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ARDUINO UNO BASED PID CONTROLLER FOR SINGLE PHASE VOLTAGE SOURCE INVERTER

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ABSTRACT
This design presents the design and perpetration of an automatic control system for a single-phase inverter using a motorist circuit governed by a Commensurable-Integral-Secondary (PID) regulator enforced on an Arduino UNO microcontroller. The primary ideal is to insure effective and stable power conversion from DC to AC with minimum harmonious deformation and enhanced dynamic response. The system is able of operating in multiple automatic modes, conforming inverter parameters in real-time grounded on cargo variations and affair feedback. The PID regulator continuously monitors the affair voltage and frequency, stoutly conforming the PWM signals transferred to the motorist circuit. This enables precise control over the Inverter's switching operations, Icing dependable performance Indeed under shifting cargo conditions. The use of Arduino UNO simply es perpetration and offers indexability for unborn advancements or integration with lot-grounded monitoring systems. Experimental results demonstrate the effectiveness of the proposed system In maintaining stable AC affair with bettered effectiveness and reduced response time. This approach is particularly suitable for small-scale renewable energy systems and movable power inventories, where maintaining harmonious power quality is critical. The Arduino UNO plays a central part in executing the control sense, enabling easy perpetration, tuning of PID parameters, and indexability in switching between modes. The inverter is tested under different cargo conditions, demonstrating its capability to maintain a stable AC affair with enhanced trustability and effectiveness. This system has wide operations in low-power renewable energy systems, smart inverters, and educational systems concentrated on power electronics and bedded control. The use of an automatic PID-grounded approach signicantly enhances the functional stability and rigidity of traditional inverter systems..
Keywords: Arduino Uno, PID controller, Bud Converter, Arduino IDE Software

I. Introduction
The design named" Arduino UNO Based PID Controller for Single Phase Voltage Source Inverter" focuses on the design and perpetration of a digitally controlled inverter system that utilizes a PID(Commensurable-Integral Secondary) control algorithm to regulate the AC affair voltage. The system is erected around an Arduino UNO microcontroller, which continuously monitors the affair voltage of the inverter through a voltage seeing circuit and stoutly adjusts the PWM (palpitation range Modulation) signals driving the inverter switches. The thing is to maintain a stable and harmonious AC voltage affair despite changes in cargo or input conditions. By integrating a PID regulator, the system improves voltage regulation, reduces overshoot and steady-state error, and enhances the overall performance of the inverter. The inverter converts a DC input into a single-phase AC affair using power electronic switches similar as Moses or IGBT, which are controlled by the Arduino through a gate motorist circuit. This design has practical operations in renewable energy systems, similar as solar inverters, as well as in uninterruptible power inventories and other AC power conversion needs. The design demonstrates how bedded systems and control proposition can be combined to produce a dependable and effective power electronics result. Conventional inverters frequently operate in fixed modes without adaptive control, making them less effective under varying cargo conditions. oscillations in affair voltage, poor frequency stability, and harmonious deformations are common issues associated with these systems. To overcome these limitations, unrestricted circle control

mechanisms similar as PID(Commensurable-Integral-Secondary) regulators are introduced to regulate the inverter's performance in real-time. This design focuses on the development of an automatic single-phase inverter system that utilizes a motorist circuit to control high-power switches and a PID regulator enforced on an Arduino UNO for precise voltage and frequency regulation. The system is designed to operate in different automatic modes, conforming it get grounded on real-time feedback from voltage and current detectors. The proposed system serves as a low-cost, flexible, and scalable result ideal for educational purposes, small-scale renewable energy systems, and introductory uninterruptible power inventories (UPS). It demonstrates how intelligent control can significantly boost the performance and trustability of conventional inverter setups.

