements [3], [4].

In this context, this paper introduces the application of the M³C to drive high-power WECSs, as is illustrated in Fig. 1. Comprehensive theoretical discussion on the control and modelling of the M³C is considered. Finally, the effectiveness of the proposed topology is confirmed by experiments using simulation models and a downscaled 5kW laboratory prototype.

GRID INTEGRATION REQUIREMENTS FOR WECS

In countries with a high penetration of renewable energies, dedicated grid code regulations have been enforced to ensure the

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    Modular Multilevel Converters Sixing Du,Apparao Dekka,Bin Wu,Navid Zargari,2018-02-22 An invaluable academic reference for the area of high power converters covering all the latest developments in the field High power multilevel converters are well known in industry and academia as one of the preferred choices for efficient power conversion Over the past decade several power converters have been developed and commercialized in the form of standard and customized products that power a wide range of industrial applications Currently the modular multilevel converter is a fast growing technology and has received wide acceptance from both industry and academia Providing adequate technical background for graduate and undergraduate level teaching this book includes a comprehensive analysis of the conventional and advanced modular multilevel converters employed in motor drives HVDC systems and power quality improvement Modular Multilevel Converters Analysis Control and Applications provides an overview of high power converters reference frame theory classical control methods pulse width modulation schemes advanced model predictive control methods modeling of ac drives advanced drive control schemes modeling and control of HVDC systems active and reactive power control power quality problems reactive power harmonics and unbalance compensation modeling and control of static synchronous compensators STATCOM and unified power quality compensators Furthermore this book Explores technical challenges modeling and control of various modular multilevel converters in a wide range of applications such as transformer and transformerless motor drives high voltage direct current transmission systems and power quality improvement Reflects the latest developments in high power converters in medium voltage motor drive systems Offers design guidance with tables charts graphs and MATLAB simulations Modular Multilevel Converters Analysis Control and Applications is a valuable reference book for academic researchers practicing engineers and other professionals in the field of high power converters It also serves well as a textbook for graduate level students   Modular Multilevel Converter Modelling and Simulation for HVDC Systems Davide del Giudice,Federico Bizzarri,Daniele Linaro,Angelo Maurizio Brambilla,2022-10-21 This book provides a comprehensive review of the models and approaches that can be employed to simulate modular multilevel converters MMCs Each solution is described in terms of operating principle fields of applicability advantages and limitations In addition this work proposes a novel and efficient simulation approach for MMCs based on sub circuit isomorphism This technique which has its roots in the electronics fields can be profitably exploited to simulate MMCs regardless of the model used to describe its sub modules including the most accurate ones Lastly this book considers a well known high voltage direct current HVDC benchmark system consisting of two MMCs After describing the implementation details of each benchmark component simulation results in several scenarios ranging from normal operating conditions to faults in the AC and DC grid are included to validate the proposed approach and showcase its key features Due to its educational content this book constitutes a useful guide for PhD students and researchers interested in the topic of MMCs and their simulation It also serves as a starting platform for junior

