International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

# Solar Car: A Step Towards Clean Mobility

Ms. Diksha P. Kale, Ms. Sakshi N. Ahire, Ms. Tanvi V. Gavali, Ms. Neha S. Pawar,
Mr. Durgesh D. Bachhav, Mr. Hitesh N. Kalunkhe, Mr. N. R. Thakre, Mr. S. S. Pawar
Dept. Of Electronics and Telecommunication Engineering
SNJB's Shri Hiralal Hastimal (Jain Brothers, Jalgaon) Polytechnic Chandwad, Dist. Nashik, India

**ABSTRACT - The automotive sector is undergoing a significant transformation driven by rising fuel costs, depleting fossil fuel reserves, and evolving global energy policies. Among various sustainable solutions, hybrid and alternative energy technologies, including hydrogen and electric vehicles, are gaining increasing attention. Solar-powered cars, being one of the earliest innovations in renewable-based transportation, continue to offer valuable insights for the expanding electric mobility sector. The integration of telemetry systems in solar race cars has further enhanced the understanding of energy consumption patterns, efficiency optimization, and design improvements, which are equally applicable to modern electric vehicles.**

**Beyond their role in competitions and experimental projects, solar cars provide a foundation for research in areas such as lightweight materials, photovoltaic integration, aerodynamics, and advanced battery management. Despite challenges like limited energy conversion efficiency, dependency on weather conditions, and high initial costs, ongoing advancements in solar panels, energy storage, and power electronics are steadily improving their feasibility for real-world applications.**

**This paper reviews the evolution of solar and electric vehicles, explores their technological progress, and presents an overview of a typical solar car model. The study also highlights future opportunities for solar mobility as a complementary technology to electric vehicles, emphasizing its potential role in achieving cleaner, smarter, and more sustainable transportation systems.**

**Keywords: Solar Car, Electric Vehicles, Renewable Energy, Telemetry, Sustainable Transportation, Photovoltaics**

## I. INTRODUCTION

The increasing demand for clean and renewable sources of energy has encouraged significant research in solar-powered transportation. Solar energy, being abundant and sustainable, presents a promising solution to reduce dependency on fossil fuels and lower environmental impact. In solar-powered vehicles, photovoltaic (PV) modules are employed to convert sunlight into usable electrical energy. Depending on the voltage requirements, PV panels can be connected in series or parallel; however, large-scale PV arrangements are often costly. To address this limitation, auxiliary systems such as batteries and power converters are integrated, which improve efficiency and make the overall system cost-effective.

The generated electrical charge from the solar panels is regulated through charge controllers to prevent battery overcharging and deep discharge, thereby extending battery life. A boost converter is then employed to step up the voltage to a suitable level for driving the Brushless DC (BLDC) motor, which serves as the primary propulsion system. For practical implementation, each component—solar panels, charge controllers, converters, batteries, and BLDC motors—must be studied individually and then integrated to form a complete system. This paper presents an overview of such integration, focusing on the performance and real-time application of solar-powered vehicles.

## II. HISTORY OF SOLAR VEHICLES

The concept of combining photovoltaic technology with electric vehicles can be traced back to the late 1970s. To promote awareness and research in this field, Hans Tholstrup organized the first major solar vehicle competition—the **World Solar Challenge (WSC)** in 1987. This 3,000 km race across the Australian outback attracted participation from leading universities, research organizations, and industry groups. General Motors (GM) secured a remarkable victory with their solar car *Sunraycer*, which achieved speeds exceeding 40 mph, demonstrating the feasibility of solar-powered transportation.

Following this success, GM collaborated with the U.S. Department of Energy to host the **GM Sunrayce** in 1990, further inspiring advancements in solar car technology. Over the years, several international competitions such as the **North American Solar Challenge (NASC)** have been conducted, with the 2005 event covering a record-breaking 3,960 km route from Austin, Texas to Calgary, Alberta.

Although these events began as industry-sponsored initiatives, they eventually fostered a unique culture of innovation among universities, research teams, and independent groups. The progress achieved through such competitions not only advanced the design of solar vehicles but also provided insights applicable to the broader electric vehicle industry. These developments highlight the potential of solar energy as a supplementary power source for sustainable mobility and as an alternative to traditional combustion-based vehicles.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

## III. LITERATURE REVIEW

Research on solar-powered vehicles and their integration with modern transportation systems has been growing steadily over the past few decades. Several studies have highlighted the potential of solar energy as a sustainable solution to the challenges posed by fossil fuel dependency and greenhouse gas emissions.

