IoT Based Inverter for Autonomous Electric Vehicle Drive using CIPOS IPM

D Sai Prasanthi
Assistant Professor
Department of Electrical
And Electronics Engineering,
Ramachandra College of
Engineering, India

Narendra Bavisetti
Assistant Professor
Department of Electrical
And Electronics Engineering,
Ramachandra College of
Engineering, India

Ch Sabitha
Assistant Professor
Department of Electrical
And Electronics Engineering,
Ramachandra College of
Engineering, India

B Pathrisamma
Assistant Professor
Department of Electrical
And Electronics Engineering,
Ramachandra College of
Engineering,India

Abstract : When it comes to improving motor control technology, intelligent power modules (IPM) are crucial. In a small and integrated design, these modules merge control circuitry with power semiconductor devices like MOSFETs and IGTs. Integrated photovoltaic modules (IPMs) provide dependable and effective solutions for smart and contemporary motor control applications, meeting the rising need for energy efficiency and reduction of carbon dioxide emissions caused by the proliferation of electrical motors. Finally, the abstract recognizes that IPMs will be important in the development of motor control in the future, which will promote sustainability and advancement in many other fields.

Keywords - IPM, IGBT, Motor Control, Sustainability, Remote Applications..

I. INTRODUCTION

Energy consumption in both rich and developing nations is defined by the pervasiveness of electrical machines, which are part of complex systems driven by sophisticated controllers. New possibilities for improved motor drive control systems have been made possible by advancements in microcontroller and microprocessor technology. Motor drives have been radically improved in every way because to these and other technological advancements, such as power switching devices, converter circuits, motor design, and transducers.

A. Background

Building an integrated circuit that combines Internet of Things (IoT) based systems with controller circuitry to manage the operation of an autonomous vehicle in harsh environments, out-of-the-way places, and other difficult-to-reach situations is a formidable task. The potential benefits of using IoT-based systems to aid humanity in the face of natural disasters like earthquakes, landslides, avalanches, and tsunamis are taken into account when designing integrated circuits for use in electric vehicles, EV chargers, photovoltaic systems, pumps (including ventilation fans, circulation pumps, air purifiers, dishwashers, and refrigerator compressor drives), and other appliances [10]. Emerging AV (Autonomous Vehicle) technology may help lower transportation costs and provide accessibility for those with mobility issues and low-income households. This revolutionary technology has far-reaching consequences and uses that go beyond what is currently thought, and it is also anticipated to have substantial repercussions. Intelligent Power Modules, a part of the Controlled Integrated Power System (CIPOS), are efficient power modules that are small, well-integrated, and suitable for a variety of motor applications. These modules rely on the most recent integrated gate driver ICs, MOSFETS, and IGBTs from Infineon. Packaging Options for CIPOS IPMs CIPOS IPMs are available in a variety of sizes and shapes, including Mini, Maxi, Nano, Micro, and Tiny.

B. Motivation

If you need to convert low-voltage direct current (DC) from sources like batteries, solar panels, or cells into alternating current (AC) to power your electronics, an inverter is a great investment. Powering electronics like computers, TVs, and mobile phones with energy extracted from a car battery is a good example. Applications in industries and motors, uninterrupted power supplies, electric vehicles ("brain of an electric vehicle"), electric charging stations, centrifugal pumps, and solar power systems are only a few examples. Inverters are sometimes referred to be the "brains" of nearly every project that is undertaken on a global scale. Our personal and professional lives are set to undergo a radical transformation because to the Internet of Things (IoT). But extensive Internet of Things (IoT) solutions dependent on flexible and long-lasting wireless connections are essential for this promise to materialize. The tiny Wi-Fi module is at the heart of this phenomena; it is essential for connecting almost any product to wireless networks. The Internet of Things (IoT) is a system that incorporates several different wireless technology standards, each with its own set of features that might affect how well IoT applications work.