electrical engineers who work in the field of power electronic converters for HVDC systems <u>Design, Control, and Application of Modular Multilevel Converters for HVDC Transmission Systems</u> Kamran Sharifabadi,Lennart Harnefors,Hans-Peter Nee,Staffan Norrga,Remus Teodorescu,2016-10-17 Design Control and Application of Modular Multilevel Converters for HVDC Transmission Systems is a comprehensive guide to semiconductor technologies applicable for MMC design component sizing control modulation and application of the MMC technology for HVDC transmission Separated into three distinct parts the first offers an overview of MMC technology including information on converter component sizing Control and Communication Protection and Fault Management and Generic Modelling and Simulation The second covers the applications of MMC in offshore WPP including planning technical and economic requirements and optimization options fault management dynamic and transient stability Finally the third chapter explores the applications of MMC in HVDC transmission and Multi Terminal configurations including Supergrids Key features Unique coverage of the offshore application and optimization of MMC HVDC schemes for the export of offshore wind energy to the mainland Comprehensive explanation of MMC application in HVDC and MTDC transmission technology Detailed description of MMC components control and modulation different modeling approaches converter dynamics under steady state and fault contingencies including application and housing of MMC in HVDC schemes for onshore and offshore Analysis of DC fault detection and protection technologies system studies required for the integration of HVDC terminals to offshore wind power plants and commissioning procedures for onshore and offshore HVDC terminals A set of self explanatory simulation models for HVDC test cases is available to download from the companion website This book provides essential reading for graduate students and researchers as well as field engineers and professionals who require an in depth understanding of MMC technology **Modeling and Control of Modular Multilevel Converter Based on Ordinary Differential Equations and Its Applications for HVDC System** Haihao Jiang,2020 High voltage direct current HVDC system is more efficient than high voltage alternating current HVAC system for long distance bulk power transmission Modularity flexibility reliability and high efficiency make the modular multilevel converter MMC the topology of choice in HVDC applications Because the increasing number of installations shows that the MMC HVDC is the HVDC of the future this thesis is continuing research to advance the capability of the MMC HVDC This thesis focuses on fast simulation capability and control strategies for the MMC HVDC The main objectives are 1 to develop a fast and accurate simulation model of a single MMC station and models of multi terminal MMC HVDC stations MTDC MMC 2 to investigate the method to design proper parameters for high damping 3 to design the MMC HVDC with the capability of power oscillation damping POD Simulation is computation intensive in MMC The thesis develops a fast and accurate method by which an MMC station is modeled by ordinary differential equations ODE The proposed MMC ODE model is implemented in MATLAB SIMULINK and its correctness is validated by the MMC Detail Equivalent Model DEM in RT LAB Taking advantage of its speed and accuracy a Four Terminal MMC HVDC system based on

the MMC ODE model is developed The ODE model meets the speed and accuracy requirements of power systems engineers who are concerned with planning operation and protection studies As the ordinary differential equations are nonlinear small perturbation about a steady state is applied to obtain the linearized time periodic matrix The steady state takes a long time to simulate because it depends on the transients to have all damped out The method of Aprille and Trick is applied Simulation converges to the steady state in one cycle of 50 Hz The resultant linearized matrix is time periodic The Floquet Lyapunov Theorem is applied to construct the state transition matrix from the linearized time periodic matrix The eigenvalues of the state transition matrix contain the coefficients of damping Graphs of damping coefficients plotted against different sizes of circuit parameters are displayed to assist designers in realizing high damping The thesis looks for opportunities to add value to the MMC HVDC The active power transmissibility of AC transmission lines is limited by the transient stability limit which is significantly below the thermal limit Extensive research and development have been pursued to increase the transient stability limit by flexible AC transmissions system FACTS This thesis seeks to use the MMC HVDC to operate as power oscillation damper to increase the power transmissibility The thesis looks for opportunities to integrate previously proven control methods into a common universal control The Universal Controller brings together the deadbeat control the circulating current suppression control CCSC the POD and the decoupled P Q strategy in the control of the MMC HVDC station by the MMC ODE model Deadbeat control enables the MMC to survive destructively large AC fault currents to improve the transient stability of AC grids   **High Voltage Direct Current Transmission** Dragan Jovcic,Khaled Ahmed,2015-07-23 This comprehensive reference guides the reader through all HVDC technologies including LCC Line Commutated Converter 2 level VSC and VSC HVDC based on modular multilevel converters MMC for an in depth understanding of converters system level design operating principles and modeling Written in a tutorial style the book also describes the key principles of design control protection and operation of DC transmission grids which will be substantially different from the practice with AC transmission grids The first dedicated reference to the latest HVDC technologies and DC grid developments this is an essential resource for graduate students and researchers as well as engineers and professionals working on the design modeling and operation of DC grids and HVDC Key features Provides comprehensive coverage of LCC VSC and half and full bridge MMC based VSC technologies and DC transmission grids Presents phasor and dynamic analytical models for each HVDC technology and DC grids Includes HVDC protection studies of DC and AC faults as well as system level studies of AC DC interactions and impact on AC grids for each HVDC technology Companion website hosts SIMULINK SimPowerSystems models with examples for all HVDC topologies   *Model Predictive Control of Modular Multilevel Converters* Andres Mauricio Lopez Canon,2018 This work addresses problems that arise with the application of Model Predictive Control MPC to Modular Multilevel Converters MMCs by aiming to reduce the complexity of the optimization problem associated with the controller while properly tracking the converter states Due to the complexity of the

