Design of a Solar Vehicle using multiple Energy Source

1Prof. Narasimha Murthy, 2Chethan, 3Preethi Palthi, 4Chandan S S
1Assistant Professor, 2,3,4Final Year Project Student
1,2,3,4Mechanical Engineering Department,
1,2,3,4T John Institute of Technology, Bangalore, India

Abstract : The conception and assembly of an experimental multiple Energy source Vehicle based on the combination of human energy contribution and photovoltaic solar energy is presented in this study. The vehicle has a battery for putting away the energy given by the two frameworks. The application’s point is to accomplish the most reduced conceivable energy utilization for the vehicle’s development, with photovoltaic modules as the primary electricity source. The advancement of the solar based vehicle was spurred by a Latin-American sun powered vehicles race about 1000km over the Atacama Desert in Chile, South America. The main constructive aspects, energy issues and experimental results are presented.

IndexTerms - MULTIPLE ENERGY SOURCE VEHICLE, SOLAR VEHICLE, ZERO-EMISSION, PHOTOVOLTAIC SOLAR ENERGY.

1. INTRODUCTION
The possibility of an electric vehicle isn’t new and has a background marked by over 100 years. Since over 10 years back, the hunting down advancements of Zero-Emission Vehicles (ZEV), Electric Vehicles (EV), and Hybrid Electric Vehicles (HEV)[1-3] has taken another motivation. These innovations can be seen in the successive automobile fairs far and wide in the state of reasonable plans. An early nearness in the market is refreshing in the most recent years, essentially with half breed innovation joining at least two vitality frameworks. As per the utilization of new and clean vitality sources, the pattern is to override interior ignition motors by footway through electric engines, thus solving a problem related with greenhouse gas (GHG) emissions[4,5].

The need to investigate for accomplishing useful zero emanation in the source and utilization notwithstanding the test of connecting the logical mechanical learning to the worldwide premiums of a manageable planet, by methods for the advancement of the utilization of elective energies, makes apparent the expect to at first have an exploratory model of HEV. In this sense, photovoltaic sun powered vitality assumes a basic job in the execution of clean energies as fundamental electricity hotspot for EVs. A zero-emission vehicle is powered by photovoltaic solar energy by means of solar panels, with storage of electric energy in batteries, and the traction is obtained by an electric motor, this is the basic idea[6]. By the by, solar based energy for vehicle applications isn't a conspicuous issue in light of the fact that few basic focuses must be deliberately examined, e.g., a) the proficiency and expenses of photovoltaic boards, b) how to expand the sun based radiation, and c) the vitality the executives and control[7].

At present there are various solar vehicle extends the world over for numerous reasons. From the connected research perspective, intriguing commitments have been exhibited over the most recent two years, e.g., in[5] a photovoltaic fuelled zero-emanation electric vehicle is displayed with regards to an instructive task. In[8] a solar and wind fuelled HEV, with an inside burning motor was proposed, and at first tried in a business item. A cross breed vitality framework for an EV is proposed in[9], including solar board, battery and super-capacitor, mutually with the framework design and control methodology investigation. A venture including battery controlled electric vehicles charged by photovoltaic boards is being completed for rural exercises in remote sloping territories in the Southern Mediterranean locale, with the intent to explore the cleaner generation of intensity henceforth lessening the utilization of diesel fills in agriculture[10]. Then again, solar vehicles are worked the world over to take part of various solar races with the intend to test and research new mechanical progressions and its potential application in zero-emission vehicles[11,12].

The origination and development of a trial solar vehicle dependent on cross breed framework that joins photovoltaic solar vitality and human vitality commitment is exhibited in this composition. The vehicle has a battery for putting away the vitality given by the two frameworks. The human intervention is given through the task of a pedal system organized in the front of the vehicle that initiates a three-stage brushless generator, going about as a correlative vitality patron. The application’s point is to accomplish the most reduced conceivable vitality utilization for the vehicle’s development, with photovoltaic modules as the primary electricity source.

