Novel Methodology for Solar Panel Efficiency Enhancement

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***Abstract*—This study explores a number of strategies for increasing solar panel efficiency, including cooling systems, corner reflectors, MPPT controllers, and dirt removal devices. Understanding how MPPT controllers use the Perturb and Observe (P&O) method to optimize electrical load in order to improve solar panel efficiency is a major area of research. This is especially true when the lead-acid battery system is bulk charging. In addition, the study explores the efficacy of strategically placed corner reflectors in rerouting sunlight onto solar panels in order to maximize energy absorption, as well as the creation of automated dirt removal devices in order to maintain panel efficiency and cleanliness. In addition, a new kind of solar tracking system is unveiled that, in contrast to traditional single-axis solar trackers, uses only one gear motor and requires less power to move the solar panel toward the sun. This novel strategy seeks to minimize energy usage while preserving effective solar panel alignment. The performance of cooling systems intended to lessen heat-induced performance degradation is also assessed in this paper. The study seeks to promote renewable energy technology and ease the world's shift to sustainable energy sources by thoroughly examining these approaches.**

***Index Terms*—MPPT, H-Bridge, solar tracker, synchronous buck converter, cooling system.**

I. INTRODUCTION

A sustainable future, a decrease in greenhouse gas emissions, and energy independence depend on effectively utilizing solar energy. Improved techniques such as dynamic sun tracking, automatic dirt remover systems, corner reflectors, MPPT controllers, and cooling systems are investigated in this study. The development of sustainable solar energy systems requires efficiency and sustainability. The global shift to sustainable energy sources is aided by enhancing the efficiency of solar panels. The future of the sector is being shaped by recent developments in energy storage, materials science, solar technology, and grid integration. Energy absorption is maximized by these cells' ability to absorb sunlight from both the front and back. Additional factors that maximize sunlight utilization and add to overall efficiency increases in solar panel technology are enhanced tracking systems and cutting-edge antireflective coatings. As a result, the solar panels' total efficiency rises as they are able to absorb a wider spectrum of sunshine wavelengths. Employment of Maximum Power Point Tracking (MPPT) is a crucial tactic for raising the efficiency of solar panels [1]. By maximizing the solar panels' electrical operating point, MPPT technology makes sure they produce their optimum amount of power. This is accomplished by continuously modifying the electrical operating point to account for variations in the amount of sunshine and shifting environmental factors point to correspond with the shifting solar intensity and environmental variables.

II. PROBLEM STATEMENT

The goal of increasing solar panel efficiency is the issue this research article attempts to solve. Solar panels have limitations, including poor energy acquisition, dirt build up, and heat-induced performance degradation, even though they have the ability to produce sustainable energy. Additionally inefficient and power-hungry are conventional tracking systems. Thus, the goal of the research is to address these problems by looking into creative solutions such as cooling systems, corner reflectors, dirt remover systems, MPPT controllers, and a unique solar tracking system that maximizes solar panel orientation toward the sun while minimizing power consumption. The goal of the project is to help progress renewable energy technologies and speed up the world's shift to sustainable energy sources by tackling these issues.

III. METHODOLOGY

The connections and working parts of a solar power system are shown in the block diagram. Its central component is the solar panel, which is improved with reflecting mirrors to better catch sunlight and is outfitted with a cooling and dust-removal system to ensure peak performance. An MPPT (Maximum Power Point Tracking) controller receives the solar panel's output and uses it to charge a battery. The sun's location is determined by the CPU, which is integrated into the system and gets light intensity information from sensors. The CPU uses this data to drive a gear motor, which changes the solar panel's position in relation to the sun. Furthermore, a real-time LCD display is integrated to show the voltage, current, battery and solar panel status during battery charging. This all-inclusive configuration maximizes battery charging, solar energy absorption, and system monitoring, augmenting overall performance and efficiency.