MMC principally attributed to the high dimension of its state space model along with the high number of discontinuous switching variables available solving the optimization problem associated with the MPC can be challenging This becomes more significant when long prediction horizons are required In order to address this problem this work presents a reduced order model that aims to reduce the complexity of the state space model of the MMC and to eliminate the discontinuities associated with the converter switches In order to validate this approach the accuracy and limitations of this model are analyzed and identified in detail Moreover with the help of the reduced order model detailed references for the MMC are carefully designed and for the case presented in this work reference parameters are selected optimally in order to reduce the voltage ripple in the converter modules The complexity of the optimization problem associated with the MPC is also reduced with the help of the reduced order model by considering just one continuous control signal per converter arm To further aid the optimization a method to derive conditions that guarantee its convexity is presented By guaranteeing convexity it is possible to use very well studied and efficient optimization algorithms easing the application of MPC on MMC especially in the case where long prediction horizons are required In order to illustrate the proposed procedure numerical examples are presented in a simulation environment eng Modeling and Control of Modular Multilevel Converters Su Zhang,2020 The investigation of improved semiconductor devices power converter topologies and modulation schemes is essential for the development of advanced power electronics technology As a preferred option of power conversion for high power applications multilevel converters especially Modular Multilevel Converters MMCs are gaining increasing popularity in both industry and academia However there are several technical challenges associated with the MMC topology One of the main challenges is the minimization of voltage variations in module capacitors In addition the circulating currents which originate from both the capacitor voltage variations and switching scheme increase the rating of power devices and power losses Typically cascaded control schemes based on Proportional Integral PI controllers and Pulse Width Modulators PWMs have predominately been used to control MMCs However tuning of multiple PI loops is difficult and also influences the performance of MMC at both steady state and transient operating conditions To overcome these drawbacks this thesis proposes a Model Predictive Direct Slope Control MPDSC scheme for MMCs This scheme is capable of handling multiple control objectives without using a modulator thus significantly simplifies the complexity of the control scheme In addition a long prediction horizon can be generated without increasing the computational burden of the control algorithm and therefore the performance of the MMC could be further improved with a shorter sampling time The viability of MPDSC is demonstrated using simulated and experimental results of a 380 VA prototype MMC as well as benchmarking against the performance of a prototype controlled by Model Predictive Direct Current Control MPDCC scheme The MPDSC offers performance that is comparable to MPDCC but with significantly reduced complexity and computational burden However this scheme considers all possible switching states to evaluate each control variable this invariably making the computational burden still heavy In

addition to this the tuning of multiple weighting factors is cumbersome and inefficient To overcome these drawbacks this thesis proposes a Hierarchical Model Predictive Control HMPC scheme for MMCs With this scheme the load currents are regulated within symmetrical bounds using a modified MPDSC and the capacitor voltages circulating currents and switching frequency are minimized through a Model Predictive Multilayer Control MPMC scheme To reduce computational burden of the control algorithm HMPC evaluates each control variable independently while minimizing the number of switching states for evaluation Instead of using conventional weighting factors HMPC utilizes the number of switching states of lower costs as a tuning factor for each control variable which makes the tuning process efficient and adaptable to any operating conditions A comparison with a conventional Finite Control Set Model Predictive Control FCS MPC scheme using simulated as well as experimental results of a prototype MMC reveals that HMPC offers superior performance With MPDSC and HMPC schemes the capacitor voltage variations of MMCs can only be reduced to a certain level Therefore this thesis presents a modified MMC topology that utilizes an Inductive Power Transfer IPT system to maintain the capacitor voltages within tight bounds This topology simplifies the control of capacitor voltages irrespective of the switching scheme and operating conditions of the converter A mathematical model of the modified topology is developed and a control scheme is also proposed The feasibility of the control scheme and the accuracy of the mathematical model are validated using simulated as well as theoretical results of a 2 kVA MMC IPT system **Advances in Renewable Energy & Electric Vehicles** Suryanarayana Kajampady,Shripad T. Revankar,2023-11-14 This book presents select peer reviewed proceedings of the International Conference on Advances in Renewable Energy and Electric Vehicles AREEV 2022 The topics covered include renewable energy sources electric vehicles energy storage systems power system protection security smart grid and wide bandgap semiconductor technologies The book also discusses applications of signal processing artificial neural networks optimal and robust control systems and modeling and simulation of power electronic converters The book is a valuable reference for academics and professionals interested in power systems renewable energy and electric vehicles **Low-Carbon Oriented Market Mechanism and Reliability Improvement of Multi-energy Systems** Minglei Bao,Sheng Wang,Liang Du,Zhengmao Li ,Weiqi Hua,2024-12-17 The energy crisis has brought great challenges to the low carbon and economic development of the energy system To achieve net zero emissions energy systems can have an increasing penetration of renewable energy and a deep coupling of multiple energy sectors i e electricity gas and heat To deal with the increasing fluctuations of renewable energy in multi energy systems the market mechanism is an effective solution for the optimal allocation of resources An optimal market design could stimulate different resources to actively assist the carbon reduction and reliability improvement of multi energy systems Therefore research on low carbon oriented market design and optimal operation is expected to improve the reliability and sustainability of multi energy systems The objective of this Research Topic is to explore the latest advances in market design and reliability improvement technologies of multi energy systems with a focus on low carbon reliability and resilience We

