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IoT-Enabled Solar Power Management System for Laptop Charging and LED Lighting

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***Abstract*— The present project provides an efficient and intelligent method of controlling solar energy using the Internet of Things based methodology for applications including charging of laptops as well as illuminating the LEDs. Solar energy is harvested efficiently using a photovoltaic panel. The energy is stored into a battery and distributed to AC and DC loads. The Maximum Power Point Tracking (MPPT) algorithm is employed for optimizing the energy capture process to ensure that all possible energy from the sun is utilized to the maximum extent possible. The stored energy is converted using an inverter for charging of the laptops whereas the energy is provided directly to LED lights. The key measurements such as voltage, current, and power and status of the battery are measured and communicated by the integrated ESP32/ESP8266 microcontroller. Such information is not only communicated via an OLED display board but also transmitted real-time to the cloud platform such as Firebase or Thing Speak.**

***Index Terms*— Solar Power Management, Internet of Things (IoT), MPPT, ESP32, Energy Monitoring, Firebase, Inverter, Battery Management, Renewable Energy.**

I. INTRODUCTION

Today's era has witnessed a steep increase in the demand for clean, efficient, and sustainable sources of energy owing to the exhaustion of conventional energy resources along with increased concerns towards the environment. Solar energy can be considered as one of the most reliable and promising sources due to the reason that it is abundant, eco-friendly, and economic too. However, there lies a major disadvantage associated with traditional solar energy systems, which is that such systems lack intelligent management techniques and monitoring features. Due to recent advancements in IoT (Internet of Things), such shortcomings have been successfully overcome by integrating smart features to the system. This report covers the design and implementation process of a solar power management system for charging laptops and lighting LEDs, which makes use of solar energy through a PV cell, storing energy in batteries with the help of MPPT technique, and distributing energy via an inverter and directly too.

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ESP32/ESP8266 is employed to keep track of significant parameters including voltage, current, power, and battery information, and display them locally through an OLED display, as well as transmit the collected data to cloud-based servers such as Firebase or Thing Speak for off-site monitoring and analysis.

II. Scope and Objectives of the Work

A. Scope

This study entails designing and implementing an Internet of Things-based Solar Energy Management System for improving energy efficiency during laptop charging and LED lighting. The hardware component of this project involves the design and integration of different hardware parts like solar panels, maximum power point tracking (MPPT) charge controller, battery, inverter, voltage/current sensors, microcontroller (ESP32/ESP8266), OLED display, and relay module to establish an efficient and reliable system. In terms of software programming, the microcontroller will be programmed to collect and analyse data, perform calculations, and manage the system effectively. This project will enable the incorporation of different cloud-based platforms like Firebase or Thing Speak for collecting and analysing data collected using the microcontroller. The system will be designed based on critical electrical parameters including voltage, current, power, and battery state of charge (SoC). IoT technology will enable the transmission of collected data to the cloud platform through Internet connectivity. Moreover, the system will facilitate effective power distribution to different devices. The system will have dual outputs; DC output will provide energy for LED lighting while AC output from the inverter will facilitate laptop charging.

B. Objectives

The primary objective of the research and development project is to create and design a system that is powered by the sun that can generate, store, and provide energy that can be used in daily activities such as charging laptops and lighting up LEDs. The project will focus on enhancing the efficiency of energy generation using the MPPT charge controller to extract maximum energy from the solar panel. The project also features a monitoring facility that will monitor critical parameters such as voltage, current, power, and battery level in order to keep users informed of the status of the system. The system has been integrated with Internet of Things (IoT) through ESP32/ESP8266, which will facilitate internet connectivity and facilitate data transfer to cloud platforms such as Firebase and Thing Speak. Therefore, users will be able to remotely monitor their systems anytime and anywhere. Lastly, the system will also provide DC and AC power for LEDs and laptops respectively.

