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Innovative Solar Panel Design for Electric Vehicle

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Abstract
We aim to develop a solar-powered system that enables e-bikes to charge while on the move, a concept we call "charging on drive." Currently, e-bike batteries are charged using fixed chargers located in specific positions. This limitation requires users to find charging outlets when the battery warning light turns on, leading to potential inconveniences if no nearby outlets are available. Our solution harnesses environmentally friendly and secure solar energy to address this issue, contributing to a healthier and sustainable future. To realize this objective, we employ a compact and adaptable photovoltaic (PV) panel, readily accessible in the market. Through the introduction of the inventive idea of "drive-and-charge," our goal is to encourage the extensive uptake of electric vehicles. To support the development of this system, we are creating mathematical models in MATLAB to analyze the fluctuation of solar panel power generation based on factors such as insolation, temperature, and Vmp (maximum power voltage).
Keywords*: Flexible solar system, EV, Thermal and solar energy, MATLAB*

1. Introduction
The urgent need to address climate change has prompted various sectors to shift towards electrification. One significant development in the technical sector is the transition from gasoline-powered vehicles to battery-powered electric cars. However, this shift comes with both advantages and disadvantages, with range anxiety being a serious concern due to the finite capacity of electric vehicle batteries. To tackle this issue, we propose leveraging solar photovoltaic electricity to enhance electric vehicle efficiency. [1] Our approach involves mounting a monocrystalline variety of flexible solar panels on the vehicle's surface. To achieve improved effectiveness, we have refined the analytical equations that characterize the parameter model while considering several influencing factors. The adjusted techniques for Maximum Power Point Tracking (MPPT) are assessed using a computerized simulation of a series-parallel cell photovoltaic (PV) module, developed within Matlab. By considering variations in solar intensity and cell temperature, our simulation mimics the attributes of a PV system, facilitating the evaluation of PV characteristics and [2] MPPT algorithms. Renewable energy sources, particularly photovoltaic technology, have proven to be both cost-effective and environmentally beneficial, thanks to advancements in sophisticated technology and efficient cells. The positive environmental impacts of solar energy compared to conventional sources are evident. The photovoltaic module serves as a crucial element in the power conversion process of a solar generator system. However, in current simulation tools, such as MATLAB/Simulink with SimPower Systems, models of wind turbines exist, but a comprehensive PV model is yet to be integrated, complicating the simulation and analysis of general photovoltaic power system models. In this study, we explore the estimation of solar insolation, cell temperature, saturation point, and declination angle using MATLAB, even without explicit panel simulation. Our research aims to contribute to a better understanding of solar power integration in electric vehicles, promoting sustainable and eco-friendly transportation solutions. [3]

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2. Proposed System

The proposed solar generator system is a crucial component for power conversion, focusing on the representation and simulation of photovoltaic (PV) modules. While the SimPower Systems tool in Matlab/Simulink offers models for wind turbines, a compatible PV model is currently absent, which complicates the analysis and simulation of general PV power systems. In this study, we leverage Matlab's capabilities to estimate solar power without physical panels by considering solar insolation, cell temperature, other variables, saturation point, and declination angle. As global fuel options diminish, the exploration [4] of alternative energy sources becomes vital, and automotive companies are actively involved in developing cutting-edge technologies like solar energy. Solar-powered vehicles equipped with flexible solar cells on their roofs offer impressive dependability, reducing their environmental burden and leaving no carbon footprint. Our designed solar power system takes into account environmental conditions and sun insolation, leading to higher efficiency compared [5] to competitors. One significant advantage of solar-powered vehicles is their ability to produce zero pollution, as they do not rely on fossil fuels or non-renewable resources. Electric motor-driven cars powered by solar energy do not contribute to greenhouse gas emissions or other forms of pollution. Electric vehicles typically operate more quietly than their conventional engine counterparts, leading to a reduction in noise pollution. For instance, a solar-powered vehicle with flexible solar cells can generate up to 576 watt-hours of energy, providing a range of 50 km. Our objective is to convert 100 watts of energy to 576 watts, demonstrating the potential efficiency of our solar power system. By better understanding the context and exploring practical examples, such as a 1 kW solar panel's maximum capacity of 5 units per day, we aim to highlight the benefits and potential of solar energy in the automotive sector. [6] The open loop simulation of the Flexible PV panel is shown in Figure 1.