II. Literature

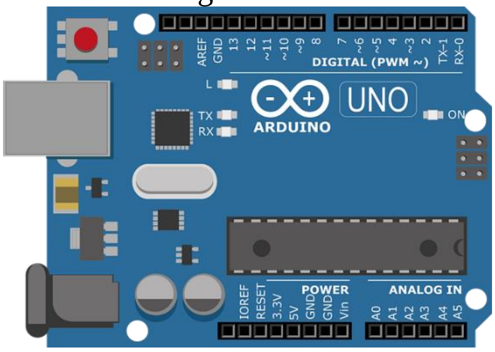
The pursuit of effective and stable power conversion has driven significant interest in Voltage Source Inverters (Isis), particularly in single-phase operations where perfection and control are consummate. The integration of control strategies similar as the Commensurable-Integral-Secondary (PID) regulator with microcontrollers like the Arduino UNO has opened doors to cost-effective and adaptable power electronics systems. Early workshop in inverter control heavily reckoned on analog feedback circles and big tackle, which, while functional, demanded inflexibility and programmability. still, with the arrival of microcontrollers, real-time digital control came doable [1]. Studies similar as those by Bose (2002) laid the root for digital control in power electronics, emphasizing the significance of perfection and responsiveness. Recent literature has decreasingly concentrated on bedding PID regulators into digital platforms. PID control remains popular due to its simplicity, effectiveness, and ease of perpetration. Experimenters like Ghost et al. (2015) explored tuning styles and performance optimization of PID algorithms for dynamic systems, including inverters. Their findings punctuate how proper tuning of PID parameters can significantly ameliorate voltage regulation and flash response [2]. The Arduino UNO, grounded on the ATmega328P microcontroller, has gained traction in academic and prototyping surroundings due to its affordability, open-source ecosystem, and straightforward programming interface. Despite its limited processing power, several studies(e.g., Rahman & Adam, 2018) have demonstrated its viability in controlling switching bias in power transformers, especially for single-phase operations. In the environment of single-phase Isis, maintaining a stable and sinusoidal affair voltage is a patient challenge due to cargo variations and non-linearities [3]. Experimenters similar as Kumar et al. (2020) presented results incorporating PID regulators to acclimate the palpitation range Modulation (PWM) duty cycle, thereby icing better voltage regulation. Their Arduino-grounded prototypes validated the approach for low-power scripts. also, relative studies like those by Singh and Raj put (2021) estimate different control schemes — PID, fuzzy sense, and adaptive control — pressing the trade-offs between complexity and performance [5]. PID regulators, while not as adaptive as ultramodern intelligent regulators, still hold ground due to their robust performance and ease of deployment, especially on tackle- constrained platforms like Arduino. In summary, the confluence of PID control and Arduino UNO for single-phase Isis represents a promising sphere where cost-effectiveness meets functional trustability. While the microcontroller imposes certain computational limitations, careful design and tuning of the PID algorithm can yield a system that's both responsive and practical for educational and small-scale artificial operations [6].

III. MODELLING & METHODLOGY

In the study, the following hardware and software components are used to develop the
ARDUINO UNO BASED PID CONTROLLER FOR SINGLE PHASE VOLTAGE SOURCE INVERTER
HARDWARE COMPONENTS
3.1 Arduino Uno
3.2 PID Controller
3.3 Bud converter

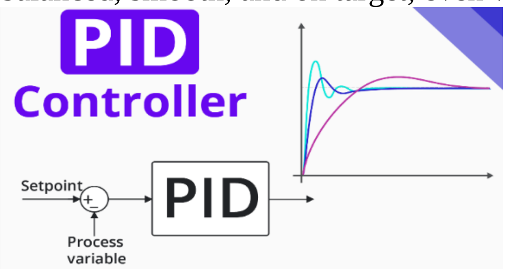
3.4 Resistors
3.5 Fuse
3.6 SOFTWARE COMPONENTS
3.7 Arduino IDE

3.1 Arduino Uno: - The Arduino Uno acts like a digital brain, brining ideas to life through code and circuits. Powered by an Atmega328p microcontroller, it reads inputs- like light from a sensor or a button press-and turns them into outputs, such as spinning a motor or lighting an LED. You write the instructions using the Arduino IDE, and once uploaded, the board follows them precisely, Creating an interactive bridge between software and the physical word. Its simple, smart, and endlessly creative.



