# Design and Implementation of Solar Charging Electric Vehicle

**Rahil Imtiyaz, Aman Kumar, Gitanjali Mehta, and Ruqaiya Khanam**

**Abstract** The accessibility of non-renewable energy sources will diminish to increment popularity and will be depleted in the near future. Along these lines, it is important to track down the substitute fuel to work the vehicles. As a sustainable power source, solar energy is utilized to make solar charging electric vehicle (SCEV) that is our venture. This kind of vehicle would be fit to supplant conventional ignition engines for ordinary vehicle exercises. The utilization of solar-based energy to control the vehicle takes into account greater appropriateness and a method for utilizing environmentally friendly power energy. Standardization of the vehicle this kind would drastically decrease the harmful emissions delivered by the vehicles and diminish the oil demand. The authors have proposed a photovoltaic (PV) integrated electric vehicle (EV) instead of conventional EV with separate PV/grid/hybrid charging station. As starters, the goal is to execute our thought on an essential model and later with the assistance of this model, by building constant solar charging electric vehicle we may broaden our future.

**Keywords** Solar charging electric vehicle · Photovoltaics · Renewable energy

## 1 Introduction

In the current circumstance, due to the increase in population, usage of assets like petrol, coal and diesel are continuously increasing. The availability of these non-environmentally friendly power source will decrease accordingly, and it will be exhausted in sometime leading to a future with fuel and mineral deficit. In this way, present patterns in energy utilization, particularly oil, cannot be supported any longer

R. Imtiyaz · A. Kumar · G. Mehta (✉)
Electrical and Electronics Engineering, Galgotias University, Greater Noida, India
e-mail: gitanjali.iitr@gmail.com

R. Khanam
Computer Science and Engineering, Center for Artificial Intelligence in Medicine, Imaging and Forensic, Sharda University, Greater Noida, India



H. Malik et al. (eds.), *Renewable Power for Sustainable Growth*,
Lecture Notes in Electrical Engineering 1086,
https://doi.org/10.1007/978-981-99-6749-0_27

[1–3]. Additionally, the use of conventional energy sources is the major cause behind environmental imbalance, ozone layer consumption and global warming which thus is a major danger to the future human race. Once more, considering the chance of a worldwide temperature alteration, these assets are assuming a negative part. Along these lines, under the present situation, it is very important to make another investigation of the common asset of energy. It is viable, more affordable or more all, it is an unending wellspring of energy. With well-enhanced energy productivity, a shift to an energy-based wealth capable of supporting predicted global economic growth is possible [4, 5].

Power can be produced utilizing environmentally friendly power sources, for example, solar, wind and biomass. Sun-based energy is the cleanest and most abundant ecologically friendly power source available. Sunlight-based solar panels convert the sunlight rays into usable solar energy. The process of turning light (photons) into electricity (voltage) is defined as the photovoltaic effect. Solar panels convert the majority of visible light and a small amount of brilliant infrared light into electricity. Solar charging innovations can harness this energy for a variety of purposes, including generating electricity, providing light or a pleasant indoor atmosphere, and warming water for domestic, commercial or industrial usage [6–8].

The authors propose to decrease the utilization of natural fuel-controlled vehicle and plan climate-amicable electric vehicle. Sunlight-oriented vehicle is principally controlled by direct sun rays. On the solar vehicle, photovoltaic (PV) cells are utilized to capture the PV rays and convert the solar-oriented energy form into electric energy form. Silicon and mixtures of indium, gallium and nitrogen are used to create this product. The semiconductors assimilate light and afterwards discharge it, creating a progression of electrons that produce power which charges 24 V battery associated with it, which runs the 375 W Brushless DC (BLDC) motor to send the ability to drive the vehicle. We are using high-strength iron square pipes for good mechanical strength. The configuration is made with the end goal that vehicle has appropriate weight to power proportion and is light in weight and strong, which is a must for any solar charging vehicle.

Habib et al. [9] have discussed the present and future status of electric vehicle (EV) and charging system implementation. The EV batteries are charged during the day by PV charging stations in parking area. Khalid et al. [10] have reviewed EV charging infrastructures and the impact it has on power quality of grid. Savio et al. [11] have analysed the energy management strategy of hybrid microgrid structured EV charging station. Tazay and Miao [12] have proposed a hybrid converter for PV charging station. Ramadhani et al. [13] have reviewed the different PV-based charging techniques for EV. Abdelsalam et al. [14] have presented the modelling and simulation of PV-powered EV charging station. Tiano et al. [15] have evaluated the potential of PV panel installation on EV body.