The improvement of the solar vehicle is an activity of cutting edge understudies, and analysts from an Electro-mechanical Engineering course, propelled by a Latin-American solar vehicles race called “Atacama Solar Challenge” in the “Solar Road” classification. This is a 1000Km race over the Atacama Desert in Chile, South America, which comprises a doled out space all together that the Latin-American nations could demonstrate the advances in photovoltaic controlled vehicles.

The main objectives of this work are the following ones: a) To transfer the obtained knowledge on the new trends in transport, electric traction and renewable energy sources to the productive sector, b) To spread the utilization of elective energies in all general public areas, and c) To make achievable the interest in the sequential “Solar Road” race releases, improving the utilized innovation. The remainder of the paper is organized as pursues: Section 2 centres around the primary pieces of the vehicle structure. Segment 3 manages the exploratory outcomes. At long last, ends are exhibited in Section 4.

Design of the Solar Vehicle
A trial solar vehicle model was worked with regards to an interdisciplinary task called ”Pampa Solar” for advancing the utilization of clean energies in multipurpose vehicles. This is a vehicle with a cross breed framework dependent on photovoltaic solar vitality as primary electricity source, and supplemented by the commitment of human energy.

A standout amongst the most significant focuses in the development of the vehicle is firmly identified with the case plan, to accomplish a basic improved work, and communicated in the least conceivable energy utilization for the vehicle’s development. The plan was
considered from a point of perspective on a high-proficiency, lightweight and stable transport, with diminished expenses, and zero discharge, in its task and in the getting of the energy.

**General Design**

The solar vehicle was made with a structure of three wheels, in the state of a reversed tricycle, for just a single rider in prostrate position. The high-productivity electric footing is accomplished by a 48V – 2kW brushless in-wheel engine. Furthermore, it has a convenience for the battery behind the seat, and a back mounted structure for obliging electronics and controllers. A "solar rooftop" contained by a rectangular aluminium structure with ribs was amassed over the vehicle and secured by glass-fibre, for appropriating and supporting the photovoltaic solar boards. This "solar rooftop" has a revolution development of 40º over an even pivot, directed by a lineal actuator, henceforth comprising a solar tracker. The general pieces of the vehicle are delineated in Figure 1.

![Figure 1. A 3D view of the solar vehicle’s design](image)

**Energy Contributions**

The solar vehicle joins the utilization of electric vitality from three distinct sources: a) photovoltaic solar vitality, b) vitality got through human commitment, and c) batteries. The square graph in Figure 2 portrays the vitality frameworks that establish the base of the solar vehicle, mutually with the collector of these energies. The photovoltaic solar vitality is acquired from five photovoltaic solar boards that supply the battery through the board's Maximum Power Point Tracker (MPPT), working in buck mode. Along these lines, it is conceivable to get the most elevated vitality of the immediate radiation relying upon the rate edge. Figure 2 likewise demonstrates the converter, the speed control and regenerative braking module, for recovering some level of vitality amid ceasing, and the in-wheel electric engine.

The physical limits of the vehicle rider are utilized for a correlative vitality commitment. In this sense, the rider works a pedal instrument in prostrate position organized in the front of the vehicle that enacts a three-stage brushless generator, going about as a vitality patron. An AC/DC correction is important before to supply a helpful DC voltage level to the battery. A three-stage rectifier was actualized for such a reason.

The batteries establish the capacity arrangement of the electric vitality and commitment when the electric engine prerequisites have a power demand more prominent than the info. The battery pack has a keen charge-release framework called Battery Management System (BMS) that screens the voltage of every phone, securing it against over-burdens and charge irregular characteristics, therefore guaranteeing the limit of the whole pack at various temperatures and its working life[13].