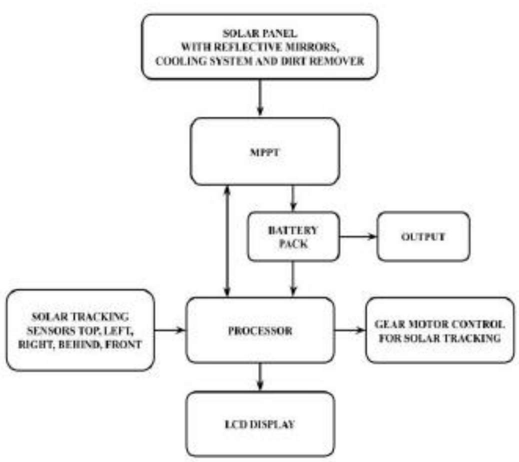

Fig.1 Block Diagram

A. Modeling and Analysis

A new method of orienting solar panels is presented by the solar tracker system, which operates efficiently with a single gear motor. Using a circular disk that is angled 15 degrees, the solar panel is installed on it. A bearing is inserted and fixed atop a metal pole in the disc's center. A wheel is attached to the gear motor's shaft and positioned so that, when the gear motor is turned on, the disc can rotate. By following the sun's path, this clever design maximizes the amount of time the solar panel is exposed to sunlight. This system uses a single gear motor instead of many, which lowers power consumption considerably and makes it a more economical and ecological way to generate solar energy than typical solar tracking systems.

Fig 2 Model

B. Solar Tracker Circuit (H-BRIDGE), Cooling and Dust Remover

The gear motor in charge of changing the solar panel's orientation is moved by means of an H-bridge circuit in the solar tracker system that is being explained. By reversing the direction of current flow through the motor, the H-bridge circuit enables the system to precisely control the rotation of the motor. With the system, the motor may be rotated in either direction to precisely align the solar panel with the sun by turning on the right pins of the H-bridge individually. By optimizing sun exposure and boosting the overall effectiveness of the solar panel system, this device makes sure that the sun's movement is tracked efficiently over the day. In order to improve longevity and performance, the system also includes a water-cooling feature and a dust remover. To keep the solar panel cool and ensure peak performance, a water pump is turned on on a regular basis. Furthermore, devices are incorporated to eliminate dust and debris, hence augmenting the panel's effectiveness in absorbing solar energy. It's important to remember that the water pump system runs in a closed loop, which means that the water that's used to clean and cool the surface of the solar panel is filtered and then used again. In addition to conserving water, this closed-loop technology helps to generate solar energy sustainably and effectively by keeping the panel clean and functional over time.

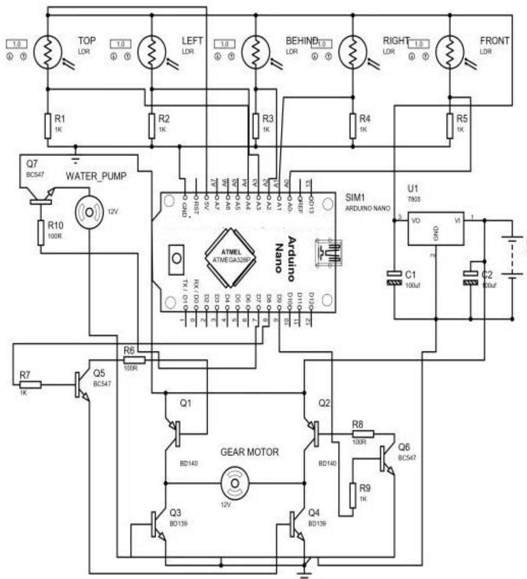

Fig 3 Solar Tracker

C. Solar Charge Controller

An MPPT (Maximum Power Point Tracking algorithm is built into a lead-acid battery charging system, which efficiently controls the charging process to provide the best possible battery health and longevity. The solar voltage, battery voltage, solar current, and battery current are all continuously monitored at the start of the process. The status of charge and the best charging plan are determined by these characteristics.

A key component in controlling the voltage applied to the battery during the charging process is the synchronous buck converter used in the circuit [5]. This converter effectively reduces the solar panel's voltage to the lead-acid battery's required charging voltage. The synchronous variation of buck converters uses synchronous rectification, which lowers power losses during switching transitions and increases efficiency compared to regular buck converters. Synchronous rectification reduces voltage dips between the switches by using a high-side and low-side MOSFET in tandem, which raises efficiency and lowers heat production. Because of the precise control this converter design offers over the charging voltage, the battery is guaranteed a steady and controlled flow of power.