Rizzo (2010) [1] provided a comprehensive overview of the various automotive applications of solar energy, emphasizing how photovoltaic technology can be incorporated into vehicles for both propulsion and auxiliary functions. Building on this, Arsie, Rizzo, and Sorrentino (2008) [2] proposed a design model for hybrid solar vehicles, stressing the importance of optimizing system efficiency through intelligent integration of solar panels, batteries, and power converters.

Connor (2007) [3] discussed the broader benefits of solar vehicle technology, noting its potential to reduce environmental impact and reliance on conventional fuels. Daniels and Kumar (2005) [4] further examined strategies for the optimal utilization of solar energy in automobiles, focusing on control mechanisms to maximize energy efficiency.

In the Indian context, Wamborikar and Sinha (2010) [5] presented the design and performance of a solar-powered vehicle, illustrating the feasibility of such systems in emerging economies. Shaheen (2004) [6] analyzed California's zero-emission vehicle mandate, which indirectly accelerated research and adoption of renewable-powered vehicles worldwide.

Huang et al. (2005) [7] introduced an intelligent solar-powered automobile ventilation system, highlighting how solar technology can improve passenger comfort and reduce fuel consumption. Similarly, Shimizu et al. (1997) [8] discussed advanced concepts in electric vehicle design, many of which continue to inform solar car development today.

Finally, Akhter and Hoque (2006) [9] investigated the performance of a PWM boost inverter for solar applications, providing valuable insights into efficient energy conversion and storage, which are critical for the reliability of solar-powered vehicles.

Collectively, these studies underline the steady progress in solar vehicle research, ranging from design optimization and energy management to policy-driven adoption. The literature establishes a strong foundation for further advancements, particularly in integrating solar technology with modern electric mobility solutions.

## IV. BASIC FUNCTIONAL DIAGRAM

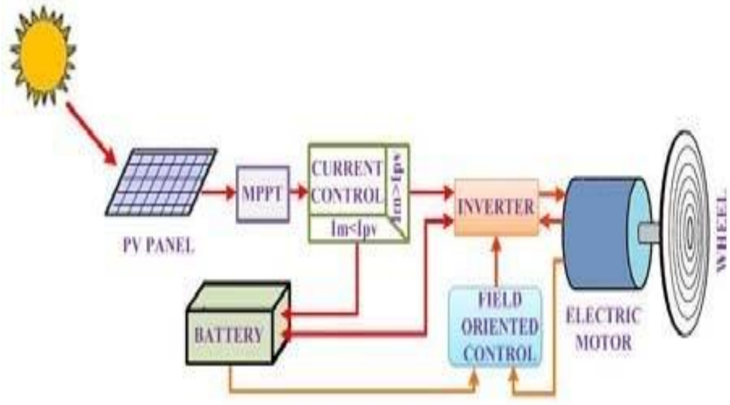


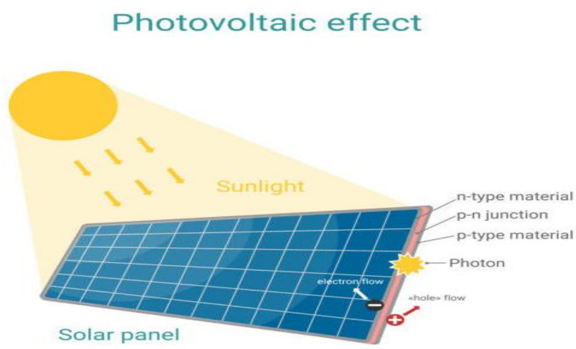

Fig.2 Basic block Diagram Representation of Solar vehicle

The working of the proposed solar powered vehicle system is illustrated in the block diagram. Solar energy from the sun is first converted into electrical energy by the photovoltaic (PV) panel. Since the output of the PV panel varies with sunlight intensity and temperature, a Maximum Power Point Tracking (MPPT) controller is employed to ensure that the panel consistently operates at its maximum efficiency, thereby extracting the optimum power. The regulated current from the MPPT is further controlled through a current control block, which matches the generated current with the demanded load current to maintain stability.

The system is integrated with a battery storage unit that stores excess solar energy and supplies power to the motor during low sunlight conditions, ensuring continuous operation of the vehicle. As the electric motor requires alternating current (AC) for operation, the direct current (DC) obtained from the PV panel or battery is converted into AC using an inverter. To achieve high efficiency, smooth operation, and better torque control of the motor, a field-oriented control (FOC) technique is implemented. Finally, the controlled AC power drives the electric motor, which in turn rotates the wheels, thereby propelling the vehicle.

