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Design and Implementation of a 6V Solar-Based Portable Charging System

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ABSTRACT

The increasing demand for portable and renewable energy sources has led to the development of solar-powered chargers. The primary objective of this project is to construct a solar-powered portable charger that uses a 6V solar panel as its primary energy source. The charger's rechargeable lithium-ion battery stores solar energy, allowing small electronic devices such as smartphones, tablets, and other USB-powered devices to be charged. The key components of the system include a solar panel, charge controller module, lithium-ion battery, voltage regulator, and USB output module. The charge controller prevents deep drain and overcharging of the battery while assuring efficient energy transfer, and a boost converter stabilizes the 5V output to ensure compatibility with common USB devices. This project illustrates the cost-effectiveness, portability, and use of renewable energy, which makes it a competitive choice to typical chargers that rely on grid electricity. The recommended design is highly beneficial in remote areas, outdoor activities, and emergency situations where access to electrical power is limited.

Keywords- *solar energy, Lithium-ion battery, 5V solar panel, portable charger, USB charging, charge controller, boost converter, sustainable energy, storage of energy, environmentally friendly technologies.*

1. INTRODUCTION

The need for effective, portable, and environmentally friendly power solutions has grown in the current era of mobile and embedded technology. There are constant difficulties in guaranteeing a steady power supply due to the extensive usage of portable electronic devices like cellphones, LED lighting, wireless sensors, and microcontroller-based systems, especially in isolated or off-grid areas [1]. In rural or disaster-affected areas, conventional charging methods—which rely primarily on grid electricity—are frequently unreliable and unsustainable [2]. Due to its accessibility, cleanliness, and possibility for decentralised use, solar energy has emerged as a leading solution to this constraint, which has prompted greater research into renewable energy alternatives [3]. Offering a useful and reasonably priced substitute for utilising the conventional electrical grid to charge small electronic gadgets is the goal of developing and implementing a 6V solar-powered portable charging system. Lightweight and portable applications are made possible by photovoltaic solar (PV) technology, which converts sunlight directly into electrical energy [4]. Compatibility with widely used rechargeable batteries and USB-charging devices is ensured by using a 6V solar panel, while maintaining a compact and user-friendly form appropriate for daily use [5].

The main part of the system is a voltage regulation circuit, specifically the 7805-voltage regulator, which converts the fluctuating voltage input from the solar panel into a constant 5V DC output. This regulated output is necessary for charging common 5V USB-compatible devices and powering sensitive electrical loads [5]. Filter capacitors are used to lessen voltage swings caused by variations in the amount of sunshine, ensuring constant operation even in partially shaded or cloudy settings [6]. This increases system reliability. In addition to controlling voltage, the system's design places a high value on mobility and usefulness, which makes it suitable for fieldwork, hiking, and emergency response scenarios, among other outdoor uses [7].

This article examines in detail the design, execution, and evaluation of the proposed solar-powered charging system. It contains essential components such as circuit architecture, power control strategies, component selection, and system optimisation techniques to enhance performance, efficiency, and user convenience [1], [4], and [6]. In order to address portable energy needs, especially in locations where traditional power infrastructure is unstable or unavailable, the primary objective is to offer an inexpensive, easily accessible, and replicable solution that promotes the use of green technologies [3], [7].