Most of the work proposes EV with PV charging stations. Our study designs and implements PV integrated EV system so as to improve the driving range and reduce battery storage size. The authors have designed and implemented PV-based EV system instead of conventional EV with PV charging stations. The advantages offered by the proposed solar charging EV system are reduced grid energy demand, increased EV driving range and reduced carbon emissions.

The paper is organized as given. Section 2 discusses the modelling of solar charging electric vehicle. Section 3 focuses on the design calculation of the EV. Section 4 discusses the design vehicle specifications and a comparison with the conventional vehicles. Section 5 gives the conclusion along with future scope of work.

## 2 Proposed Work

The block diagram of solar charging electric vehicle with a battery charge/discharge controller is shown in Fig. 1. The SCEV project was at first begun in the fall of 2021. The required number of parts were bought, and associations were done with the creation shop close by for joint welding to the edges of the vehicle: 3 × 6 ft length 1.5″ square iron pipe body, 2-rods at the end, 1-steering for 2 front wheel, 1-solar plate, 1 steering set, 1-brake build near to handle, 4 small wheels, 2 battery, 1 reverse switch, 1 chain set, 375 W BLDC motor, controller, 7 × bearings and 1 brake cable [16–18].

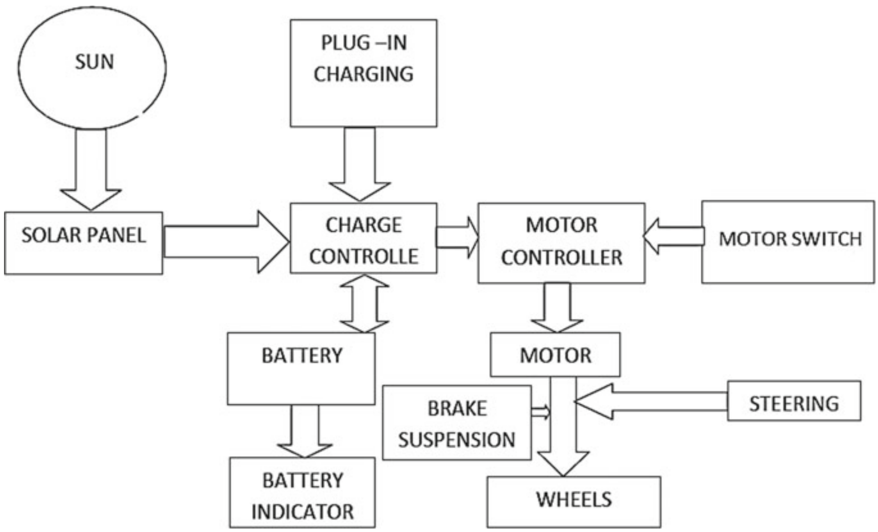


**Fig. 1** Block diagram of solar charging electric vehicle

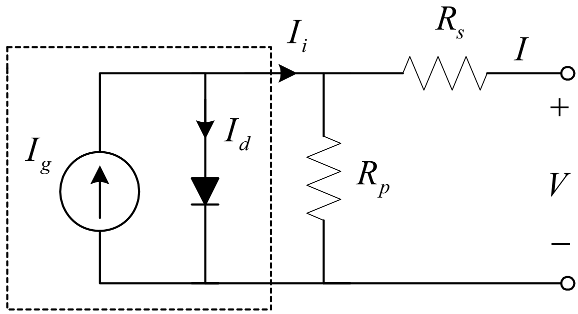


**Fig. 2** Equivalent circuit of a single PV cell

## *2.1 Solar Panel*

Solar cells are generally constructed of silicon that has been specially processed to shape an electric field. The back is heavily doped with boron, while the phosphorus-doped negative side is exposed to the sun. At the point when photons from sun rays hit the solar cells, making electron-opening sets, electrons are extracted from the particles in the semiconductor material. Figure 2 shows the block diagram of a single PV cell. Assuming electrical conduits are connected to the +ve and −ve sides, an electrical circuit is shaped and the moving electrons make electric flow $I_g$ (photocurrent). The more noteworthy the power of daylight, the more prominent is the progression of power [19–24].