## V.EQUIPMENT REQUIRED

**1. Solar Panel**



International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

A solar panel, also known as a photovoltaic (PV) module, is an advanced device engineered to convert sunlight directly into electrical energy through the photovoltaic effect. It is composed of multiple interconnected solar cells, typically fabricated from semiconductor materials such as monocrystalline or polycrystalline silicon. When sunlight strikes the surface of these cells, photons are absorbed by the semiconductor material, causing the release of electrons and thereby generating direct current (DC) electricity.

The overall efficiency of a solar panel is influenced by several factors, including the type and quality of semiconductor material, cell configuration, temperature, and solar irradiance. In the proposed solar vehicle system, the solar panel functions as the primary energy source, continuously providing electrical power during daylight conditions. The generated DC power is processed through a Maximum Power Point Tracking (MPPT) controller to ensure optimal energy extraction under varying sunlight conditions.

Additionally, the modular and scalable design of solar panels allows for flexible integration into the vehicle's architecture, supporting not only propulsion but also auxiliary systems such as lighting, ventilation, and onboard electronics. This enhances the vehicle's energy independence, sustainability, and operational efficiency, making solar panels a vital component of the proposed system.

2. MPPT


A Maximum Power Point Tracking (MPPT) controller is an intelligent power electronic device designed to maximize the energy output from a solar panel by continuously adjusting its operating point. Since the voltage and current characteristics of photovoltaic (PV) modules vary with solar irradiance, temperature, and load conditions, the MPPT controller ensures that the system operates at the Maximum Power Point (MPP) — the point on the current-voltage (I-V) curve where the product of current and voltage (and thus power) is highest.

The MPPT controller functions by tracking and dynamically regulating the voltage and current from the solar panels to extract the maximum possible power at any given time. It employs advanced algorithms such as Perturb and Observe (P&O), Incremental Conductance, or Fuzzy Logic Control, depending on the system's design and complexity. These algorithms allow the controller to adapt quickly to changing environmental conditions, ensuring high conversion efficiency and minimal power loss.

In the proposed solar vehicle system, the MPPT controller plays a crucial role as an interfacing unit between the solar panels and the energy storage or propulsion system. It converts the unregulated DC output from the solar panels into a stable, optimized DC supply, which can then be used to charge the battery or power the motor drive circuit. This not only enhances the overall performance and reliability of the solar vehicle but also improves battery life by maintaining optimal charging conditions.

Overall, the MPPT controller is an essential component in modern photovoltaic systems, ensuring maximum energy harvesting, efficient power management, and sustainable operation of solar-powered applications such as the proposed **solar vehicle.**

**3. Battery**


A battery is a vital energy storage component in a solar vehicle system, responsible for storing the electrical energy generated by the solar panels and supplying it when direct solar power is unavailable or insufficient. It acts as a buffer and backup source, ensuring uninterrupted power delivery for both propulsion and auxiliary systems. In photovoltaic applications, batteries typically store direct current (DC) electricity, which can later be utilized to drive motors or power onboard electronics during low irradiance or nighttime conditions.

The choice of battery technology significantly influences the overall performance, efficiency, and lifespan of the solar vehicle. Common types used in such systems include Lithium-Ion (Li-Ion), Lithium Iron Phosphate ($LiFePO_4$), and

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

Lead-Acid batteries. Among these, Li-Ion and $LiFePO_4$ batteries are preferred due to their high energy density, lightweight design, fast charging capability, and longer cycle life compared to conventional lead-acid types.

In the proposed solar vehicle system, the battery serves as the secondary power source, storing excess energy produced by the solar panel during peak sunlight hours through the MPPT controller. This stored energy is then efficiently released to power the motor and support auxiliary circuits when solar generation is reduced. To ensure safety and reliability, a Battery Management System (BMS) is typically integrated to monitor key parameters such as voltage, current, temperature, and state of charge (SOC), thereby preventing issues like overcharging, deep discharging, and thermal runaway.

Overall, the battery plays a crucial role in maintaining energy stability, system efficiency, and operational continuity, making it an indispensable component in the sustainable design of the proposed solar vehicle.

**4. Current Control Unit**


A Current Control Unit (CCU) is a critical component in a solar vehicle system, responsible for regulating and managing the flow of electrical current from the battery or solar panels to the electric motor or other onboard loads. By controlling the current, the CCU ensures that the motor operates efficiently, protects the electrical components from damage due to overcurrent, and maintains stable and smooth vehicle performance under varying load conditions.