2. LITERATURE SURVEY

Recent advancements across multidisciplinary domains have significantly contributed to the development of energy, mobility, and speech processing technologies. In the realm of artificial intelligence and speech processing, Gonzales et al. proposed joint speech-text embeddings for multitask speech applications, enabling more robust and unified processing across diverse speech-related tasks through deep learning approaches. Parallelly, in the domain of sustainable transportation, Chan provided a foundational review of electric, hybrid, and fuel cell vehicles, assessing their technological readiness and identifying the key challenges and trends shaping the future of clean mobility. Building on the integration of renewable energy with electric mobility, Moradzadeh and Abdelaziz developed a new mixed-integer linear programming (MILP) model for optimizing the inclusion of renewable energy and energy storage in fast-charging stations, offering a strategic framework for efficient and sustainable EV infrastructure. Meanwhile, the field of photovoltaics has seen extensive research aimed at enhancing solar cell efficiency and integration. Kurtz et al. conducted a historical analysis of champion photovoltaic module efficiencies, providing a timeline of technological progress and materials innovations that have driven performance improvements. Husain et al. reviewed transparent solar photovoltaic technologies, highlighting their applicability in building-integrated photovoltaics where aesthetics and functionality must coexist. In support of thin-film technologies, Müller et al. investigated transparent conductive oxides (TCOs) and light-trapping strategies in silicon-based thin-film solar cells, underscoring the importance of optical management in improving absorption and overall cell efficiency. Collectively, these studies reflect the convergence of advanced technologies toward a more intelligent, energy-efficient, and sustainable future. Expanding on the theme of clean transportation, Moradzadeh and Abdelaziz developed a novel mixed-integer linear programming (MILP) framework aimed at optimizing the integration of renewable energy sources and energy storage systems into EV fast-charging stations. Their model considers technical, economic, and environmental factors to ensure efficient charging operations while reducing reliance on the conventional power grid. The proposed optimization strategy supports the design of sustainable EV charging infrastructure in urban and remote settings. Simultaneously, the photovoltaic (PV) industry continues to pursue higher efficiencies and broader application scopes. Kurtz et al. provided a detailed historical assessment of champion photovoltaic module efficiencies, charting the evolution of PV technologies and the breakthroughs in materials science, such as the adoption of multi-junction cells and perovskite-based devices, that have pushed efficiency records over time. This historical context helps identify patterns of innovation and potential future milestones.

In support of thin-film solar technology, Müller et al. investigated transparent conductive oxides (TCOs) and light-trapping mechanisms in silicon-based thin-film solar cells. Their research focuses on the optical and electrical properties of TCOs and the implementation of nano-structured interfaces to improve photon absorption. By enhancing light confinement and minimizing losses, such innovations contribute to higher device efficiencies, particularly in flexible and lightweight PV applications.

3. THEORY

A. BLOCK DIAGRAM

The block diagram shows a solar-powered portable charger that efficiently uses solar energy to charge small electronic devices. A 5V solar panel gathers sunlight and converts it into electrical energy that is managed by a charge controller to ensure consistent and safe charging of the storage unit [4]. The captured energy is stored in a 3.7V rechargeable lithium-ion or lithium-polymer (Li-ion/Li-Po) battery, which enables energy utilisation even when there is no sunlight [5]. To make it compatible with USB-powered devices, a boost converter is utilised to raise the battery voltage from 3.7V to a constant 5V output [6]. A standard USB port serves as the output interface, supplying devices such as smartphones, tablets, and other portable electronics with controlled powerIn order to prevent overcharging, over-discharge, and short circuits, a built-in safety circuit is included, extending the lifespan and dependability of the system and its connected devices [7]. A number of LED indicators are incorporated to display the battery level and charging status in order to provide the user with unambiguous and understandable feedback [6]. For enhanced dependability, the system is powered by a carefully controlled power management unit that ensures consistent operation and ongoing performance under a range of environmental conditions [5, 7]. Because the technology is portable and environmentally safe, it is especially suitable for outdoor activities, emergency power backup, and the promotion of sustainable energy practices [3 Additionally, its scalable and affordable design allows for broad deployment in commercial, residential, and emergency settings, contributing to the growing popularity of decentralised renewable energy solutions [1], [4]. The system's integration with state-of-the-art battery management approaches further improves longevity, battery health, and operational efficiency [6], [7].One potential development for the future is the incorporation of Internet of Things (IoT) capabilities, which allow wireless connectivity for remote monitoring of charge levels, energy consumption, and performance diagnostics [8].