![Figure 2. Block diagram of the energy systems](image)
Electric Generator

A mix of human body's lower limits muscles is utilized in a regular bike to move it by methods for a patterned development at speed somewhere in the range of 60 and 80rpm, contingent upon the idea of the bike rider[14]. The counselled list of sources permits examining a few qualities that measure the power that a person can supply without enduring physical harm. A few factors, for example, temperature, weight, height, and moistness have a significant impact. Thinking about this factors, a person of an ordinary physical constitution can pedal for a few hours without enduring weakness, and a quick recuperation is conceivable with a consistent accelerating proportional to around 75W[15]. Be that as it may, the bike rider can understand a work of three or multiple times more than the incentive to reach roughly 300W in brief timeframes. This vitality is utilized as commitment for giving, in typical musicality, a power supply in a scope of 30–70W, contingent upon the charge condition of the battery.

The framework comprises of a chain-based transmission between a driver gear haggle sprocket wheel gathered on the electric generator's hub. The fundamental pieces of the framework are the accompanying ones: a) 54 tooth driver gear wheel, b) pedals joined to the driver wheel, c) 12 tooth sprocket wheel, d) chain, e) three-stage brushless generator, and f) AC/DC rectifier.

Photovoltaic Solar Panels

The solar modules establish the primary electricity source and are in charge of the vitality age utilized in the vehicle's activity. The "solar rooftop" has a rectangular shape (1.2m x 2.5m), forced by the solar race standards, and comprises of a variety of 171 monocrystalline solar cells circulated in 5 solar boards, 4 of them have 36 cells and 27 the staying one. A variety of 4 sequential associated boards was executed to get the important 48V with the likelihood to have a fifth board to be associated for producing vitality as well. Consequently, by methods for the "solar rooftop" with a zone of 3m2 is conceivable to acquire a pinnacle intensity of 445W.

The monocrystalline silicon solar cells have an element of 125mm x 125mm, and an effectiveness of 18% determined for a solar irradiance of 1kW/m2 at 25°C. Figure 3 demonstrates the solar cells utilized in this task and the sequential interconnection process. Figure 4 demonstrates a solar board with the solar cells interconnected and typified. The solar cells were interconnected and epitomized in modules through a procedure completely done in our research centres.

**Battery Choosing**

The right elements of the battery set up the independence level of the solar vehicle. The objective is to scan for a reasonable connection among weight, volume, lifetime, cost, vitality thickness, and natural effect. In the meantime, these variables must be communicated in the most reduced conceivable weight and volume of the vehicle. For our situation a thorough investigation of options and existing innovations available was made for deciding an advantageous connection among the parameters.

After completed a lot of preliminaries and a similar examination of the primary attributes of various kinds of vitality accumulators[1,13,16,17], a Lithium-Iron-Phosphate (LiFePO4) stockpiling battery made out of 16 clusters in arrangement, every one of them with 7 cells in parallel (16S7P) was picked for getting 48V - 40Ah.

At the point when contrasted and great batteries, LiFePO4 batteries have significant qualities for electric vehicle applications, considering cell normal voltage of 3.2V – 3.3V, gravimetric vitality thickness of 100Wh/Kg, volumetric vitality thickness of 200Wh/l and a high cycle existence with around 2000 cycles (at 80% DOD)[13]. Moreover, speaks to roughly 1/2 of the volume and 1/3 of the heaviness of the lead-corrosive battery. About the ecological effect this sort of innovation is certify by the Restriction of Hazardous Substances (RoHS) order.

**Electric Motor Characteristics**

The high-efficiency electric traction is achieved through a 48V - 2kW brushless hub-motor provided with a brake disk, capable to reach a speed of 626rpm in its maximum performance point[18]. The motor is provided with a programmable controller to easily change parameters, and obtain diagnostic information[19].

The electric motor has the possibility of regenerative braking, i. e., the energy contribution exploiting the vehicle’s dynamic during deceleration.