have the following research goals 1 Effective market mechanisms and interaction frameworks to support the operation of energy systems 2 Advanced operation and control methods for flexible resources such as traditional units energy storage electric vehicles electric hydrogen production etc 3 Advanced planning strategies and portfolio management for flexible resources in multi energy systems 4 Advanced evaluation methods for flexibility resilience and carbon emissions of energy systems 5 Effective applications of integrated demand response in energy systems with new technical and economic models Original research and review articles in theoretical methodological or practical focuses such as models policies algorithms and applications are all welcome Research areas may include but are not limited to the following Low carbon oriented market mechanism Interaction framework designs for flexible resources Modeling and optimization technologies for multi energy systems Evaluation methods for the system resilience flexibility and carbon emissions Operation control and planning methods of multi energy systems Applications of artificial intelligence technology in reliability improvement Renewable energy prediction and integration   *Model Predictive Control of Modular Multilevel Converters* Andres Mauricio Lopez Canon,2018 This work addresses problems that arise with the application of Model Predictive Control MPC to Modular Multilevel Converters MMCs by aiming to reduce the complexity of the optimization problem associated with the controller while properly tracking the converter states Due to the complexity of the MMC principally attributed to the high dimension of its state space model along with the high number of discontinuous switching variables available solving the optimization problem associated with the MPC can be challenging This becomes more significant when long prediction horizons are required In order to address this problem this work presents a reduced order model that aims to reduce the complexity of the state space model of the MMC and to eliminate the discontinuities associated with the converter switches In order to validate this approach the accuracy and limitations of this model are analyzed and identified in detail Moreover with the help of the reduced order model detailed references for the MMC are carefully designed and for the case presented in this work reference parameters are selected optimally in order to reduce the voltage ripple in the converter modules The complexity of the optimization problem associated with the MPC is also reduced with the help of the reduced order model by considering just one continuous control signal per converter arm To further aid the optimization a method to derive conditions that guarantee its convexity is presented By guaranteeing convexity it is possible to use very well studied and efficient optimization algorithms easing the application of MPC on MMC especially in the case where long prediction horizons are required In order to illustrate the proposed procedure numerical examples are presented in a simulation environment eng

State Space Modelling and Control of the Modular Multilevel Converter Dennis Bräckle,2021   Analytical Efficiency Evaluation of Modular Multilevel Converter (MMC) for High Voltage Direct Current System (HVDC) Ehtasham Mustafa,2016-02-25 Master s Thesis from the year 2014 in the subject Electrotechnology University of Peshawar University of Engineering and Technology Peshawar Pakistan course High Voltage Direct Current language English abstract Modular

