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Design and Analysis of a Solar-Powered Induction Motor Drive Using a Modified SEPIC Converter

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Abstract—**In designing photovoltaic systems connected to the grid system usually DC-DC converter is required to increase the output voltage of the photovoltaic. The most commonly design of DC-DC converters are typically used a converters with high gain static in order to increase the output voltage of the photovoltaic and obtain a high conversion efficiency. One type of converter used is a SEPIC converter topology. However, the conventional DC-DC converter topologies such as SEPIC converters can only increase by 5 times of the input voltage when the Duty Cycle is set to 0.82. Meanwhile, to meet the dc input voltage of the inverter, the input voltage of the converters have to increase above than 10 times. Therefore, to overcome these problems, this paper proposes the design of DC-DC modified SEPIC converter topologies for photovoltaic applications. Modifications to the conventional SEPIC converter is done by adding capacitors and diodes. From the experimental results shows that this converter can increase the output voltage about 10 times and has the efficiency about 91.5%. Furthermore, topology of the this converter can be effectively applied for photovoltaic system.**

Index Terms—Photovoltaic (PV) system, DC-DC converter, Modified SEPIC converter, High voltage gain, Grid-connected system, Renewable Energy, Power conversion efficiency, Solar energy applications.

I. INTRODUCTION

The increasing demand for electrical energy, rapid industrial growth, and the depletion of conventional energy resources such as coal, oil, and natural gas have created a strong need for alternative and sustainable energy solutions. Among the various renewable energy sources, solar energy has become one of the most promising options because it is clean, abundant, eco-friendly, and freely available. In countries like India, where sunlight is available for most of the year, solar energy can play a major role in meeting future energy demands.

Photovoltaic (PV) systems are commonly used to convert solar energy into electrical energy. These systems generate direct current (DC) power by converting sunlight through solar panels. However, the output of PV panels is highly dependent on environmental conditions such as solar irradiance, temperature, and shading. Due to these variations, the generated voltage and current are not constant, which makes it difficult to maintain stable power delivery and extract maximum available energy from the system.

To improve the efficiency of solar energy utilization, Maximum Power Point Tracking (MPPT) techniques are used. MPPT helps the PV system operate at its optimal point by continuously adjusting the operating conditions to obtain maximum possible power under changing atmospheric conditions. This improves the overall performance of the solar-powered system and reduces power losses.

Even after maximum power extraction, the voltage obtained from the PV panel is usually not sufficient to directly drive high-power loads such as induction motors. Therefore, a DC-DC converter is required to increase and regulate the voltage. In this work, a Modified SEPIC (Single-Ended Primary Inductor Converter) is used because of its ability to provide both step-up and step-down voltage conversion while maintaining the same output polarity. Compared to conventional converters, the modified SEPIC converter offers higher voltage gain, reduced ripple, improved efficiency, and better voltage stability.

After voltage regulation, the DC power must be converted into AC power because induction motors operate using AC supply. This is achieved using an inverter, which converts the regulated DC voltage into a controlled three-phase AC output. The inverter plays an important role in maintaining proper voltage and frequency, ensuring smooth motor operation and reducing harmonic distortion.

Induction motors are widely used in industrial and agricultural applications such as water pumping, fans, compressors, and other mechanical systems due to their simple construction, reliability, and low maintenance requirements. Operating these motors using solar energy requires proper coordination between the PV system, converter, inverter, and control system to ensure stable and efficient performance.

This paper focuses on the design and analysis of a solar-powered induction motor drive using a Modified SEPIC Converter. The proposed system aims to improve voltage boosting capability, enhance power conversion efficiency, and provide reliable motor performance under varying solar conditions. The entire system is modeled and analyzed using MATLAB/Simulink, and important parameters such as voltage, current, motor speed, and torque are studied to evaluate system performance.

The proposed system provides an effective solution for renewable energy-based motor drives and can be applied in rural and remote areas where grid supply is limited or unavailable. By integrating solar energy with advanced power electronic converters, the system promotes sustainable energy usage and supports the development of efficient green energy technologies.

