

# The Basic Electrical and Electronic Components of a Solar Electric Car and Their Working

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**Abstract**—The Solar-Electric vehicles what we refer as SEV's representing a pivotal advancement in sustainable transportation combine photovoltaic energy harvesting with advanced and efficient electric propulsion systems, representing a paradigm shift in sustainable mobility. This report explores the basic electrical and electronic components of a solar electric car, detailing their functionalities and interactions along with their working. Key components of a SEV include the solar panel, converting solar energy to electrical; the MPPT controller, which optimizes the energy extraction from the solar panel; and the battery storage system, is designed to store energy for later use. The report highlights the importance of real-time data monitoring through a Battery Management System to ensure the longevity and efficiency of the battery pack while maintaining optimal motor performance. The inverter and motor controller ensure the efficient conversion and regulation of energy to power the motor. Also, auxiliary components like the onboard charger and energy management system coordinate energy flow across the vehicle.

The powertrain components also work in synergy to deliver power to the wheels while maximizing energy efficiency. This paper also discusses the integration of these components and their roles in achieving optimal performance by their roles in energy generation, storage, and propulsion. The report provides insights into how these components collectively contribute to the development of sustainable and efficient solar-powered electric vehicles. sheet.

**Keywords**— *solar electric car, solar panel array, maximum power point tracking, battery storage system, inverter, motor controller, motor, powertrain, sustainable transportation component*

## I. INTRODUCTION

The global transition towards sustainable energy solutions has led to significant advancements in the development of solar electric vehicles, particularly solar-powered electric cars. These vehicles by harnessing solar energy, aim to minimize carbon emissions and reduce dependence on non-renewable energy sources, aligning with global efforts to combat climate change and promote green mobility. The use of electric cars offers nearly double the advantages compared to conventional fuel-powered ones, making them a more environmentally sustainable option [1].

The first acknowledgment of solar energy dates back to 1839 when French physicist, Edmund Becquerel, discovered that some materials would produce an electric current when they were exposed to sunlight. From there, Albert Einstein won a Nobel Prize after his work with photovoltaic technology in 1905. The first photovoltaic module was built in 1954 by Bell Laboratories, but lacked

widespread use because too little was still known about the capabilities of it. Moving forward to the 1960's, solar energy was used to generate power aboard a spacecraft, enhancing its reliability and feasibility of use. Finally, in the 1970's, during the energy crisis, solar energy was adapted for commercial use.

This paper delves into the fundamental electrical and electronic components of a solar electric car, examining their individual functions and interconnections within the system. The discussion extends to the working principles of these components, highlighting their roles in achieving seamless energy conversion, storage, and utilization. By understanding these elements, researchers and engineers can contribute to the refinement of solar electric vehicle technology, paving the way for a sustainable future in transportation.

A solar electric car integrates various electrical and electronic components, each playing a critical role in energy conversion, storage, and distribution. The primary component, the solar panel, converts sunlight into electrical energy through photovoltaic cells. This energy is regulated by the Maximum Power Point Tracking (MPPT) controller, which optimizes power extraction under varying sunlight conditions. The electrical energy is then stored in a high-capacity battery system, ensuring consistent power supply even in the absence of sunlight. The inverter converts the stored direct current (DC) into alternating current (AC), which is required to drive the electric motor. The motor controller regulates the motor's operation, translating driver inputs into efficient vehicle motion.

In addition to these core components, a solar electric car includes auxiliary systems such as an onboard charger, energy management system (EMS), and various sensors. The onboard charger facilitates energy input from external sources when solar energy is insufficient or unavailable. The EMS oversees the flow of energy across components, ensuring optimal performance and longevity of the powertrain. Sensors are also an integral part as they monitor parameters like battery state, motor temperature, and vehicle speed, providing real-time data for system optimization.

The powertrain of a solar electric car consists of the following key components: Solar Panel Array converts solar radiation into electrical energy; Battery Pack stores electrical energy for consistent power delivery; MPPT Controller maximizes energy extraction from the solar panels; Inverter inverts/converts DC to AC for motor operations; Electric Motor drives the wheels of the vehicle and last but not the least the drivetrain transfers power from the motor to the wheels.

The integration of these components involves careful consideration of energy efficiency, weight optimization,

and thermal management. For instance, the solar panel's placement and angle significantly impact energy absorption, while the battery's design determines the vehicle's range and performance. Advanced cooling systems are also essential to prevent overheating of the motor and battery during operation.

