IGBT-based Three-Phase Inverter using Arduino – Applicable in Micro grid Systems

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***Abstract*- IGBT-based three-phase inverters are developed for microgrids and sustainably powered industrial operations. This inverter converts DC electricity into three-phase AC for reliable power conversion. Insulated Gate Bipolar Transistors (IGBTs) replace MOSFETs in the system. The recommended technique creates 223V AC square waves at each phase using a 12V DC battery. This conversion requires accurate switching of three power IGBT stages. The IGBTs switch under PWM signals from an Arduino Uno R3, ensuring accurate and flawless phase conversion. IGBT stages include six components, totaling eighteen, allowing the inversion operation to be done individually for each of the three single-phase connections. The Arduino Uno R3 generates PWM signals with a 120-degree phase offset to assure synchronization. Three center-tapped step-up transformers at the IGBT outputs increase the signal. A 60W incandescent lamp is employed in each load testing phase to evaluate system performance. The results reveal that the three-phase line can meet operational parameters with 386.25V and 0.58A. Electronic circuit design and simulation with Proteus 8.9 Professional ensures system reliability. The Arduino IDE creates Arduino Uno programming scripts for easy integration and control. The practical testing step checks the system's operation and performance in real-world situations to confirm its readiness for deployment in microgrids and industrial sites that need sustainable power conversion solutions.**

Index Terms: **Arduino UNO, IGBT, Three phase connection, AC, DC, Proteus.**

I. INTRODUCTION

The use of fossil fuels continues to be the dominant source of energy worldwide, which is a substantial contributor to the destruction of the environment. The answer has been an increase in the amount of effort put into transitioning to alternate energy sources. In addition, the ever-increasing demand for electricity presents difficulties for power distribution networks, which subsequently results in grid instability and frequent power outages. In order to address these concerns, there has been a rapid increase in the use of environmentally friendly technology, with microgrid systems emerging as a potentially useful alternative. It is possible to achieve decentralized power distribution through the utilization of microgrids, which incorporate a variety of renewable energy sources such as solar, wind, and tidal power. This kind of distributed generation makes it possible for families that have access to renewable energy sources to contribute to the grid, which helps to alleviate problems associated with peak demand and reduces the cost of power. In spite of this, an inversion system is required in order to simplify the functioning of AC appliances and power tools in residential settings. This is because renewable energy sources typically provide direct current (DC) sources of electricity. An inverter, which is a piece of electrical equipment that can convert direct current (DC) electricity into alternating current (AC) power while preserving the correct voltage and frequency, is an essential component in this scenario. Inverters are capable of having a variety of output phase configurations, the most common of which being single-phase and three-phase variations. The development of a Three Single-phase Parallel Inverter that makes use of Insulated Gate Bipolar Transistors (IGBTs) is the primary subject of this study. Voltage Source Inverters (VSI) and Current Source Inverters (CSI) are the two primary classifications that inverters are often classified into. The work in question makes use of a voltage source inverter (VSI), which is a device that transforms a DC power supply's fixed voltage into AC electricity with a variable frequency. To be more specific, Pulse-width Modulated (PWM) voltage source inverters are employed because of the excellent electrical efficiency they possess.

Switching power semiconductor devices, such as IGBTs, are utilized in pulse width modulation (PWM) in order to generate continually altering analog signals. Single-pulse modulation, multiple-pulse modulation, and sinusoidal pulse-width modulation are some of the other types of pulse-width modulation (PWM) approaches that are available. In the context of this research, IGBTs are utilized to create pulse width modulation (PWM) signals. Single-pulse modulation with 120-degree displacement is achieved. Microcontrollers, such as Arduino Uno R3, are often used to create pulse width modulation (PWM) signals. These microcontrollers provide a platform that is both user-friendly and cost-effective for programming electrical devices. Multiple digital input/output pins are included on the Arduino Uno R3, which enables the production and control of pulse width modulation (PWM) signals. To summarize, the work that has been given is centered on the development of a Pulse-width Modulated inverter that makes use of IGBTs for the purpose of achieving efficient power conversion in microgrid systems. Taking this method makes it possible to include renewable energy sources into the grid, which in turn contributes to the development of an energy infrastructure that is more sustainable and robust.

