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An IoT-enabled device for remotely monitoring and controlling solar photovoltaic systems

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Abstract

This article presents an Internet of Things (IOT) solution that focuses on managing and tracking the operation of a solar system and is intended for both home and commercial application. A MOSFET driver, a DC-DC SEPIC converter, a single-phase voltage source inverter with active clamping, and a DC-DC Landsman converter are all used by the system to condition electricity. This allows for real-time online contact with an internet server and includes measurements of the output voltage and current from the solar panel and battery to monitor DC load and AC load. The ESP32 Wi-Fi MOD and PIC microcontroller work together to seamlessly provide an online connection to the internet server. The outcomes of the experiments demonstrate how well voltage control works and how well IOT functions. Through a user-friendly GUI interface on the internet, users can effortlessly control the DC-DC converter and get real-time data on battery voltage, current, and state of charge by combining solar energy with the power source.

Keywords: IOT, Landsman converter, SEPIC converter, PV system, DSPIC30F2010 microcontroller, ESP32 Wi-Fi module, Blynk Application.

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1. Introduction

At present, invention has fundamentally supplanted civilization as a principal strength globally. Large improvement is taking place in hardware and electrical fields, resulting in more up-to-date and important disclosures. Generating large quantities of electrical energy is the main obstacle all developing countries face. Power demands happen naturally as the company and industry develops. Everyone is now seeking a favorable approach to meet energy demands over the long term as various fields grow, which is why there is a collective pursuit for environmentally friendly power. For instance, to create solar power plants, smart observation and interaction are required to propel low-energy engineering invention as the low-energy engineer directed to zero-engineering.

The Internet of Things is a trendy idea. Many consumers, and respondents connect up not only relevant devices but also networks, images, and even people [1]. By obeying definitions in the cloud, an opportunity is created not only for intelligent functioning within a device's own domain, but also to make other networks smarter through connection. With the help of the Internet of Things, the efficiency of the PV module can be measured by assessing the attending temperature, humidity, power, voltage, and current. Thus, since preventive action can be considered by comparing the test results, a real-time PV module monitoring system can contribute to improving the reliability of solar modules; a real-time report system for a solar power factory. The Internet of Things taping function facilitates usage wherein the main control station can decide and change the whole system, executed in a forceful manager in the context of a solar power plant.

The Internet of Things enables remote object control and detection, simplifying the integration of the physical world with programmable systems and reducing the level of interaction of a human with an object, which boosts the efficiency, affordability, and accuracy level. Using IoT technology, people may control a solar power facility, monitor its operation in real-time and carry out maintenance [2]. The SEPIC converter, LANDSMAN converter, Sine PWM Inverter, MOSFET driver, ESP32MOD, and dsPIC30F2010 microcontroller are critical parts of the proposed prototype, which includes control over both AC and DC loads and real-time monitoring of voltage and current for batteries and PV panels [3,4].

Designing an IoT-enabled device for remotely monitoring and controlling solar photovoltaic (PV) systems involves integrating various sensors, communication modules, and control mechanisms [5].

Solar Panels: The core component of the PV system that generates electricity from sunlight.
Inverter: Converts the DC electricity generated by the solar panels into AC electricity suitable for use in homes or businesses.
Battery: Stores excess energy generated during the day for use during periods of low sunlight or high demand.
IoT Gateway: Acts as a bridge between the local PV system and the internet, facilitating data transmission and remote control.
Sunlight Intensity Sensor: Measures the intensity of sunlight to optimize panel positioning.
Temperature Sensor: Monitors the temperature of the panels to ensure optimal efficiency using DHT11sensor.
Voltage and Current Sensors: Measure the electrical output of the panels and the system using Current sensors ACS712, 30Amps [6,7].
Battery Charge Controller: Monitors the state of charge of the battery.
Microcontroller: Processes sensor data, manages communication with the IoT gateway, and controls system operation using dsPIC 30F2010 microcontroller.
Communication Module: Enables wireless communication with IoT gateway, typically using protocols like Wi-Fi using ESP32 MOD for IOT interference
User Interface: A web-based dashboard or mobile application for users to monitor system performance, receive alerts, and control system parameters remotely using Blynk IoT.
Remote Monitoring: Real-time data on electricity generation, consumption, battery charge level ble), and system efficiency [8].
Remote Control: Start/stop the DC motor connected to SEPIC converter and to control the speed of DC motor using mobile application (Blynk IoT) [9,10]

By integrating these components and functionalities, an IoT-enabled device for monitoring and controlling solar PV systems can provide users with greater visibility, control, and optimization of their renewable energy assets.