Solar electric cars face several challenges, including variable solar energy availability, high initial costs, and limitations in energy storage technology. Despite these hurdles, advancements in photovoltaic efficiency, battery technology, and lightweight materials are continuously improving the feasibility and practicality of these vehicles. Innovations such as perovskite solar cells and solid-state batteries promise to enhance energy density and durability, addressing critical bottlenecks in solar electric vehicle development.

Moreover, the paper emphasizes the significance of the powertrain's integration in overcoming operational challenges. By leveraging advancements in electrical engineering and electronics engineering and renewable energy, solar electric cars can play a pivotal role in reducing greenhouse gas emissions and promoting eco-friendly mobility solutions. Through this exploration, the study aims to provide a comprehensive overview of the technology underpinning solar electric vehicles, fostering innovation and inspiring further research in this promising domain.

## II. BASIC ELECTRICAL AND ELECTRONIC COMPONENTS OF SOLAR ELECTRIC CAR

### A. Solar Panels

First, In a solar electric car, the solar panel serves as a critical electronic component that converts sunlight into electrical energy, enabling the vehicle to operate without reliance on conventional fuels. These panels are composed of numerous photovoltaic (PV) cells, typically made from semiconductor materials like silicon, which are adept at absorbing photons from sunlight. When these photons interact with the PV cells, they excite electrons, creating an electric current through the photovoltaic effect. An individual PV cell is usually small, typically producing about 1 or 2 watts of power. This direct conversion of solar energy into electricity distinguishes PV cells from other solar technologies that first convert solar energy into heat before generating electricity.

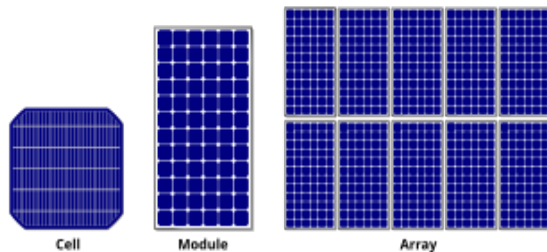


Fig. 1. Cells, modules and arrays [3]

In order to withstand the outdoors for many years, cells are sandwiched between protective materials in a combination of glass and/or plastics. To boost the power output of PV cells, they are connected together in chains to

form larger units known as modules or panels. Modules can be used individually, or several can be connected to form arrays (as in Fig. 1.). One or more arrays is then connected to the electrical grid as part of a complete PV system. Because of this modular structure, PV systems can be built to meet almost any electric power need, small or large. [2]

The electricity generated by the solar panels is then directed to the car's battery system, where it is stored for immediate or future use. This stored energy powers the electric motor, propelling the vehicle. The efficiency of this process depends on factors such as the quality of the PV cells, the intensity of sunlight, and the surface area of the panels. Advancements in solar technology have led to the development of more efficient and flexible solar panels, enhancing the practicality and performance of solar electric cars. Solar arrays on solar cars are mounted and encapsulated very differently from stationary solar arrays. Solar arrays on solar cars are usually mounted using industrial grade double-sided adhesive tape right onto the car's body. The arrays are encapsulated using thin layers of Tedlar.

Some solar cars use gallium arsenide solar cells, with efficiencies around thirty percent. Other solar cars use silicon solar cells, with efficiencies around twenty percent. Typically, high-efficiency solar panels are used, with power output ranging from 200W to 1kW, depending on the car's energy requirements. This energy is conditioned by a maximum power point tracker (MPPT) for optimal utilization [5].

### B. Batteries(Energy Storage)

Solar electric cars use rechargeable batteries, such as lithium-ion or lead-acid batteries, to store energy for use during low solar irradiance or nighttime. The battery pack stores DC electricity through electrochemical reactions. These batteries are designed to handle deep discharge cycles and high energy density. For instance, a lithium-ion battery system can offer efficiencies exceeding 95%, enabling long-range performance and fast charging capabilities. Additionally, regenerative braking systems recharge the battery during deceleration [6][7].

### C. Electric Motor

The electric motor, typically a brushless DC (BLDC) or an induction motor (that operates through electromagnetic interactions) converts electrical energy into mechanical energy to propel the vehicle. BLDC motors are favoured for their high efficiency (up to 96%), lightweight design, and low maintenance. They are controlled by an electronic controller that optimizes power delivery based on speed and torque requirements [6][7].