C. Objective

In this project, we will build a printed circuit board (PCB) with a circuit that can run different types of motors without human intervention using a server. This will enable the user to supply AC power in places where batteries aren't an option, making the device more portable and eliminating the need for bulky power cords. Humans will mostly benefit from this system's use of unmanned aerial aircraft (UAVs), auto-agricultural equipment (Auto-Agri), and other types of electric vehicles. Instead of drawing electricity from an external DC source, the inverter uses it. You can find power inverters that are all electronic, or you can find those that combine electrical circuitry with mechanical components like rotating gear.

II. RELATED LITERATURE

This section provides a synopsis of related initiatives by reviewing academic sources like research papers, journal articles, and publications.

A new, very effective electrical gadget known as a "Intelligent Power Module" (IPM) was created by a group of researchers [1]. This IPM is perfect for demanding applications due to its ability to handle 450 amps of current at 600 volts. Electronic switches, packaging, and control circuits were the three main areas of concentration. These switches, known as IGBTs, are engineered to power on and off rapidly while wasting as little energy as possible.

The housing is small and well-thought-out, with plenty of places to plug in cables and other parts. The control circuits are responsible for operating the motor, safeguarding it from harm, and communicating any issues.

The PV-IPM is a unique "smart power module" (PV) developed by Mitsubishi Electric for use in solar panels [2]. This module enhances the efficiency of converting solar energy into electricity. To make it more user-friendly and secure, it employs cunning strategies like minimizing energy consumption and including built-in controls.

"Intelligent Power Modules" (IGBT-IPMs) are powerful electronic devices utilized in autos and industries, according to a research [3]. These modules first appeared in the 1980s and have since undergone continuous improvement, allowing them to manage greater power with greater efficiency. Three factors contributed to this enhancement: wiser control and protection mechanisms, improved design of the primary switching components (IGBT chips), and the addition of built-in sensors to monitor the module. The most recent IGBT-IPMs are light years ahead of the standard, commercially available models.

In order to provide energy to a residence in a distant part of Tunisia, a customized power system was constructed [4]. Several methods of producing energy were developed using local weather and solar data: A small diesel generator for emergencies, solar panels to harness the sun's energy, wind turbines to harness the force of the wind, and batteries to store the electricity for later use. Homer Pro was the tool they used to experiment with various configurations of these factors until they found the optimal one. With this optimal setup, the home's electrical demands might be met for as little as 41.5 cents per kilowatt-hour (kWh). It was also more eco-friendly than diesel because it relied on renewable energy sources like wind and solar power.

III. THE PROPOSED SYSTEM

A. System Overview

Figure 1 shows the block diagram of the system's internal components, including the following: CIPOS IPM, TACO speed sensor, USB Type-C for programming and serial communication, DC link and JTAG for traditional programming, ESP2, and standalone microcontrollers ATMEGA 328-AU and 8A-AU. The power source for the ATMEGA 8 and 328p controllers will be provided by USB Type C. Here, we're programming the microcontroller device using the USB Chip Programmer, which is a versatile and user-friendly programming tool that supports a wide range of chips. When using a USB port as a serial port, the signals can be directly connected to the RX and TX pins of the microcontroller. To ensure proper communication, connect the digital serial Rx to the MCU TX and digital serial Rx to the MCU Rx. Sallen-Key filters have the ability to boost the output voltage beyond what the input voltage can handle. An easy way to regulate the voltage gain of a non-inverting op-amp amplifier is to supply it with an input voltage. It will also serve to filter out any extraneous signals that may be present in the power source.