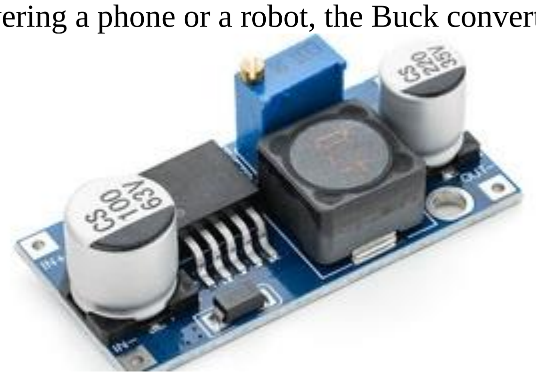
Arduino UNO

3.2 PID controller: - A PID controller works like a smart autopilot for systems—it constantly watches, thinks, and corrects. It compares what's happening (the actual output) to what should happen (the desired set point), then calculates the error. Using three powerful strategies—Proportional (P) for immediate reaction, Integral (I) for past mistakes, and Derivative (D) for future predictions—it fine-tunes control in real-time. Like a skilled driver adjusting speed and steering, the PID keeps things balanced, smooth, and on target, even when conditions change.



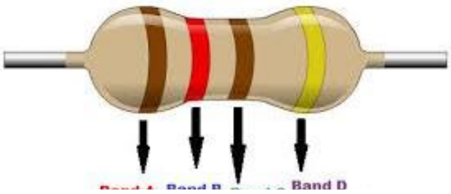
PID Controller

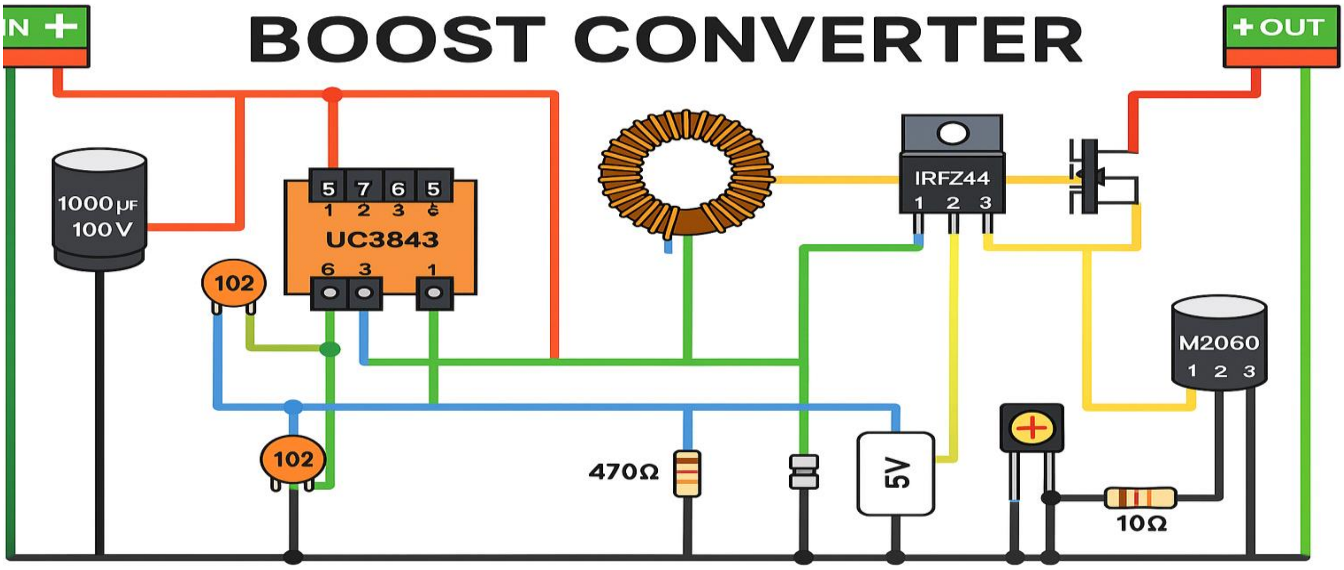
3.3 Bud converter: - A Buck converter is like a voltage sculptor—it takes high voltage and expertly carves it down to a lower, usable level. Using a fast-switching transistor, an inductor, and a capacitor, it chops the input into pulses, then smooths them into a steady lower voltage. It's super-efficient, wasting little energy, and acts like a power-smart bridge between batteries and electronics. Whether powering a phone or a robot, the Buck converter keeps things running cool and steady.



