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Design and Control of Single AC-DC Buck Converter for Drive Applications

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Abstract: *This project presents the design and implementation of a single AC-DC buck converter for drive applications. The system converts single-phase AC supply into controlled DC output suitable for operating motor drive systems. A bridge rectifier is used to convert AC input into DC, while the buck converter regulates the output voltage according to load requirements. The control circuit is developed using a microcontroller to generate switching pulses for the power devices, ensuring stable and efficient operation. The proposed converter improves voltage control, reduces power losses, and enhances overall system performance. Hardware implementation and testing confirm that the converter provides reliable output with good efficiency, making it suitable for industrial and motor drive applications. This system offers a compact, cost-effective, and efficient solution for modern power conversion needs.*

Keywords: AC-DC Converter, Buck Converter, Motor Drive, Voltage Control, Microcontroller, Power Electronics

I. INTRODUCTION

Power electronic converters play a major role in modern electrical and industrial systems by enabling efficient conversion and control of electrical energy. Among these converters, AC-DC converters are widely used in applications where alternating current from the utility supply must be converted into controlled direct current for operating various loads such as motor drives, battery chargers, electric vehicles, and industrial automation systems [1]. The increasing demand for efficient power conversion has made AC-DC converter technology an important area of research and development.

Motor drive applications require stable and controllable DC voltage for proper speed and torque control. Conventional rectifier circuits can convert AC into DC, but they often suffer from poor voltage regulation, higher ripple content, and lower efficiency under varying load conditions [2]. To overcome these limitations, buck converters are commonly used after rectification to regulate and step down the output voltage according to the application requirement [3]. A buck converter provides improved efficiency, reduced switching losses, and better output voltage control compared to traditional linear regulation methods.

The rapid growth of automation and electric drive systems has increased the need for compact and reliable power converters. In industrial applications, accurate voltage control directly influences motor performance, efficiency, and system reliability [4]. Poor voltage regulation can lead to overheating, torque fluctuations, and reduced lifespan of electrical machines. Therefore, advanced control techniques are required to maintain steady output under changing input and load conditions [5].

Microcontroller-based control methods have gained significant attention in converter design because of their flexibility and low cost. These controllers can generate precise switching pulses for power semiconductor devices and improve dynamic response of the system [6]. By adjusting duty cycle through pulse width modulation (PWM), the converter output can be controlled efficiently. This approach reduces power loss and enhances overall converter performance [7].

Single-phase AC supply is commonly available in residential and small-scale industrial environments, whereas many drive systems require controlled DC input. Designing an efficient single AC-DC buck converter offers a practical solution for such applications [8]. The converter combines rectification and voltage regulation in a compact system, making it suitable for low and medium power drive operations. Proper selection of switching devices, filter components, and control algorithms significantly improves converter efficiency and output quality [9].

This project focuses on the design and control of a single AC-DC buck converter for drive applications. The system aims to achieve efficient AC to DC conversion with controlled output voltage, reduced ripple, and improved performance. Hardware implementation and experimental analysis are carried out to evaluate converter operation under practical conditions. The proposed system offers a cost-effective and efficient solution for modern drive applications [10].

II. PROBLEM STATEMENT

In motor drive applications, maintaining a stable and controlled DC output from an AC supply is essential for efficient performance and reliable operation. Conventional AC-DC conversion methods often suffer from problems such as high output ripple, poor voltage regulation, increased power losses, and reduced efficiency under varying load conditions. These issues can negatively affect motor speed control, torque stability, and overall system performance. Therefore, there is a need to develop an efficient single AC-DC buck converter that can provide regulated DC output with reduced losses, improved voltage control, and better dynamic response for drive applications.

III. OBJECTIVES

- To design a single AC-DC buck converter for efficient power conversion in drive applications.
- To convert single-phase AC supply into regulated DC output with minimal ripple.
- To develop a control system for maintaining stable output voltage under varying load conditions.
- To improve converter efficiency by reducing switching and conduction losses.
- To analyze the performance of the converter through hardware implementation and testing.

IV. LITERATURE SURVEY

Mohan, Undeland, and Robbins (2003) discussed AC-DC power conversion techniques in their book “Power Electronics: Converters, Applications and Design.” They explained the working of rectifiers, buck converters, and switching control methods used in motor drive systems. Their study highlighted that buck converters provide efficient voltage regulation with reduced switching losses. However, converter performance depends greatly on the control strategy and component selection.

Erickson and Maksimovic (2001) presented detailed analysis of DC-DC converter topologies in “Fundamentals of Power Electronics.” They described the buck converter as one of the most efficient step-down converters for regulated DC output. Their work showed that PWM control improves voltage regulation and dynamic response. However, high-frequency switching may introduce harmonics and electromagnetic interference.

Rashid (2014) explained modern converter technologies in “Power Electronics: Circuits, Devices and Applications.” He emphasized the importance of controlled AC-DC converters in industrial motor drives and automation systems. The study showed that efficient switching devices such as MOSFETs and IGBTs improve overall system performance. However, thermal management remains a critical challenge in high-power applications.