A signal proportionate to the current flowing through the motor is produced by a current sensor. The car can thereafter be controlled using the produced signal. An integral part of many on-board systems, the speed sensor measures the motor's magnetic rotation speed and outputs a voltage proportional to that speed. The board may accept DC power supplies through the DC connection. Motors for a wide range of uses can be driven by CIPOS (inverters), which transform DC power into AC power.
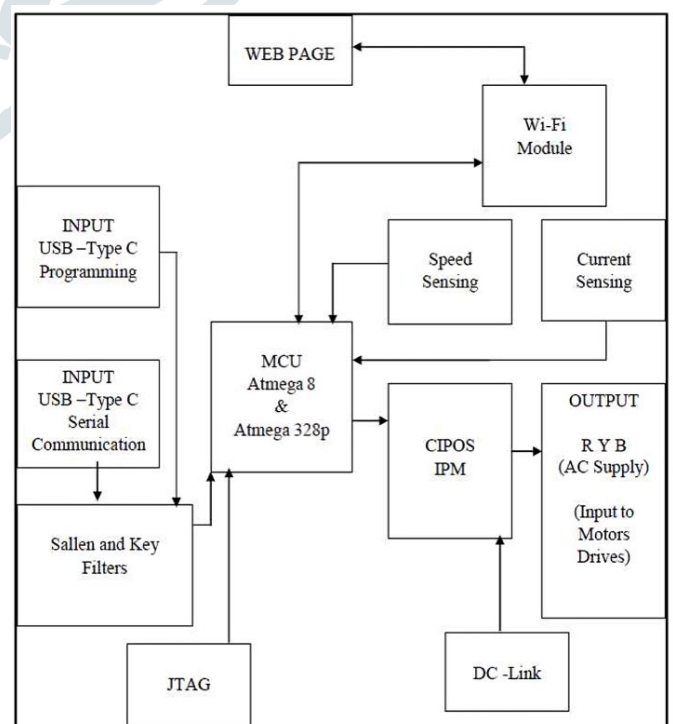

Figure1: Block Diagram

B. Methodology

Figure 2 demonstrates that the initial phase of this project proposal is to use Ki-CAD to create the schematic. There should be no space for technical mistakes in the schematic since it should be well-designed and tested. The latter can be handled using the software's built-in design rule check capability. Once the design is complete, the following step is to test the entire schematic on a Vero board. This will help verify the design, identify any vulnerabilities, and fix them before moving on to the layout process. Afterwards, we move on to the printed circuit board layout, which involves precise positioning and routing. The next step, when the PCB design is complete, is to create the fabrication details, or Gerber files, and send them to the manufacturer. We need to
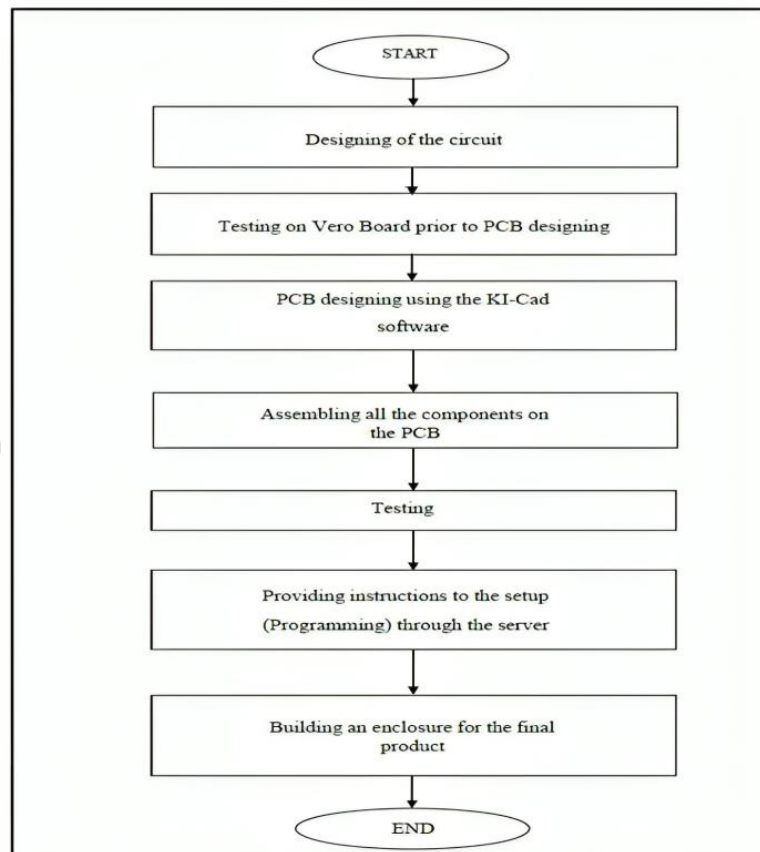

Figure 2: Flow Diagram

put everything together after the PCB is prepared. The next step is to minimize the massive amount of heat loss from the inverter by creating a heat sink that is specifically designed to absorb CIPOS. After we fill the board, we go on to the testing face to put the integrated design through its paces with different loads, such an AC induction motor, among others. Once the board is ready, we may use the mild steel to construct an enclosure. Controlling the product with effective motor control approaches, such as PID, follows hardware establishment. The next step is to set up a web server and link the board to it using the ESP32 module. After that, we use the server to send commands to the MCU, allowing it to operate the motor independently.