**Electronic Systems**

Electronic systems that are part of the solar vehicle consist of the brushless motor controller, and the modules fully developed in our Faculty, including software and hardware, as follows: a) A switching DC-DC power supply (Vin = 48V, Vout = 24V) for powering the linear actuator that commands the “solar roof” positioning, and light systems, b) A switching DC-DC power supply (Vin = 48V, Vout = 12V) for controlling the information obtaining framework, c) An exchanging DC-DC control supply (Vin = 48V, Vout = 19V) for fueling a versatile PC with USB correspondence, that runs the product and realistic interface for review the physical factors, and d) Signal molding modules to quantify and screen the physical factors, including: flow delivered by photovoltaic and human commitment, separately, electric engine utilization and temperature, battery voltage, battery temperature, GPS information, and direction of actuators.
The photo in Figure 5 demonstrates the back collected structure containing the electronic frameworks of the solar vehicle. As it very well may be found in the Figure there are different electronic modules, including: a) brushless engine controller, b) metallic help for all the exchanging power supplies, c) versatile PC, d) microcontroller-based securing framework with USB interface for speaking with the PC, e) MPPT module, f) flag moulding modules and sensors, g) brushless engine current detecting framework.

What’s more, the back amassed metallic structure thinks the wiring for electronic and electric establishment, and terminal associations for light frameworks.

The vehicle rider can realize the present vitality state of the portable, the position, the perfect speed to reach at decided point with the accessible vitality, and the likelihood of acting through the generator if it is fundamental. Thusly, it has data about the need to adjust the edge about the flat position of the "solar rooftop" to get best utilization of the vitality. This data is accessible on a realistic interface, available through a 8-Inch VGA screen organized in the front of the vehicle.

![Figure 5. Electronic systems of the experimental solar vehicle](image)

**Results**

Figure 6 shows a photograph of the current version of “Pampa Solar” experimental vehicle during solar cars exhibition previous to the competition across the Atacama Desert.

![Figure 6. Experimental solar vehicle “Pampa Solar”](image)

**Performance of Solar Modules**

The collected boards were contrasted and business ones of comparative attributes, getting acceptable outcomes. For such a reason a PC-based procurement framework was used to acquire the voltage and flows created by the boards stacked through a variable resistor. The outcomes for one solar board contained by 36 solar cells and appeared differently in relation to a business board of comparative qualities are exhibited in Table 1, where $A_n$ is the zone of one solar cell in $[m^2]$, $I$ is the solar irradiance in $[W/m^2]$, $V_{max}$ and $I_{max}$ are the greatest voltage and current acquired from the board at the purpose of most extreme power $P_{max}$, in $[V], [A],$ and $[W]$ individually, $V_{oc}$ is the open-circuit voltage and $I_{sc}$ is the short out current.
Table 1. Measured parameters for both assembled and commercial solar panels

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Solar Panel</th>
<th>Assembled</th>
<th>Commercial</th>
</tr>
</thead>
<tbody>
<tr>
<td>A [m²]</td>
<td></td>
<td>0.014</td>
<td>0.013</td>
</tr>
<tr>
<td>Number of cells</td>
<td></td>
<td>36</td>
<td>36</td>
</tr>
<tr>
<td>I [W/m²]</td>
<td></td>
<td>600</td>
<td>600</td>
</tr>
<tr>
<td>I_{sc} [A]</td>
<td></td>
<td>3.93</td>
<td>3.28</td>
</tr>
<tr>
<td>V_{oc} [V]</td>
<td></td>
<td>19.8</td>
<td>20.2</td>
</tr>
<tr>
<td>I_{max} [A]</td>
<td></td>
<td>3.12</td>
<td>2.68</td>
</tr>
<tr>
<td>V_{max} [V]</td>
<td></td>
<td>16.6</td>
<td>15.1</td>
</tr>
<tr>
<td>P_{max} [W]</td>
<td></td>
<td>51.7</td>
<td>40.4</td>
</tr>
</tbody>
</table>

The evaluation of the performance of the integrated solar cells has been made by means of the fill factor (FF), as in (1).

\[ FF = \frac{V_{MAX} \times I_{MAX}}{V_{OC} \times I_{SC}} \] (1)

This is the ratio of the product of maximum obtainable power of the solar panel, determined by \( V_{\text{max}} \) and \( I_{\text{max}} \), to the product of \( V_{\text{oc}} \) and \( I_{\text{sc}} \) (theoretical power). In our case, and using the values from Table 1, FF=0.66 for the assembled panel and FF=0.61 for the commercial panel.

