ICEAIST-24
International Conference on Exploring AI, IOT, Science & Technology-24
ESP Journal of Engineering Technology Advancements / ISSN: 2583-2646

Original Article

Advanced Single Dc Source Five-Level Boost Inverter for Enhanced Dc-Ac Conversion in Renewable Energy Systems

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Abstract: *This project presents a novel single DC source five-level boost inverter designed for efficient power conversion in modern electrical systems. The proposed inverter topology integrates a single DC source with a five-level output, significantly enhancing voltage boosting capability and power quality. The inverter utilizes a unique switching scheme that minimizes harmonic distortion and reduces the stress on power components, ensuring reliable and efficient operation. This design is particularly suited for renewable energy applications, such as photovoltaic systems and energy storage units, where efficient DC-AC conversion is crucial.*

A comprehensive hardware model is developed to validate the theoretical analysis and simulation results. The hardware implementation demonstrates the practical feasibility and effectiveness of the proposed inverter, highlighting its potential for real-world applications. The experimental results confirm the high performance of the inverter in terms of voltage boosting, reduced harmonic distortion, and overall efficiency. This innovative approach to DC-AC conversion offers a cost-effective and reliable solution for various power electronics applications, contributing to the advancement of renewable energy technologies and grid integration.

Keywords: *Single DC Source, Five-Level Boost Inverter, DC-AC Conversion, Renewable Energy Systems, Enhanced Efficiency, Power Electronics, Voltage Boosting, Inverter Design, Multilevel Inverter, Renewable Energy Integration.*

INTRODUCTION

In the recent past, Aviation industries have grown very quickly at a rate of 5% per annum. As the numbers of aircraft are rising, the utilization of fossil fuel would increases eventually, results in increase gas emission. Which have an unassertive impact on the environment. The global aviation industry generates about 2% of all human-induced carbon dioxide (CO2) emissions as a report, and about 12% of all transportation sources CO2 emissions. In order to minimize emissions, system performance and efficiency need to be improved and the use of electrical energy should be increase since it is more efficient than the other three types of energy, i.e. mechanical, hydraulic and pneumatic. Multilevel inverters have been used extensively in industries because of their higher voltage handling capability, lower harmonics, high efficiency, and less voltage rating of power semiconductor switches. The multilevel inverters have several topologies: theiFC, neutral pointlamped (NPC), cascadediH-bridge (CHB), and the hybrid . A five-level inverter with a single DC source requires, ten switches and three flying capacitors is presented . For the NPC inverter, the common dc-link is divided into n-levels and each neutral point is connected to phase output through diodes. This configuration is not suitable for high power application because switches in this topology have to bear higher voltage or the full dc-link voltage.

SYSTEM IMPLEMENTATION

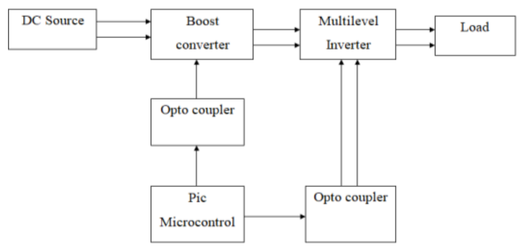
2.1 Existing System:

The existing systems in five-level inverter projects are sophisticated and multifaceted, involving advanced topologies, control strategies, and applications tailored to improve efficiency, reduce harmonics, and enhance the power quality of electrical systems. Research and development continue to push the boundaries in this field, focusing on new semiconductor materials, control techniques, and integration methods to meet the evolving demands of various industries.

2.2 PROPOSED SYSTEM

The proposed five-level inverter system introduces a hybrid topology with advanced neural network-based control, enhanced harmonic elimination techniques, and robust integration with renewable energy sources. It emphasizes thermal management, fault tolerance, digital control, and modular design, aiming for high performance, efficiency, and reliability. This innovative approach not only addresses the limitations of existing systems but also sets a new benchmark for future multilevel inverter designs.

