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Research Paper on Connecting High-Capacity Offshore Wind Turbines to Modular Multilevel Converters for Enhanced Energy Transfer

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***Abstract* -** *The integration of multi-megawatt offshore wind turbines with modular multilevel converters (MMCs) provides an efficient and scalable way to deliver long-term renewable energy. Offshore wind farms, which are often located far from the shore, face problems such as different energy sources and the need for high power transmission. MMCs, known for their design, provide better performance, fault tolerance, and reduced variability, making them ideal for use in high-voltage direct current (HVDC) transmission. This paper examines how MMCs are used to influence offshore wind turbines, convert AC to DC power, and stabilize transmission to onshore grids. The system improves power quality, has good performance, and improves error-free operation, while advanced control strategies promote stable plans and black-start capabilities. Continuous research is aimed at improving reliability, improving control methods, and lower costs, placing MMC-based HVDC as a key technology for the development of Coastal winds.*

Key Words- Offshore Wind Turbines,Multi-Megawatt Capacity, Modular Multilevel Converters (MMCs), High-Voltage Direct Current (HVDC), Power Conversion ,Energy Transmission

I. INTRODUCTION

In - Offshore wind energy has emerged as one of the fastest-growing renewable energy sources, driven by its ability to harness powerful and consistent wind speeds over ocean surfaces. With global capacity surpassing 60 GW as of 2023, the offshore wind sector is poised for rapid expansion, with targets set to exceed 200 GW by 2030, led by countries like China, the UK, and the United States. This growth has been fueled by significant technological advancements, particularly the development of larger wind turbines,

with modern units now exceeding 12 MW in capacity. These advancements enable higher energy generation per turbine, making offshore wind farms an increasingly viable solution for meeting global energy demands. Additionally, offshore wind offers key advantages, including access
to higher wind speeds and abundant space, allowing for large-scale installations that can operate with greater efficiency and reduced land-use conflicts compared to onshore wind farms. This introduction sets the stage for exploring the technological, economic, and environmental aspects of offshore wind energy as a

critical component of the global transition to clean energy.

The interfacing of multi-megawatt offshore wind turbines with modular multilevel converters (MMCs)

		CS	DFIG	GFC	DD
Cost, size and weight		+	+/-	+/-	-
Suitability for 50 and 60 Hz grid		-	-	+	+
Audible noise from blades		-	+	+	+
Energy yield	Variable speed	-	+	+	+
	Gearbox	-	-	-	+
	Generator	+	+	+	-
	Converter	+	+/-	-	-
Reliability and maintenance	Brushes	+	-	+	- (PM: +)
	Gearbox	-	-	-	+
	Mechanical loads	-	+	+	+
	Complexity	+	-	-	-
Power quality	'Flicker'	-	+	+	+
	V & f control possible	-	+	+	+
	Harmonics	+	-	-	-
Grid faults	Fault currents	+	-	-	-
	Fault ride-through	+	+/-	+	+
	Restoring voltage	-	+/-	+	+

enables efficient transmission of renewable energy from remote offshore locations to onshore grids. Offshore wind turbines generate alternating current (AC), which is converted to direct current (DC) by MMCs for high-voltage direct current (HVDC) transmission, minimizing power losses over long distances. MMCs, known for their modularity and scalability, provide enhanced fault tolerance, improved power quality, and flexible control strategies to manage the fluctuating energy output from wind turbines. This integration ensures stable grid connections, supports reactive power control, and offers the ability for black-start operations. Research continues to focus on optimizing converter efficiency, reducing costs, and improving reliability, positioning MMC-based HVDC systems as a crucial technology for the large-scale deployment of offshore wind energy.

II. PROBLEM STATEMENT

- Use adaptive control for variable-speed WECSs.
- Regulate flying capacitors without affecting currents and voltages.
- Ensure input supports variable speed and MPPT.
- Ensure output meets grid connection and compliance.
- Manage capacitor oscillations for similar
- input/output frequencies.

III. WIND ENERGY CONVERSION SYSTEM

Table 3.1: Comparison of four wind turbine generator concepts: + strength, - weakness

IV. PROPOSED SYSTEM

- The generator-side control uses a cascaded structure with:
  - Outer loop for MPPT.
  - Inner loop for generator current regulation using dq control for PMSG-based WECSs.
- The grid-side control includes LVRT for symmetrical and asymmetrical faults, using:
  - Resonant Controllers for positive and negative sequence voltage regulation.
  - Fast-convergence DSC method for sequence component separation.

- Controller design criteria for tuning the cascade control systems are briefly explained.