II. LITERATURE REVIEW

Chowdhury et al.'s study from 2021 describes a three-phase inverter powered by power MOSFETs that is based on Arduino. The inverter, which is made for microgrid systems, makes it easier to convert DC electricity into three-phase AC power effectively. The study emphasizes the usefulness of MOSFET technology in the integration of renewable energy sources. It was published in the International Journal of Electrical and Electronic Engineering & Telecommunications. The study addresses the rising need for dependable energy sources and advances sustainable power distribution systems.

In their 2012 work, Nandurkar and Rajeev primarily addressed the design and modeling of a three-phase inverter specifically intended for grid-tied solar power systems. The inverter's 30KW power output is intended to effectively transform DC electricity from solar panels into three-phase AC for grid integration. Through improved solar system performance and grid compatibility, this work advances the field of renewable energy technology. The study, which was published in the Power journal, emphasizes how important dependable inverters are to optimizing solar energy use in grid-connected applications.

The paper by Zhang et al. (1997) introduces a three-phase inverter featuring a neutral leg and space vector modulation. Presented at the Applied Power Electronics Conference (APEC) '97, the research explores innovative techniques for enhancing inverter performance. By incorporating space vector modulation, the inverter aims to achieve superior control and efficiency in three-phase AC power generation. The study contributes to advancements in power electronics by proposing novel methods for optimizing inverter operation. Published by IEEE, this research highlights the ongoing pursuit of innovative solutions in the field of applied power electronics.

III. EXISTING SYSTEM

A novel approach to designing a three-phase inverter system that makes use of Arduino microcontrollers and power MOSFETs is presented in the article titled "Arduino-based Three-Phase Inverter using Power MOSFET for Application in Microgrid Systems," which was published in the International Journal of Electrical and Electronic Engineering & Telecommunications in the year 2021. In the context of microgrid systems, which are gaining more and more significance for the distribution of decentralized energy, an inverter system of this kind carries a substantial amount of value.

When it comes to the implementation of a three-phase inverter, the research conducted by Chowdhury and colleagues focuses on making use of components that are easily accessible and inexpensive, such as Arduino microcontrollers and power MOSFETs. This approach not only lowers the overall cost of the system but also improves its accessibility, which makes it appropriate for a wide range of applications inside microgrid systems.

The employment of Arduino microcontrollers enables versatile control and monitoring capabilities, which in turn enables the inverter system to be managed and operated in an effective manner. In addition, the use of power MOSFETs makes it possible to switch at high speeds and guarantees that the inverter will work reliably.

One of the most important advantages of the technique that has been suggested is that it has the potential to be scalable and adaptable, which enables it to be adapted to a variety of microgrid configurations and needs. Furthermore, the use of components that are easily accessible by the general public streamlines the processes of maintenance and repair, which contributes to the overall dependability of the system.

However, despite the fact that it has many positive aspects, the document can have certain shortcomings or restrictions that need to be solved. As an illustration, the scalability of the system can be restricted due to the limitations of the Arduino microcontrollers in terms of their processing power and memory consumption. In addition, the effectiveness and performance of the inverter system should be extensively assessed under a variety of load circumstances and grid disruptions in order to determine whether or not it is feasible for use in microgrid applications that are implemented in the real world.

Using Arduino microcontrollers and power MOSFETs, the study proposes a viable way to developing a three-phase inverter system for microgrid applications. In summary, the paper presents this technique. It is necessary to do more research in order to address potential limits and validate the performance of the proposed system across a variety of different operating situations. Some of the advantages that the suggested system provides include cost-effectiveness and flexibility.

IV. PROPOSED SYSTEM

By replacing power MOSFETs with Insulated Gate Bipolar Transistors (IGBTs), the suggested system intends to improve upon the architecture of a three-phase inverter that is currently used for microgrid systems. It is recommended that this adjustment be made in order to address certain constraints and perhaps increase the performance and efficiency of the inverter system with this modification.

Through the utilization of IGBTs in place of MOSFETs, the suggested system intends to take advantage of the benefits that are made available by IGBT technology. These benefits include greater voltage and current ratings, reduced conduction losses, and improved thermal stability. Because of these features, IGBTs are particularly well-suited for high-power applications such as microgrid systems, which place a premium on both reliability and efficiency.