3. Design calculation

The study determined that the ideal battery capacity is approximately 576 watt-hours (Wh). During an experiment covering a distance of 1.6 km, only 18 Wh of electrical energy was consumed. For a 50 km distance, the electrical energy requirement is calculated to be 563 W [7]. Divide the number of watt-hours by the voltage to convert watt-hours to amp-hours. Using the formula: 1 watt-hour = Amp-hour x Volt. The E-bike under consideration is equipped with a 48-volt, 12 amp-hour (Ah) LiFePO4 battery to achieve the desired 50 km range. To convert 100 watts to 576 Wh, it needs to meet the specified battery capacity. To put this into perspective, a 1 kW solar panel provides a maximum capacity of 5 units per day. Depicts of the PV panel subsystem is shown in Figure 2.

3.1 Mathematical Model of Pv

The mathematical model for PV can be described using the following equations:

a. Equation (I) determines the current (I) in a PV panel: I = IP - IS * exp
b. Equation (II) calculates the peak current (IP) based on the incident solar intensity (H) and temperature factors: IP = [IS + Kt * (Tc - Tr)] * H
c. Equation (III) computes the reverse saturation current (IS) using the temperature coefficient factors (IR) and the panel temperature (Tc) about the reference temperature (TR): IS = IR * (Tc / TR) ^3

3.2 Mathematical Parameters

- **Ip:** The current generated by light in the PV cell.
- **Is:** The dark current's cell saturation.
- **q:** Electron charge with a value of q = 1.6 x 10^-19 C.
- **K:** Boltzmann's constant with a value of k = 1.38 x 10^-23 J/K.
- **Tc:** The PV cell's operating temperature.
- **A:** The ideal factor in the PV cell.
- **Rsh:** Shunt resistance in the PV cell.
- **Isc:** Short-circuit current of PV cells at 25 °C and 1 kW/m2.
- **Kt:** The temperature coefficient of the short-

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circuit current in the PV cell.

- **Tr:** The temperature reference for the PV cell.
- **H:** The unit of solar insolation is kW/m2.
  IRS: The PV cell's reverse saturation current.
- **Eg:** Band gap energy of the semiconductor used in the PV cell.
- **Np, Ns:** The number of solar modules stacked in parallel and series, respectively.

Table 1 Calculation of Peak Time and Dawn Time

Time (Hr)	V(Volt)	I(Amp)
9.00 AM	48	3.5
10.00 AM	50	4.0
11.00 AM	52	4.5
12 (Noon)	56	5.0
1.00 PM	58	5.2
2.00 PM	56	5.0
3.00 PM	54	4.8
4.00 PM	52	4.7