LITERATURE REVIEW

Tunahan Sapmaz et al. (2022) designed an efficient induction motor drive system with improved motor performance and reduced operational losses. Their work mainly focused on minimizing torque ripple to achieve smooth motor operation and enhancing thermal stability for long-term reliability. The study also improved overall energy efficiency and supported renewable energy integration, making the system highly suitable for solar-powered motor drive applications.[1]

S. Reddy et al. (2025) developed a solar-powered induction motor drive system using advanced converter topologies. Their proposed system significantly improved voltage stability and reduced ripple content in the output. The overall efficiency of the motor drive was enhanced, and reliable performance was achieved under dynamic operating conditions. The work is especially useful for rural and off-grid renewable energy applications. [2]

J. Patel et al. (2024) proposed a soft-switching DC-DC converter for photovoltaic applications. Their design successfully minimized switching losses and improved efficiency at higher power levels. The converter also reduced thermal stress on switching devices and enhanced voltage gain while maintaining stable output voltage. Experimental validation confirmed the effectiveness of the proposed converter for solar applications. [3]

K. Sharma et al. (2023) studied the performance of inverters used in solar-powered motor drive systems. Their research mainly focused on reducing harmonic distortion and improving the quality of the output waveform. By applying advanced control techniques, the inverter provided stable AC output and improved motor efficiency. The study highlighted the importance of inverter performance in maintaining reliable induction motor operation. [4]

V. Singh et al. (2025) proposed a hybrid renewable energy system for improving overall system performance. Their work maximized solar energy utilization and enhanced power quality under varying environmental conditions. The integration of renewable sources with motor drives improved cost-effectiveness and system reliability, promoting sustainable and efficient energy solutions. [5]

H. Suryoatmojo et al. (2023) introduced a high-gain modified SEPIC converter for photovoltaic systems. Their design significantly improved voltage boosting capability and reduced output ripple effectively. The converter maintained stable DC output and achieved higher efficiency under varying operating conditions. The study strongly supports the use of modified SEPIC converters in solar-powered applications. [6]

M. Maheshwari (2023) developed a quadratic boost SEPIC converter capable of achieving high voltage gain using an integrated converter topology. The design improved converter efficiency, minimized switching losses, and maintained stable output voltage. Simulation results verified the converter’s strong performance, making it suitable for renewable energy systems requiring high voltage boosting. [7]

Poojavarshini S. et al. (2023) designed DC-DC converters integrated with MPPT techniques for photovoltaic systems. Their work improved maximum power extraction and enhanced voltage regulation under changing solar conditions. Faster system response and stable operation were achieved, and simulation results confirmed the effectiveness of the design for solar-powered applications. [8]

J. Rodriguez, J. S. Lai, and F. Z. Peng (2002) presented a comprehensive survey of multilevel inverter topologies. Their study highlighted the advantages of reduced harmonic distortion, improved power quality, and better efficiency. They also discussed challenges related to switching complexity and control strategies. [9]

E. Babaei (2008) introduced a new cascaded multilevel inverter topology with a reduced number of switches and DC sources. The proposed design improved system efficiency while maintaining good output waveform quality. The study focused on reducing converter complexity and improving practical implementation. [10]

S. Mekhilef, M. N. Kadir, and N. A. Rahim (2011) reviewed multilevel inverter applications in renewable energy systems. Their work showed how inverter topologies improve energy conversion efficiency and reduce harmonic distortion. The study strongly supported renewable-based motor drive systems. [11]

Y. Hinago and H. Koizumi (2012) proposed a switched-capacitor multilevel inverter capable of voltage boosting without additional DC sources. Their design improved efficiency and reduced the need for separate boosting circuits. The system was highly effective for low-voltage renewable energy applications like solar PV systems. [12]

III.METHODOLOGY

The proposed system is designed to operate an induction motor efficiently using solar energy by integrating a photovoltaic (PV) panel, Maximum Power Point Tracking (MPPT), a Modified SEPIC Converter, an inverter, and an induction motor drive. The process begins with the PV panel, which converts solar energy into direct current (DC) power using the photoelectric effect. Since the output of the PV panel varies continuously with changes in solar irradiance, temperature, and shading conditions, an MPPT technique is used to ensure maximum power extraction under all operating conditions. The MPPT controller continuously monitors the PV voltage and current and adjusts the operating point so that the system always works at its maximum power point, improving efficiency and reducing power losses.

