Solar Power: Perspective on Renewable Energy for Electric Vehicles

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Introduction

Greenhouse gas emissions by the burning of fossil fuels have represented a major issue in the modern world. Serious health problems caused by pollution and the devastating impact on the world's ecosystem and economy make the development of clean energy extremely urgent. The transportation sector accounts for 28% of global greenhouse gas emissions. Therefore, new automotive technology is required to mitigate the exponential trend of pollution. The rise of the electric vehicle (EV) industry is undoubtedly a significant step towards a greener future. Moreover, solar energy represents one of the most popular renewable and clean energy sources in recent years, as new kinds of solar-powered electric vehicles and innovative charging stations are gradually paving their way into the EV industry. Compared to conventional EVs, solar-powered electric vehicles (SPEVs) have no internal combustion engine, clutch, and gearbox, but are made up of panels, storage appliances, and electromotors, which can convert solar energy directly into electricity. Therefore, an increase in the share of SPEVs can effectively improve the integration of renewable energy and reduce greenhouse gas emissions. The two main methods of solar energy charging are direct charging through photovoltaic (PV) panels mounted on the roof of the automobile and through a solar-powered charging station. In this poster, we discuss the disadvantages of the two approaches in detail, possible ways to improve performance, and the prospect of future development in integrating solar power into the EV industry.

Photovoltaic Backgrounds

Sunlight is composed of photon-packets of solar energy, which contain varying amounts of energy that correspond to the different wavelengths of the solar spectrum. When photons strike a PV cell, they may be reflected or absorbed, or they may pass right through.

PV cells are conventionally comprised of semiconductors, such as silicon, gallium arsenide, and so on, which absorb a fraction of the photons entering the junction and force electron in one direction creating a flow of electrical current.

Photons (including light) are absorbed by the semiconductor material when they hit the PV cell.

The absorption of photons excites atoms in the semiconducting material, which results in knocking loose negatively charged electrons.

PV cells are designed such that electrons can only move in a single direction, resulting in the production of an electrical current.

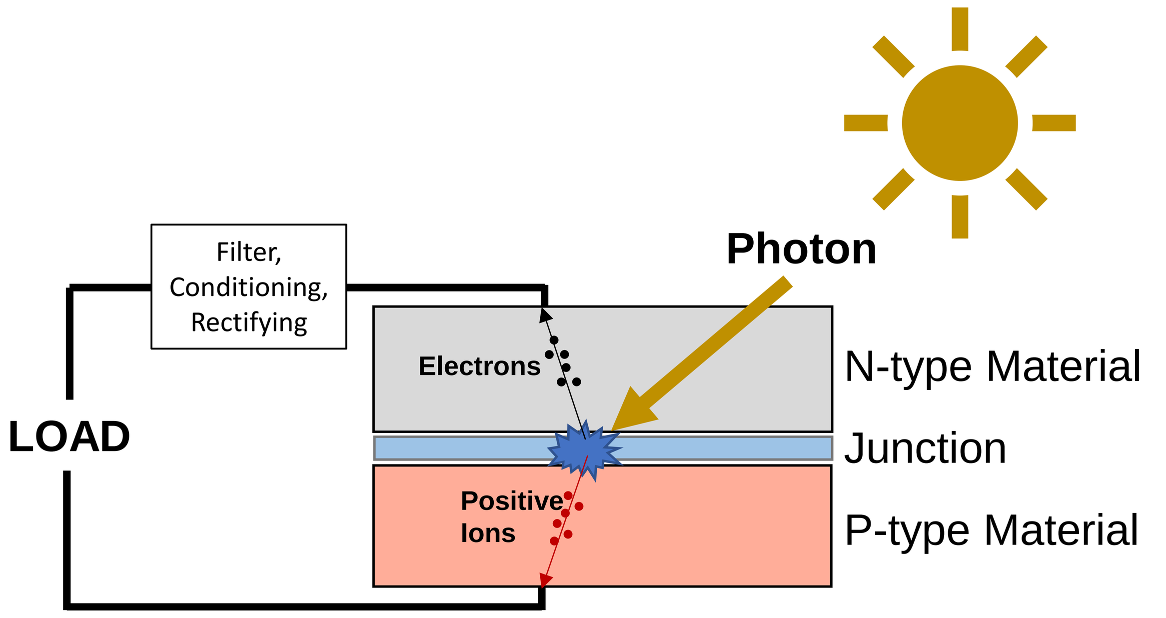

Figure 1. Schematic of photovoltaic cell converting light into electricity.

