SINGLE PHASE BOOST DC LINK INTEGRATED MODULAR MULTILEVEL CONVERTER FOR PHOTOVOLTAIC APPLICATIONS

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ABSTRACT: This paper presents a new boost DC-link integrated modular multilevel converter (BDIMMC) topology for single-phase stand-alone photovoltaic applications. The BDIMMC is realised by the integration of two two-level boost DC-link converters (TBDCs) with a hybrid H-bridge inverter using symmetrical voltage sources. Conventional modular multilevel converters require a large number of isolated DC source and circuit components. On the other side, switched capacitor multilevel converter topologies require less number of sources and components, but need bulky capacitors. The proposed TBDC units charge the capacitors to the desired voltage with the high switching frequency, hence require less capacitance and component count. The proposed topology with proper selection of capacitor voltage levels can produce 9-, 11, 13 and 17-level outputs without altering any circuit components. Besides, the proposed topology produces low-frequency common-mode voltage. The comprehensive analysis of BDIMMC in comparison with recent multilevel converter topologies is presented.

Key words: Boost Dc link modular multilevel converter , Two level boost dc link , H-Bridge Inverter.

I.INTRODUCTION

It highlights the challenges associated with conventional converters and introduces the propose solution, emphasizing the integration of a single-phase boost DC link with a modular multi-level converter. The focus is on enhancing voltage levels, improving power conversion efficiency, and optimizing grid integration to meet the specific requirements of photovoltaic applications.This introduction lays the groundwork for the innovative approach taken in the converter design to address current limitations in photovoltaic energy conversion.Moreover, the increasing adoption of modular multilevel converter (MMC) topologies in high-voltage applications has highlighted their potential for enhancing power conversion efficiency and mitigating grid disturbances.Motivated by the need to address these challenges and capitalize on the benefits of modular multilevel converters, this paper proposes a novel approach: the Single Phase Boost DC Link Integrated Modular Multilevel Converter (SP-BDCIMMC) for PV applications. The SP-BDCIMMC integrates the advantages of both boost converters and MMCs, offering improved performance, enhanced grid compatibility, and greater flexibility in single-phase PV systems.

II. PROPOSED SYSTEM

The proposed system integrates a Single Phase Boost DC Link Integrated Modular Multilevel Converter (SP-BDCIMMC) with an extension to an induction motor, aiming to efficiently harness solar energy for driving mechanical loads.