The contribution of research involves:

- The technology is innovative because it may enhance household renewable energy systems' usability and efficiency as well as remote control and real-time data monitoring. An IoT gateway is required for the system to be connected to the internet. In addition to managing the converter, it collects information from multiple sensors [11].
- The communication module, which is responsible for accepting control commands from a remote user interface and transmitting data from the sensors to the Internet of Things gateway, is one of the system's advantages. This module makes use of WiFi technology. The collected data is logged and reviewed. It can provide opinions about the effectiveness, output, and functionality of the system.
- Utilizing an intelligent controller and a Landman converter, the system maximizes the amount of electricity generated by the solar panel. The sensors are used to monitor and present the parameters, which include voltage, current, temperature, humidity, and battery voltage, over the Internet of Things.
- Using the Blynk IoT mobile application, a SEPIC converter modifies the duty cycle to control the speed of a PMDC motor. Here, the motor's speed, voltage, current, and torque are tracked and evaluated to provide more precise results.
- The proposed system can optimize energy output and consumption in a way that is remotely manageable, user-friendly, and efficient by merging these components [12]. The general objective is furthered by this kind of Internet of Things-based monitoring and control system. [13]

Key aspects of research on IoT-enabled devices for remotely monitoring and controlling solar photovoltaic systems focus on integrating Internet of Things (IoT) technology to enhance the efficiency, reliability, and management of solar energy systems [14].

Hardware Components: Selection of sensors (temperature, irradiance, current, voltage), microcontrollers, communication modules.

Software Components: Development of firmware for device control, data acquisition, and communication protocols. Use of IoT platforms such as Blynk IoT for data management and analysis.

Data Storage and Management: Efficient storage of large datasets generated by the PV system using cloud-based solutions for easy access and analysis [15].

Control Mechanisms: Development of mechanisms for remote control of PV system components such as inverters, battery storage, and shading devices [16].

Automation: Implementing automated decision-making processes based on data analysis to optimize system performance, such as adjusting the angle of solar panels or managing energy storage.

Energy Forecasting: Using predictive analytics to forecast solar energy generation and consumption patterns for better energy management [17].

Efficiency Improvement: Identifying and addressing inefficiencies in the PV system to maximize energy output and reduce operational costs.

User Dashboard: Creating user-friendly dashboards for real-time monitoring and control of the PV system, accessible via mobile applications [18].

Pilot Projects: Implementing pilot projects to test the IoT-enabled PV systems in real-world conditions and gather practical insights [19].

Performance Evaluation: Conducting detailed performance evaluations of the deployed systems to assess their effectiveness, reliability, and return on investment [20].

2. Literature Review

The integration of Internet of Things (IoT) technology with solar photovoltaic (PV) systems has garnered significant attention in recent years. This combination promises enhanced efficiency, real-time monitoring, automated control, and predictive maintenance, which are crucial for optimizing solar energy utilization [21]. This literature review explores various aspects of IoT-enabled monitoring and control in solar PV systems, including the architecture, benefits, challenges, and recent advancements [22].

Sensors and Data Acquisition: Sensors are deployed to measure various parameters such as solar irradiance, temperature, voltage, current, and power output. These sensors are crucial for real-time data collection, which forms the foundation for further analysis and control [23].

Communication Networks: Reliable communication is essential for transmitting data from sensors to cloud-based platforms. Commonly used communication technologies include Wi-Fi, Zigbee, LoRa, and cellular networks. Each has its advantages and limitations concerning range, power consumption, and data rate.

Cloud Storage and Data Processing: Collected data is transmitted to cloud servers where it is stored and processed. Cloud computing provides scalable storage and powerful analytics capabilities, enabling the handling of large datasets generated by numerous sensors.

Data Analytics and Decision Making: Advanced analytics, including machine learning and artificial intelligence, are applied to the collected data to derive insights and make informed decisions. These analytics can predict system failures, optimize energy production, and provide actionable recommendations [24].

Enhanced Monitoring and Control: IoT allows for continuous, real-time monitoring of solar PV systems, enabling immediate detection of performance issues and faults.

Predictive Maintenance: By analyzing historical data, IoT systems can predict potential failures and maintenance needs, thereby reducing downtime and maintenance costs.

Energy Optimization: IoT systems optimize energy production by adjusting parameters such as the angle of solar panels or by controlling the load based on real-time data.

Remote Accessibility: IoT enables remote monitoring and control, allowing operators to manage systems from anywhere, which is particularly beneficial for large-scale solar farms spread across vast areas.

Integration with Smart Grids: IoT-enabled solar PV systems are being integrated with smart grids to improve overall grid stability and efficiency.

3. Methodology

The suggested system utilizes a Landsman converter to maximize the electricity generated from solar panels. It monitors various parameters such as real-time voltage and current of the solar panel, voltage and current of the battery, DC load, and AC load. Additionally, it incorporates sensors for IoT technology to enable remote control of both AC and DC loads [25]. The intended structure of the monitoring and controlling system is depicted in the block diagram shown in Fig. 1. The experimental setup of the system includes a solar panel, a regulated power supply, an ESP-32 Wi-Fi module, a voltage sensor, a current sensor, and a PIC microcontroller.