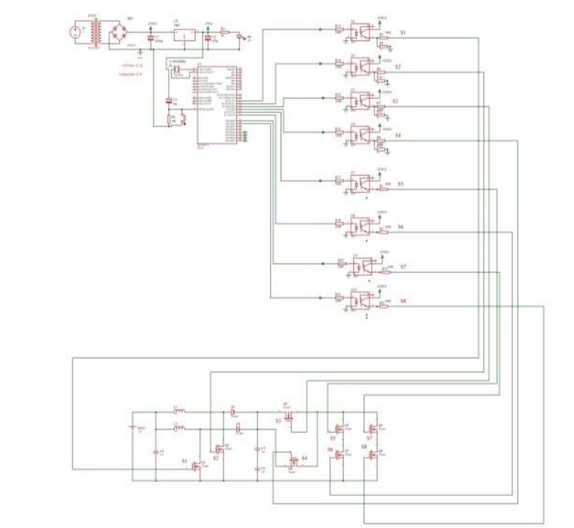
2.3 Block Diagram:



2.3.1 Block Diagram Description:

- **DC Source:** Supplies the initial DC voltage. A 12V battery or a solar PV array.
- **Boost Converter:** Steps up the DC voltage to a higher level. Receives PWM signals from the PIC microcontroller to adjust the output voltage.
- **Multi-Level Inverter:** Converts the high-level DC voltage into a five-level AC voltage. Driven by PWM signals from the PIC microcontroller to create the desired AC output waveform.
- **Load:** The end device that utilizes the AC power. An AC motor or any AC-operated appliance.
- **Opto Coupler: To** Provide isolation and signal transmission. One optocoupler for isolating the feedback from the boost converter, another for isolating feedback from the inverter stage.
- **PIC Microcontroller:** Central control unit for generating PWM signals and managing the overall operation. Equipped with ADC for feedback processing, PWM modules for generating control signals, and communication interfaces for system monitoring.

2.4 Circuit Digram:



2.4.1 Circuit Diagram Description:

The positive terminal of the DC source connects to one end of the inductor (L).The other end of the inductor connects to the drain of the MOSFET (S).The source of the MOSFET connects to ground.A diode (D) is connected between the inductor-MOSFET junction and the output capacitor (C) (anode to the junction, cathode to the capacitor).The capacitor (C) connects between the positive output terminal and ground. The positive terminal of the output capacitor of the boost converter connects to the input of the multi-level inverter. The ground remains common. The output of the multi-level inverter provides the stepped AC voltage to the load. Opto Coupler 1: Connected between the output of the boost converter and the ADC input of the PIC microcontroller. The anode of the LED in the optocoupler is connected to the output voltage of the boost converter through a current-limiting resistor. The cathode is connected to ground.The phototransistor side of the optocoupler connects to the microcontroller's ADC input and ground. Opto Coupler 2: Connected between the output of the multi-level inverter and the microcontroller. Similar configuration as Opto Coupler 1 for feedback from the inverter stage. PWM Outputs Connected to the gate of the MOSFET in the boost converter and the gates of the switches in the multi-level inverter. ADC Inputs Receive feedback from the optocouplers for monitoring the output voltages. Control Algorithm Processes the feedback signals and adjusts the PWM signals to control the boost converter and multi-level inverter.

HARDWARE DETAILS

3.1 Boost Converter:

Switched mode supplies can be used for many purposes including DC to DC converters. Often, although a DC supply, such as a battery may be available, its available voltage is not suitable for the system being supplied. For example, the motors used in driving electric automobiles require much higher voltages, in the region of 500V, than could be supplied by a battery alone. Even if banks of batteries were used, the extra weight and space taken up would be too great to be practical. However, if this low output level can be boosted back up to a useful level again, by using a boost converter, the life of the battery can be extended.