Multilevel Converter MMC has become the most concerned converter topology in the High Voltage Direct Current HVDC transmission system in recent times The low switching frequency low converter losses and flexible control made it most attractive topology It is important to make a research on the loss calculation method of MMC and state formulae for the losses as it is a vital step during the design stage of the MMC based HVDC system In this research work the structure of MMC based HVDC system is discussed Three sub module topologies half bridge full bridge and clamp double sub module are discussed A method based on the average and root mean square RMS values of the current passing through the sub module is discussed The conversion losses in the switching devices of the sub modules are calculated using the method A cases study is taken into consideration then with certain parameters Using these parameters a MATLAB program is developed With the help of the program the losses and efficiency curves for each switching device by taking each sub module separately are obtained respectively A comparison of the losses and efficiency of each sub module is also discussed At the end those factors which effect the losses and efficiency of the sub module are discussed along with the certain aspects for the directions of future work **Investigation of Modulation Dynamics and Control of Modular Multilevel Converter for High Voltage DC Grids** Ashok Nampally,2017 Developing the MMC average model in DQ0 frame was a challenging task because of the multiplication terms in the MMC average model in ABC frame The proposed approach to overcome this challenge is considering generic form for the product variables and multiplying them in ABC frame and then transferring only the DC and fundamental frequency components of the results to DQ0 frame The comparisons between detailed model and the average model validated the effectiveness of the average model in representing the dynamics of MMC It is at least one hundred times faster than the detailed model for the same simulation time step Finally a dynamic analytical MMC model and associated controls have been proposed To enable the model application to a broad range of system configurations and various dynamic studies the model is built on a modular modelling approach using four sub systems an AC system Phase Locked Loop PLL system MMC system and a DC arrangement The developed MMC system model has been linearized and implemented in state space form To select the best open loop controller gains eigenvalue analysis is performed for each particular test system The rationality and correctness of the proposed model are verified against non linear PSCAD EMTDC simulations and good accuracy is obtained in the time domain analysis Further the model is also verified in the frequency domain and it is concluded that the developed model can be employed for dynamic analysis below 300 Hz *Modelling, Control and Optimisation of Low Capacitance Modular Multilevel Converters* Sumeet Singh Thakur,2022 *Design, Analysis, and Control of the Modular Multilevel DC/DC Converter for Medium- and High-voltage DC Grids* Ramin Razani,2022 Nowadays renewable energy sources have gained escalating importance due to environmental and economic reasons However these energy sources are primarily located in remote areas and distant from load centers High voltage dc HVDC and medium voltage dc MVDC systems have been proposed in the last decades for efficient and reliable integration of renewable energy

resources To date a noticeable number of these dc systems are established around the world Recently researchers have proposed the concept of DC grids which can be realized by connecting the existing point to point dc systems This structure can improve the efficiency and stability of the power system However one of the most concerning challenges related to this concept is the interconnection of already built dc systems Because existing dc systems are built through time they possibly have different voltage levels and grounding systems To address this challenge the dc dc modular multilevel converter MMC is proposed in the literature as one of the most promising solutions This converter offers the advantages of modularity scalability and high efficiency Few studies have been conducted on the modeling and control of the dc dc MMC The literature falls short in several aspects such as improved design analysis of operation limits fault tolerant operation converter analysis under uncertainty and development of advanced controllers and efficient fault blocking capability This research aims to 1 develop an augmented design approach that considers both control and hardware aspects of the converter 2 investigate the operation limit of the hybrid dc dc MMC caused by the capacitors voltages unbalance 3 develop a tailored fault tolerant operation strategy without additional submodules SMs 4 analyze the unsymmetrical operation of the dc dc MMC caused by parametric uncertainty 5 develop an advanced controller based on the model predictive control for the dc dc MMC and 6 realize an efficient fault blocking capability by proper selection of SMs The first study in this thesis facilitates the dc dc MMC design with a smaller number of SMs and higher efficiency Unlike the previous literature the analytical results of the second study show that the capacitors voltages balance in the hybrid dc dc MMC limits the operation range of the converter In the third study first the unique features of the dc dc MMC are investigated These features make the fault tolerant operation possible without the need for additional SMs Then utilizing these features a tailored fault tolerant operation strategy is developed to cope with several SMs failures When the parametric uncertainty comes into action it can force the converter to work in unsymmetrical conditions The fourth study develops steady state models representing the behavior of the converter in unsymmetrical conditions and then the maximum tolerable variation of parameters is found in different practical cases An advanced controller based on the model predictive control is developed in the fifth study to improve the steady state and transient performances of the dc dc MMC Finally an efficient fault blocking capability is realized by adequately selecting the number and type of SMs Detailed time domain simulations under the MATLAB Simulink environment validate the analytical results This research contributed to the fundamental understanding of the dc dc MMC operation and significantly improved the converter efficiency reliability and steady state and dynamic performances **Model Predictive Control of a Modular Multilevel Converter** Xiaonan Gao,2022 **Design and Control of Modular Multilevel Converters** Baljit Singh Riar,2015 An increasing awareness of energy efficiency has led to the development of several improved semiconductor devices power converter topologies and control schemes within the field of power electronics Recent advances in multilevel converters especially Modular Multilevel Converters M2LCs have improved upon existing power conversion technology in