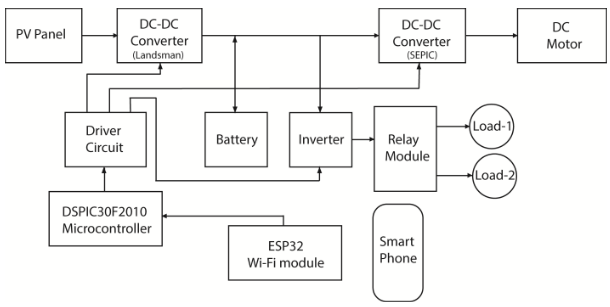

Figure 1. Block diagram of proposed system

The proposed system incorporates a LANDSMAN converter as the maximum power point tracking (MPPT) mechanism and a SEPIC converter for DC loads. The utilization of a Landsman converter allows for the extraction of a stable voltage from the solar PV panel, surpassing the capabilities of traditional converters [26]. As for the second-stage DC-DC conversion for DC loads, a SEPIC converter is employed. In this prototype, a PMDC Motor is connected. To ensure a reliable power source for AC loads, inverters are utilized for DC-AC conversion while maintaining a steady voltage [27]. Solar photovoltaic systems not only supply power but also store energy in the connected battery. In case of any climatic changes or abnormal conditions, grid power serves as a backup source for the battery. For the advancement of end-point Internet of Things, the ESP32MOD serves as an affordable wireless transceiver [28]. An embedded program can be employed to monitor and regulate the real-time voltage and current of the solar photovoltaic system, as well as the current of the DC motor, by connecting to the internet using an ESP32 Wi-Fi module

3.1. ANN-based PV MPPT techniques using a Landsman converter

In photovoltaic (PV) systems, a Landsman converter is a type of power converter specifically used for maximum power point tracking, or MPPT. MPPT is essential for maximizing the power production from solar panels since it continually modifies the operating point to guarantee that the PV array extracts the highest amount of electricity possible under a range of environmental circumstances [29].

Artificial neural networks (ANNs) have been increasingly used in MPPT algorithms due to their ability to learn complex patterns and adapt to changing conditions. ANNs can effectively model the nonlinear behavior of PV systems and provide accurate MPPT control.

Here's how ANN-based MPPT techniques can be applied using a Landsman converter using steps mentioned below:

- To collect data from the PV system under various operating conditions, including different levels of irradiance and temperature. This data will serve as the training dataset for the ANN.
- Create an ANN architecture that is suitable for MPPT. Choosing the number of layers, neurons per layer, activation functions, and network topology are usually involved in this. A feed-forward neural network is frequently utilized for MPPT applications.
- The collected data is utilized to train the ANN. Throughout the training process, the ANN acquires knowledge about the correlation between the input variables, such as voltage and current from the PV array, and the output variable, which is power. This training procedure entails fine-tuning the weights and biases of the network in order to minimize the prediction error.
- After training the ANN, merge it with the Landsman converter control system. The ANN forecasts the best operating point of the PV array using input variables (voltage and current) from the PV system. Subsequently, the Landsman converter modifies its operating parameters (such as duty cycle) to maximize power extraction.
- Verify the performance of the ANN-based MPPT system by testing it in a range of real-world scenarios. In this stage, the projected maximum power production from the ANN is compared to the actual power output.
- Fine-tune the ANN and the control parameters of the Landsman converter if necessary to further improve performance and robustness.
- Implement the ANN-based MPPT system into the PV system.

By quickly turning on and off the input voltage and adjusting the duty cycle of the switches, the Landsman DC-DC converter modifies the average voltage applied to the output stage. The converter may effectively change the DC voltage level while preserving the intended output parameters. By using the Landsman converter instead of the traditional Buck-Boost converter, the maximum power point is reached. Using a Landsman converter has the advantage of eliminating ripple in the battery current as well as having a larger voltage gain than a traditional buck-boost converter. As shown in Fig. 2, mode 1 of the Landsman Converter is operating. The inductors L_2 and L_1 are activated, the capacitor is charged, and the voltage V_s biases the diode when the regulator is in mode 1 [30].