The DC input to a boost converter can be from many sources as well as batteries, such as rectified AC from the mains supply, or DC from solar panels, fuel cells, dynamos and DC generators. The boost converter is different to the Buck Converter in that it's output voltage is equal to, or greater than its input voltage.

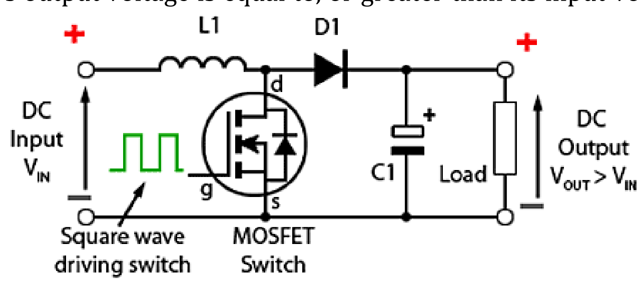


Fig. 3.1 Basic Boost Converter Circuit

3.2 Micro Controller Pic16f877a:

PIC 16F877 is one of the most advanced microcontroller from Microchip. This controller is widely used for experimental and modern applications because of its low price, wide range of applications, high quality, and ease of availability. It is ideal for applications such as machine control applications, measurement devices, study purpose, and so on.

3.2.1 Pic Controller Circuit Diagram:

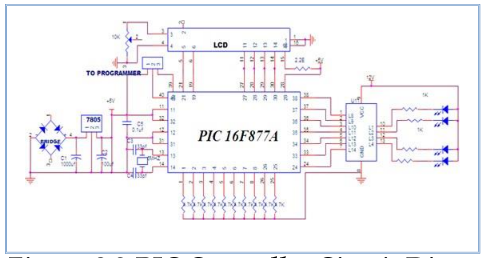


Figure. 3.2 PIC Controller Circuit Diagram

3.3 Mct2e - Phototransistor Optocoupler:

MCT2E is a phototransistor Optocoupler, as the name —phototransistor‖ suggests it has a transistor which is controlled based on light (photon). When the IR led is powered the light from it falls on the transistor and it conducts. The arrangement and pin-outs of the IR LED and the photo-transistor is shown below.

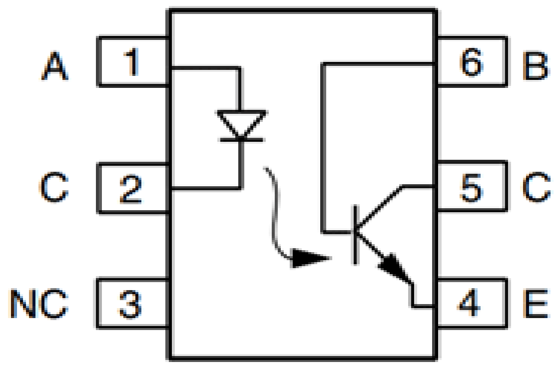


Figure. 3.3 Optocoupler

This IC is used to provide electrical isolation between two circuits, one part of the circuit is connected to the IR LED and the other to Photo-transistor. The digital signal given to the IR LED will be reflected on the transistor but there will be no hard electrical connection between the two. This comes in very handy when you are trying to isolate a noisy signal from your digital electronics, so if you are looking for an IC to provide optical isolation in your circuit design then this IC might be the right choice for you.

3.4 Single Power Supply:

Power supply gives supply to all components. It is used to convert AC voltage into DC voltage. Transformer used to convert 230V into 12V AC.12V AC is given to diode. Diode range is 1N4007, which is used to convert AC voltage into DC voltage. AC capacitor used to charge AC components and discharge on ground. LM 7805 regulator is used to maintain voltage as constant. Then signal will be given to next capacitor, which is used to filter unwanted AC component. Load will be LED and resister. LED voltage is 1.75V.if voltage is above level beyond the limit, and then it will be dropped on resister.