The CCU typically works in conjunction with the Motor Drive System, modulating the current based on the driver's input, battery state of charge, and power availability from the solar panels. Advanced CCUs use pulse-width modulation (PWM) techniques or field-oriented control (FOC) methods to provide precise and responsive control over motor torque and speed. This results in optimized propulsion efficiency, reduced energy losses, and improved overall performance of the solar vehicle.

In the proposed solar vehicle system, the Current Control Unit serves as an intermediary between the power sources (battery/solar panel via MPPT) and the electric motor, ensuring that the current supplied matches the motor's requirements at all times. It also provides overcurrent protection, thermal protection, and fault detection, thereby safeguarding the vehicle's electrical system and enhancing reliability.

Overall, the Current Control Unit is an essential component in the solar vehicle architecture, enabling efficient energy utilization, smooth acceleration and deceleration, and safe operation of the vehicle under diverse driving and environmental conditions.

5. Inverter


An inverter is a crucial power electronic device in a solar vehicle system, responsible for converting direct current (DC) electricity stored in the battery or generated by the solar panels into alternating current (AC) when required by the electric motor or other AC loads. This conversion is essential in vehicles that use AC motors, as they provide higher efficiency, better torque characteristics, and smoother operation compared to DC motors.

Modern inverters employ advanced switching technologies such as Insulated Gate Bipolar Transistors (IGBTs) or MOSFETs, along with sophisticated pulse-width modulation (PWM) techniques to produce a stable, high-quality AC output with minimal harmonic distortion. The inverter also allows dynamic control of motor speed and torque, enabling precise vehicle performance under different driving conditions.

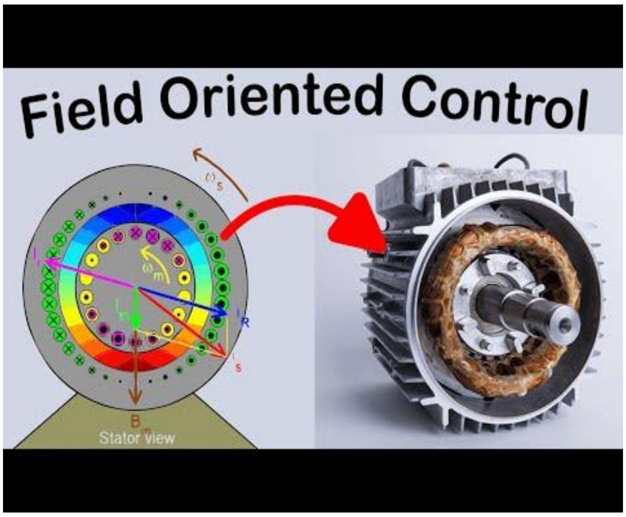
In the proposed solar vehicle system, the inverter acts as the interface between the DC power sources (solar panels and battery) and the AC motor, ensuring efficient energy conversion and optimal utilization of available power. Some inverters also include bidirectional capability, allowing them to manage regenerative braking by converting AC energy

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

from the motor back into DC to recharge the battery, thus enhancing the vehicle's overall energy efficiency.

Overall, the inverter is an indispensable component in a solar-powered vehicle, facilitating efficient DC-to-AC conversion, motor control, and energy recovery, while contributing significantly to the performance, reliability, and sustainability of the system.

6. Field Oriented Control




Field Oriented Control (FOC), also known as vector control, is an advanced motor control technique used in modern electric and solar vehicles to achieve precise and efficient operation of AC motors. Unlike conventional control methods, which directly manage voltage or current, FOC decouples the motor's magnetic flux and torque components, allowing independent control of both. This enables smooth torque production, rapid dynamic response, and optimal efficiency across a wide range of speeds and loads.

FOC operates by transforming the three-phase stator currents into a rotating reference frame aligned with the rotor flux, using mathematical transformations such as Park and Clarke transforms. This allows the controller to regulate the torque-producing current and magnetizing current separately, resulting in precise motor torque control with minimal energy loss. It is commonly implemented through a microcontroller or digital signal processor (DSP) integrated into the motor drive system.

In the proposed solar vehicle system, FOC enhances the performance and efficiency of the electric motor by providing high torque at low speeds, smooth acceleration and deceleration, and reduced power consumption. When combined with the Current Control Unit and inverter, FOC ensures that the vehicle operates reliably, responsively, and efficiently under varying load and driving conditions, including regenerative braking scenarios.