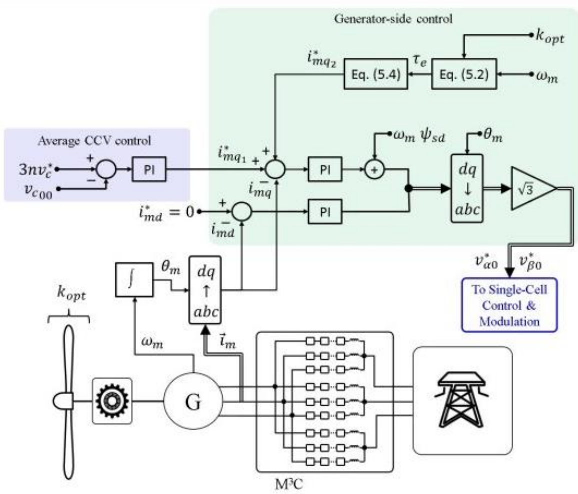

Figure 2: M3C Controller design criteria used to tune the cascade control system

V.SIMULATION

The described system is simulated in the models and Three WGs each with a power of 5 MW are connected in parallel. The process is simulated, when, at the initial common wind speed of 12 m/s, the wind speed of WG3 drops by 1 m/s in the interval (5–7 s); at t = 7 s, the common wind speed increases to 15 m/s, and at t = 12 s, it drops to 7 m/s. The start process is not simulated; itis supposed that the capacitors of the line have been already charged with the help of the VSI-Gr.Some results for the model, with the Sw in the position a, are shown in Although most WGs send the produced electric energy to the power system, there are many units operating without the grid, permanently or from time to time. Because the demanded wind speed does not always exist, such units operate together with other sources of electric energy, for instance, with batteries or diesel generators, which begin to operate when the wind speed drops lower than the necessary level. When WG works in isolation, the load control is of essential importance, as has been already said in the beginning of this chapter. At this, the WG must fabricate the wanted voltage, frequency, and power by itself. the DC/DC boost converter is set at PMSG output that controls the voltage Uci across the capacitor Ci, as in the previous model. At the VSI PWM input, the three-phase quantity with the frequency of 50 Hz that is modulated by amplitude with the output of the output voltage controller comes.

Table 5.1: Input parameters of Permanent Magnet Synchronous Generator (PMSG).

Initial parameters	
Wind Turbine parameters	
Rated power (MW)	10
Rotor speed (rpm)	12.3
Rotor diameter	154
Tip speed ratio	7,8
Generator parameters	
Rated Voltage (V)	3300
number of pole pairs	160
rated wind speed (m/s)	12
air mass density (kg/mˆ3)	1.225
Stator phase resistance (Ohm)	0.0366
Phase inductance (mH)	3.6
Generator efficiency %	0.99
Calculated parameters	
Power at the generator shaft (MW)	10,7
Generator moment of inertia (kg.mˆ2)	0.62
Torque (M Nm)	7.4

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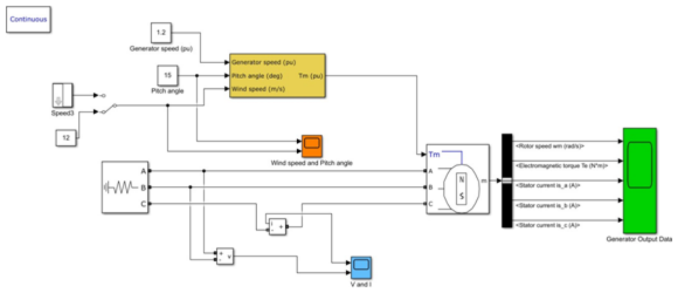

Figure 5.1: Wind Turbine and Generator part of MATLAB Simulink model.

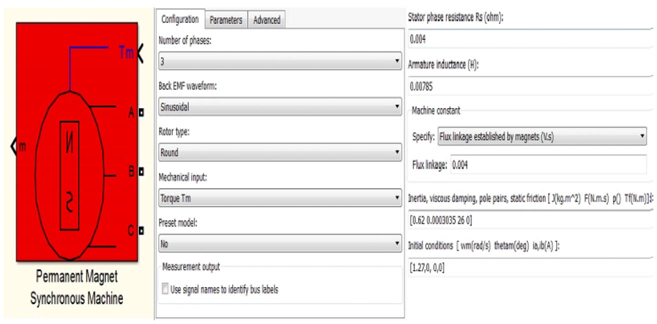

Figure 5.2: MATLAB Simulink block parameters for Permanent Magnet Synchronous Generator (PMSG).

RESULTS:

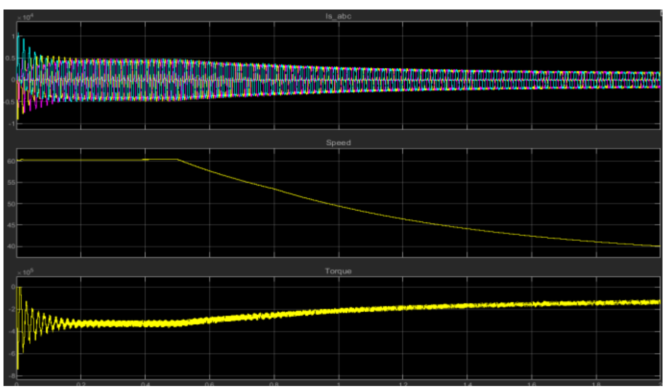

Figure 5.3: output. Generator speed current and torque

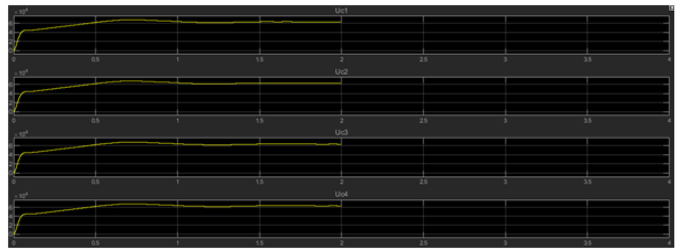

Figure 5.4: Combine output of all generator

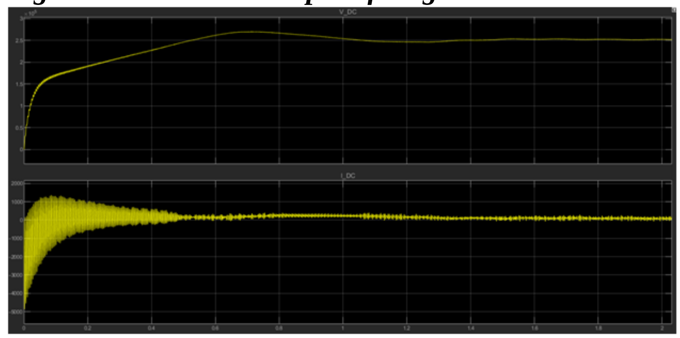

Figure 5.5: Waveform Dc Voltage and current of transmission line

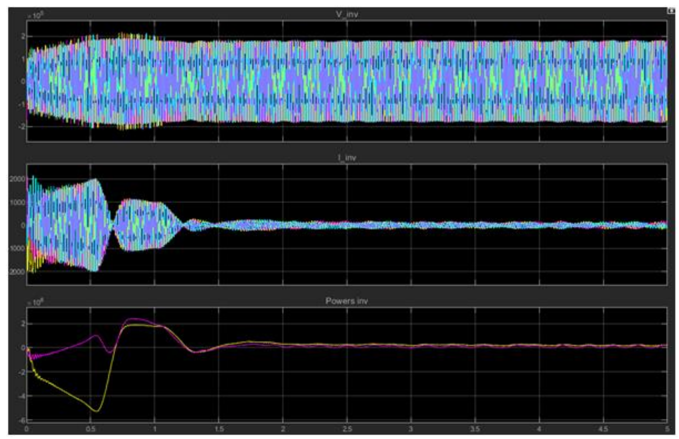

Figure 5.5. waveform MMC Inverter

V.CONCLUSION

The Two-level inverters are simpler, easier to design, and widely studied, but interest in MMCs for wind energy is growing.Designing back-to-back MMCs is challenging due to: Complex generator-side MMC control. Long simulation times (e.g., 12 hours for a 5-second 11-level model). Multiple control levels make tuning slow and complex. High-power wind turbines need reliable, efficient systems, making MMC research crucial for future large-scale applications. This thesis provides initial insights but suggests future studies with advanced tools like supercomputers for detailed simulations, including unstable wind conditions.

REFERENCE

1. Control and analysis of a fault-tolerant offshore HVDC link fed by a bipolar DC collection network 2024, International Journal of Electrical Power and Energy Systems Show abstract

2. Optimization & control strategy for offshore wind turbine based on a dual fed induction generator 2022, Materials Today: Proceedings Show abstract

3. An Enhanced Series-Connected Offshore Wind Farm (SC-OWF) System Considering Fault Resiliency 2024, IEEE Transactions on Power Delivery

4. Wind energy-harvesting technologies and recent research progresses in wind farm control models 2023, Frontiers in Energy Research A critical survey of technologies of large offshore wind farm integration: summary, advances, and perspectives

5. 2022, Protection and Control of Modern Power Systems Design Methodology for the DC Link Current Controller of a Series-Connected Offshore Wind Farm

6. W. Erdman and M. Behnke, "Low Wind Speed Turbine Project Phase II: The Application of Medium-Voltage Electrical Apparatus to the Class of Variable Speed Multi-Megawatt Low Wind Speed Turbines Low Wind Speed", November 119.

7. . 2022, 2022 14th Seminar on Power Electronics and Control, SEPOC 2022

8. M. Liserre, R. Cardenas, M. Molinas, J. Rodriguez, R. Cardenas, M. Molinas, J. Rodriguez, et al., "Overview of Multi-MW Wind Turbines and Wind Parks", IEEE Transactions on Industrial Electronics, vol. 58, no. 4, pp. 1081-1095.

9. V. Yaramasu, B. Wu, P. C. Sen, S. Kouro and M. Narimani, "High-power wind energy conversion systems: State-of-the-art and emerging technologies", Proceedings of the IEEE, vol. 103, no. 5, pp. 740-788, 2015.