

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 2040. 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 largely 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

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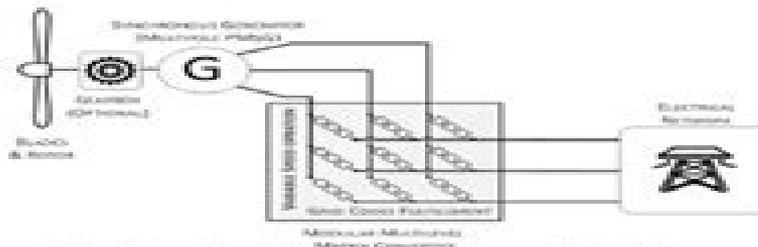


Fig. 1. Proposed topology to drive a High-power Wind Turbines

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 (MPC) 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 extensibility 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 MPC to drive high-power WECSs, as is illustrated in Fig. 1. Comprehensive theoretical discussion on the control and modelling of the MPC 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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