When there is no daylight, the sunlight-based cell is certainly not a functioning gadget, and it fills in as a diode. In the event that it is associated with an outer stockpile, it creates a current, $I_d$, called diode current. Figure contains a flow source, $I_g$, the diode and an arrangement opposition addressing the inner obstruction of a cell $R_s$. As a result, the difference between $I_g$ and $I_d$ is the net current $I$ expressed as:

$$I = I_g - I_d = I_g - I_0\left(e^{\frac{\beta(V+R_s I)}{\alpha}} - 1\right), \quad (1)$$

where $\alpha$ is the diode ideality factor, $\beta$ is the inverse thermal voltage, $k$ is Boltzmann's gas constant, $V$ is cell voltage and $I_0$ is the diode reverse saturation current.

## *2.2 Battery*

A battery is an electrical component that changes chemical energy into electrical energy and the other way around. Positive cathode and negative anode are the two terminals that it usually possesses. During a prospective shift (charging or releasing) the framework relies on the synthetic response of electrolyte (fluid or glue arrangement). Particles will pass between the two terminals because of the electrolyte (cathode and anode) or the dynamic materials of the battery, enabling electricity to flow from the battery in order to complete necessary tasks.

The battery's applications are limitless. For all electrical devices that necessities high energy stockpiling limit or for any gadget that requirements low energy yield (versatile gadgets like cell, PC and so forth), battery is utilized for either to capacity energy or to go about as a force supply. Along with technological advancements that increase the capacity limit, size and lifetime of batteries, new battery applications are gradually emerging [17–20].

For the solar-based vehicle, we were utilizing battery for a backup to store energy which has ceaseless yield. To do that we need explicit determination of battery to play out our undertaking effectively which require clear comprehension of its boundaries just as its inclination of conduct.

State of charge (SOC) is a statement of the current battery limit as a level of greatest limit. SOC is for the most part determined utilizing current incorporation to decide the adjustment of battery limit over the long run. It can likewise be clarified as:

$$SOC = \frac{\text{Available Capacity}}{\text{Nominal Capacity}} \tag{2}$$

Depth of discharge (DOD) defines the level of battery capacity that has been discharged with respect to the most extreme limit. Figure 3 shows the charging and discharging of the battery. The SOC represents an alternative form of DOD measurement, and hence, DOD is expressed as:

$$DOD = 1 - SOC \tag{3}$$

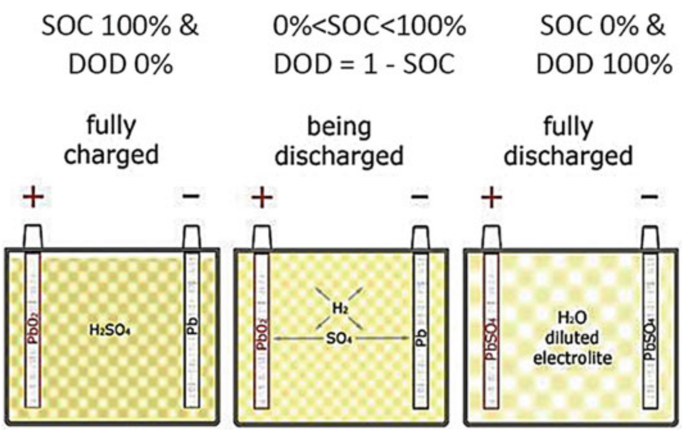


**Fig. 3** Battery charging and discharging (SOC vs. DOD)

## 3 Design Calculation for Solar Charging Electric Vehicle

The solar vehicle is manufactured at the cost of INR 30,000. The vehicle has a wheelbase of 1066 mm (42 in.). The vehicle uses four wheels, two wheels in front and two in rear. The body material uses seamless square iron pipe for better mechanical strength. The ground clearance from the driver seat is 101.4 mm (4 in.). The ground clearance is decided as per the vehicle structure. There is square iron pipe bumper in the front and the rear of the vehicle. Two jack point is provided near the rear wheel. The driver's exit is so easy that he/she can exit from the vehicle within 5 s. Driver visibility is two hundred degrees (200°) field of vision and one hundred degrees (100°) to both sides of the driver. Steering system is well connected with the front two wheels. Proper braking system is attached with the rear wheels supporting by the disc. The BLDC motor is used with the power 375 W, and running voltage is limited to 24 V. Battery capacity is 24 V and 30 Ah all the time. Figure 4 shows the overview of the developed solar charging electric vehicle. Figure 5 displays the different parts of the SCEV. Figure 5a shows the braking system with the rear wheel, and Fig. 5b shows the wheel side view. Figure 5c shows the battery charge/discharge controller, and Fig. 5d shows the solar panel. Figure 5e shows the battery pack and Fig. 5f the chain set. Table 1 shows the dimensions of the designed solar charging electric vehicle. Table 2 gives the solar charging electric vehicle specifications. Table 3 shows the calculated values for angular velocity, frequency, peak torque, peak power, continuous torque, continuous power, continuous speed, air resistance and rolling resistance derived from Eqs. (4) to (12).