The equation of Landsman converter as stated below.

$$I_{L1MAX} = I_{L1MIN} + \frac{DV_{in}T}{L_1} \quad (1)$$

From the equation I_{L1} consider D=S,

$$I_{L1MAX} + I_{L1MIN} = 2I_{L1} = \frac{2S}{(1-S)^2}\frac{V_{in}}{R} \quad (2)$$

$$I_{L1MAX} = \left[\frac{S}{(1-S)^2} + \frac{RT}{2L_1}\right]\frac{SV_{in}}{R} \quad (3)$$

$$I_{L1MIN} = \left[\frac{D}{(1-S)^2} - \frac{RT}{2L_1}\right]\frac{SV_{in}}{R} \quad (4)$$

$$I_{L2MAX} = I_{L2MIN} + \frac{V_{in}}{L_2}ST \quad (5)$$

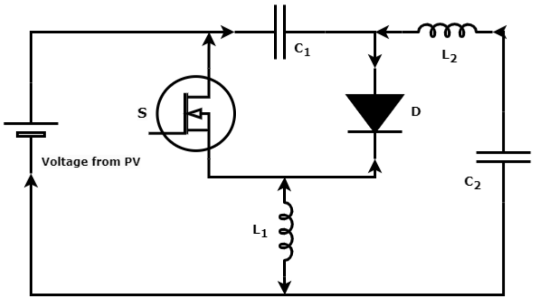

Figure 2. Circuit diagram of landsman converter

3.2. SEPIC converter

The continuous current conduction mode (CCM) is used with the SEPIC converter and other DC-DC converters. The reference current obtained from the MPPT approach is matched against the inductor at a 50 kHz switch current during this PWM switching procedure. The switching pulse is then produced by comparing the error signal with a repeating waveform and using it as a control signal [31].

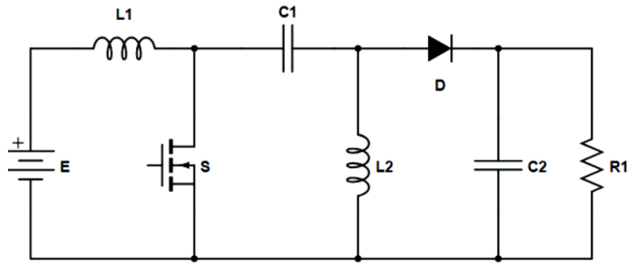

Figure 3. Circuit diagram of SEPIC converter

3.3. SEPIC converter operation

The non-inverting converter SEPIC is capable of operating in both buck and boost modes [32]. The incoming voltage V_{in} powers the inductor L_1 when the MOSFET is triggered. Concurrently, inductor L_2 receives energy transfer from capacitor C_1, which discharges. Capacitor C_2 cannot discharge to the loads due to the diode's reverse bias. On the other hand, L_1 charges and discharges C_1 when the MOSFET is off. As seen in Fig. 3, in this case, the current i_{L1}+i_{L2} flows through the diode, charges C_2, and provides the load [33].

The static switch S, the diode D, the inductors L_1 and L_2, and the capacitors C_1 and C_2 make up the SEPIC converter. The output filter capacitor C_2's capacitance value must be increased to reduce output voltage ripple [34]. Because the output of the SEPIC converter design is coupled to a pulsing diode (D), the output voltage ripples naturally increase in magnitude. As was previously noted, diode D conducts when switch S is OFF and does not conduct when it is ON. As a result, the converter's output receives a pulsating current. Consequently, to effectively reduce any voltage ripple brought on by the diode's pulsating current, C_2 needs to have a large capacitance [35].

The following formulae are used to design the SEPIC converter:

$$\text{Inductor current } (I_L) = \frac{I_{out} x V_o x 40\%}{V_{in}(min)} \quad (6)$$

$$\text{Inductor } L_1 \text{ and } L_2 = \frac{V_{in}(min) x D_{max}}{\Delta I_L x F_{sw}} \quad (7)$$

$$\text{Output ripple voltage} = \frac{I_{out}(max)}{C_{in} x\, F_{sw}} X \frac{V_{out}}{V_{in}+V_{out}+V_d} \quad (8)$$

$$\text{Output capacitor} = \frac{I_{out} x D_{max}}{V_{rip} x 0.5x\, F_{sw}} \quad (9)$$

During switch ON, the inductors voltages and capacitors currents expression can be written as

$$V_s = L_1 \frac{d_{i1}}{d_t} \quad (10)$$

$$Vc_2 = L_2 \frac{d_{i2}}{d_t} \quad (11)$$

$$-i_2 = C_1 \frac{dV_{c1}}{d_t} \quad (12)$$

$$-\frac{V_{c2}}{R} = C_2 \frac{dV_{c2}}{d_t} \quad (13)$$

During switch OFF, the inductors voltages and capacitors currents expression can be written as

$$V_s - Vc_1 - Vc_2 = L_1 \frac{d_{i1}}{d_t} \ (14) \quad Vc_2 = L_2 \frac{d_{i2}}{d_t} \ (15)$$