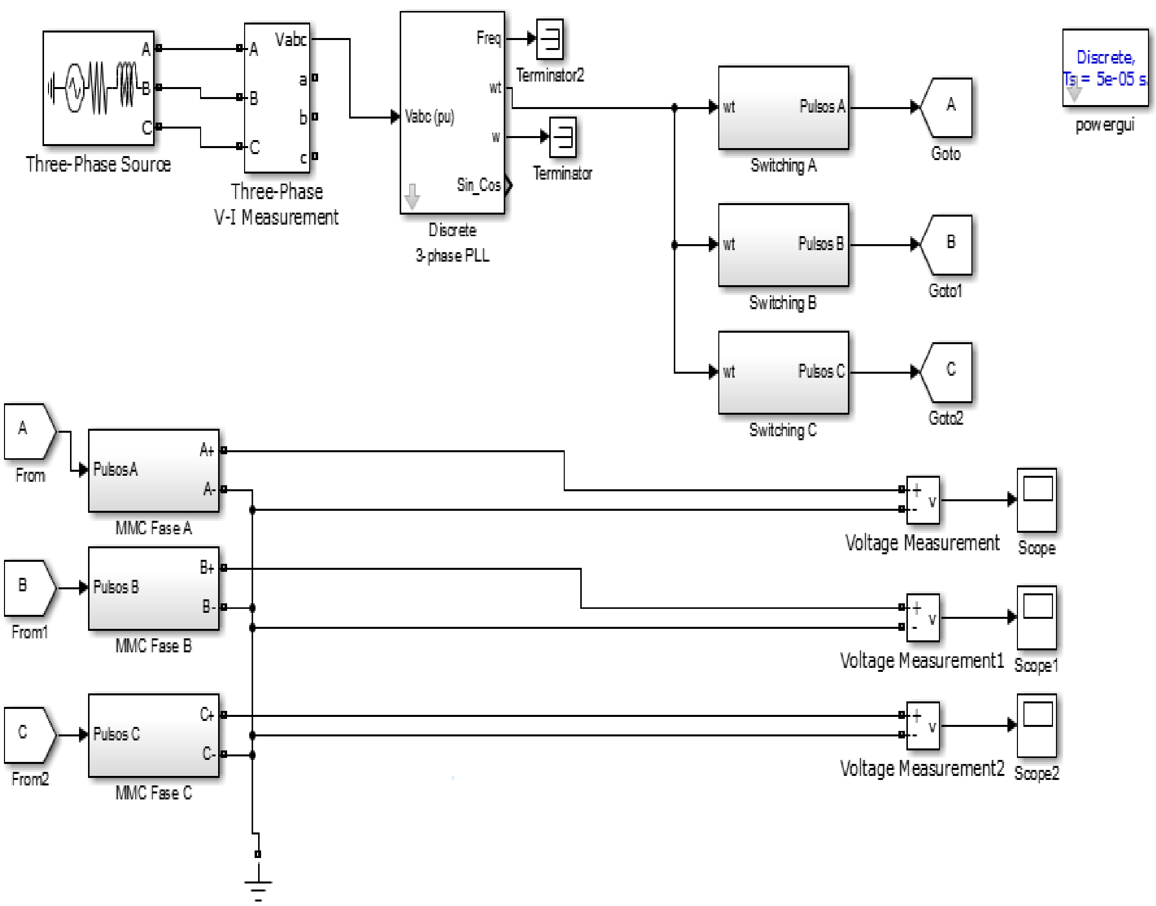

Fig:1 circuit diagram of modular multilevel converter

Single Phase Boost DC Link Integrated Modular Multilevel Converter (SP-BDCIMMC):

Converts variable DC output from a photovoltaic (PV) array into stable AC suitable for driving the induction motor.Incorporates a boost DC link to efficiently increase the DC voltage from the PV array.Utilizes a modular multilevel converter topology for improved power quality and efficiency.Ensures synchronization with the grid for seamless integration with the electrical grid.

Photovoltaic Energy Generation: Solar panels generate DC voltage from sunlight. This DC voltage serves as the primary input to the system.

Boost DC Link Integration: The DC voltage from the solar panels is directed through a boost DC link. The boost function increases the voltage level, addressing limitations and optimizing the power conversion process.

Modular Multi-Level Converter (MMC): The boosted DC voltage is then fed into a modular multi-level converter. The MMC structure utilizes multiple voltage levels to produce a high-quality AC output waveform. The modular design allows for precise control, reducing harmonic distortion and improving the overall quality of the AC power generated.

AC Power Generation: The modular multi-level converter produces high-quality AC power suitable for grid integration or local consumption. The controlled voltage levels contribute to the stability and efficiency of the AC output.

Grid Integration or Local Consumption: The AC power generated by the converter can be fed into the grid for broader distribution and utilization, contributing to the overall power supply. Alternatively, it can be used locally to meet specific energy needs.

Control and Monitoring: The entire system is managed through control and monitoring systems. These systems ensure the efficient operation of the boost DC link, modular multi-level converter, and other components, adapting to changing solar conditions and grid requirements.

A.Extension to Induction Motor:

Directly utilizes the AC output from the SP-BDCIMMC to drive mechanical loads. Enables precise control over motor speed and torque. Eliminates the need for additional power conversion stages or energy storage systems. Enhances overall system efficiency by utilizing solar energy for motor. In cases where motor drive is required, additional components such as an inverter for motor control are integrated. The modular multi-level converter provides the necessary high-quality AC power for efficient induction motor operation.