Applications in industries and motors, uninterrupted power supplies, electric vehicles ("brain of an electric vehicle"), electric charging stations, centrifugal pumps, and solar power systems are only a few examples. Inverters are sometimes referred to be the "brains" of nearly every project that is undertaken on a global scale. Our personal and professional lives are set to undergo a radical transformation because to the Internet of Things (IoT). But extensive Internet of Things (IoT) solutions dependent on flexible and long-lasting wireless connections are essential for this promise to materialize. The tiny Wi-Fi module is at the heart of this phenomena; it is essential for connecting almost any product to wireless networks. The Internet of Things (IoT) is a system that incorporates several different wireless technology standards, each with its own set of features that might affect how well IoT applications work.

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C. Detailed Implementation.

An adaptable answer to the problems of increasing dependability, decreasing system costs, optimizing PCB size, and integrating many power and control components is the CIPOS Maxi IM828 product. Its high-performance inverter design makes it ideal for active power factor correction and other power-hungry motor driving applications. The internal electrical schematic of the CIPOS is shown in figure 3. The NTC, which is linked to VSS, may be accessed directly through the VTH pin. In order to detect over currents, the IM828 links the ITRIP input to the MOSFET drain current feedback. [8]

This product idea is designed to suit the needs of power applications that require outstanding thermal performance (Thermal resistance versus Thermal Temperature) and overload protection, as shown in Figure 4. It achieves remarkable electrical performance by integrating a three-phase inverter with 6-channel SOI gate driver optimization and 1200V Cool SiC MOSFETs [5].
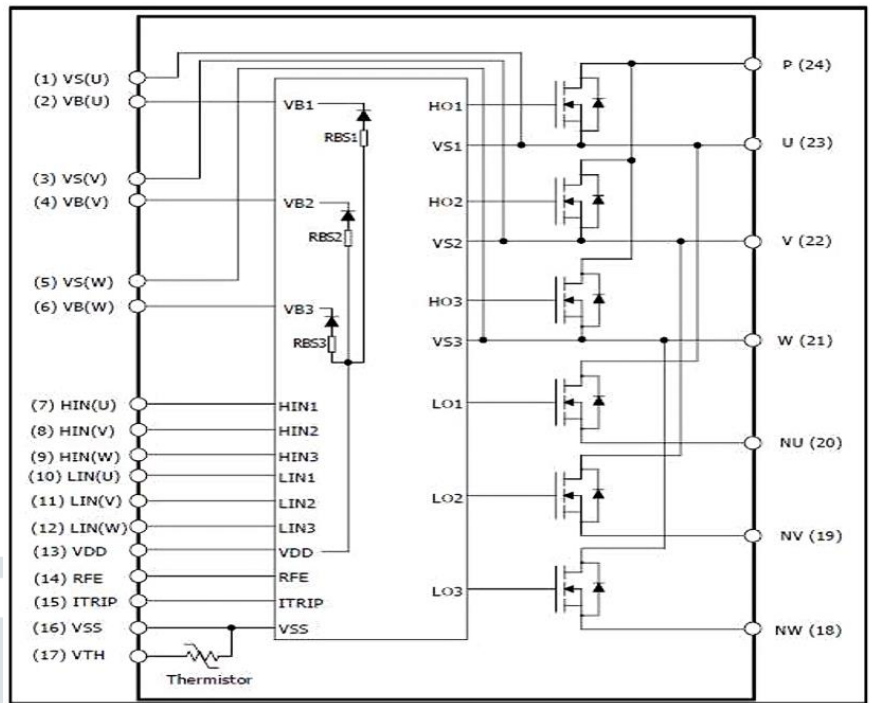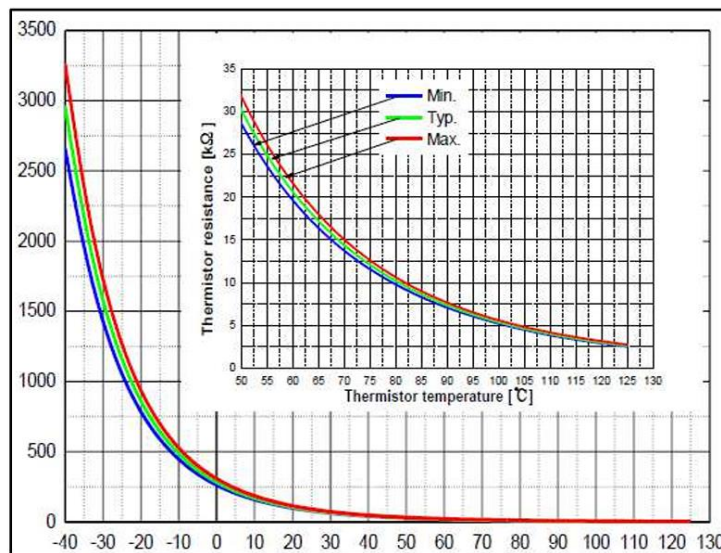