Furthermore, as comparison to MOSFETs, IGBTs have a higher level of ruggedness and durability, which makes them more ideal for performing high-voltage and high-current switching operations that are commonly seen in three-phase inverters. The enhanced resilience of the microgrid system has the potential to add to the system's overall lifetime as well as its operational stability.

In addition, the utilization of IGBTs may make it possible for the proposed inverter system to function more effectively in the presence of variable load situations and disturbances in the grid. The increased switching properties of IGBTs, when paired with updated control algorithms, have the potential to optimize power conversion processes and decrease energy losses, hence contributing to an overall improvement in the efficiency of the microgrid system.

In addition, IGBTs provide better design flexibility and scalability, which makes it possible to install higher-power inverter systems without dramatically increasing the complexity or expense of the system. The scalability of this system is especially advantageous when it comes to extending microgrid installations or supporting future increases in the demand for electricity.

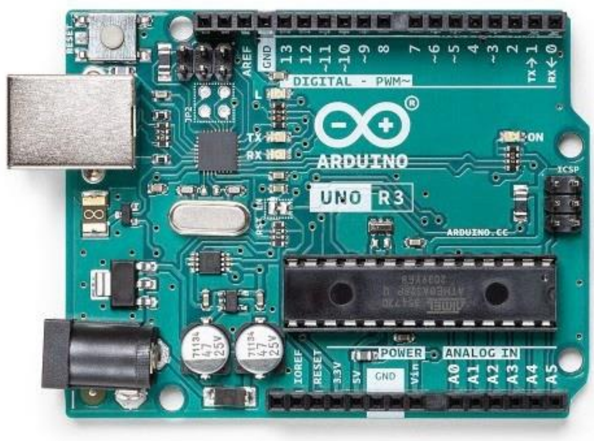
On the other hand, it is essential to keep in mind that the use of IGBTs may result in the introduction of certain trade-offs, such as higher switching losses and more complexity in driver circuits in comparison to designs that are based on MOSFET integration. In order to achieve the highest possible levels of performance and efficiency, it is necessary to conduct a comprehensive study and optimization of the design parameters and control techniques contained within the proposed system.

As a conclusion, the suggested replacement of MOSFETs with IGBTs in the three-phase inverter system for microgrid applications has the potential to increase performance in terms of reliability, efficiency, and scalability. However, in order to guarantee the effective implementation of the proposed system in microgrid deployments in the real world, it is required to give serious thought to the trade-offs and conduct a comprehensive performance evaluation.

V. HARDWARE DESCRIPTION

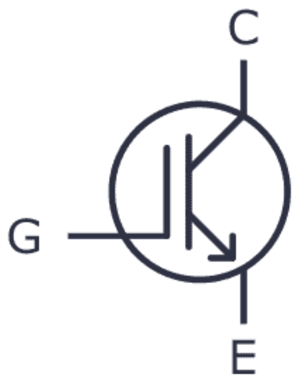
Arduino UNO:

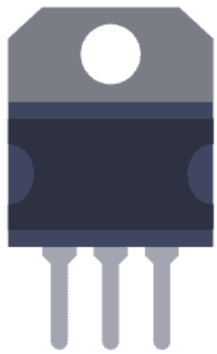
The Arduino Uno is a well-known open-source microcontroller board that is frequently utilized for projects involving prototyping and do-it-yourself electronics. An Atmega328P microcontroller is included in it, and it has 14 digital input/output pins, six of which are capable of being utilized for pulse width modulation (PWM) output. In addition to that, it has a USB connection for programming and power supply, as well as six analog input pins. Considering that Arduino Uno allows for simple interface with a wide variety of sensors and actuators, it is an excellent choice for both novice and experienced users alike. Because of its ease of use and adaptability, it has become an indispensable tool for the maker community in the process of developing interactive electrical gadgets. The Arduino IDE, which is a user-friendly development environment based on the C/C++ programming language, is utilized in the process of programming the Arduino Uno module. Projects involving electronics and programming may benefit from quick prototyping and experimentation thanks to Arduino Uno's extensive ecosystem of libraries and community support.