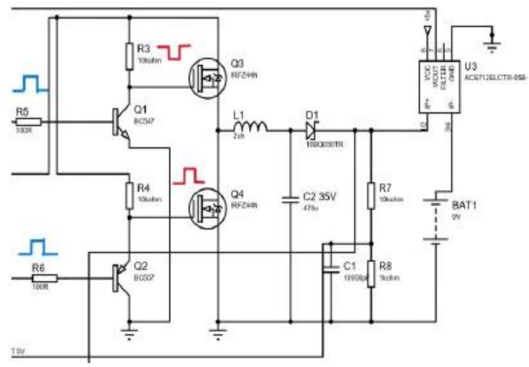

Fig 4. Synchronous Buck Converter

In order to effectively recharge the battery when it is in the bulk charging mode, the system gives priority to quick charging. The pulse width modulation (PWM) signal, which controls the charging circuit's duty cycle, is adjusted to do this. For the solar panel to function at its maximum power point, the MPPT algorithm known as the Perturb and Observe (P&O) approach is essential [4]. The system may monitor changes in the power output of the solar panel through the P&O approach, which dynamically optimizes the duty cycle based on variations in solar output. By continuously monitoring and adjusting the PWM signal, the system maximizes the power transmission from the solar panel to the battery, hence improving the overall efficiency of charging.

The system switches to the absorption charging mode when the battery voltage gets close to the absorption voltage threshold. In order to avoid overcharging and lessen battery stress, the charging current is progressively decreased in this instance. The battery is shielded from damage by overcharging or excessive current by the system, which closely checks battery characteristics to make sure charging stays within safe bounds.

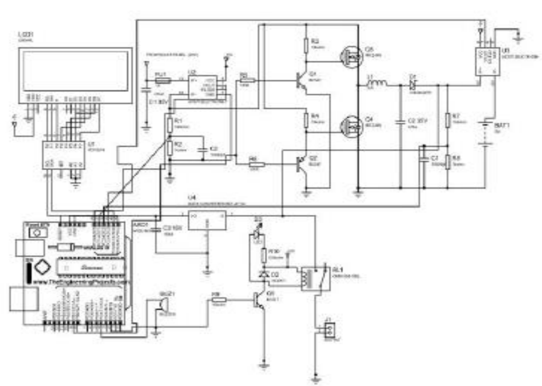

Fig 5. Lead Acid Battery Charge Controller

The system also has safety features that disable the load when the battery voltage drops below a predetermined level, preventing battery over-discharge. This guarantees the longevity of the battery and guards against the irrevocable harm that deep discharge might inflict. All things considered, the system's use of MPPT technology and meticulous control over the charging procedure allow for the effective use of solar energy while preserving the health of the batteries, supporting dependable and sustainable energy storage solutions.

IV. FUTURE SCOPE

(i) Materials Innovation: Studies on new materials for solar panel production may yield more durable and efficient solar panels. Investigating novel materials like quantum dots and perovskites has the potential to transform solar cell technology and reduce manufacturing costs.

(ii) Storage Solutions: To ensure that solar energy can meet demand even when the sun isn't shining, it is crucial to develop effective and affordable energy storage solutions. The reliability of solar electricity could be improved by developing battery technology and investigating other storage options like thermal or hydrogen storage.

(iii)Smart Grid Integration: By incorporating solar energy into smart grid systems more thoroughly, energy consumption and distribution could be optimized. Demand-responsive techniques and sophisticated monitoring and management systems could optimize solar energy advantages while maintaining grid resilience and stability.

(iv)Off-Grid Solutions: Increasing solar energy access in isolated or off-the-grid locations is still a major challenge. The creation of scalable and reasonably priced off-grid solar solutions, like microgrids or portable solar kits, has the potential to greatly enhance socioeconomic development and energy access in underprivileged areas.