Figure 3: Internal electrical schematic

Figure 4: Thermistor resistance vs temperature curve

For burning and flashing user-defined code for different purposes, the suggested solution uses an ATMEGA 328P. The Atmega 328 IC may be programmed using the ATMEGA 8U MCU, which functions as a serial communicator. Many of the integrated circuits and other parts on the board that controls the device get their electricity via USB "Type C" ports. Bypass capacitors, or decoupling capacitors, are used to store energy and are positioned close to the integrated circuit.

A popular hardware interface, JTAG allows your computer to communicate directly with the microchips on a circuit board. When connecting an ESP32 or FT232RL converter to an ATMEGA 328P, a DIP switch acts as a coordinator to ensure proper Rx and Tx signaling. If you want to convert serial data from a USB connection to a format that a UART interface can understand, the FT232RL is the way to go. Data transmission from the controller to the WEBPAGE is facilitated by the ESP32, a Wi-Fi module. The CIPOS incorporates a thermistor into its gate driver circuit and offers a three-phase power source as an output. The Schmitt trigger, shown in the previous image, supplies the high-end and low-end sides of CIPOS with floating-point IC supply voltages, respectively. In order to flip the PWM signal that is sent into the Schmitt trigger SN54HC7001, the NOT gate 7404 is utilized. The setup for speed sensing retrieves data from an encoder attached to the motor shaft, passes it on to the ATMEGA328 microcontroller unit (MCU), and then, after displacing the speed in RPM and other required readings, sends it back to the WEBPAGE for control of the motor speed (RPM). An open-loop current sensor measures the main current's magnetic flux through a hall device, which is focused in a magnetic circuit. Our board's current sensing capabilities are provided by an ACS712 sensor.