Methods

Direct charging consisting of an installed PV array atop the car

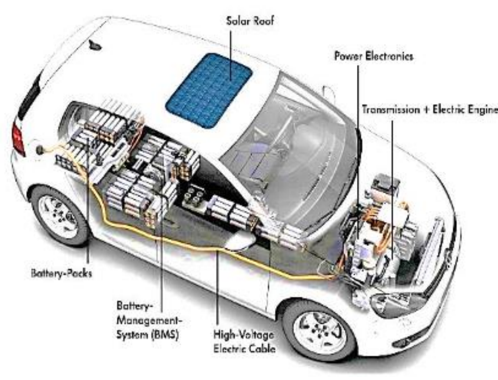

Figure 2. Schematic of traditional solar-powered EV with mounted PV array.

Direct integration of solar energy as a charging method involves the installation of PV cells atop an EV. The advantages are minimal energy transmission losses and reduced reliance on connected grids for power generation. Often, though, the solar panels installed on the roof are not powerful or efficient enough to fully power the car. Due to temperature, latitude, and shadow caused by clouds, trees, and constructions, the biggest problem is that most lightweight photovoltaic cells suitable for cars are only 10-15% efficient, which means that less than a quarter of the solar energy received by the cells is converted into electricity. Therefore, the average PV efficiency is insufficient to support long-distance driving, and connection to the grid is often required.

Indirect charging through solar-power recharging stations

By constructing PV charging stations and installing PV roofs on buildings or carports, maximum solar energy can be obtained from the optimal Angle over a longer period, thereby reducing the cost of energy and increasing energy input. The drawbacks of charging stations mainly lie in poor energy storage efficiency and the large gap between photovoltaic power output and vehicle charging demand changes. Moreover, since EV charging stations are the connection point between the utility grid and EVs, although they can provide energy to the grid during off-peak hours. They are often understood as additional, highly variable loads that worsen the network's carrying capacity and the overall performance of the existing grid.

Figure 3. A solar-powered charging station.

Development & Improvement

The direct approach of installing a photovoltaic charging electric vehicle on the roof or hood is challenging in terms of cost and energy efficiency. However, the development of materials for solar panels has led to increased efficiency and reduced costs. A new design of a new flat panel optoelectronic (CPV) system for electric vehicles is presented. Unlike conventional PVs, sunlight first reflects off an array of mirror coated lenses and then hit a tapered prism in a planar waveguide. The prism is covered by dichromatic mirrors that divide the solar spectrum into two bands. The low-energy band is transmitted and reaches the GaInAsP/GaInAs dual-junction solar cells. The mid-energy band is reflected at the prism surface and coupled inside the waveguide. The exit port of the waveguide is attached with GaInP/GaAs dual-junction solar cells.