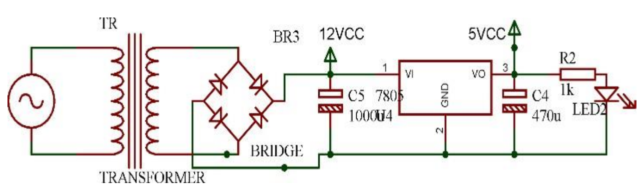


Figure. 3.4 Single Power Supply Circuit

3.5 Mosfet(Irf840):

Third generation Power MOSFETs from Vishay provide the designer with the best combination of fast switching, ruggedized device design, low on-resistance and cost-effectiveness. The TO-220AB package is universally preferred for all commercial-industrial applications at power dissipation levels to approximately 50 W. The low thermal resistance and low package cost of the TO-220AB contribute to its wide acceptance throughout the industry.

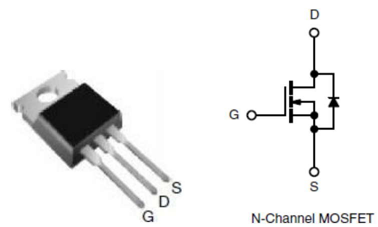


Figure. 3.5 Mosfet(IRF840)

RESULT

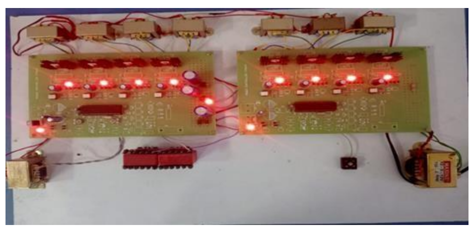


Figure 4.1: Hardware setup

The above figure 4.1 prototype model for Single DC Source Five-Level Boost Inverter hardware setup using microcontroller.

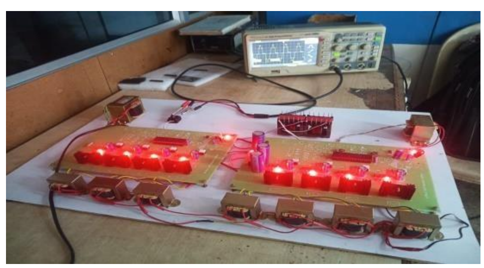


Figure 4.2: Hardware setup with CRO output

The above Fig 5.2 is Single DC Source Five-Level Boost Inverter hardware setup with CRO output.

Figure 4.3: Boost converter Gate pulse

The Fig 4.3 is PWM pulse for boost converter MOSFET gate for hardware model.

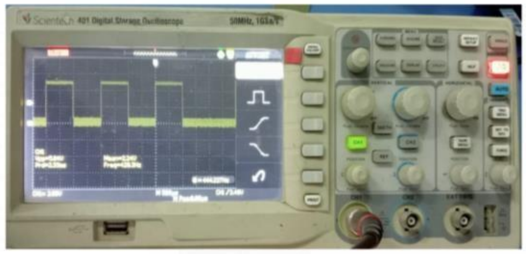


Figure 4.4: Inverter Gate pulse

The above figure 4.4 is square pulse for multilevel inverter MOSFET switching pulse.

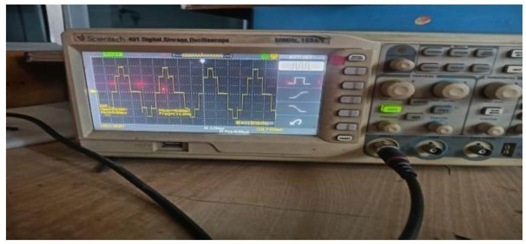


Figure 4.5: Output for the five level inverter in CRO output.

CONCLUSION

The five-level inverter demonstrated improved performance over traditional two-level inverters, including reduced total harmonic distortion (THD) and better voltage waveform quality. This improvement is critical for applications requiring high power quality and efficiency, such as renewable energy systems and electric drives. The five-level inverter project demonstrated that this topology offers significant advantages in terms of power quality, efficiency, and application versatility. It represents a viable solution for modern power conversion needs, balancing complexity and performance effectively.

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