The 3D perspective of the fully filled board of the suggested design is shown in figure 5 below. This bird's-eye view makes it easy to see every detail.
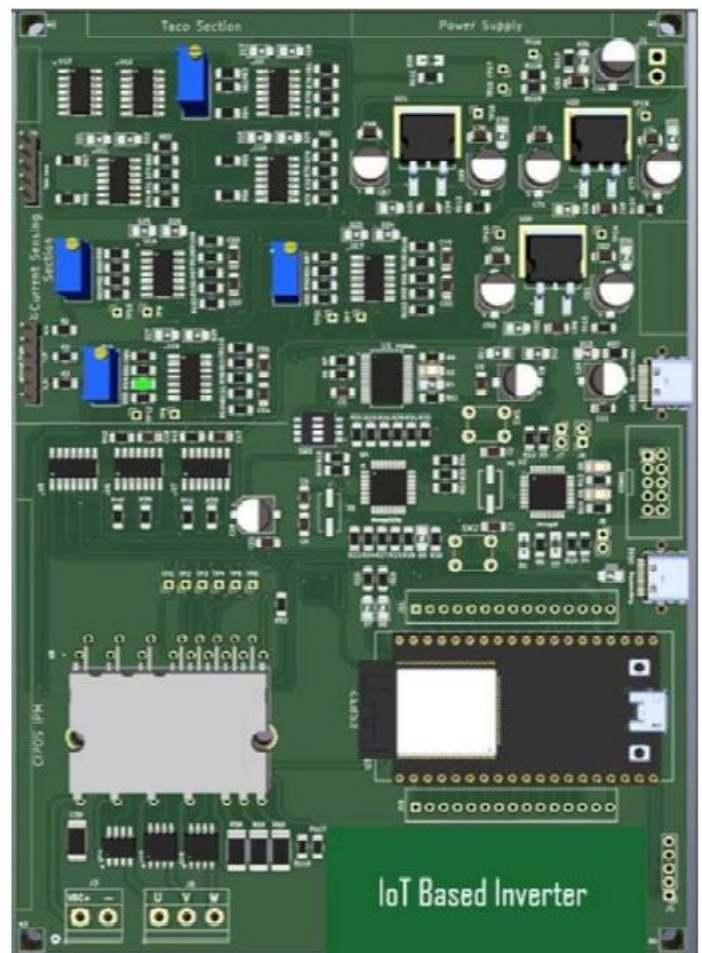

Figure 5: 3D view of the final board

IV. RESULT

A laptop and a CRO are used to view the result in this experiment. Presented in the following subscription are the outcomes that the board determined.

A. Testing and assembly

The testing and assembly method necessitates the configuration of AVR and ESP32 software. There are five distinct parts to the board shown in figure 6, and testing of each one must adhere to the specified sequence.

Connect the USBasp programmer, which contains a pre-programmed Atmega8A, to the AVR controller assembly board via JTAG. Use the USB connection to link the USBasp programmer to your PC. Please connect the jumper J7 to the 1.4 board. Click on this link to download the USB driver software: https://github.com/mariusgreuel/USBasp. To modify the settings of the AVRDUDUES program, open the picture and follow the instructions. When you press the "detect" option, ATMEGA8A will be detected. To alter the CPU clock and other configuration parameters, one must modify the FUSE bits. You can see the values of the fuse bits in the picture. Type in the FUSE values under "Fuse and lock bits," and then hit "write" to set the fuse bits to burn.To load the bootloader, choose the hex file from the "flash" menu. You may locate the file named "usbasp. atmega8.2018-06-25.hex" in the 'firmware' folder, which is located inside the 'bin' folder of the USBasp driver that you first downloaded. To upload the hex file to the controller, just choose the "Write" option and hit the "Go" button. When you've finished writing in AVR, bros. The D5 and D6 LEDs will light up to show that the boot loading process was successful. With that, the ATMEGA8A is ready to go.

To test the UART and the ESP32, link the two devices together using the berg strips that were soldered in the earlier steps. The board has two USB ports—USB 1 for programming and USB 2 for serial communication—that you should connect to your computer.Switches 3 and 4 on SW3 must be turned on. The FTR23RL, a UART to USB converter, is connected to the Atmega328p's UART port by this switch. Launch the Eclipse IDE and import the 'AVRUART' application.Get Eclipse's serial monitor up and running, then choose the USB2 COM port and baud rate (9600 dB) (you can find this information in the device manager) [6]. You may see a "hello" message on the screen. Selecting "1" and "2" on the SW3 allows the ESP32 and ATMEGA328p UART connection to be activated. Using the 'uartasyncrxtxtasks' built-in example in ESP32 ESP-IDF, launch the program in Atmega328p and import the 'ESP32 AVR UART' software. Make sure they are talking to each other by using serial monitors.