The DC output from the PV system is then supplied to the Modified SEPIC Converter, which increases and regulates the voltage to provide a stable DC output. Unlike conventional converters, the modified SEPIC converter offers both step-up and step-down voltage conversion with the same output polarity, along with improved voltage gain, reduced ripple, and better efficiency. This regulated DC power is then converted into three-phase AC power using an inverter, which controls the voltage and frequency required for smooth induction motor operation. The induction motor acts as the final load and converts electrical energy into mechanical energy for applications such as water pumping and industrial drives. The entire system is modeled and analyzed using MATLAB/Simulink by observing parameters such as PV voltage, DC link voltage, motor speed, stator current, and line voltage to evaluate the overall system performance, stability, and reliability.

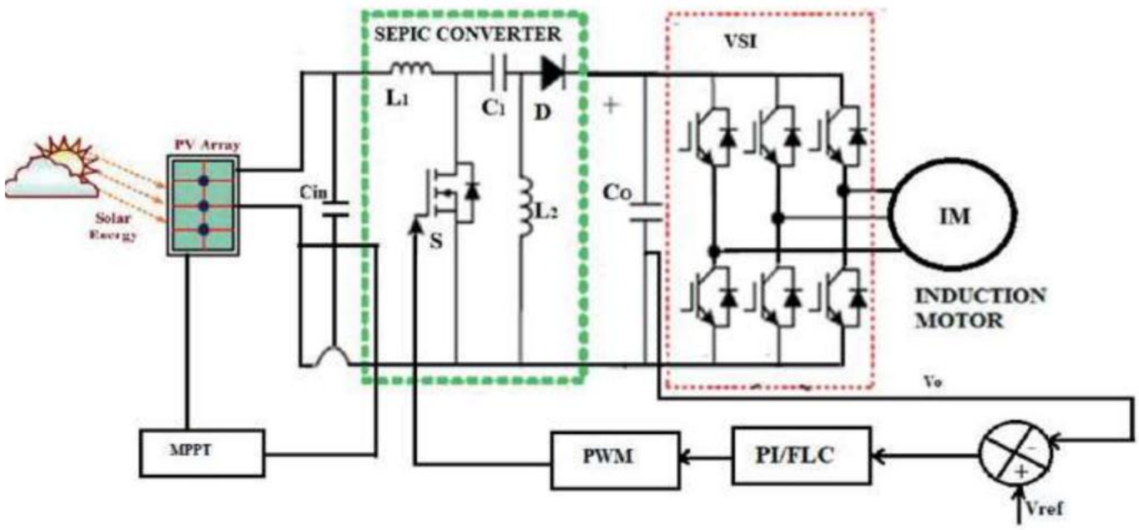


Fig.1.Circuit diagram for Design and Analysis of a Solar-Powered Induction Motor Drive Using a Modified SEPIC Converter

IV.ANALYTICAL STUDY AND SIMULATION DIAGRAM

The analytical study of the proposed system focuses on the effective use of solar energy for operating an induction motor through a Modified SEPIC Converter. The system starts with the photovoltaic (PV) panel, which converts solar energy into direct current (DC) power using the photoelectric effect. Since the output of the PV panel changes continuously due to variations in solar irradiance, temperature, and shading conditions, maintaining stable power becomes a major challenge. To overcome this issue, a Maximum Power Point Tracking (MPPT) technique is used to ensure that the system always operates at the maximum power point and extracts the highest possible energy from the solar panel.

The DC output from the PV panel is then supplied to the Modified SEPIC Converter, which is responsible for voltage boosting and regulation. The conventional converter cannot provide sufficient voltage gain for driving high-power loads like induction motors, so a modified SEPIC converter is used to improve performance. It provides both step-up and step-down voltage conversion while maintaining the same output polarity. Additional capacitors and diodes are included to improve voltage gain, reduce output ripple, and increase efficiency. This helps in maintaining a stable DC link voltage for the next stage of the system.

The regulated DC output is then given to the three-phase inverter, where it is converted into AC power required for operating the induction motor. The inverter controls the voltage and frequency using switching devices such as MOSFETs or IGBTs to ensure smooth motor operation and reduced harmonic distortion. The induction motor acts as the final load and converts electrical energy into mechanical energy for applications like water pumping, fans, and agricultural systems. The complete system is modeled and simulated using MATLAB/Simulink, where important parameters such as PV voltage, PV current, DC voltage, line voltage, motor speed, stator current, and stator voltage are analyzed to evaluate system efficiency, stability, and overall performance.