**Fig. 4** Overall view of solar charging electric vehicle

**(a) Braking system with the rear wheel**

**(b) Wheel Side View**

**(c) Battery Charge / Discharge Controller**

**(d) Solar Panel**


**(e) Battery Pack**

**(f) Chain set**

**Fig. 5** View of different parts of solar charging electric vehicle

**Table 1** Dimensions of the designed solar charging electric vehicle

| Parameter | Value (m) |
|---|---|
| Length | 1.828 |
| Width | 0.914 |
| Height | 1.219 |
| Ground clearance | 0.101 |
| Wheelbase | 1.066 |

**Table 2** Solar charging electric vehicle specifications

| Parameter | Value |
|---|---|
| Weight of the vehicle | 80 kg |
| Speed | 20–25 km/h |
| Diameter of wheel | 0.4 m |
| Weight of battery | 20 kg |
| Average speed | 20 km/h |
| Range | 20 m |

**Table 3** Calculation results

| Parameter | Value |
|---|---|
| Angular velocity | 27.75 rad/s |
| Frequency | 265.12 RPM |
| Peak torque | 19.6 N-m |
| Peak power | 543.9 W |
| Air resistance | 32 W |
| Rolling resistance | 147.2 W |
| Continuous power | 179.2 W |
| Continuous speed | 104.66 RPM |
| Continuous torque | 16.34 N-m |

- **Wheel angular velocity calculation**

Considering Linear Velocity = 20 km/h

Speed = 20 × (5/18) m/s = 5.55 m/s

Wheel Diameter = 0.4 m

$$\begin{aligned} \text{Angular Velocity} &= \text{Linear Velocity} \div \text{Radius} \\ &= 5.55/0.2 = 27.75\,\text{rad/s} \end{aligned} \quad (4)$$

$$\begin{aligned}\text{Angular Speed} &= 2 \times \text{frequency} \times \pi \\ \text{Frequency} &= \text{Angular Speed}/2\pi\,\text{RPS} = \text{Angular Speed} \times 60/(\pi \times 2)\text{RPM} \\ &= 27.75 \times 60/(3.14 \times 2)\text{RPM} = 265.12\,\text{RPM} \end{aligned} \tag{5}$$

- **Peak torque calculation**

$$\begin{aligned}\text{Peak Torque Wheel} &= (\text{Wt. of Vehicle} + \text{Wt. of Battery}) \\ &\quad \times \text{Acceleration due to gravity} \\ &\quad \times \text{Slope\%} \times \text{Radius of wheel} \\ &= (80 + 20) \times 9.8 \times 0.2 \times 0.1\,\text{N-m} = 19.6\,\text{N-m} \end{aligned} \tag{6}$$

$$\begin{aligned}\text{Power Required} &= \text{Angular Velocity} \times \text{Torque} \\ &= 27.75 \times 19.6\,\text{W} = 543.9\,\text{W} \end{aligned} \tag{7}$$

- **Air resistance calculation**

$$\begin{aligned}\text{Air Resistance} &= (5/100{,}000) \times \text{Wt. of vehicle} \times (\text{Average Speed})^3 \\ &= (5/100{,}000) \times 80 \times 203 = 32\,\text{W} \end{aligned} \tag{8}$$

- **Rolling resistance calculation**

$$\begin{aligned}\text{Rolling Resistance} &= 0.092 \times \text{average speed} \times \text{Wt. of the vehicle} \\ &= 0.092 \times 20 \times 80 = 147.2\,\text{W} \end{aligned} \tag{9}$$

- **Continuous power calculation**

$$\begin{aligned}\text{Power Required (Continuous)} &= \text{Rolling Resistance} + \text{Air Resistance} \\ &= 147.2 + 32 = 179.2\,\text{W} \end{aligned} \tag{10}$$