Proceed to solder the CIPOS IPM and Current Sensing sections in accordance with the design. Plug the board's USB 1 connector into your computer's USB port. To upload the file to the target MCU atmega328p, open Eclipse, import the AVR PWM program, and then click create project. Right now Use an oscilloscope to inspect the PWM signals at test points TP1, TP2, TP3, TP4, TP5, and TP6 after connecting the board to a 14V power source. Note that there are three terminals here, with two connected to ground,

and connect a DC-link supply voltage (maximum 900V) at connector J3. Join the probes at Connector J6 and observe the waveform of the phase-to-phase voltage across all three terminals on the oscilloscope, which is the three-phase output of the CIPOS IPM (U V W). When all three voltages produce a square waveform at the inverter's output, we know we've nailed it. Take a look at the ADC UART program in Eclipse, then transfer the code to the atmega328p. Take note of the ADC value shown in Eclipse's serial monitor window. Changes to the gain at the amplifiers, as indicated by knob turns, can alter this value.

Figure 6: The board when plugged in with 15V for testing.

B.   Server

Software, in conjunction with hardware, can allow for remote server-based autonomous motor control. This is where you can see the outcomes of playing about with the Sinusoidal Amplitude and Frequency. At first, we'll take a look at the website's outcomes, which include feedback graphs for the start-stop and edit modes. Starting from a condition of no output, the following figure shows the SPWM method starting at 20 kHz with an amplitude of 41. The RMS value, which is determined by dividing the maximum value every 20 ms by the square root of 2, is plotted on the graph and is derived from the filtered output, which lowers the V peak from 20 V to 12 V. Keep in mind that this is only a simpler method of determining the maximum of the filtered waveform and not a true root-mean-square (RMS). Only one HTML file, "index.html," includes all of the website's code, including script, CSS, and the two logos, "iisc_logo.png" and "publogo.png" [9]. The server is first configured entirely in Arduino. Figure 7 shows the login credentials being requested upon IP address access.
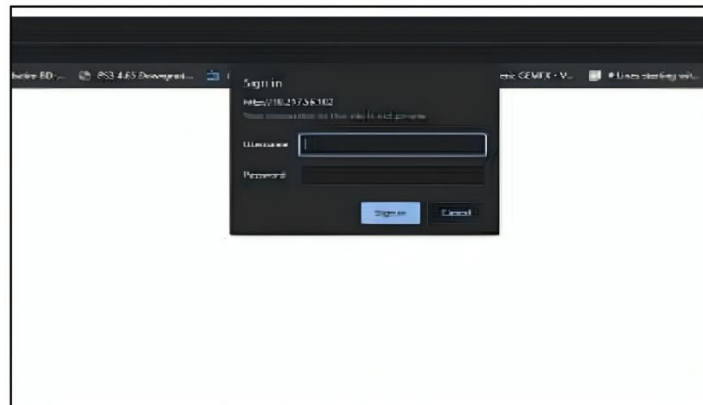

Figure 7: Login Page

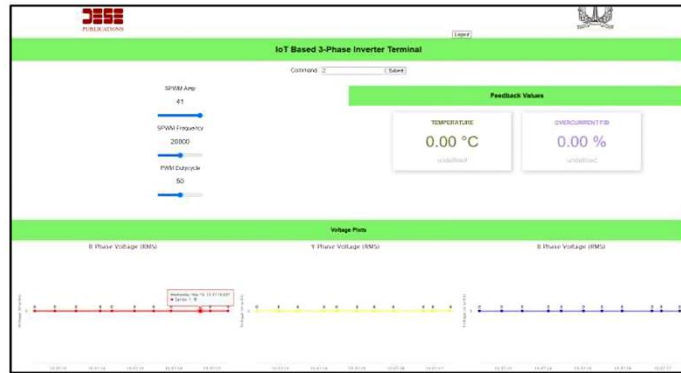You can see the current webpage after logging in in figure 8.