BUD Conveter

3.4 Resistors: - Resistors are the traffic controllers of electricity—they don't stop the current, but guide and limit its flow with precision. Like narrowing a water pipe to control pressure, resistors reduce voltage and current to safe, usable levels for delicate components. Whether dimming an LED or setting the speed of a motor, they quietly do their job, ensuring circuits stay balanced, protected, and efficient. Small but mighty, resistors are the unsung heroes of electronics.





BLOCK DIAGRAM

IV. EXPERMENTAL INVESTIAGATION

In this experimental journey, the Arduino UNO takes the lead role as a digital conductor, orchestrating the behaviour of a single-phase Voltage Source Inverter (VSI) with precision. A PID controller, finely tuned and embedded into the Arduino, becomes the brain behind the system—constantly sensing, analyzing, and adjusting. The setup begins with the inverter converting DC to AC, while the Arduino constantly monitors the output voltage through sensors. Any deviation from the desired voltage is immediately detected. The PID algorithm—coded and uploaded onto the Arduino—responds by adjusting the PWM signals sent to the inverter's switching devices. This real-time correction ensures the output voltage remains stable, even under fluctuating loads or varying input conditions.

Data is collected to analyze the system's dynamic response, settling time, overshoot, and steady-state error. Graphs of output voltage versus time reveal a smooth waveform shaped by the PID's intelligent corrections. With each test run, the system proves its ability to maintain voltage integrity, confirming the Arduino-PID combination as a powerful, low-cost control solution for smart power electronics. This project shows the working in fig 6 &fig 7.


Fig 6. Driver Circuit

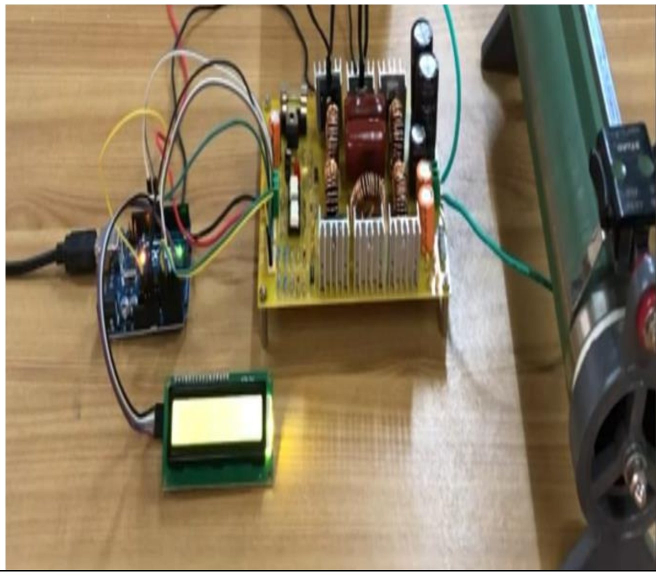


Fig 7. Connection Diagram

This hands-on investigation not only validates the controller's effectiveness but also showcases the Arduino UNO as a practical tool for real-world inverter control—bringing theory to life with digital finesse.

V. CONCLUSION

This exploration bridges the world of embedded control and power electronics, proving that precision doesn't always require complexity. The Arduino UNO, coupled with a well-tuned PID controller, demonstrated remarkable capability in stabilizing the output of a single-phase Voltage Source Inverter. Despite its simplicity and affordability, the system responded intelligently to voltage fluctuations, minimizing error and ensuring consistent performance.

The experiment highlights how open-source platforms like Arduino can effectively manage real-time control challenges in power applications. It's a testament to how innovation can thrive with accessible tools—transforming a basic microcontroller into the heart of a smart, adaptive inverter system. This work lays a strong foundation for scalable, efficient, and cost-effective inverter control systems, where performance meets practicality.

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