V.EXPERIMENT RESULTS

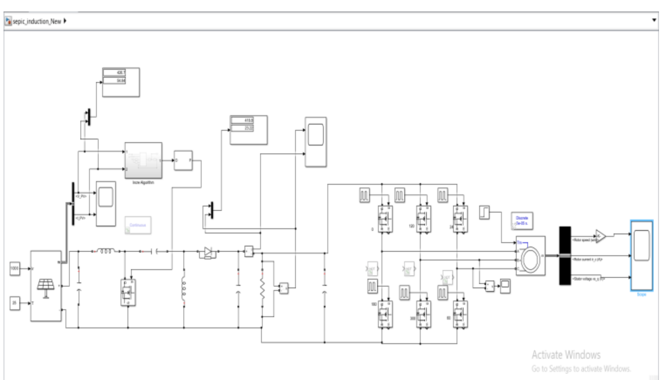


Fig.2.SimulationDiagram

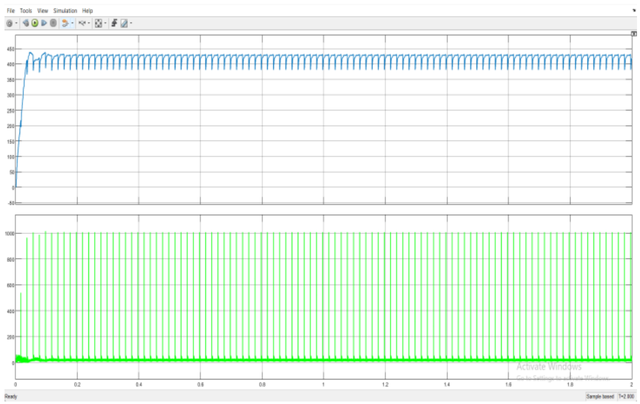


Fig.3.Output DC voltage and current

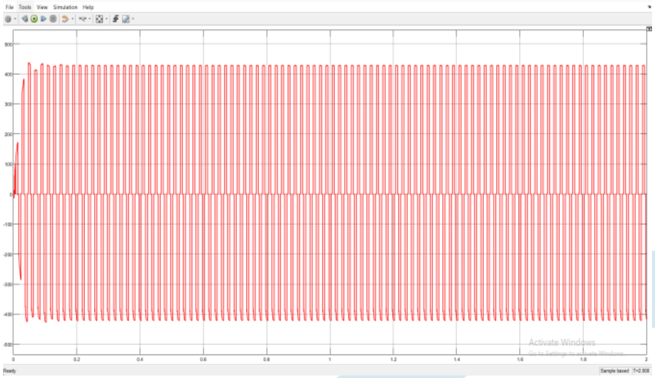


Fig.4. Line Voltage

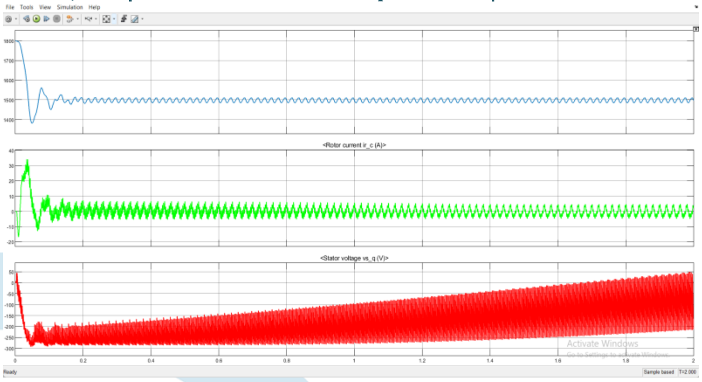


Fig.5. Speed, Stator Current and Stator Voltage

The simulation results of the proposed solar-powered induction motor drive system confirm the effective performance of the Modified SEPIC Converter and the overall system. The three-phase voltage source waveform shows balanced sinusoidal voltages with equal phase displacement of 120°, which ensures proper power delivery to the induction motor. The photovoltaic (PV) voltage and current waveforms indicate that the Maximum Power Point Tracking (MPPT) technique successfully extracts maximum available power from the solar panel under varying environmental conditions. The PV voltage remains stable, and the current is maintained smoothly, proving efficient solar energy harvesting.