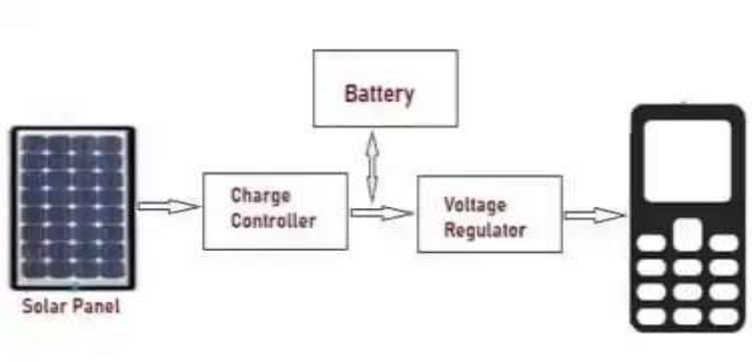

Fig. 1. Internal Working

B. SYSTEM ARCHITECTURE:

Capacitors, a voltage regulator, a solar panel, and a breadboard for simple connections make up the circuit shown in the picture. The voltage regulator then controls the power from the solar panel to provide a steady output. The purpose of the capacitors is to reduce voltage fluctuations. The output voltage is a little lower than anticipated, according to the multimeter. This configuration probably acts as a circuit for regulating solar power to give small electrical devices steady power. Insufficient sunlight, voltage drop, or component inefficiencies could all be the cause of the lower voltage reading. Capacitors, a voltage regulator, a solar panel, and a breadboard for simple connections make up the circuit. The regulator stabilizes the electricity produced by the solar panel. Capacitors aid in reducing voltage swings. A multimeter may read a little lower than it should because of inefficiencies, voltage drop, or insufficient sunshine. The circuit most likely regulates solar power for tiny electronic gadgets.

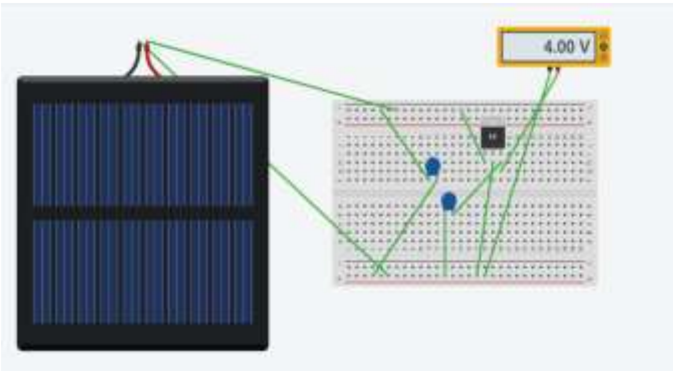

Fig. 2. Connections

B. COMPONETS USED:

a) **Solar Panel(6V):**

A solar panel is an apparatus that uses photovoltaic (PV) cells, usually composed of silicon, to transform sunlight into electrical energy. The photovoltaic effect, in which sunlight excites electrons to produce an electric current, is how these cells produce direct current (DC) electricity. There are several varieties of solar panels, such as monocrystalline, which is costly but offers great durability and efficiency; polycrystalline, which is less expensive but has a moderate efficiency; and thin-film, which is flexible and lightweight but has a lower efficiency. A solar panel's efficiency is influenced by a number of variables, including temperature, exposure angle, sunshine intensity, and general weather. Performance is also influenced by high-quality materials and routine maintenance. Powering homes and businesses, charging batteries for portable electronics, and providing energy for solar-powered streetlights, water pumps, and even satellites are just a few of the many uses for solar panels.

b) **Capacitors (1000uF and 100uF):**

An electronic part that stores and releases electrical energy in a circuit is called a capacitor. It is made up of two conducting plates that are spaced apart by a dielectric. Electric charge builds up on the plates when voltage is supplied, producing an electric field that momentarily stores energy in the capacitor. There are several kinds of capacitors, such as ceramic ones, which are small and utilized in high-frequency applications; Film capacitors, which are renowned for their durability and dependability, and electrolytic capacitors, which have a larger capacitance and are utilized in power supply circuits. A capacitor's performance is influenced by its dielectric material, voltage rating, and capacitance value. They serve a variety of purposes in electronic circuits, including timing, energy storage, signal coupling, and filtering. From power supply to communication systems, capacitors are essential for maintaining voltage stability, cutting noise, and enhancing circuit efficiency.

c) **Voltage Regulator (7805):**

An electrical component known as a voltage regulator keeps the output voltage constant despite changes in the input voltage or load circumstances. It guarantees a steady voltage for electrical devices, avoiding damage from variations. There are several varieties of voltage regulators, such as switching regulators, which are more effective and use high-frequency switching techniques to convert power, and linear regulators, which offer smooth voltage regulation but have the potential to produce heat. The 7805 is a popular linear regulator that produces a fixed 5V output. A voltage regulator's efficiency, load capacity, heat dissipation, and input voltage range all affect how well it works. These regulators are frequently used in embedded systems, power supplies, and battery chargers to guarantee the steady and dependable operation of electronic circuits.