$$-i1 = C_1 \frac{dV_{c1}}{d_t} \quad (16)$$

$$-\frac{V_{c2}}{R} = (i_1+i_2) = C_2 \frac{dV_{c2}}{d_t} (17)$$

4. Simulation Results and Discussion

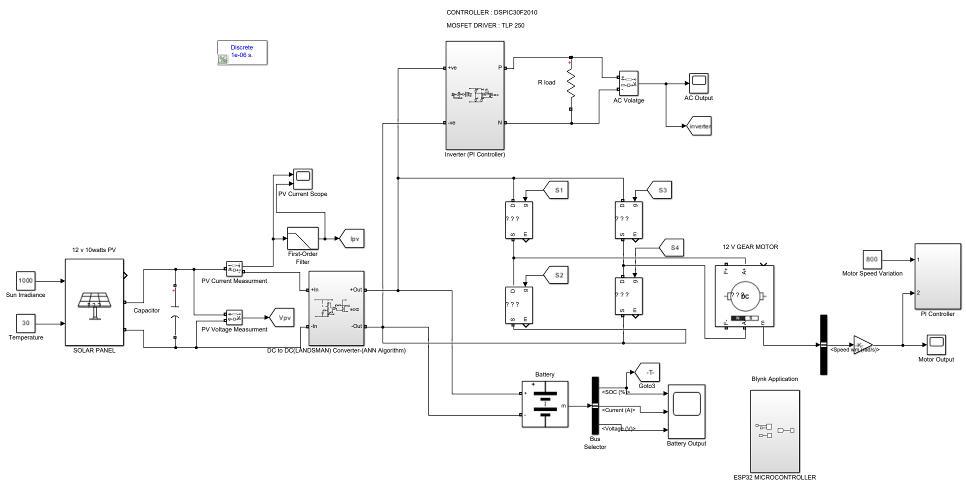

Figure 4. Proposed simulation model

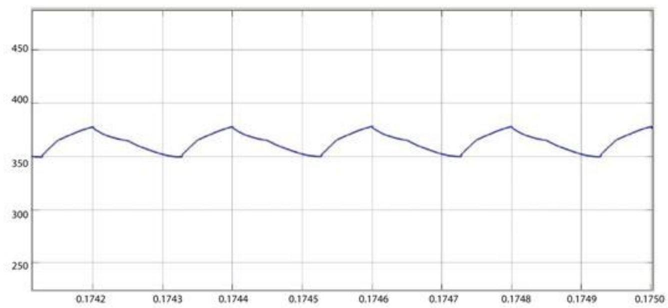

Figure 5. Output voltage of landsman converter

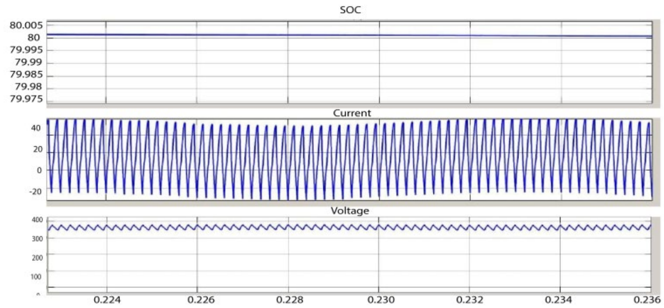

Figure 6. Battery Output SOC (%), Current & Voltage Waveform

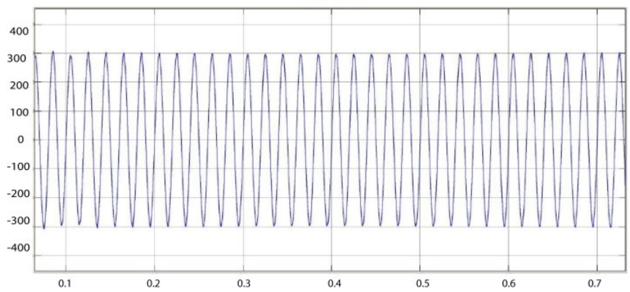

Figure 7. Inverter output voltage

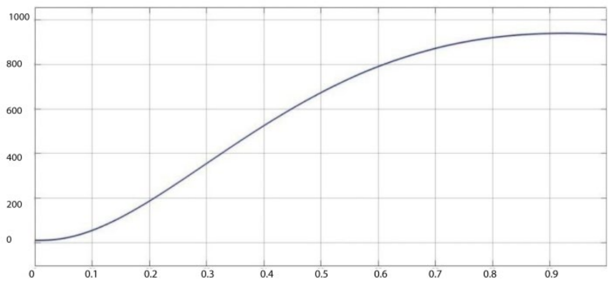

Figure 8. Output of SEPIC Converter

In this article, the control, monitoring, and effective utilization of solar panel in home and commercial applications are discussed. The input to the 12V, 10 watt solar panel is sunlight, i.e., sun irradiance is set to 1000W/Sq.m, and temperature is 30 degrees Celsius, which is converted into electrical energy. The output voltage at maximum power is 100V, and the current at maximum power is 28A, as shown in Fig. 4. In place of MPPT (maximum power point tracking), a LANDSMAN converter is used; here, it has more advantages over conventional converters; hence, the variable DC input voltage from the PV panel is regulated to a fixed DC voltage to charge the battery [36]. The LANDSMAN output wave form is shown in Fig. 5. The battery is charged by the DC-DC converter, and its output is connected to the bus selector, where the SOC (%) is 80% at no load, the current is 45A, and the voltage is 350V, as shown in Fig. 6.

The inverter and DC-DC converter (SEPIC) are connected to the grid for supplying AC load and DC load in the system. Here are two resistive loads for controlling AC loads, and PMDC is used as a DC load for controlling and monitoring [37]. The inverter is mainly used for DC-AC conversion and also to regulate the AC supply at the load without power fluctuation [38]. The output voltage of the inverter