IGBT (Insulated gate bipolar transistor):

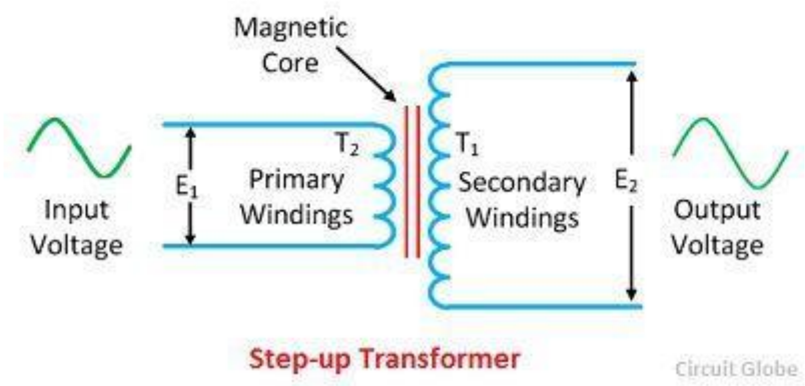
Insulated Gate Bipolar Transistor, often known as IGBT, is a semiconductor device that exhibits high power and is frequently utilized in applications related to power electronics. All of the benefits that are associated with MOSFET and bipolar junction transistor (BJT) technologies are combined in this device. An IGBT is a device that has a gate, a collector, and an emitter. It has a device structure that consists of three terminals. Because of its insulated gate, it is able to regulate high currents and voltages in an effective manner, which results in it being suited for switching enormous quantities of power. IGBTs are employed in a variety of applications, including motor drives, inverters, and power supply, all of which need a high level of efficiency and dependability. As a result of their low conduction losses and high switching rates, power conversion systems are able to achieve greater energy efficiency. IGBT modules are offered in a variety of voltage and current ratings to cater to the various requirements that are imposed by the industrial sector. IGBTs are an essential component in contemporary power electronics systems due to the sturdy performance and adaptability on which they are based.





Step-up Transformer:

There is a type of transformer known as a step-up transformer that raises the voltage levels from the input to the output of the transformer. This device is made up of two coils that are twisted around a core, with the secondary coil having a greater number of turns than the primary coil. As a result of the flow of alternating current through the main coil, a fluctuating magnetic field is created, which in turn causes the secondary coil to generate a greater voltage. Step-up transformers are often used in power distribution systems for the purpose of elevating voltage for the purpose of long-distance transmission. Additionally, step-up transformers are utilized in electronic gadgets for the purpose of enhancing voltage levels amongst various components. It is because of their contributions that electrical energy may be transferred from one application to another in an effective manner.



VI. SOFTWARE DESCRIPTION

Proteus:

Proteus is a well-liked software program for PCB (Printed Circuit Board) layout, simulation, and electronic circuit design. It is a feature-rich set of tools for creating and testing electrical circuits in a virtual environment, developed by Labcenter Electronics Ltd. With Proteus, users can effortlessly construct intricate circuits because to its extensive collection of electronic components, which includes resistors, capacitors, integrated circuits, and microcontrollers. Thanks to its simulation features, users may examine circuit behavior and verify functionality before to actual implementation. Proteus also provides tools for PCB layout design, enabling users to design circuit boards of expert caliber. Engineers, students, and enthusiasts use Proteus extensively for electronic design and prototyping because to its intuitive interface and robust functionality.

Arduino IDE:

A software platform called the Arduino Integrated Development Environment (IDE) is used to program Arduino microcontroller boards. The Arduino IDE is a user-friendly interface designed by Arduino LLC that makes it easy to write, compile, and upload code to Arduino boards. It is suitable for both novice and expert programmers since it offers a condensed version of the C and C++ programming languages. Syntax highlighting, automated code formatting, and pre-built libraries for integrating with different sensors and actuators are just a few of the features available in the IDE. For troubleshooting and tracking data sent between the Arduino board and the PC, it also provides a serial monitor. The Arduino IDE has established itself as the go-to tool for creating projects and prototypes with Arduino boards thanks to its ease of use and adaptability.