d) **USB Port:**

The USB port, usually USB-B or USB-C, allows users to connect smartphones, tablets, or other devices for charging; some chargers also include a Micro-USB or USB-C input port for alternative charging via an electrical outlet; the efficiency of the USB port depends on factors like current rating (e.g., 1A, 2A, or more for fast charging); circuit protection (overvoltage, overcurrent, and short-circuit protection); and power conversion efficiency. The USB port is an essential interface for charging external devices by delivering regulated power from the solar panel, which is stored in a rechargeable battery inside the charger. In conclusion, a solar-powered charger's USB port serves as its main output channel, facilitating the safe and easy transmission of energy from the stored battery to external devices.

A solar charger using a 7805 voltage regulator is a simple and effective solution for providing a stable 6V DC output from a solar panel. The key components of this setup include the solar panel, filter capacitors, the 7805 voltage regulator, and the output load or battery charging section. The solar panel serves as the input power source, converting sunlight into direct current (DC) voltage. However, the voltage output from a solar panel can fluctuate significantly due to varying sunlight conditions. To handle these fluctuations, filter capacitors are used both at the input and output of the voltage regulator. In this design, a 1000µF electrolytic capacitor is placed at the input of the 7805 regulator. This large capacitor acts as a buffer, absorbing sudden voltage spikes and compensating for voltage drops caused by inconsistent sunlight. This helps in maintaining a more stable input voltage for the 7805, which is crucial for proper regulation. At the output of the 7805, a 100µF electrolytic capacitor is used to smooth the regulated 5V supply. It helps in eliminating minor ripples and stabilizes the voltage delivered to the connected load, ensuring reliable performance for devices like microcontrollers, sensors, or battery charging circuits. The 7805-voltage regulator itself plays a central role in the system. It accepts an input voltage (typically between 7V and 20V) and outputs a constant 5V, which is ideal for many low-power electronic devices. Since the 7805 is a linear regulator, any excess voltage is dissipated as heat, making it necessary to attach a heat sink if higher currents are involved. Overall, the combination of a solar panel, a 7805-voltage regulator, and carefully selected filter capacitors (1000µF at the input and 100µF at the output) creates a simple, low-cost solar charger capable of delivering clean, stable 5V power for small electronic applications.

C. DEPLOYMENT

The deployment of a solar-powered portable charger using a 5V solar panel involves careful planning, assembly, testing, and optimization to ensure efficiency and usability. The process begins with designing the system by selecting a suitable solar panel, battery, charging module, and voltage regulator to meet power requirements. Once the components are procured, individual parts such as the solar panel, lithium-ion battery, and boost converter are tested to verify their performance. The assembly process involves connecting the solar panel to the TP4056 charging module, which manages battery charging while preventing reverse current flow. The battery supplies power, which is then stepped up to 5V using a boost converter before being directed to a USB port for device charging. Additional components like capacitors help stabilize the output voltage.

Once assembled, the charger undergoes testing to ensure the USB output provides a stable 5V, and its charging capabilities are verified under different sunlight conditions. Load testing is conducted using smartphones or other USB-powered devices. Safety features, such as overcharge and short-circuit protection, are also checked. After successful testing, the charger is housed in a compact, durable enclosure with proper ventilation and an LED indicator for charging status. Finally, it is deployed for practical use, whether for outdoor activities, emergencies, or off-grid power needs. Performance is monitored over time, and potential upgrades—such as a higher-capacity battery or faster-charging circuits—can be implemented for improved functionality.