is 300V, and its wave form is as shown in Fig. 7. A SEPIC converter is used to regulate the output of the 12V PMDC motor. Here, to get more accurate results of the motor, like speed, voltage, current, and torque, the speed of the motor is gradually increased from 0 to 900 RPM, as indicated in Fig. 8. Hence, the complete block diagram illustrates the accurate output of the DC-DC converter, inverter, battery, DC motor, and AC load connected to the grid [39-40]. In this paper, combination of LANDSMAN and SEPIC converters is introduced found more efficient and provides reliable output.

5. Hardware Results and Discussion

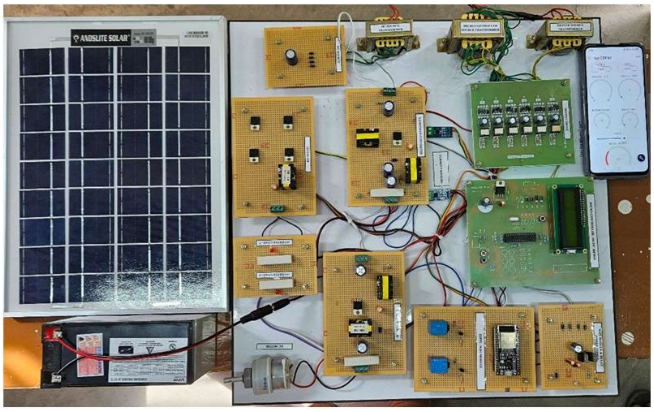

Figure 9. Prototype of the proposed system

The hardware of the proposed system consists of a solar panel, a DC-DC converter (Landsman), a battery, a DC-DC converter (SEPIC), inverter and an ESP32 Wi-Fi module. The prototype of the proposed system is presented in Fig. 9. The hardware is interfaced with the smart phone using the ESP32 module. Using the Blynk application installed on a smart phone, which is used to control the speed of a DC motor, The block diagram of the Blynk IoT server, as indicated in Fig. 10. However, using this application, solar panel voltage, solar panel current, battery voltage, battery current, and motor current can be measured, as displayed in

Fig. 11. The slider available in the Blynk application is used to control the duty cycle of the SEPIC converter. Fig. 12–13 indicates the speed control using the Blynk application of a DC motor for a load current of 0.1A–0.46A, respectively.

The various components used in hardware, such as the DC-DC converter, solar panel, and battery, are integrated using the dsPIC 30F2010 microcontroller and ESP32 MOD for IOT interference. Two numbers of current sensors (ACS712, 30 A) are used for measuring the real-time current from the solar panel and battery.