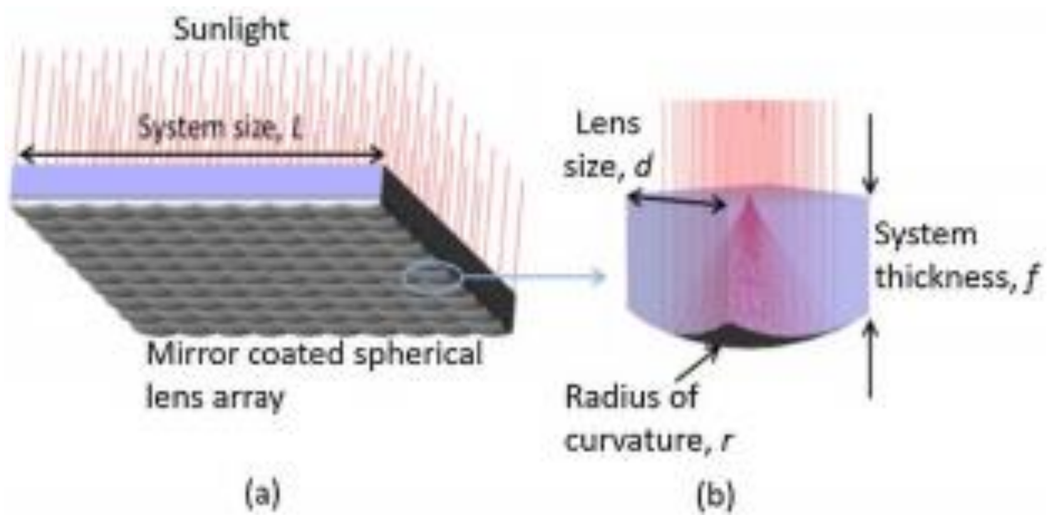

Figure 4. A lens array with coated mirror at bottom site and (b) the detail of a single lenslet.

The simulation results utilizing the prism revealed that the maximum conversion efficiency was 32.88% at a high concentration ratio. The system is 35mm thick, which is as thin as a traditional flat PV panel, and the system supports a transverse solar tracking mechanism. However, In low direct normal irradiance (DNI) areas, using this design, the total energy collection for the year was only 4% higher. Thus, the system is more suitable for areas with high DNI.

The gap between photovoltaic power output and vehicle charging demand varies greatly. Therefore, additional support is required from the public distribution network or storage facilities to handle residual power. Therefore, a new grid-connected solar electric vehicle (EV) charging station based on vehicle-to-grid (V2G) technology is proposed.

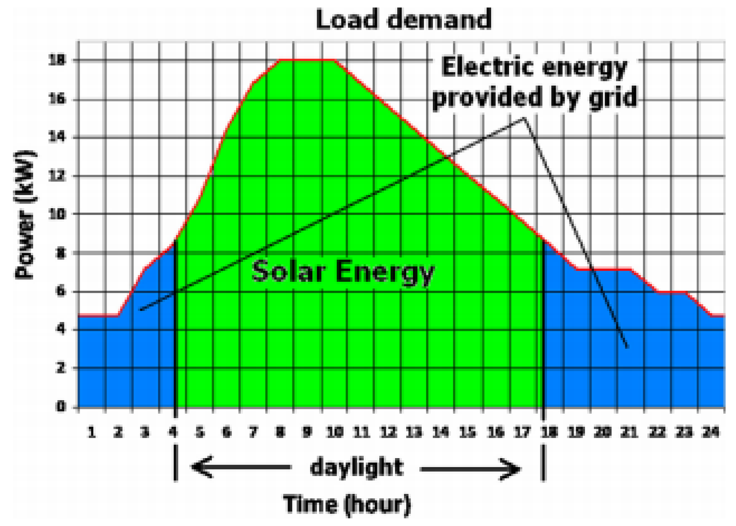

Figure 5. Charging profile: Green portion is produced using solar energy, and the blue portion is provided by the grid.

This is a grid-connected solar electric vehicle charging station that maximizes the conversion of solar energy into electricity, because it uses a new fast and high-precision MPPT technology. The solar powered EV charging station consists of a photovoltaic (PV) array, a DC/DC converter dedicated to the PV array, a maximum power point tracking(MPPT) controller, 15 bidirectional DC/DC converters dedicated to the 15 charging stations provided for charging EVs, and a bidirectional DC/AC inverter connected between the charging station and grid.