The DC voltage and current waveforms demonstrate the strong voltage regulation capability of the Modified SEPIC Converter. The converter successfully boosts the low PV output voltage to a higher stable DC link voltage required for inverter operation. The output voltage remains nearly constant with very low ripple, which improves the reliability of the inverter and motor drive system. The line voltage waveform of the inverter shows proper three-phase AC conversion with reduced harmonic distortion and balanced voltage output. This confirms that the inverter provides stable voltage and frequency control for smooth motor operation.

The induction motor performance is analyzed using rotor speed, stator current, and stator voltage waveforms. The motor reaches steady-state speed quickly and maintains stable operation without major fluctuations. The stator current and voltage remain balanced, indicating smooth electromechanical energy conversion and efficient motor performance. These results prove that the proposed system provides reliable operation under varying solar conditions and can be effectively used for applications such as water pumping, agriculture, and industrial motor drives using renewable solar energy.

VI.HARDWARE RESULTS

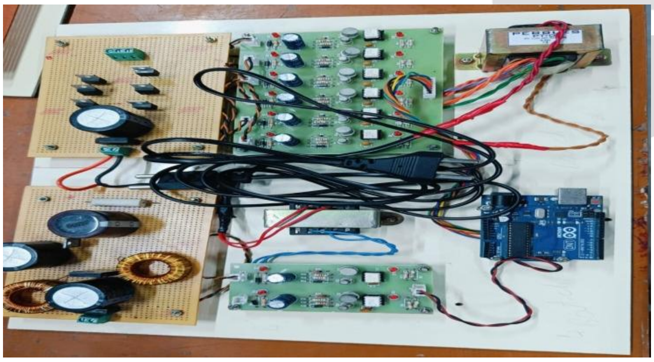
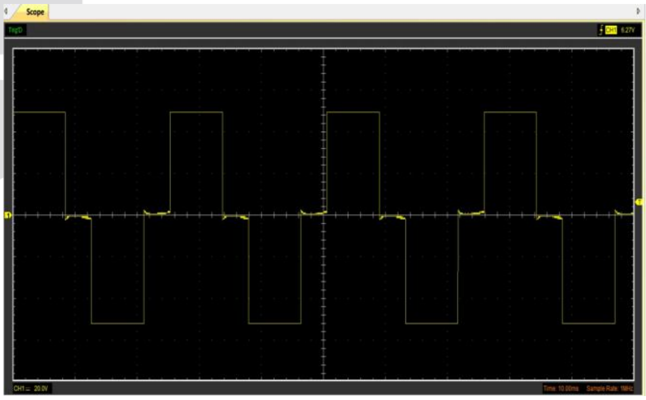


Fig. 6.HardwareKit



Fig, 7. Inverter Output

VII.CONCLUSION

The proposed solar-powered induction motor drive system using a Modified SEPIC Converter has been successfully designed and analyzed. The system effectively utilizes solar energy by integrating a photovoltaic (PV) panel, Maximum Power Point Tracking (MPPT), a Modified SEPIC Converter, an inverter, and an induction motor. The MPPT technique ensures maximum power extraction from the solar panel under varying environmental conditions, while the Modified SEPIC Converter provides higher voltage gain, reduced ripple, and improved voltage stability compared to conventional converters. This helps in maintaining a stable DC output suitable for inverter operation.

The inverter successfully converts the regulated DC power into three-phase AC supply required for the induction motor, ensuring smooth motor starting, stable speed control, and reduced harmonic distortion. Simulation results obtained using MATLAB/Simulink confirm that the system performs efficiently under different operating conditions. Important parameters such as PV voltage, DC link voltage, line voltage, motor speed, stator current, and stator voltage show stable and reliable performance throughout the operation.

Overall, the proposed system offers an effective solution for renewable energy-based motor drive applications such as water pumping, agriculture, and rural industrial systems where grid supply is limited or unavailable. By improving voltage boosting capability, system efficiency, and motor reliability, the project supports the practical implementation of clean and sustainable energy systems. This work highlights the importance of combining renewable energy sources with advanced power electronic converters for future green energy applications.

VIII. ACKNOWLEGMENT

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