- **Continuous speed calculation**

$$\begin{aligned}\text{Continuous Speed} &= \text{Average Speed} \times 60/(2 \times \text{Wheel Radius} \times \pi) \\ &= 20 \times (5/18) \times 60/(2 \times 0.2 \times \pi) = 104.66\,\text{RPM} \end{aligned} \tag{11}$$

**Table 4** SWOT analysis

| Strength | Weakness | Opportunities | Threats |
|---|---|---|---|
| Light in weight and long-lasting chassis | Not suitable for long drives | Environment-friendly vehicle | Bad weather condition and not getting proper sunlight rays |
| Directly run-on solar power | Performance varies with change in weather | Directed towards a green and clean future | Roads are not settled everywhere |

- **Continuous torque calculation**

$$\begin{aligned}\text{Torque Required} &= (\text{Air Resistance} + \text{Rolling Resistance}) \\ &\quad \times 60/(2 \times \text{Continuous Speed} \times \pi) \\ &= (32 + 147.2) \times 60/(2 \times 104.66 \times \pi) = 16.34\,\text{N-m} \qquad (12)\end{aligned}$$

## 4 Solar Charging Electric Vehicle Specifications

It's just a DC transformer with a chopper circuit that allows it to go up or down in voltage. We can increase the yield voltage by changing the semiconductor switch's obligation pattern. To avoid a sudden shift in current, we may simply charge the battery through an inductor. We may connect the DC motor to the circuit in a similar manner. Table 4 presents the SWAT analysis for SCEV. Table 5 gives a comparison of solar charging electric vehicle with petrol vehicle and electric vehicle. Table 6 provides a comparison of running cost for petrol vehicle, electric vehicle and solar electric vehicle.

## 5 Conclusions

A four-wheeled minimal expense photovoltaic integrated electric vehicle is achievable and practicable. Our SCEV, a solitary situated vehicle controlled by 375 W BLDC-centred motor can be a decent decision for the Asian market. A multivariate specialized gathering has improved the design and manufacturing of our SCEV, ensuring that it stays a safe, elite and cost-effective electric sun-based vehicle. Utilization of square iron pipes for strong mechanical strength, utilization of ergonomically planned solar vehicle inside, moving on direct sunlight-based energy without

**Table 5** Comparison of solar charging electric vehicle with petrol vehicle and electric vehicle

| Petrol versus solar charging electric vehicle | Solar charging electric vehicle versus electric vehicle | Environment-friendliness |
|---|---|---|
| Fixed number of non-renewable resources and will end in coming years | Not possible to charging on shadow or any covered halt | No pollution and $CO_2$ emit |
| Too costly | For charging using power supply required rated power supply | Better use of sun rays |
| Not safe/dangerous | On moving constant charging not possible due to uneven sunlight rays | Will be helpful to reduce global warming |
| Environment disaster | If charging on EVs charging stations is time taking | The vehicle is manufactured of eco-friendly material |
| Very high running cost and maintenance are expensive | Should not be best for long-distance travel | |
| | Maintenance cost is less but once after battery dies replacement of battery is expensive | |
| | It is environment-friendly but not be best for every place | |

**Table 6** Comparison of running cost

| Parameters | Petrol vehicle | Electric vehicle | Solar vehicle |
|---|---|---|---|
| Fuel | Petrol | Electricity | Solar electricity |
| Rate of fuel | INR 98/L | INR 28/Full charge | Free |
| Vehicle mileage | 12–20 km/L | 100–200 km/charge | 50–200 km/charge |
| Running cost per km | INR 4–7 | INR 0.2 | Free |
| Running cost per year (18,000 km) | INR 72,000–126,000 | INR 3600 | Free |
| Yearly saving | – | INR 68,400–122,400 | INR 72,000–126,000 |

external source, utilization of a few electronic gadgets like solar board heat sensors, advanced cooling framework and so forth have reinforced the vehicle as a high-level SCEV ready for worldwide market. Thus, the authors have designed a photovoltaic integrated electric vehicle which has numerous advantages when compared with conventional EV with the requirement of separate charging station.