VII. CODE

```
void setup() {
  pinMode(11, OUTPUT);
  pinMode(10, OUTPUT);
  pinMode(9, OUTPUT);
  pinMode(8, OUTPUT);
  pinMode(7, OUTPUT);
  pinMode(6, OUTPUT);
}

void loop() {
  int var=0;
  digitalWrite(11, HIGH);
  digitalWrite(7, LOW);
  digitalWrite(9, LOW);
  digitalWrite(10, LOW);
  digitalWrite(6, HIGH);
  digitalWrite(8, HIGH);
  delayMicroseconds(6670); // Adjusted delay to microseconds
  digitalWrite(9, HIGH);
  digitalWrite(8, LOW);
  while(var==0){
    delayMicroseconds(3330); // Adjusted delay to microseconds
```

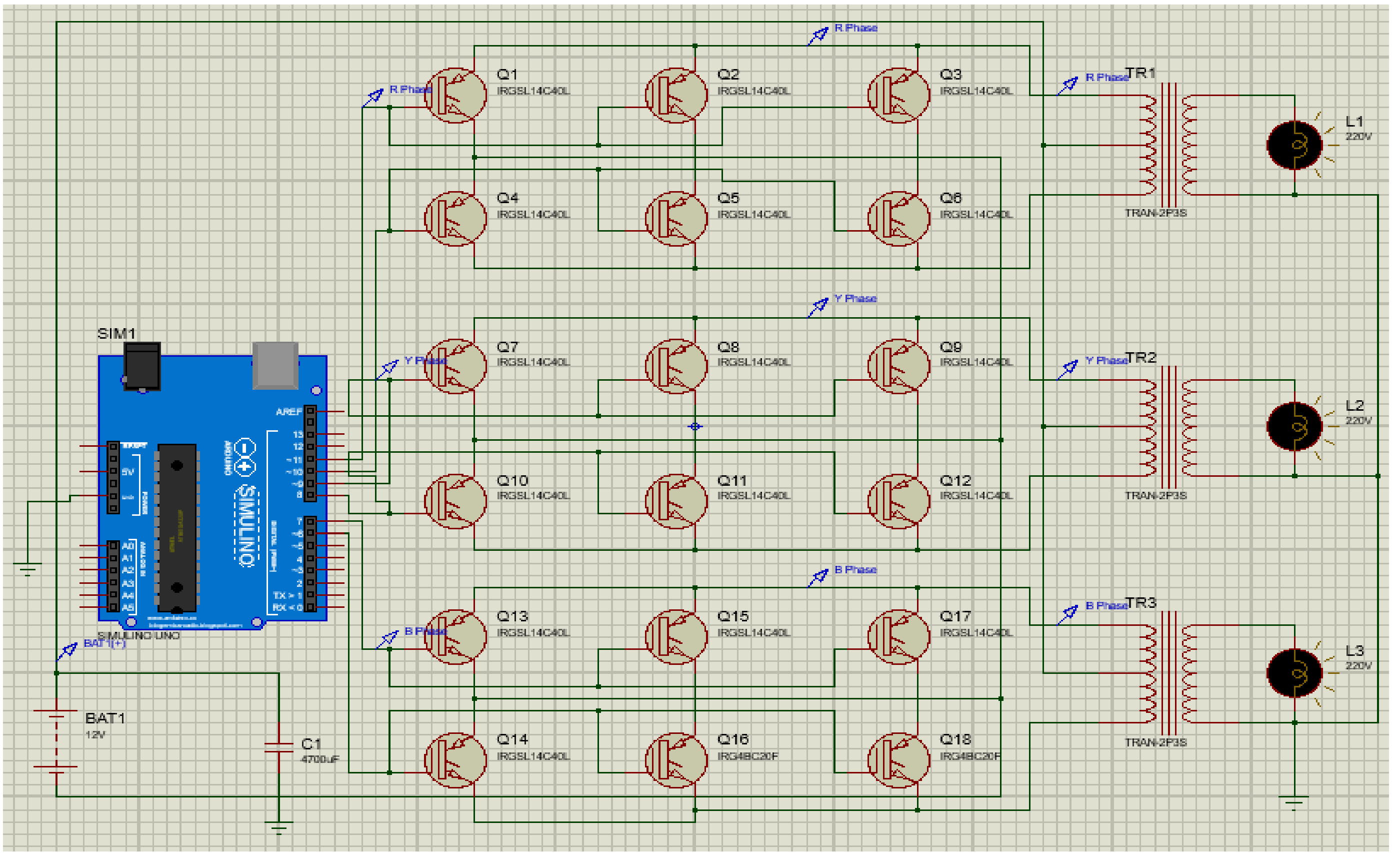
```
    digitalWrite(11, LOW);
    digitalWrite(10, HIGH);
    delayMicroseconds(3330); // Adjusted delay to microseconds
    digitalWrite(7, HIGH);
    digitalWrite(6, LOW);
    delayMicroseconds(3330); // Adjusted delay to microseconds
    digitalWrite(9, LOW);
    digitalWrite(8, HIGH);
    delayMicroseconds(3330); // Adjusted delay to microseconds
    digitalWrite(11, HIGH);
    digitalWrite(10, LOW);
    delayMicroseconds(3330); // Adjusted delay to microseconds
    digitalWrite(7, LOW);
    digitalWrite(6, HIGH);
    delayMicroseconds(3330); // Adjusted delay to microseconds
    digitalWrite(9, HIGH);
    digitalWrite(8, LOW);
  }
}
```