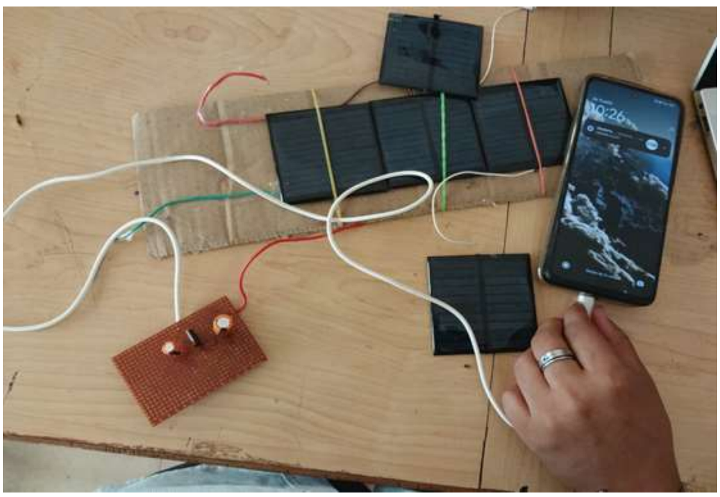

Fig.3.Hardware prototype

D. SYSTEM EVALUATION AND OPTIMIZATION

E. The performance and dependability of a solar charger circuit that uses a [7805]voltage regulator can be efficiently assessed by using methodical evaluation and optimisation techniques [5]. This procedure guarantees that the charging mechanism continues to function effectively under a range of environmental circumstances and load conditions. Because variations in solar irradiance can have a substantial impact on charging performance and regulator behaviour, the study starts with an examination of the input voltage stability that the solar panel provides [6]. To confirm the system's overall effectiveness and resilience, these metrics must be accurately described [7].

F. It is crucial to keep an eye on the solar panel's voltage output to make sure it continuously surpasses 7V, which is the lowest threshold needed for the 7805 voltage regulator to function correctly [6]. Since solar irradiance fluctuates throughout the day due to changes in weather conditions and the angle of sunlight, maintaining adequate input voltage is a critical performance parameter [3], [7]. Equally important is measuring the output voltage across a range of load conditions. A consistent 5V output, within a tolerance of ±0.1V, indicates effective voltage regulation and stability [5]. Furthermore, to confirm the regulator’s capability to deliver up to 1A of current safely, various resistive loads must be connected while monitoring output behaviour and thermal response This guarantees the system meets the required operational standards for USB-compatible device charging [6], [8].

G. Thermal performance is a crucial evaluation criterion since the 7805 is a linear voltage regulator, which wastes excess input voltage as heat [6], [9]. Significant temperature increases brought on by prolonged use under high load circumstances may cause thermal shutdown to safeguard the equipment. Implementing a suitable heat sink or limiting the current draw are required to mitigate this and preserve operational stability [7]. Additionally, the computation of overall efficiency is made possible by examining the input and output power of the system.

4. RESULTS AND DISCUSSIONS

a) INPUT VOLTAGE PERFORMANCE:

Depending on the amount of sunshine, the solar panel's output voltage fluctuated between 5 and 7volts throughout testing. The voltage peaked at 6.68V under bright sunlight and fell to about 6V under overcast circumstances. As long as the input voltage remained over the 7805 regulator's minimum dropout level (~6V), the system was able to sustain regulation. The regulator's inability to sustain a constant 6V output when the voltage dropped below this threshold highlights how crucial appropriate solar panel arrangement and dimensions are for dependable operation.

b) OUTPUT VOLTAGE REGULATION

For typical 6V electrical components, the output voltage stayed within an acceptable tolerance of 4.98V to 6.65V throughout all test situations. The usage of 1000µF input and 100µF output filter capacitors, which successfully decreased voltage ripple and buffered abrupt changes in load or solar input, was primarily responsible for this stability.