## References


1. Spina MA, de la Vega RJ, Rossi SR (2012) Source issues on the design of a solar vehicle based on hybrid energy system. Int J Energy Eng 2:15–21
2. Mehta G, Yadav VK (2018) Impact of renewable distributed generators in competitive electricity markets considering economic factors. In: IEEE international conference on power electronics, drives and energy systems, Chennai
3. Saxena N, Hussain I, Singh B, Vyas AL (2018) Implementation of a grid-integrated PV-battery system for residential and electrical vehicle applications. IEEE Trans Ind Electron 65(8):6592–6601
4. Gobhinath S, Boobalan S, Ashwin R, Meshach J, Rajkumar K (2020) A practical approach in design and fabrication of solar-powered four-wheeled electric vehicle. In: Innovations in electrical and electronics engineering. Lecture notes in electrical engineering, vol 626. Springer, Singapore
5. Chellaiah C, Thangamani K, Subin PG, Rathinakumar P, Muthukrishnan P (2013) Design of a fuel free electric vehicle. In: Mobile communication and power engineering. Communications in computer and information science, vol 296. Springer, Berlin
6. Surya S, Williamson SS (2022) Energy storage devices and front-end converter topologies for electric vehicle applications. In: E-Mobility. EAI/Springer innovations in communication and computing. Springer, Berlin
7. Ben Said-Romdhane M, Skander-Mustapha S (2021) A review on vehicle-integrated photovoltaic panels. Advanced technologies for solar photovoltaics energy systems. In: Green energy and technology. Springer, Berlin
8. Duan et al (2018) A solar power-assisted battery balancing system for electric vehicles. IEEE Trans Transp Electrification 4(2):432–443
9. Habib S, Khan MM, Abbas F, Sang L, Shahid MU, Tang H (2018) A comprehensive study of implemented international standards, technical challenges, impacts and prospects for electric vehicles. IEEE Access 6:13866–13890
10. Khalid MR, Alam MS, Sarwar A, Asghar MJ (2019) A comprehensive review on electric vehicles charging infrastructures and their impacts on power quality of the utility grid. E-Transportation 1:100006
11. Savio DA, Juliet VA, Chokkalingam B, Padmanaban S, Holm-Nielsen JB, Blaabjerg F (2019) Photovoltaic integrated hybrid microgrid structured electric vehicle charging station and its energy management approach. Energies 12(1):168
12. Tazay A, Miao Z (2018) Control of a three-phase hybrid converter for a PV charging station. IEEE Trans Energy Convers 33(3):1002–1014
13. Ramadhani UH, Shepero M, Munkhammar J, Widén J, Etherden N (2020) Review of probabilistic load flow approaches for power distribution systems with photovoltaic generation and electric vehicle charging. Int J Electr Power Energy Syst 120:106003
14. Abdelsalam MA, Obaid W, Ahmad FF, Hamid AK, Ghenai C (2020) Modeling and simulation of a solar powered golf cart charging station in Sharjah. In: Advances in science and engineering technology international conferences
15. Tiano FA, Rizzo G, Marino M, Monetti A (2020) Evaluation of the potential of solar photovoltaic panels installed on vehicle body including temperature effect on efficiency. E-Transportation 5:100067
16. Mehta G, Singh M, Dubey S, Uzair, Mishra Y (2021) Design of auto-braking system for accident prevention and accident detection system using IoT. In: Smart sensors for industrial internet of things. Springer, Berlin
17. Mi C, Masrur A (2018) Hybrid electric vehicles principles and applications, 2nd edn. Thomas Kurfess
18. Taha Z, Md Sah J, Passarella R, Abd Rahim N (2014) A review on energy management system of solar car

19. Dwivedi M, Mehta G, Iqbal A, Shekhar H (2017) Performance enhancement of solar PV system under partial shaded condition using PSO. In: International conference on computing, communication and networking technologies
20. Ahmad MW et al (eds) (2022) Intelligent data analytics for power and energy systems. Springer, Singapore, p XXII, 641. ISBN: 978-981-16-6081-8. https://doi.org/10.1007/978-981-16-6081-8
21. Tomar A et al (eds) (2022) Proceedings of 3rd international conference on machine learning, advances in computing, renewable energy and communication: MARC 2021, vol 915, p XV, 781. ISBN: 978-981-19-2830-7. Springer Nature. https://doi.org/10.1007/978-981-19-2828-4
22. Bhavnani SH (1994) Design and construction of a solar-electric vehicle. ASME J Sol Energy Eng 116(1):28–34
23. Giannouli M, Yianoulis P (2012) Study on the incorporation of photovoltaic systems as an auxiliary power source for hybrid and electric vehicles. Sol Energy 86:441–451
24. Araki K, Ota Y, Yamaguchi M (2020) Measurement and modeling of 3-D solar irradiance for vehicle-integrated photovoltaic. Appl Sci 2020(10):872