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Control of the Modular Multilevel Matrix Converter for Wind Energy Conversion Systems

The nominal power of single Wind Energy Conversion Systems has been steadily growing, reaching power ratings close to 10MW. In the power conversion stage, medium-voltage power converters are replacing the conventional low-voltage back-to-back topology. Modular Multilevel Converters have appeared as a promising solution for Multi-MW WECSs due to their characteristics such as modularity, reliability and the capability to reach high nominal voltages. Thereby, this thesis discusses the application of the Modular Multilevel Matrix Converter (M^3C) to drive Multi-MW Wind Energy Conversion Systems (WECSs).

The modelling and control systems required for this application are extensively analysed and discussed in this document. The proposed control strategies enable decoupled operation of the converter, providing maximum power point tracking capability at the generator-side, grid-code compliance and Low Voltage Ride Through Control at the grid-side and good steady state and dynamic performance for balancing the capacitor voltages of the converter.

The effectiveness of the proposed control strategies is validated through simulations and experimental results. Simulation results are obtained with a 10 MW, 6.6 kV M^3C based WECS model developed in PLECS software. Additionally, a 5 kVA downscale prototype has been designed and constructed during this Ph.D.

The downscale prototype is composed of 27 H-Bridges power cells. The system is controlled using a Digital Signal Processor connected to three Field Programmable Gate Array which are equipped with 50 analogue-digital channels and 108 gate drive signals. Two programmable AMETEK power supplies emulate the electrical grid and the generator. The wind turbine dynamics is programmed in the generator-side power supply to emulate a generator operating in variable speed/voltage mode. The output port of the M^3C is connected to another power source which can generate programmable grid sag-swell conditions.

Simulation and experimental results for variable-speed operation, grid-code compliance, and capacitor voltage regulation have confirmed the successful operation of the M^3C based WECSs. In all the experiments, the proposed control systems ensure proper capacitor voltage balancing, keeping the flying capacitor voltages bounded and with low ripple. Additionally, the performance of the generator-side and grid-side control system have been validated for Maximum Power Point Tracking and Low-Voltage Ride Through, respectively.