Singh et al. (2008) studied power factor correction techniques for AC-DC converters in industrial applications. Their research showed that improved converter control can reduce harmonic distortion and enhance input power quality. The proposed methods increased system efficiency and reliability. However, the circuit complexity increased due to additional control components.

Blaabjerg, Teodorescu, and Liserre (2006) focused on control strategies for power electronic converters used in drive applications. Their work highlighted that digital controllers provide better accuracy and faster response compared to conventional analog control. They found that microcontroller-based PWM control improves output stability under variable load conditions. However, software complexity and tuning requirements can increase development time.

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Krein (1998) analyzed switching power converters for electrical drive systems in "Elements of Power Electronics." He demonstrated that buck converters are highly suitable for low and medium power motor drives due to their simple structure and efficient voltage control. The study concluded that proper filtering reduces output ripple and improves drive performance. However, improper filter design may cause voltage fluctuations and reduced efficiency.

Comparison Table

Author & Year	Method Used	Advantages	Limitations
Mohan et al. (2003)	AC-DC Buck Converter	Efficient voltage control	Needs proper control
Erickson (2001)	PWM Buck Converter	High efficiency	Causes harmonics
Rashid (2014)	MOSFET/IGBT Converter	Reliable performance	Thermal issues
Singh et al. (2008)	Power Factor Correction	Better power quality	Complex circuit
Blaabjerg et al. (2006)	Digital PWM Control	Fast response	Software complexity
Krein (1998)	Switching Converter	Simple and effective	Ripple if poorly filtered

V. WORKING OF SYSTEM

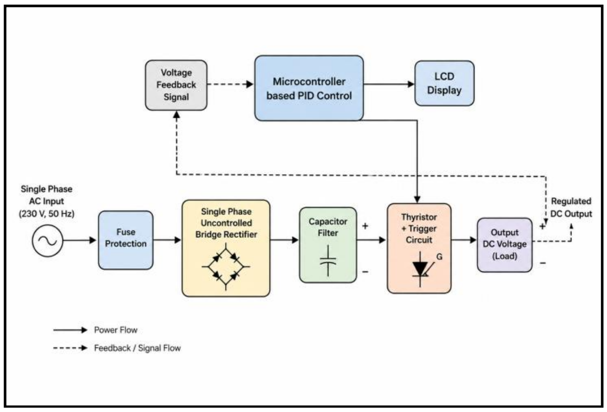

Fig 1: Design of the system

1. Input Power Supply

The system operates using a single-phase AC supply (230 V, 50 Hz), which serves as the main input source for the converter circuit.

2. Protection Circuit

Before entering the main circuit, the AC supply passes through a fuse protection unit. This protects the system against overload, short circuit, and excessive current conditions.

3. AC to DC Conversion

The protected AC supply is fed to a single-phase uncontrolled bridge rectifier. The rectifier converts the AC input into pulsating DC output using diode rectification.

4. Filtering Stage

The rectified DC contains unwanted ripple components. A capacitor filter smooths the pulsating DC and reduces voltage fluctuations to obtain a nearly constant DC output.

5. Feedback Monitoring

A voltage feedback circuit continuously senses the output voltage and sends the measured value to the control unit for comparison and regulation.

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6. PID Control Operation

The microcontroller-based PID controller compares the feedback voltage with the reference voltage. Based on the error, it calculates corrective action to maintain stable output voltage.

7. Triggering Circuit

The controller generates control signals for the thyristor trigger circuit. This circuit controls the firing angle of the thyristor to regulate power flow.

8. Output Regulation

By adjusting the thyristor switching, the converter controls the output and provides a regulated DC voltage according to load requirements.

9. Display Unit

An LCD display is used to show system parameters such as output voltage and operating status for easy monitoring.

10. Final Output

The system delivers a stable and controlled DC output suitable for drive applications, ensuring efficient performance and reduced power loss.

VI. SYSTEM DESIGN

System Overview

The proposed Single AC-DC Buck Converter for Drive Applications is designed to convert single-phase AC supply into regulated DC output for efficient operation of drive systems. The system uses power conversion, filtering, feedback sensing, and control techniques to maintain stable output voltage under varying load conditions. The AC input is first rectified into DC, filtered to reduce ripple, and then regulated using a thyristor-based control circuit. A microcontroller with PID control continuously monitors the output through a feedback mechanism and adjusts the triggering signals to maintain the desired voltage.

Main Components of the System

Single Phase AC Input Supply

Fig 2: Single Phase AC Input Supply

Provides the primary input power (**230 V, 50 Hz AC**) to the system.