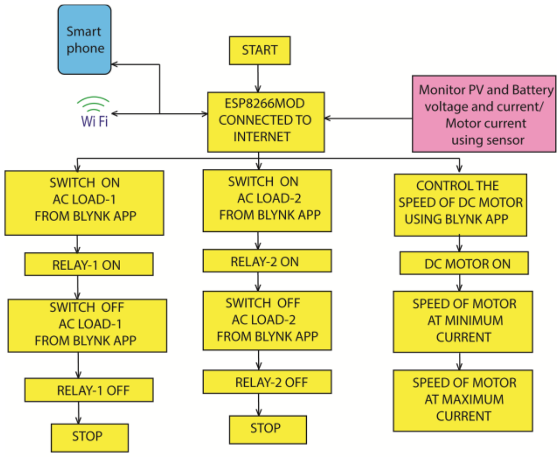

Figure 10. Block diagram for Blynk IOT server

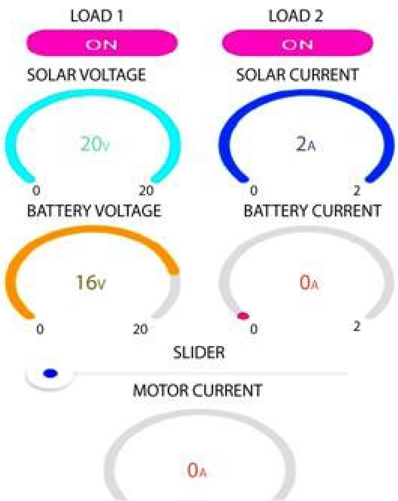

Figure 11. Blynk mobile device shows AC load ON condition

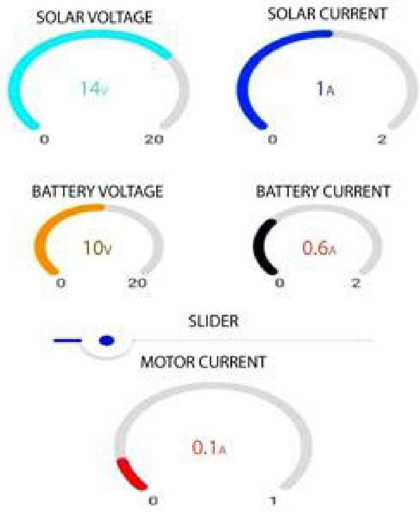

Figure 12. Blynk mobile device shows DC motor current 0.1 Amps

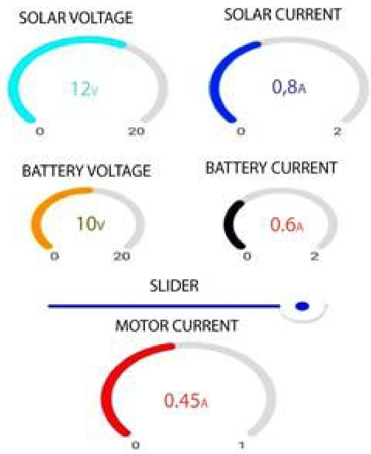

Figure 13. Blynk mobile device shows DC motor current 0.45 Amps

Figure 14. Landsman converter input and output voltage

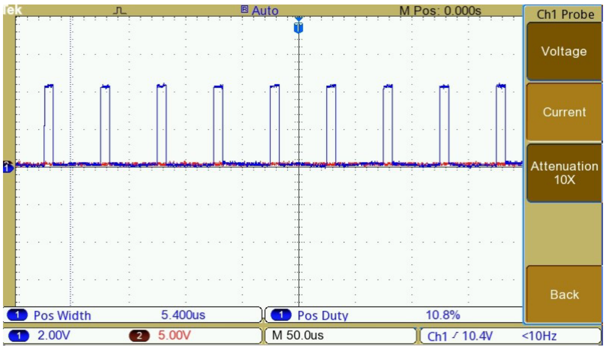

Figure 15. SEPIC Converter pulse at duty Cycle of 0.2

The power generated by the solar panel (12V, 10W) is delivered to the input of the Landsman converter. The input voltage, which varies from 10V to 12V, is converted to 14 VDC by a Landsman converter, as displayed in Fig. 14. The battery voltage drives the DC motor using a SEPIC converter. The switching pulse SEPIC converter for the duty cycles of 0.2 and 0.8 is displayed in Fig. 15 and 16 respectively. The battery charging voltage is indicated in Fig. 17.

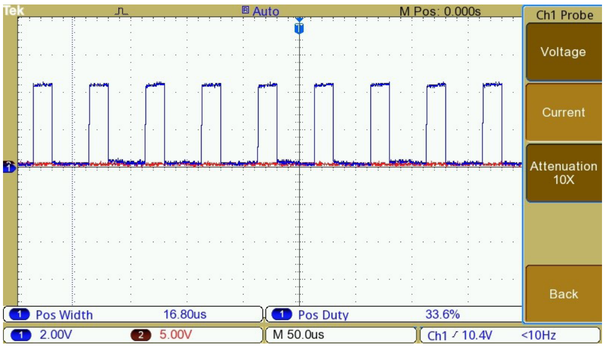

Figure 16. SEPIC Converter pulse at duty Cycle of 0.8

At a duty cycle of 0.2, the DC motor runs at a speed of 180 RPM with a load current of 0.02 A at a terminal voltage of 14 VDC. By increasing the duty cycle, the voltage across the motor will increase, resulting in higher speed. At a duty cycle of 0.8, the DC motor runs at a speed of 260 RPM with a load current of 0.35 A at a terminal voltage of 20 VDC. Finally, at a duty cycle of 0.8, the DC motor runs at a speed of 800 RPM with a load current of 0.78 A at a terminal voltage of 30 VDC, as indicated in Table 1. The various components used for the development of hardware, as indicated in Table 2.