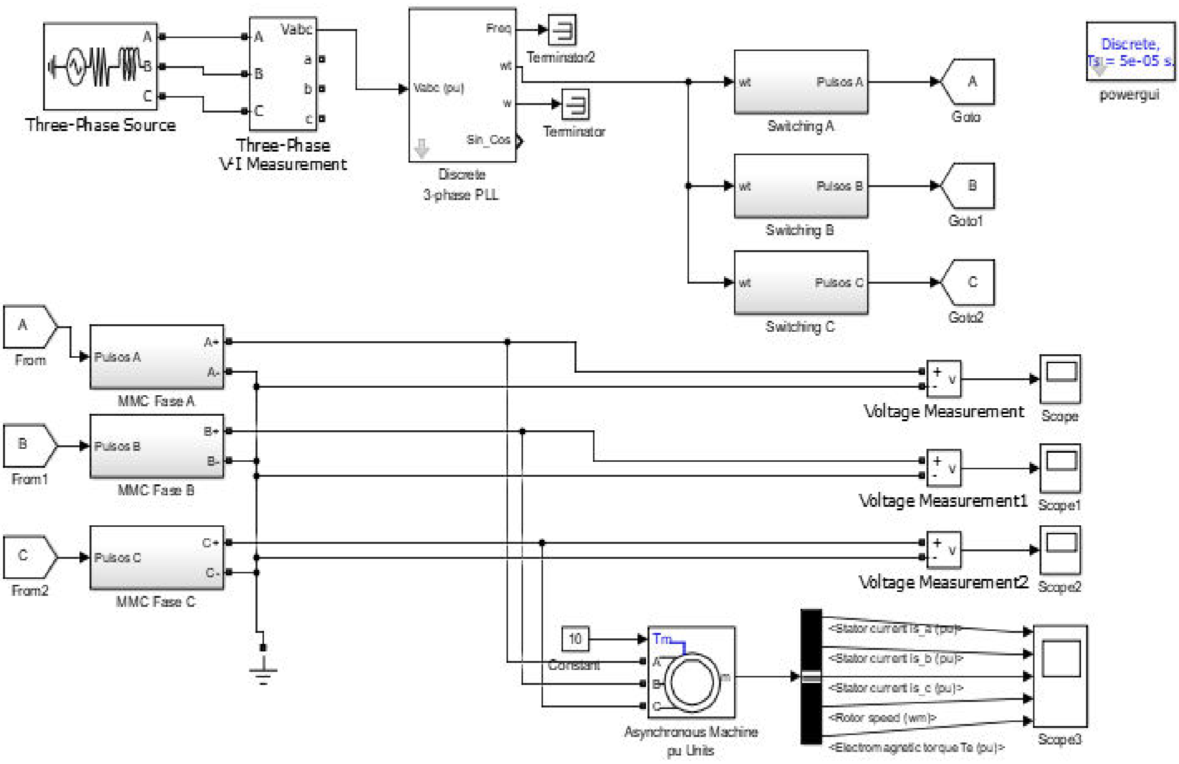

Fig:2 circuit diagram of modular multilevel converter with induction motor

B.SWITCHING SYSTEM OF MMC

Modeling the MMC: You need to model the MMC converter in MATLAB Simulink. The MMC converter consists of multiple converter arms, each comprising several sub-modules. Each sub-module can be represented using appropriate switching models. MATLAB Simulink provides various blocks for modeling power electronic converters, including the Switch block for implementing switching functions.

Modeling the Induction Motor: You also need to model the induction motor in Simulink. This involves representing the motor's electrical and mechanical dynamics. MATLAB/Simulink provides blocks for modeling various types of electrical machines, including induction motors.

Control Strategy: Develop control algorithms for both the MMC converter and the induction motor. The control strategy for the MMC converter typically involves implementing a modulation technique (e.g., Pulse Width Modulation) to generate the switching signals for the converter arms. For the induction motor, you'll need to implement a suitable control strategy such as Field-Oriented Control (FOC) or Direct Torque Control (DTC).

System Integration: Integrate the models of the MMC converter and the induction motor in a single Simulink model. Connect the outputs of the MMC to the input of the motor and vice versa. Ensure that appropriate control signals are exchanged between the converter and the motor.

Simulation and Analysis: Once the simulation model is set up, simulate the system under various operating conditions to evaluate its performance. You can analyze parameters such as current, voltage, speed, torque, and efficiency to assess the system's behavior.