III. Proposed Methodology and Block Diagram

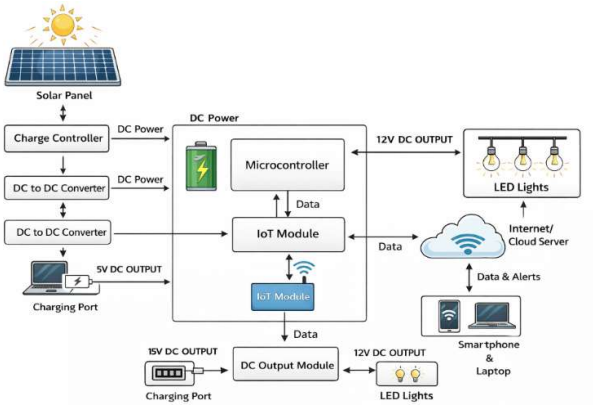

Fig. 1: Overall block – diagram of the proposed system

The system was built through the assembly of the solar power generator that employs a photovoltaic cell to harness solar energy and produce electricity. The use of an MPPT-based charge controller has been adopted to effectively control power production from the solar cell. The battery serves as a source of energy storage. In addition to this, voltage and current sensors are included in the system for accurate measurement of variables like battery voltage and load current. Finally, the ESP32/ESP8266 microcontroller is interfaced with these sensors to gather necessary information and manage the system operation. In addition, there will be an inverter which is linked to the battery that helps in converting the DC energy to AC energy for charging laptops, as well

as for supplying the DC energy needed for lighting LEDs. Internet of things connectivity will be done by connecting the ESP32 or ESP8266 to cloud servers like Firebase. The safety measures will involve low battery and overload cut-off through the relay module, which will be controlled by the microcontroller.

Fig 1 shows how our project works. The design and development of an Internet of Things (IoT) solar power management system contribute to efficient production, storage, and usage of solar energy that can be applied to tasks like charging laptops and LEDs. The IoT-powered solar energy management system allows for providing power even in places where there is not enough power supply or no electricity available at all. It uses a solar panel to collect and convert solar energy into electricity. Then, this energy is regulated by an MPPT charge controller, which ensures maximum efficiency in energy collection.

In turn, the produced electricity is stored in a rechargeable battery, while different loads can get this energy depending on necessity. In the designed system, the whole process of power generation, management, and usage is controlled by an ESP32/ESP8266 microcontroller. It reads information from voltage and current sensors constantly to control the operation of the system. The information received is displayed on an OLED display, while it is sent to the cloud via Wi-Fi, for example, Firebase or ThingSpeak cloud platform. As a result, the system is possible to monitor online. There is an inverter needed to transform the produced DC energy into AC when it comes to laptop charging.

IV. Advantages and Disadvantages of the Proposed System

A. Advantages of the Proposed System—

- Efficient Use: This system makes efficient use of solar energy by relying less on traditional forms of energy and maximizing its utility.
- Reduced Cost: It saves money on electricity costs over time due to using renewable forms of energy.
- Continuous Tracking: The ability of users to track voltage levels, currents, and batteries in real-time due to IoT integration.
- Positive Environmental Impact: The use of solar energy contributes to lowering pollution levels, contributing to sustainable development.
- Two Kinds of Output: The system has the capability to provide AC power for computers as well as DC power for LED lighting.

B. Disadvantages of the Proposed System

- Insufficient Power Output: This system works best for smaller loads since it cannot support heavier electrical requirements.
- Unpredictable Conditions: Its performance relies on sunlight; thus, it is bound to perform poorly in rainy or cloudy conditions.
- Maintenance Required: The battery used in this device needs to be regularly maintained and has a limited service life.
- Stable Internet Connection: Reliable Internet is needed in order for remote tracking capabilities to work.
- Initial Costs: Setting up solar-powered equipment and IoT requires an expensive initial investment.

V. Applications

- Residential Purposes
- In Rural and Off-Grid Locations
- In Educational Facilities
- Small Businesses and Factories
- Backup Energy Source
- Monitoring Energy Systems
- Mobile Energy Management

VI. Conclusions

In conclusion, the invention of the IoT-based solar energy management system marks an important milestone in the efficient and intelligent management of renewable energy for small-scale applications. By carefully designing the product, integrating appropriate solar energy elements, and using IoT monitoring systems, the product was able to realize its intended purpose of ensuring a reliable and affordable source of energy for charging laptops and powering LED lights.

The capability of the system to efficiently produce, store, and utilize solar energy, as well as monitor relevant parameters like voltage, current, and battery levels, significantly improves its functionality. Other notable features of the system that improve its reliability and durability include the battery cut-off and overload protection. In general, the combination of solar technology with IoT makes energy management easy while minimizing reliance on traditional power sources and promoting sustainable energy use.

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