### D. Motor controller

The motor controller regulates the voltage and current supplied to the motor thereby regulates the speed and torque of the electric motor. Controller processes input from the accelerator pedal and adjusts the motor's voltage and current to meet driving demands. Advanced controllers incorporate features such as regenerative braking, torque control, and fault diagnostics. These components ensure that the motor operates at peak efficiency under varying conditions, enhancing overall vehicle performance [6].

### E. Maximum Power Point Tracker (MPPT)

The MPPT ensures optimal energy extraction from the solar panels by continuously adjusting the operating point of the photovoltaic cells.

The working principle is very dynamic. The MPPT controller dynamically tracks the voltage and current characteristics of the solar panels under varying sunlight conditions to determine the point of maximum power output. By adapting the electrical load, the system maximizes energy transfer to the battery or motor controller, ensuring efficient use of solar resources. Advanced MPPT systems are microprocessor-controlled, enhancing performance and offering real-time diagnostics [6][7].

### F. Battery Management System(BMS)

The Battery Management System (BMS) is a crucial component responsible for monitoring and managing the performance and safety of the battery pack. It optimizes the battery's operation by performing several key functions. First, the BMS prevents overcharging and over-discharging by tracking the state of charge (SOC), ensuring that each cell remains within safe voltage and capacity limits, thereby avoiding premature degradation. Additionally, it maintains thermal stability by monitoring temperature during charging and discharging processes, which helps prevent overheating and reduces the risk of thermal runaway—a critical safety measure.

The BMS also balances the battery cells, ensuring uniform charging and discharging across all cells in the pack. This not only enhances the efficiency of the battery but also extends its lifespan. By providing real-time energy data, the BMS ensures consistent power delivery to the motor, thereby optimizing vehicle performance. Moreover, it improves safety and reliability by detecting anomalies such as short circuits or cell malfunctions, allowing for preemptive measures to prevent potential failures.

Overall, the BMS plays a pivotal role in ensuring energy efficiency, operational safety, and the durability of the battery system in solar electric vehicles [6][7].

### G. DC-DC Converters

The DC-DC converter is a critical component in solar electric vehicles, responsible for adjusting voltage levels to power auxiliary systems such as lighting, infotainment, and dashboard electronics. It ensures stable operation by converting the high-voltage output from the battery into lower, usable voltages required by these systems. Typically, a buck-boost converter is employed, as it is capable of stepping down (buck) or stepping up (boost) the voltage depending on the input voltage relative to the required output. This flexibility is particularly useful in managing fluctuations in battery voltage during varying load conditions. By providing a consistent and efficient power supply, the DC-DC converter enhances the reliability and functionality of auxiliary systems, ensuring seamless operation across different vehicle states [7].

### H. Inverter

The inverter is a vital component in a solar electric vehicle, responsible for converting direct current (DC) electricity from the battery into alternating current (AC)

required by the electric motor. This conversion enables the motor to operate efficiently and effectively under varying load conditions. The inverter employs semiconductor-based switches, such as insulated-gate bipolar transistors (IGBTs), metal-oxide-semiconductor field-effect transistors (MOSFETs), to generate AC waveforms of variable frequency and amplitude. This capability provides precise control over the motor's speed and torque, optimizing the vehicle's performance. Additionally, modern inverters incorporate regenerative braking functionalities, which capture mechanical energy during deceleration and convert it back into electrical energy for battery storage. This feature significantly enhances energy efficiency and contributes to extending the vehicle's range [6].

### I. Auxiliary Systems

Auxiliary systems in a solar electric vehicle are essential for enhancing functionality and maintaining the vehicle's operational safety. The lighting and dashboard electronics, powered by the battery, provide essential visibility and relay critical vehicle status information to the driver. Advanced dashboards often incorporate features such as energy efficiency indicators, navigation systems, and real-time diagnostics to improve user experience and operational awareness. Additionally, the cooling system plays a vital role in maintaining optimal operating temperatures for critical components such as the motor, inverter, and battery. This is achieved through effective thermal management systems, which may include active mechanisms like liquid coolants and fans, as well as passive solutions such as heat sinks. These measures ensure the longevity, reliability, and safety of the vehicle's electronic and electrical systems, even under high-stress operating conditions.

## III. POWERTRAIN COMPONENTS OF SOLAR ELECTRIC CAR

The powertrain of a solar electric car forms the core of its propulsion system, integrating advanced technologies to ensure efficient energy generation, storage, and utilization. This system includes a combination of components, each playing a vital role in converting solar energy into mechanical power while ensuring smooth operation, energy efficiency, and environmental sustainability. Below is a detailed explanation of the primary powertrain components of a solar electric car.