VIII. RESULTS

According to the information that has been supplied, the system that has been presented entails the development of an Arduino-based three-phase inverter that makes use of IGBTs rather than MOSFETs during operation. This is how the sections may be updated to reflect the new information:

Simulations were run with Proteus 8.9 Professional in order to validate and assess the functioning of the proposed system. The results of these simulations are presented in the following paragraphs. The functioning of the system was evaluated from the perspective of both the operational principles and the programmed codes.displays a snapshot of the simulation, illustrating the lighting of three lights or bulbs, so verifying that the various inversion operations were successful. In addition, transient reactions were investigated in order to guarantee that the system met the requirements of the design. Please illustrate the input-output signals, confirming that square alternating current (AC) waves are being generated with a phase shift of 120 degrees between each of the three phases.

Software Implementation and Results: The three-phase inverter system that was proposed was effectively realized by making use of the components and peripheral devices that were described in the Proteus design. shows the operational condition of the system that has been deployed, with illuminated lights certifying the functionality of each single-phase inverter in accordance with the results of the simulation.



DISCUSSION:

This research was conducted with the intention of designing and implementing a three-phase inverter that was based on Arduino and was suited for use in microgrid applications. It is possible to drive a variety of three-phase household appliances or power tools using the inverter system that has been designed since it provides a square wave output of 223 volts and has a phase displacement of 120 degrees between each phase. In spite of the fact that the functionality of the system has been confirmed, it is common known that sinusoidal signals are necessary for the operation of the majority of three-phase appliances or instruments. As a result, the focus of future development will be on incorporating a filter at the output in order to transform the square wave into a sinusoidal wave. This will result in the system being compatible with a larger variety of applications.

IX. CONCLUSION

Using Arduino, a three-phase inverter system has been designed and developed that uses Insulated Gate Bipolar Transistors (IGBTs) rather than MOSFETs. This system may be used in microgrid applications since it can provide 223V square wave outputs from a 12V battery. The suggested system's functionality has been thoroughly confirmed by simulation and real-world application, confirming its suitability for widespread use. The Arduino is powered by a 12V battery and has a separate voltage regulator to provide steady operation at 10V. The inverter system contains three single-phase connections and a total of eighteen IGBTs; however, by integrating more powerful IGBTs, this number may be lowered to six. Using 60W incandescent light bulbs as loads, each phase of the inverter system is tested to show that it can provide 386.25V for three-phase operation and 223V for single-phase output. Additionally, the system meets the criteria for powering a variety of electrical instruments that are frequently used in microgrid systems or small industrial facilities by delivering a current of 0.58A. To put it briefly, the suggested IGBT-based three-phase inverter system provides a dependable and effective way to power three-phase appliances in microgrid configurations, guaranteeing compatibility with a variety of industrial applications needing strong and long-lasting power supplies.

X. ACKNOWLEDGMENT

The preferred spelling of the word "acknowledgment" in America is without an "e" after the "g". Avoid the stilted expression, "One of us (R. B. G.) thanks . . ." Instead, try "R. B. G. thanks". Put applicable sponsor acknowledgments here; DO NOT place them on the first page of your paper or as a footnote.

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