Overall, Field Oriented Control is a critical component of advanced motor control systems, enabling precise torque management, improved energy efficiency, and superior driving performance, making it highly suitable for solar-powered electric vehicles.

7. Electric Motor

An electric motor is a core component of a solar vehicle system, responsible for converting electrical energy stored in the battery or generated by the solar panels into mechanical energy to drive the wheels. Unlike internal combustion engines, electric motors offer high efficiency, instant torque, low maintenance, and quiet operation, making them ideal for sustainable and energy-efficient transportation.

Modern solar vehicles typically employ brushless DC (BLDC) motors or three-phase AC induction/synchronous motors, chosen for their high power-to-weight ratio, efficiency over a wide speed range, and compatibility with advanced control techniques such as Field Oriented Control (FOC). These motors work in conjunction with the Current Control Unit and inverter to ensure precise control over speed, torque, and direction of rotation.

In the proposed solar vehicle system, the electric motor receives regulated DC or AC power from the energy management system, which includes the battery, MPPT controller, and inverter, depending on the motor type. The motor's performance is further enhanced by Field Oriented Control, enabling smooth acceleration, deceleration, and regenerative braking while minimizing energy losses.

Overall, the electric motor is a key driver of vehicle propulsion, providing efficient, reliable, and environmentally friendly performance. Its integration with advanced control systems ensures that the solar vehicle operates optimally under various driving and environmental conditions, maximizing the utilization of harvested solar energy.

International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 14 Issue 12 , December - 2025

## VI. CONCLUSION AND FUTURE SCOPE

Solar-powered vehicles represent a promising alternative to conventional automobiles, offering a sustainable and environmentally friendly mode of transportation. By utilizing renewable energy from the sun, these vehicles can significantly reduce dependence on fossil fuels and minimize greenhouse gas emissions. Although current systems face limitations such as relatively low speeds, high initial investment, and limited energy conversion efficiency (around 17%), these challenges are gradually being addressed through advancements in photovoltaic technology, energy storage, and power electronics. The development of high-efficiency solar cells with conversion rates of 30–35% and lightweight materials will further enhance the practicality of solar vehicles.

In the future, continuous research and innovation are expected to make solar cars more cost-effective, reliable, and commercially viable. Integration with smart grid systems, improved battery management, and hybrid configurations combining solar with other renewable sources can expand their applications beyond experimental and racing models. Moreover, government policies, incentives, and public awareness will play a crucial role in accelerating their adoption.

With the rapid global shift towards clean energy and sustainable mobility, solar automobiles hold immense potential for future transportation systems. They not only provide a pathway toward reducing environmental pollution but also contribute to building a smarter, greener, and more energy-secure future.

## REFERENCES

[1] Rizzo, G. (2010), Automotive Applications of Solar Energy, IFAC Symposium Advances in Automotive Control, July 12 - 14 2010, Munich, Germany.
[2] Arsie I, Rizzo G, Sorrentino M “A Model for the Optimal Design of a Hybrid Solar Vehicle”, Review of Automotive Engineering, Society of Automotive Engineers of Japan (JSAE), 2008, ISSN 1349-4724. 29-3: 439-447
[3] John Connor “solar vehicles and benefits of the technology”, ICCEP paper 2007
[4] M. W. Daniels and P. R. Kumar, “The optimal use of the solar power Automobile,” Control Systems Magazine, IEEE, vol. 19, no. 3, 2005.
[5] Yogesh Sunil Wamborikar, Abhay Sinha “Solar powered vehicle”, WCECES Paper 2010.
[6] S.Shaheen, “California’s zero-emission vehicle mandate,” Institute of Transportation Studies, vol. UCD-ITS-RP-04-14, 2004.
[7] K. D. Huang, S.-C. Tzeng, W.-P. Ma, and M.-F. Wu, “Intelligent solar-powered automobile-ventilation system,” Applied Energy, vol. 80, pp. 141–154, 2005.
[8] H. Shimizu, J. Harada, C. Bland, K. Kawakami, and L. Chan, “Advanced concepts in electric vehicle design,” IEEE Transactions on Industrial Electronics, vol. 44, no. 1, pp. 14–18, 1997.
[9] Rafia Akhter and Aminul Hoque, Analysis of a PWM Boost Inverter for Solar Home Application, Proceedings of World Academy of Science, Engineering and Technology Volume 17, December 2006, pp.212-216.