Figure 8: Home page with control terminals and plots

Changes to the Sinusoidal Amplitude and Frequency yielded the results shown in the graphic. Initially, we will be presented the website results, which contain feedback graphs for the start/stop and edit modes. At 20 kHz and an amplitude of 41, Figure 9 depicts the initial stages of the SPWM technique, when there is no output whatsoever. Figure 10 shows the root-mean-square (RMS) value that is calculated from the filtered output. By finding the greatest value every 20 ms and dividing by the root of 2, this technique reduces the V peak to peak voltage from 20 V to 12 V.
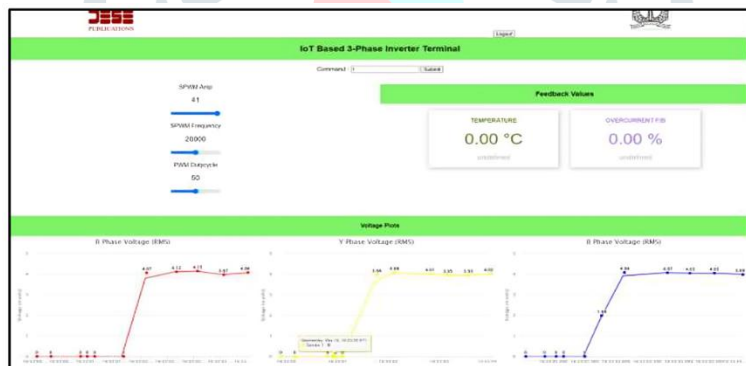

Figure 9: Command 1 at 20kHz, 41Amps default SPWM

Figure 10: SPWM Operation Feedback @ 20 kHz 41 Amp default SPWM

The next step is to minimize the RMS due to a decrease in the fundamental component of the output by lowering the SPWM Amplitude to 11 at the same frequency. This is done in figure 11 by switching to the edit mode of command 2.

Figure 11: SPWM Operation Feedback @ 20 kHz 11 Amp default SPWM

Figure 12 concludes with the application of instruction 3, which stops the procedure and sets all outputs to zero.

Figure 12: Stop by giving command 3 while running @ default SPWM.

IV. CONCLUSION

The constructed and showcased equipment functions as an inverter that can be operated wirelessly and has an extensive set of configurable settings. This lays the groundwork for very low latency closed-loop control, where the data loop may be completed in as little as 5ms under ideal circumstances. That way, its functioning will be unaffected in the event of a delay in the display of commands and feedback. Another option for increasing range with low delay is to use pass-through ESP32s. And within the Wi-Fi range (for the server) and the ESP-NOW range (for the control board + inverter), you may put them wherever is most convenient. Implementing a CPU-intensive control scheme, such as SPWM, demonstrates its adaptability when controlling parameters like duty cycle, amplitude, and frequency in real-time. Multiple applications inside the same monitored and regulated zone can be expanded to this sort of structure. The product's intelligence is now split between the server and receiver PWM boards, but it's easily modifiable so that the server side has all the intelligence and the rest of the microcontrollers just send signals through.

It was previously necessary to manipulate the voltage and frequency concurrently in order to alter the speed of an induction motor in open-loop systems. However, a reliable and inexpensive option has been discovered: the ATMEGA328P microcontroller. This little chip can command the speed of the motor like a conductor thanks to its three pulse width modulators (PWMs). Although the majority of ATMEGAs only provide two built-in PWMs, a third may be created ingeniously within the software and then sent out via a specific port pin. On the other hand, the IoT is subtly but surely changing our world. As a network of interdependent "things" including sensors, actuators, and commonplace electronics, we may learn more about and enhance our lives via the sharing of data. Just picture a symphony of data begging to be mined and put to good use, emanating from billions of sensors all quietly communicating with one another online. The Internet of Things has several potential applications, including smart homes and building automation. Actuators control features like lighting and temperature, while sensors keep an eye on your surroundings. Plus, what's even better? Everything is under your remote control, accessible through your mobile device. It's like if you had a digital butler who could read your mind and meet all of your demands. Now tell me how this relates to controlling a motor. A plethora of opportunities become available when the ATMEGA-powered inverter is linked to the Internet of Things. Envision yourself able to remotely control motor speeds, track energy usage, or even program automated processes. With all the data going through the IoT, the possibilities are practically limitless.

For future industrial projects, this general-purpose board can be utilized for a variety of uses, including high-performance engine and vehicle dynamics, electric vehicle and hybrid propulsion, solar mobility, and the possibility of developing AC chargers for automatic control rather than manual control. A controller like the PID controller can do this.

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