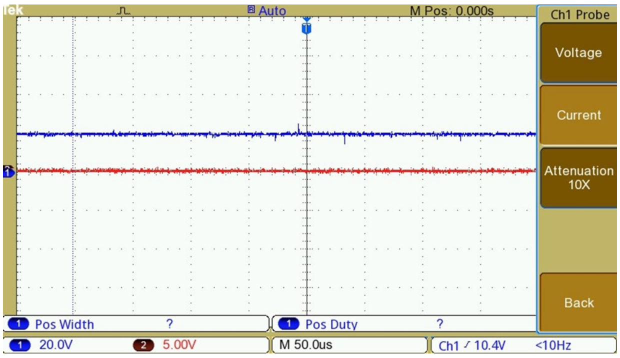

Figure 17. Battery charging voltage

Table 1. The output of SEPIC fed to DC motor

Duty cycle	Input Voltage Volts	Output Voltage Volts	Motor speed RPM	Motor current Amps
0.2	14V	14V	180	0.02
0.8	14V	20V	260	0.35
0.8	14V	30V	800	0.78

Table 2. Hardware components, specifications and cost

Component	Features	Task	Cost (INR)
Power supply unit	Input 220VAC to output 12VDC	Converts AC-AC-DC	1800
Landsman converter	Input DC: (10-12V) Output DC: 14V	DC voltage: 14V	580
SEPIC converter	Input DC: (125-14V) Output DC: 0-30V	Buck-boost, DC-DC converter	750
Inverter	Input; 12VDC Output:230VAC	Converts DC-AC	520

Electromagnetic Relay	Nominal switching capacity: 10 A 250 V AC Max. Switching voltage: 250 V AC, 100 V DC Max. switching current; 10 A (AC), 5 A (DC) Size: 29.3 x 7.3 x 2.9 cm; 40 Grams	High contact capacity: 10 A	390
PV Cell	Nominal Maximum Power: 10Watts/12V Voltage of Open Circuit: 22.0V 0.6A for short circuit current 18.0V for maximum power voltage Current at Maximum Power: 0.56A	Highly Classified A-Grade Solar Cells for Lesser Degradation and High Energy	2300
DHT11	Operating voltage range: 3.5-2.5 volts 0.3 mA of operating current (measuring) 60 uA Serial data is the output. Range of temperatures: 0°C to 50°C; range of humidity: 20% to 90%	Measures Temperature and Humidity	580
Battery	Nominal voltage: 12 V. Capacity: 7.2 AH. Maximum 450 cycles of loading and unloading at a 50% discharge depth correspond to the lifespan (cycle). EUROBAT (functioning in standby mode at 20°C)	Converts DC-AC	1800
Pulse driver	MCT2E-optocoupler Diode forward voltage is 1.25V Collector-emitter voltage is 30V On-state collector current is 5mA Transistor HFE is 300 Rise time is 5us and fall time is 5us.	MCT2E is a phototransistor opto-coupler	1600
Microcontroller	dsPIC 30F2010 24-bit wide instructions, 16-bit wide data path Wide operating voltage range (2.5V to 5.5V) Dual data fetch	Pulse generation to drive the switch	2200
ESP8266MOD WI-FI Module	Node MCU Operating Voltage: 3.3V Wi-Fi 802.11 b/g/n Integrated low power 32-bit MCU Wi-Fi 2.4GHz, support WPA/WPA2 4-MB flash memory	The ESP-8266 is a self contained 802.11 b/g/n WiFi enabled microcontroller	3400
ACS712, 30 A Current sensors	Current Sense Type: Linear Hall Supply Voltage - Max:5.5V Supply Voltage - Min: 4.5V Output Type: Ratiometric	Allegro's current sensors include fast over-current detection.	620
Blynk IoT	Mobile APP	To control Arduino, NodeMCU via the Internet	Free APP
		Total cost	**16,540 INR**

6. Conclusion

This article presents the utilization of an internet of things application to regulate and supervise various parameters such as solar panel voltage, solar panel current, battery voltage, battery current, and motor current. By utilizing a Landsman and SEPIC DC-DC converter, the research illustrates the efficacy of the digitally controlled system that has been built to govern the voltage output. The authors also claim that the ESP32MOD's and microcontroller's adaptability makes them the perfect instrument for providing remote and instantaneous monitoring and control of the suggested model. By integrating the energy generated from solar power into the grid, it can be effectively utilized to meet the growing energy demand. This functionality also enhances the capability to monitor the loads connected to the network. The battery's state of charge (SOC%) is determined at different intervals by operating the DC motor with a duty cycle of 0.2, resulting in a speed of 180 RPM and a current of 0.02 A. Additionally, the system offers supplementary features that empower users to make informed decisions regarding network security and quality maintenance.

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