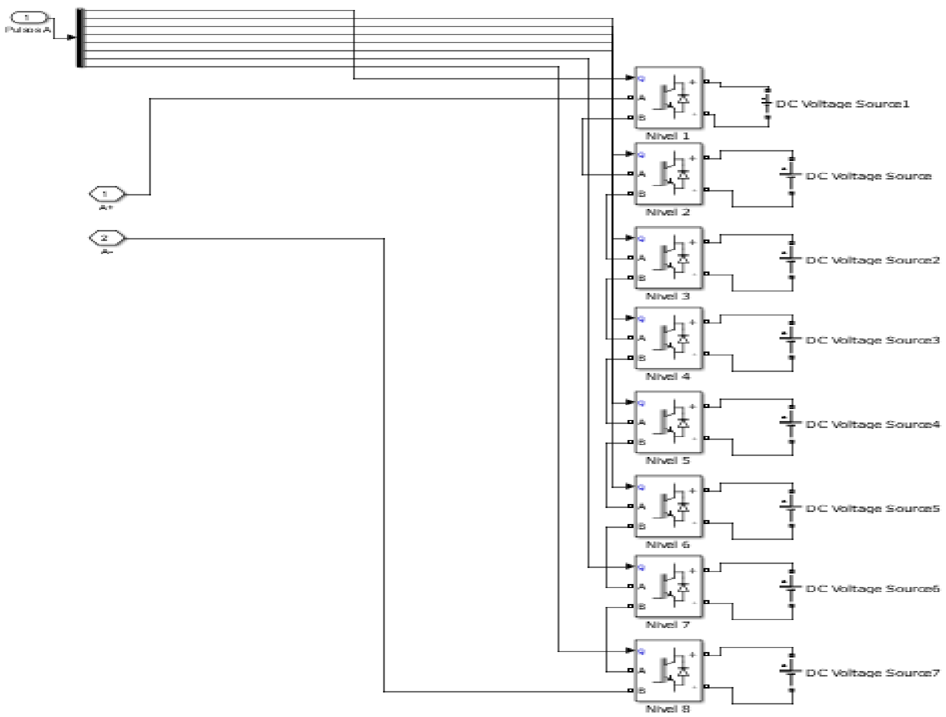

Fig: 3 Switching system of mmc

III. Simulation studies

Voltage and Current Waveforms:

Voltage and current waveforms at different points in the system: These include the input voltage from the PV array, the output voltage of the boost converter, the capacitor voltages in the MMC, and the output voltage at the grid connection point.
These waveforms provide a visual representation of how the system operates over time and allow engineers to verify that the converter is functioning as expected.

Converter Efficiency:

Efficiency of the converter under different operating conditions: This indicates how effectively the converter is converting input power from the PV array into usable output power for grid connection. Efficiency calculations typically consider losses in the boost converter, MMC, and other components of the system.

Power Quality Analysis:

Harmonic distortion in the output voltage and current: This indicates the presence of unwanted harmonics generated by the converter.
Total Harmonic Distortion (THD) is a common metric used to quantify harmonic distortion and assess the quality of the output power.

Control Performance:

Response of control loops: This includes the performance of voltage and current control loops in regulating the output voltage and frequency of the converter.
Transient response to changes in operating conditions or grid disturbances: This evaluates how quickly the system responds to changes and whether it maintains stable operation.

Grid Synchronization:

Grid synchronization performance: This includes the ability of the converter to synchronize its output voltage and frequency with the grid, ensuring seamless integration into the grid.
Parameters such as phase angle difference and frequency deviation are analyzed to assess synchronization performance

Stability of the converter system:

This involves analyzing the dynamic behavior of the system to ensure it remains stable under various operating conditions and disturbances.
Bode plots, Nyquist plots, and transient response analysis may be used to assess stability.

Overall System Performance:

Overall assessment of the system's performance: This includes evaluating key performance metrics such as power output, efficiency, power quality, and grid integration capability.Comparison with design specifications and standards to ensure compliance and identify areas for improvement.