several aspects including efficiency power quality modularity and reliability There are however several challenges associated with the M2LC topology which include capacitor voltage variations voltage balancing circulating currents and increased complexity of the overall control scheme This thesis contributes to the ongoing research on the M2LC topology by proposing the following solutions to the aforementioned challenges Typically schemes with cascaded control loops have been used to control M2LCs and these schemes could affect the performance of the converter Model Predictive Direct Current Control MPDCC which has a single loop is proposed to keep load currents within tight bounds while minimising both capacitor voltage variations and circulating currents Moreover the width of the current bounds sets the level of Total Harmonic Distortion THD of the currents Simulated and experimental results for a 860 VA prototype M2LC are presented to demonstrate the effectiveness of the MPDCC scheme A modified M2LC topology that employs a full bridge module in each arm is proposed to minimise both circulating currents and capacitor voltage variations The modified topology allows for decoupled control of the load and circulating currents where the load and circulating currents are controlled by the half bridge and full bridge modules respectively A comparative investigation with respect to a conventional topology using theoretical as well as experimental results for a 800 VA prototype converter reveals that the modified topology offers superior performance Capacitor voltage variations are difficult to control within the conventional M2LC because the variations are coupled to arm currents and load currents An alternative M2LC topology that uses Inductive Power Transfer IPT technology is proposed to simplify the control of the capacitor voltages The IPT system keeps the voltage variations within bounds irrespective of the operating conditions of the converter The feasibility of the concept and improvements achieved with the alternative topology are demonstrated using simulations of a 800 VA converter **Information Technology Applications in Industry, Computer Engineering and Materials Science** S.Z. Cai,Q.F. Zhang,2013-09-18 Selected peer reviewed papers from the 2013 3rd International Conference on Materials Science and Information Technology MSIT 2013 September 14 15 2013 Nanjing Jiangsu China **Operation, Control, and Simulation of Modular Multilevel Converters with Embedded Energy Storage** Nuwan Madushanka Herath Herath Mudiyanselage,2019 Modular Multilevel Converters MMCs with storage have become popular to interconnect energy storage into power systems The complexity of the converter makes the EMT simulation inefficient This thesis presents a detailed equivalent model DEM which can be used to efficiently and accurately simulate MMCs with storage accurately Operation and control methods of these converters are studied The developed DEM is validated against a detailed switching model DSM implementation of a single phase MMC with storage An application case of the MMC with storage in a microgrid is also studied for simulation efficiency and the impact of storage on a network A prototype is used to validate simulation results developed from the DEM The thesis shows that the DEM can produce accurate simulation results for MMCs with storage Reduction of computing time achieved by the DEM is validated The waveforms obtained from a prototype further validates the accuracy of the DEM <u>Design, Control and</u>

Testing of Modular Multilevel Converter Prototype Carlos Collados Rodríguez,2017 This Master Thesis presents the design control and testing of a Modular Multilevel Converter MMC prototype This Voltage Source Converter VSC topology provides several advantages compared to previous generations for High Voltage Direct Current HVDC applications such as reduced harmonic distortion and lower switching losses Today most of the planned VSC HVDC projects are based on the MMC technology First a mathematical model of the MMCs is obtained Based on the analytical description of the converter two di erent control strategies for MMCs are studied and its performance is evaluated by means of time domain simulations developed in Matlab Simulinkr The second part describes the construction of a 5 kVA MMC prototype focusing on the converter submodule design A procedure to de ne its main circuits including the components selection is detailed Then the layout of the submodule PCB is designed using Altium Designerr Finally an experimental MMC prototype is built based on the developed hardware design Then the studied control strategies are implemented in order to analyze their performance in a real setup The control and modulation of the MMC is programmed in a Digital Signal Processor DSP The obtained experimental results show an adequate behavior of the prototype for the implemented controllers Carlos Collados

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