4. Simulation Diagram

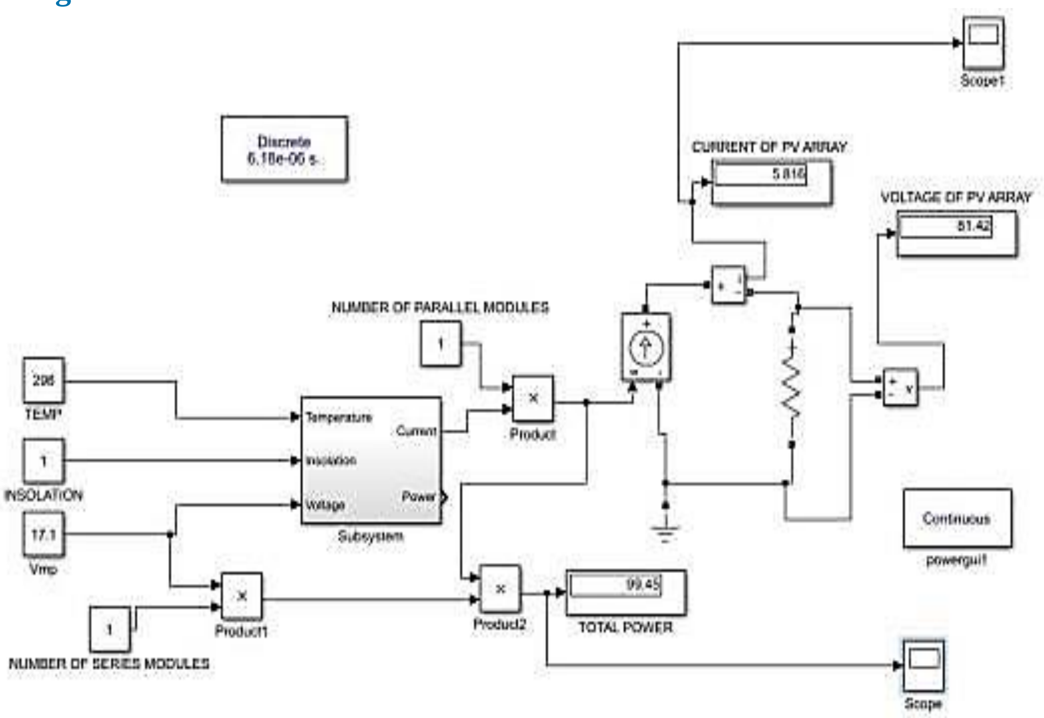

Figure 1 Illustrates the Open-Loop Simulation of The Flexible PV Panel

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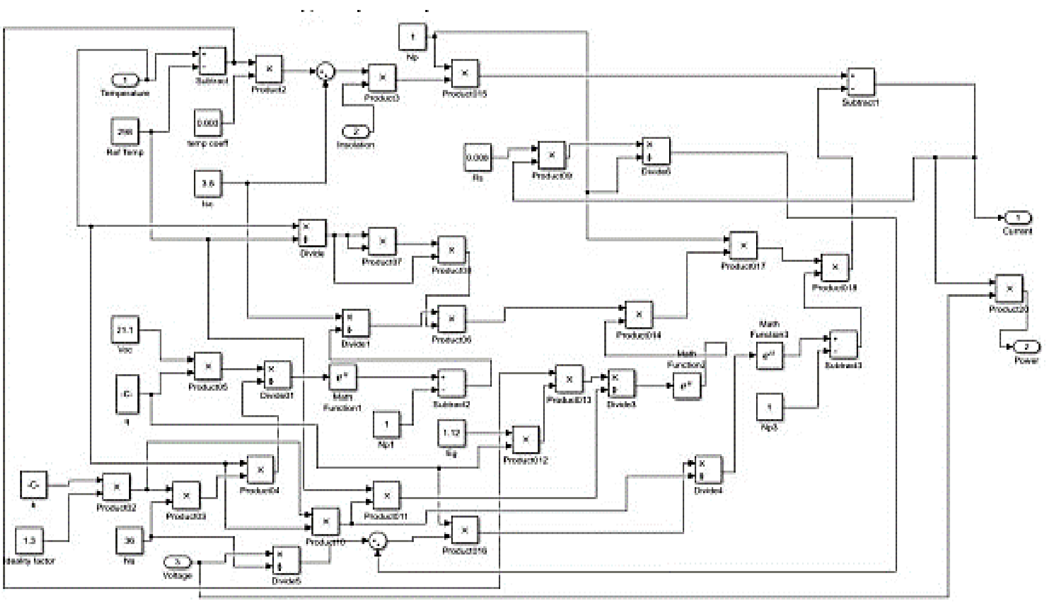

Figure 2 Depicts the PV Panel Subsystem

4.1 Details of the Simulated Model

The simulations of the model involved varying degrees of solar insolation and temperature to analyze and validate the nonlinear PV module's I-V and P-V output characteristics. The simulation results are shown in Figures 3, 4, and 5, and the following are the simulated PV module's technical specs:[8]

Characteristics: Specifications

- Peak Power (P_{peak}): 70 W
- Peak Voltage (V_{peak}): 16.79 V Peak Current (I_{peak}): 3.8 A
- Short-Circuit Current (ISC): 3.6
- An Open-Circuit Voltage (VO): 20.1 V
- Temperature Coefficient (TSC): 0.002

The simulations were carried out across varying temperatures and solar radiation conditions. The outcomes illustrate that with rising temperature, the short-circuit current within the PV cell increases, resulting in a reduction of the cell's maximum power output. Due to the increase in Output, current reduces proportionately more than voltage decreases as temperature rises, and the total power output decreases. Furthermore, when the solar insolation is amplified by a factor of 32, the simulations indicate an augmentation in both the PV module's maximum power output and short-circuit current. The voltage across the open circuit exhibits a logarithmic increase with heightened solar insolation, while the correlation between short-circuit current and solar irradiation exhibits a linear trend. [9]

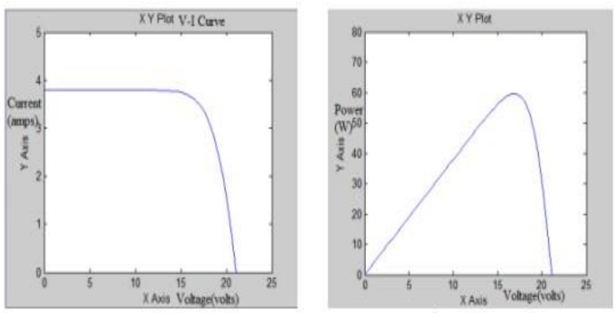

Figure 3 Voltage-Current (V-I) And Power-Voltage (P-V) Traits at A 25°C Temperature