RESULTS

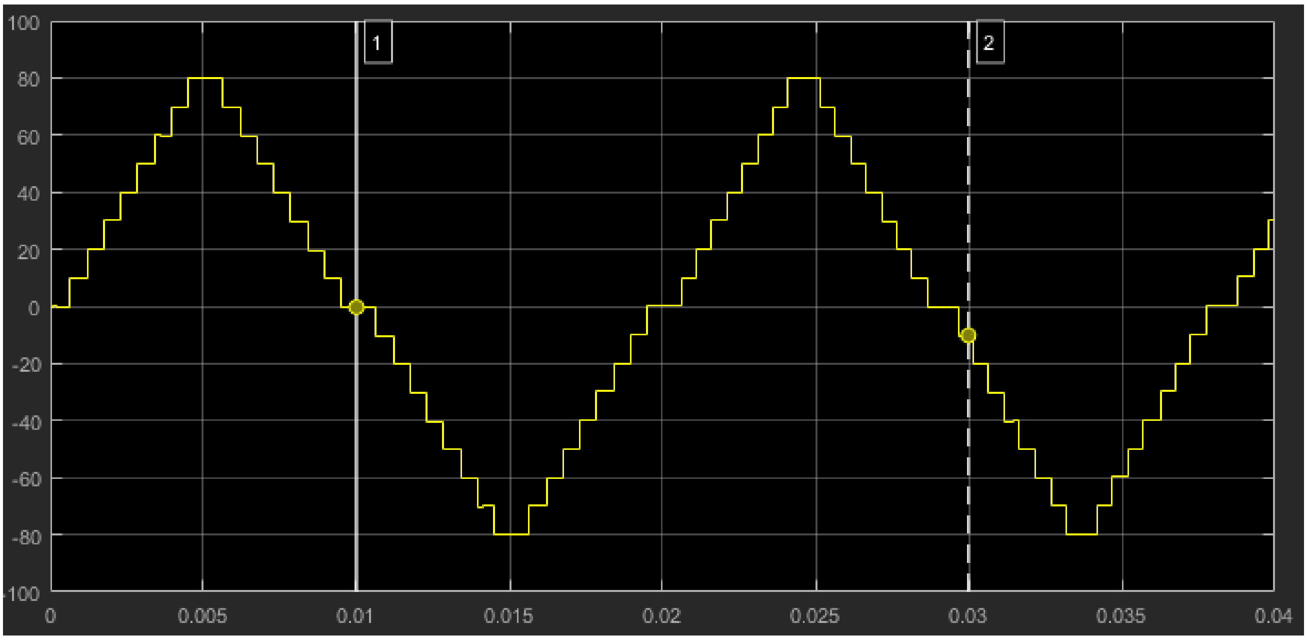

Fig: 4 Waveform of MMC phase-A

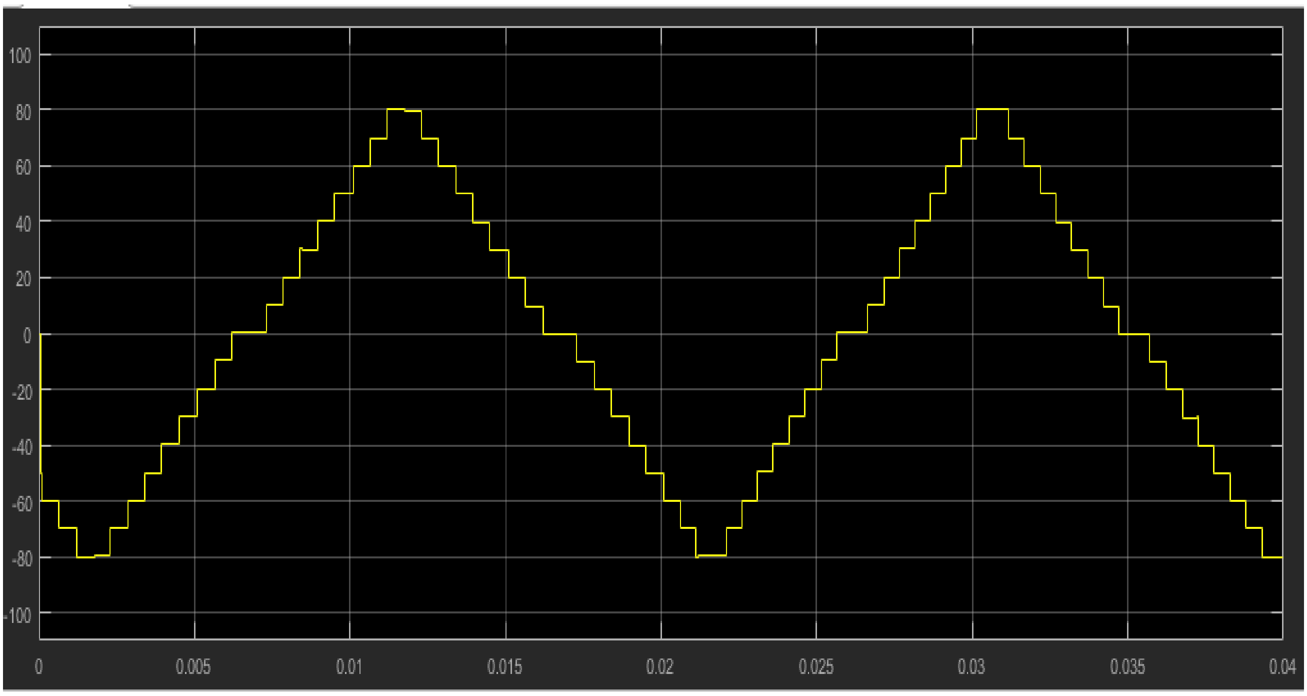

Fig: 5 Waveform of MMC phase-B

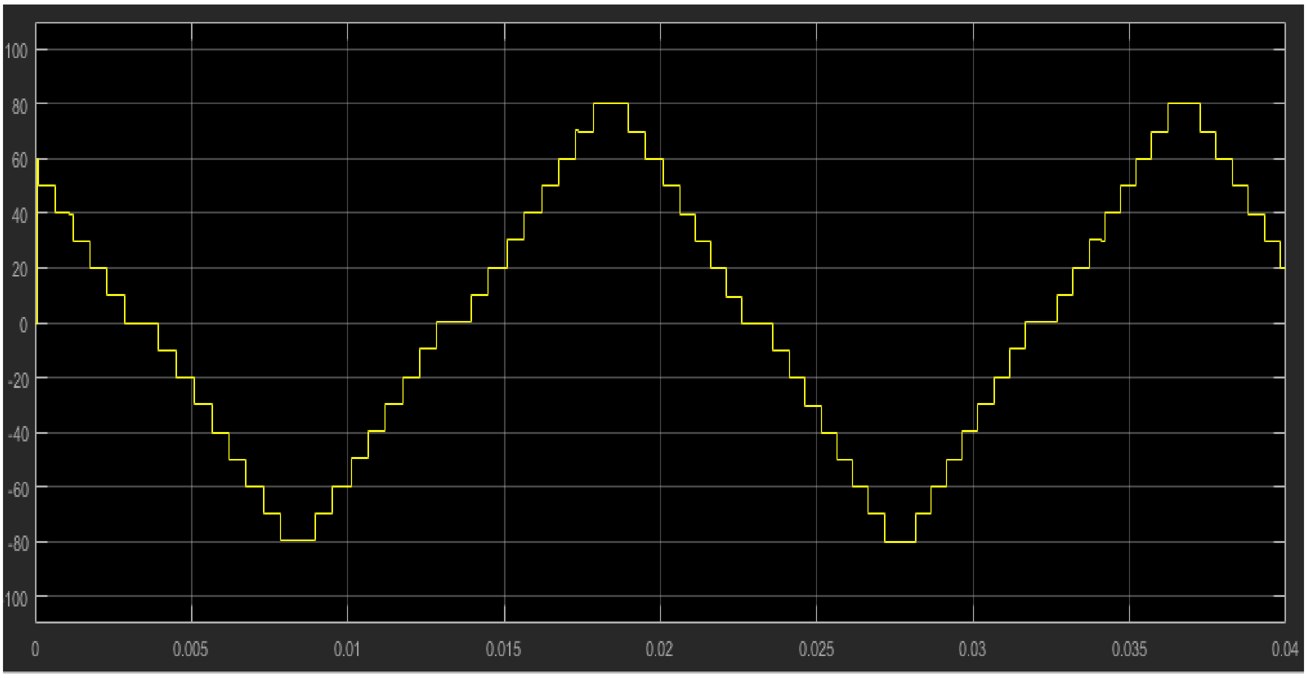

Fig: 6 Waveform of MMC phase-C

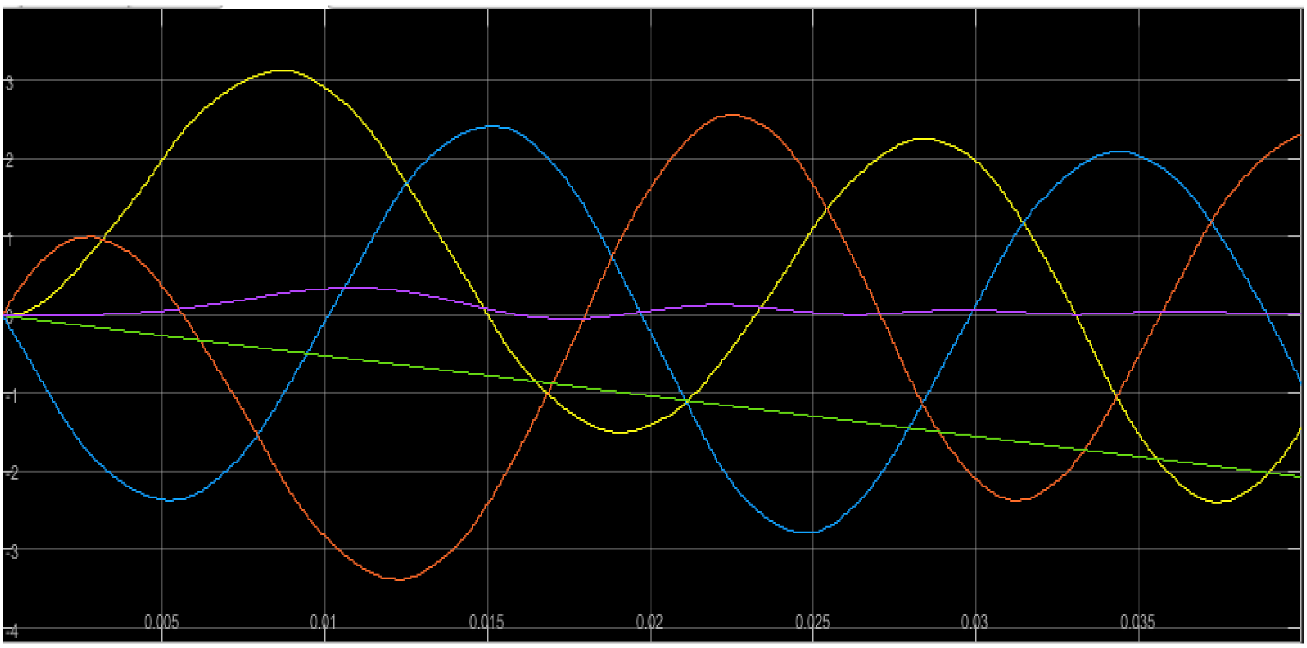

Fig: 7 Output waveform of MMC with induction motor characteristics

CONCLUSION

The single-phase boost DC link integrated modular multilevel converter shows promise for photovoltaic applications, offering improved efficiency, reduced harmonic distortion, and enhanced voltage regulation. Its integration enables better utilization of PV array output voltage, leading to increased energy conversion efficiency. The modular multilevel topology facilitates precise output voltage control, enhancing system performance. Further research should focus on experimental validation and optimization for real-world PV systems. The integration of a single-phase boost DC link with a modular multi-level converter presents a promising solution for enhancing the efficiency of photovoltaic energy conversion. The boost functionality addresses voltage limitations, while the modular multi-level converter ensures precise control over the output waveform, reducing harmonic distortion and improving power quality. This integrated approach is tailored to the specific requirements of photovoltaic applications, offering increased efficiency, improved grid integration, and potential advancements in scalability and adaptability.

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