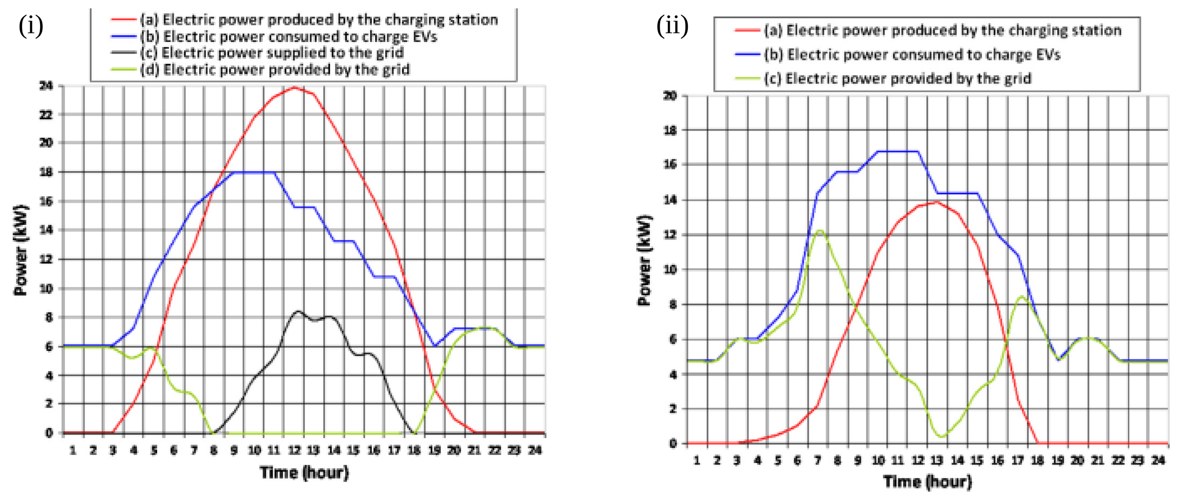

Figure 6. (i) Experimental results: different powers measured hour by hour during a sunny day in summer. (ii) Experimental results: different powers measured hour by hour during a cloudy day in winter.

The experimental results obtained from the daily operation of the constructed EV charging station demonstrated that the charging station produces enough electric energy to charge EVs during sunny days, and balances load demand in the grid during cloudy days.

Future Work

To fully realize the construction of "zero-emission" vehicles, fully renewable sources of energy, such as solar or wind, must be integrated. However, inefficient capturing, utilization, and distribution of solar energy hinder future applications of electric vehicles. In addition to PV-mounted arrays and solar-powered charging stations, several studies have explored using solar energy and bacteria or algae to convert carbon dioxide into liquid fuel. This process could replace carbon capture and storage in coal and methane power plants, while also creating additional fuel. The most common fuel used in this process is methanol. The high performance in CO2 conversion process can be achieved by using an effective catalyst. In general, the development of the required catalyst can be used as a solution.

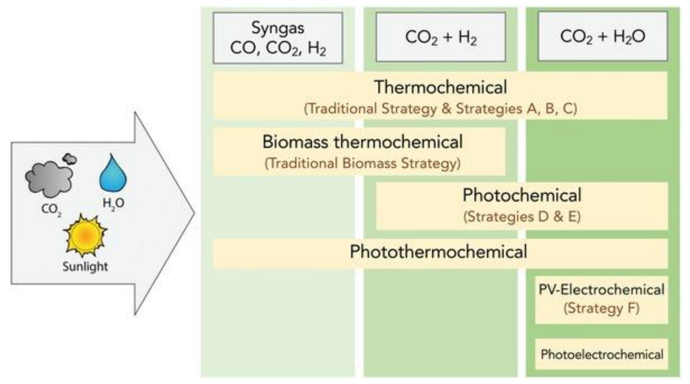

Figure 7. Traditional and solar methanol production technologies. Technologies can be used with feedstocks shown in gray.

Conclusion

Solar energy is a renewable and clean energy source which requires further attention and research in order to realize its environmental benefits. As society becomes increasingly conscious of widespread pollution, solar energy integration continues to represents a direct method of establishing emission-free transportation. In addition, the cost of solar cars will fall due to the cost-effectiveness of solar cell technology, which will make consumers more willing to buy electric cars. In this poster, two improved methods are introduced, one is a flat concentrator photovoltaic (CPV) system for electric vehicle application, which can attain a maximum electricity conversion efficiency of 32.88% at the high direct normal irradiance area. Another one is a novel grid-connected solar powered electric vehicle (EV) charging station with vehicle-to grid (V2G) technology, which can generate enough electricity to charge electric vehicles on sunny days and balance the load demand on the grid on cloudy days. Actually, in order to fully achieve the construction of "zero emission" vehicles, the capture and use of solar energy must be made more efficient.

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