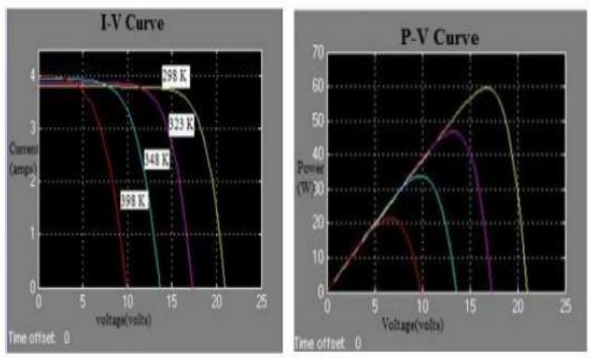

Figure 4 Traits at A 25°C Temperature

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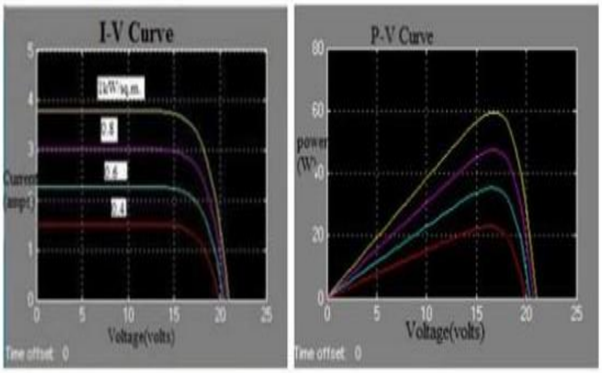

Figure 5 (Current-Voltage) Characteristic Curves at Different Cell Working Temperatures

5. Hardware For Solar Panel

For our hybrid electric vehicle charging system incorporating solar drive charging, we meticulously determined the dimensions of the flexible solar photovoltaic (PV) panel intended for installation on the car's roof. Both our prototype and the configuration shown in Figure 5 employ a 2x3ft panel, [10] with a weight of approximately 11 pounds. This panel's surface area is ample for generating adequate energy to reach the subsequent charging station within a reasonable timeframe. The exceptional flexibility and lightweight design of the panel stem from its capability to be flexed up to a concavity of 248 degrees. Comprising 90 cells, the flexible solar panel generates a cumulative 125 watts from each cell at a voltage of 0.52 volts. It's important to note that this panel's availability in substantial quantities might entail some waiting period for procurement. Moreover, the series resistance (Rs) of the solar cells is a crucial parameter to consider during the evaluation of the panel's performance. [11]

Conclusion

The reliability of a standard PV module was assessed using readily available market components. The proposed model takes into account the solar irradiance and the cell's internal temperature, generating corresponding IV and P-V characteristics for different scenarios. This model can be utilized in studies related to solar photovoltaic conversion devices and the implementation of MPPT (Maximum Power Point Tracking) technology. The developed methods for extracting photovoltaic module information are valuable as various factors like dust, humidity, temperature, and age can influence performance. Currently, there is a lack of a readily available PV model suitable for integration into Matlab/Simulink software's Sim Power System utility, which utilizes advanced electronics simulation technology. Consequently, the simulation and analysis of general power system models face significant challenges.

Future Scope

The electric vehicle market is experiencing notable developments, driven in part by declining battery costs and the introduction of more affordable electric vehicles with a range of 200 miles. Plug-in hybrid vehicles, like the Chevrolet Volt and Toyota Prius Plug-in, are also gaining popularity, offering an all-electric range of 30-35 miles. Initiatives are in progress to improve the charging infrastructure, a pivotal step in addressing concerns about the limited driving range that may deter prospective electric vehicle (EV) purchasers. To illustrate, Southern California Edison is preparing to establish an initial set of 1,500 charging stations, with plans to add 28,500 more, all to accommodate a projected one million electric vehicles on California's roads by the year 2023. Additionally, various enterprises such as Coca-Cola, Google, and Walgreens are also playing a role in promoting EV adoption by implementing their charging station networks. Major players in the automotive industry, such as Tesla, GM, Nissan, BMW, and Ford, are heavily investing in their electric vehicle lines, indicating the industry's increasing acceptance of electric vehicles. Honda's CEO, Takahiro Hachigo, even predicts that 66% of Honda's portfolio will consist of electric vehicles by 2020. The future of electric vehicles looks promising, as ongoing technological advancements and infrastructure improvements continue to drive widespread EV adoption, transforming the transportation landscape.

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