V. RESULTS AND DISCUSSION

Through the use of several cutting-edge techniques, the project produces encouraging results in enhancing solar panel performance and efficiency. First of all, by effectively modifying the electrical load and therefore raising total energy output, the use of MPPT controllers improves power optimization significantly. There is an improvement in efficiency by 40% with the MPPT Controllers. In addition, the new solar tracking system, driven by a single gear motor, boasts accurate alignment capabilities that support energy generation and guarantee steady solar absorption. To further enhance the efficiency of the panel in capturing solar energy, a water pump system for panel cooling and dust removal mechanisms is incorporated. This system makes a substantial contribution to the maintenance of ideal operating conditions. Furthermore, the synchronous buck converter that is utilized during the battery charging procedure is responsible for controlling voltage levels, prolonging the life of the battery, and facilitating dependable energy storage. Notably, by effectively filtering and reusing water resources, the project's use of a closed-loop water pump system highlights its dedication to sustainability. The project's overall outcomes demonstrate a thorough and significant approach to improving solar panel resilience, efficiency, and environmental stewardship, which will promote the broad use of renewable energy sources.

VI. CONCLUSION

In summary, the efficiency of solar panels appears to have a bright future. Innovations in materials science, technology, and manufacturing processes have made solar panels more efficient, adaptable, and economical. These developments are essential for hastening the use of solar energy as a sustainable and renewable energy source. Further advancements in solar panel efficiency are anticipated as a result of ongoing research and development spending, which will increase the appeal of solar energy as a means of supplying our expanding energy needs while lowering our carbon footprint. The continuous endeavors to augment the effectiveness of solar panels signify a noteworthy advancement in the direction of sustainable energy. With further research into novel materials and state-of-the-art technologies, even further efficiency gains appear possible. Furthermore, combining solar energy with energy storage and smart grid technologies would provide a more dependable and robust energy infrastructure that can satisfy the needs of contemporary civilization. In conclusion, innovation, sustainability, and affordability will be the main forces behind future advancements in solar panel efficiency. We can slow down global warming and offer future generations with cleaner, more sustainable energy by advancing solar panel efficiency.

REFERENCES

[1] Rahul Santhosh, Aswin Ramachandran, Abhiram S,.R. Mahalakshmi, “Hardware design of Single axis solar tracker and MPPT charge controller using PIC18F4520”, International Conference on Electronics and Renewable Systems (ICEARS), March 2022.

[2] K. Poojitha, L. Ashwini, B. S. Anjali and J. Ramprabhakar, "Solar tracker using Maximum Power Point Tracking algorithm," 2019 International Conference on Intelligent Computing and Control Systems (ICCS), 2019, pp. 1528-1531, doi: 10.1109/ICCS45141.2019.9065554.

[3] W. X. García-Quilachamin, J. Evangelina Sánchez-Cano, F. Ulloa, E. Velesaca-Zambrano and J. Herrera-Tapia, "Analysis of the parameters of a solar tracker system, based on movements of a power generation system," 2021 16th Iberian Conference on Information Systems and Technologies (CISTI), 2021, pp. 1-6, doi: 10.23919/CISTI52073.2021.9476478

[4] Dalila BERIBER, Abdelaziz TALHA, "MPPT Techniques for PV Systems," 4th International Conference on Power Engineering, Energy and Electrical Drives, POWERENG-2013At: Istanbul, Turkey.

[5] Mohamed El-Zanaty, Mohamed Orabi, "Review of Synchronous Buck Converter Design Optimization," 12th International Middle-East Power Conference (MEPCON), Aswan- Egypt, March 2008

[6] S. Raviteja, G. M and R. Mahalakshmi, " Implementation of Control Tactics on Standalone Solar PV System, & quot; 2019 International Conference on Smart Systems and Inventive Technology (ICSSIT), Tirunelveli, India, 2019, pp. 870-875.

[7] Ali Jawad Alrubaie, Ameer Al-Khaykan, R. Q. Malik, Suhair Hussein Talib, Mohammed Imran Mousa, Ashraq Mohammed Kadhim, “Review on MPPT Techniques in Solar System”, 8th International Engineering Conference on Sustainable Technology and Development (IEC), 23-24 February 2022