### A. Solar Panels

The solar panels serve as the starting point of energy generation in the system. Positioned strategically on the vehicle, these panels capture sunlight and convert it into electrical energy through the photovoltaic effect. High-efficiency solar panels maximize energy capture under varying sunlight conditions, often using advanced materials to enhance conversion rates. This electrical energy is then fed into the energy management system for storage or direct use in propulsion.

### B. Battery Packs

The battery pack functions as the energy storage unit, holding the electricity generated by the solar panels for use during low sunlight conditions or at night. Modern solar electric cars primarily use lithium-ion batteries due to their high energy density, longevity, and efficiency. The battery

management system (BMS) ensures the safe and optimized operation of the battery, regulating charge and discharge cycles, maintaining thermal stability, and balancing individual cells to prolong the battery's lifespan.

### C. Electric Motors

At the heart of the propulsion system is the electric motor, which converts electrical energy into mechanical energy to drive the wheels. Typically, solar electric cars use brushless DC (BLDC) or induction motors due to their high efficiency, lightweight design, and minimal maintenance requirements. These motors provide instant torque, enabling smooth acceleration and responsive driving performance. The motor's operation is finely controlled to deliver optimal power based on real-time driving conditions.

### D. Power Electronics

The power electronics encompass a suite of devices, including inverters, DC-DC converters, and maximum power point trackers (MPPT). The inverter converts the DC power from the battery into AC power for the motor, allowing precise control over its speed and torque. DC-DC converters regulate voltage levels to power auxiliary systems such as lighting and infotainment. The MPPT optimizes the energy extracted from the solar panels by continuously adjusting their operating point, ensuring maximum energy capture under variable sunlight conditions.

### E. Transmission System

The transmission system in a solar electric car transfers torque from the motor to the wheels. Unlike conventional internal combustion vehicles, the transmission in electric cars is typically simpler due to the wide torque range of electric motors, which often eliminates the need for complex multi-speed gearboxes. This simplification reduces energy losses and improves efficiency, ensuring smooth and seamless power delivery.

### F. Regenerative braking

A key innovation in solar electric vehicles is the regenerative braking system, which captures kinetic energy during braking and converts it into electrical energy. This energy is stored in the battery for future use, significantly improving overall efficiency and extending the driving range. Regenerative braking not only enhances energy utilization but also reduces wear and tear on the mechanical braking components.

### G. Charger

The charger provides an alternative source of energy when solar input is insufficient. This component allows the battery to be charged from external sources, such as household power outlets or dedicated charging stations. Advanced chargers are equipped with fast-charging capabilities and are designed to minimize energy losses during the charging process.

### H. Structural component and chassis

The chassis and structural components complete the powertrain by providing a robust framework to house all

the electrical systems while maintaining aerodynamic efficiency. Lightweight and durable materials are often used to improve energy efficiency and vehicle performance.

Together, these components form a cohesive and highly efficient system, enabling the solar electric car to harness renewable energy effectively and provide a sustainable mode of transportation. By integrating innovative technologies and focusing on energy efficiency, the powertrain components exemplify the potential of solar energy in revolutionizing the automotive industry [5][6][7].

## IV. CONCLUSION

The use of solar energy and electric systems in solar electric vehicles (SEV) is a step closer towards creating environmentally friendly methods of transportation. This paper examined the major parts of these vehicles, their working principles and more importantly, their parts' structure and key features that assist in energy conversion, storage, and utilization. From car solar panels that receive solar energy, to the MPPT controller, the inverter, the battery pack and the electric motor, all these parts are components necessary for the car to work. Their optimization, as well as optimization of the auxiliary systems, aids in the efficiency and satisfaction of the systems.

The combination of the solar panel array with the MPPT controller, the battery, the inverter, the electric motor, and the drive train combines to form the powertrain of a solar electric car. The synergy created by the combination of these components enables the conversion of solar energy to mechanical energy that can power the vehicle. Aspects such as energy storage and variability of solar energy are being resolved allowing solar powered vehicles to be practical as technology evolves.

Solar powered vehicles thus have the potential of minimizing carbon emissions, through their ability to convert solar energy to mechanical energy. The integration of advanced electrical and electronic systems within these vehicles underscores their potential as a viable alternative to traditional automotive technologies, paving the way for a greener future in transportation.

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This project has not only deepened my understanding of the technical aspects of solar electric vehicles but has also inspired me to contribute to the broader mission of sustainable transportation solutions.

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