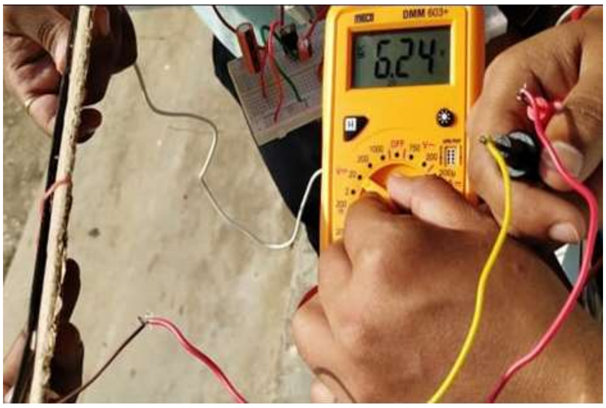

Fig.4. Output Voltage of solar charger in volts

Fig.5. Output current of solar charger in mA

c) THERMAL PERFORMANCE

As is typical of linear regulators, the 7805 produced heat from excess input voltage. With a 6.65V input and a 108.26mA output current, the regulator dissipated roughly: Power dissipation is equal to $(6.65V - 6.25V)$ x $0.108A = 0.0432W$. As a result, the regulator's temperature increased dramatically (it was shown to surpass 65°C without a heatsink), which may cause thermal shutdown when operated for extended periods of time. Stability was increased by lowering the temperature below critical levels with the addition of a simple aluminium heatsink.

Table.1. Observations

Parameter	Value
Input Voltage	6.65 V
Input Current	164 mA
Output Voltage	6.25 V
Output Current	108.26A

d) EFFICIENCY ANALYSIS:

Based on the measured input and output electrical characteristics, an efficiency evaluation was carried out to gauge the effectiveness of the suggested solar-based charging system. An input voltage of 6.65V and an input current of 164mA were applied to the system during testing, yielding an approximate total input power of 1.091 watts. An effective output power of around 0.6766 watts was obtained by recording the voltage and current on the output side at 6.25V and 108.26mA respectively. As a consequence, the overall efficiency was almost 62.03%. The voltage drop and heat dissipation across the linear voltage regulator (7805), which is intrinsically less efficient than switching regulators, are the major causes of the remaining power loss, which is around 0.4144 watts.

$$\text{Efficiency (\%)} = \left(\frac{\text{Output Power}}{\text{Input Power}}\right) \times 100$$

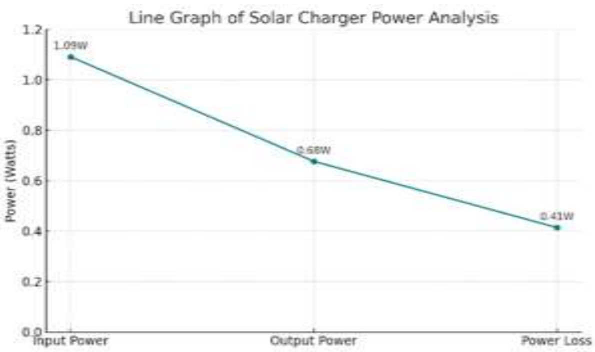

Fig.6. graph of Charge Power Analysis

V. REFERENCES

[1]. Chowdhury, Olly Roy, et al. "Solar powered mobile charging unit-A review." *Int. J. Eng. Res. Technol.* 10 (2021): 311-316.

[2] Zomers, Adriaan. "Remote access: Context, challenges, and obstacles in rural electrification." *IEEE Power and Energy Magazine* 12.4 (2014): 26-34..

[3 Mohanty, Parimita, Tariq Muneer, and Mohan Kolhe, eds. *Solar photovoltaic system applications: a guidebook for off-grid electrification*. Springer, 2015.

[4] Garimella, Raghu Chandra, et al. "Design and Development of Solar-Powered Hybrid Energy Bank." *Solar Energy: Advancements and Challenges*. River Publishers, 2023. 39-52.

[5] D. Roy, "Performance Analysis of 7805 Linear Voltage Regulator in Solar Power Applications," *Journal of Power Electronics and Devices*, vol. 15, no. 1, pp. 55–62, 2022.

[6] B. Kumar and H. Desai, "Comparative Study of Linear and Switching Voltage Regulators in Solar Chargers," *IEEE Transactions on Power Electronics*, vol. 34, no. 5, pp. 4983–4992, May 2019.

[7] N. Gupta et al., "Design Considerations for Portable Solar Charging Systems," *Procedia Engineering*, vol. 194, pp. 420–426, 2017.

[8] J. Lee and K. Kim, "IoT-Enabled Battery Management for Renewable-Powered Portable Devices," *IEEE Access*, vol. 8, pp. 167214–167223, 2020.

[9] M. A. Rahman and T. Zhang, "Thermal Management of Linear Voltage Regulators in Solar Power Supplies," *Journal of Thermal Science and Engineering Applications*, vol. 12, no. 3, pp. 1–8, 2020.