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Fuse Protection Circuit

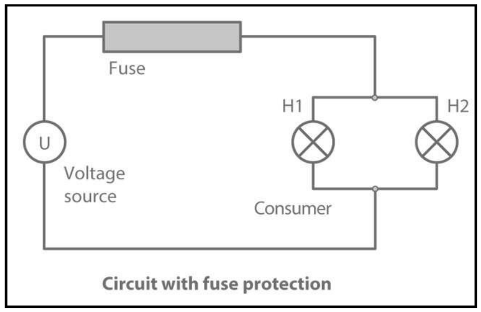

Fig 3: Fuse Protection Circuit

Protects the converter from overcurrent, short circuits, and electrical faults.

Bridge Rectifier

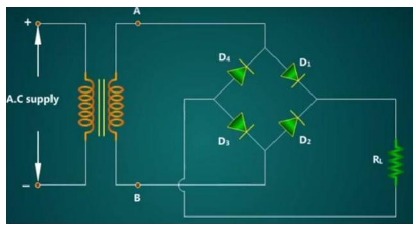

Fig 4: Bridge Rectifier

Converts the AC input into pulsating DC output using diode rectification.

Capacitor Filter

Fig 6: Capacitor

Smooths the pulsating DC and reduces ripple to obtain a stable DC supply.

Voltage Feedback Circuit

Monitors the output voltage and sends feedback to the controller for regulation.

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Microcontroller (PID Controller)

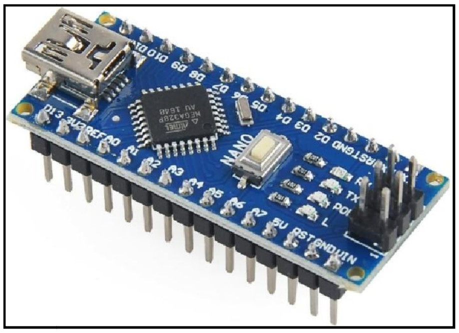


Fig 5: Fuse Protection Circuit

Acts as the main control unit, compares reference and actual voltage, and generates control signals.

Thyristor with Trigger Circuit

Controls switching operation by adjusting firing angle to regulate output voltage.

LCD Display

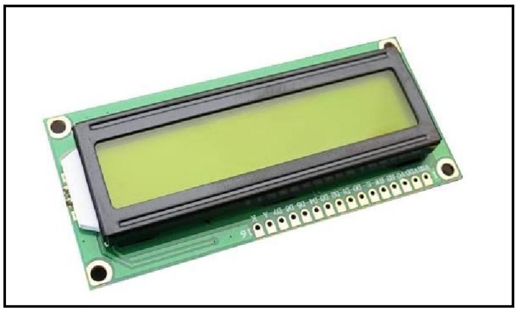


Fig 5: Fuse Protection Circuit

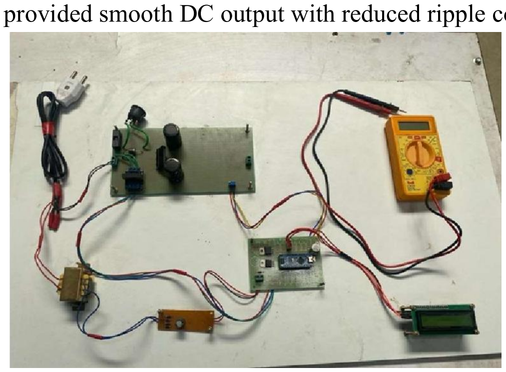
Displays output voltage and system status for monitoring and analysis.

Load / Drive System

Receives the regulated DC output for operating motor drive applications efficiently.

VII. RESULTS

The developed single AC-DC buck converter system was successfully designed and tested for drive applications. The system effectively converted the single-phase AC input into a regulated DC output with improved voltage stability. The bridge rectifier and capacitor filter provided smooth DC output with reduced ripple content.



Experimental observations showed stable converter operation, fast response to voltage changes, and improved efficiency with reduced power losses. The LCD display accurately monitored output parameters during operation. Overall, the system demonstrated reliable performance and proved suitable for motor drive and industrial power conversion applications.

VIII. CONCLUSION

The design and control of the single AC-DC buck converter for drive applications was successfully implemented and analyzed. The system efficiently converted single-phase AC supply into a regulated DC output suitable for drive operations. By using a bridge rectifier, capacitor filter, and microcontroller-based PID control, the converter achieved improved voltage regulation, reduced ripple, and better efficiency under varying load conditions. The experimental results confirmed stable performance, fast response, and reliable operation. Overall, the proposed system provides a cost-effective, efficient, and practical solution for modern motor drive applications.

IX. FUTURE SCOPE

The proposed single AC-DC buck converter can be further improved by integrating advanced control techniques such as fuzzy logic, artificial intelligence, or adaptive control for better dynamic response and higher efficiency under varying load conditions. Future development may include the use of high-speed switching devices like SiC or GaN semiconductors to reduce switching losses and improve thermal performance. The system can also be extended for electric vehicle charging, renewable energy systems, smart grids, and high-power industrial drives. Adding IoT-based remote monitoring and fault detection can further enhance reliability, safety, and real-time performance analysis.

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