Figure 7 represents I vs. V characteristic for the assembled panel jointly with the theoretical characteristic determined by the rectangle, thus illustrating the concept of fill factor. Figure 8 shows P vs. V characteristic for the assembled panel in which it is possible to observe the peak power point. The efficiency of the panel is obtained through (2) where \( N_c \) is the number of the cells integrated within the panel.

\[ \eta = \frac{P_{\text{MAX}}}{I \times A \times N_c} \] (2)

The efficiency is 17% and 14.5% for the assembled and the commercial panel, respectively.

Figure 7. Characteristic I vs. V for the assembled solar panel

Vehicle during the Solar Race

Figure 9 demonstrates a photo of the solar vehicle going around the Atacama Desert, amid the solar vehicles race, over a requesting street extend with stamped inclines. This geography is fascinating to dissect the vehicle's execution as far as electric engine flow necessities and battery voltage levels. The electric engine flow accepts positive and negative qualities as appeared in Figure 10 that delineates the development of the flow engine as an element of the time portrayed with blue line.

Figure 9. The solar vehicle travelling around the Atacama Desert

Figure 8. Characteristic P vs. V for the assembled solar panel
Figure 10. Brushless electric motor current and battery voltage as a function of time

It is conceivable to watch the negative estimations of the engine current because of the vitality recovering amid braking and decelerations. In these circumstances the battery voltage expands its incentive as it tends to be found in Figure 10, showed with red line. A pinnacle of - 8.8A was enlisted comparing to battery voltage of 47.6V. Conversely, at the most extreme positive pinnacle of the engine current (33.9A) was enlisted the base battery voltage (44.9V).

Figure 11 demonstrates the vehicle speed as a component of time over a street extend with moderately few slants on the off chance that it is contrasted and the case appeared in Figure 9. For this situation, and thought about a time of roughly 60 minutes, the vehicle built up a normal speed of 33km/h.

As definite remark, it is imperative to see a few issues firmly related with the helpful usage of solar vitality amid the race. As delineated in Figure 9, the "solar rooftop" displays a tendency because of the revolution development of 40º over the even pivot conceded by the solar tracker framework. This reality together with the accessible online data of vitality balance made conceivable to get the best utilization of solar vitality amid the challenge.

The vehicle was assembled utilizing at any rate half of its vitality given by the solar boards, as forced by the race rules. The outcomes have been affirmed amid the race, in which the vehicle was granted with the prize of best utilization of photovoltaic solar vitality in the "Solar Road" classification.

Figure 11. Vehicle speed as a function of time over a road stretch with few slopes

Conclusions

The primary parts of the plan of a test solar vehicle dependent on half and half framework that consolidates photovoltaic solar vitality and human vitality commitment was introduced and depicted in this original copy. Exceptional accentuation has been worried to the photovoltaic solar vitality as primary electricity wellspring of the solar vehicle. Great outcomes identified with transmission, weight, and adaptability were acquired utilizing styrene base polymer to exemplify the solar cells. The last expense of the solar board is littler than the business solar modules. The examination in various phases of the task prompted the use of LiFePO4 batteries as a result of its important qualities for its utilization in electric vehicles. The acquired outcomes on test preliminaries of the vitality frameworks, the tests did over photovoltaic solar boards, mechanics, electric and electronic frameworks are palatable. These outcomes have been affirmed amid the solar vehicles race in the "Atacama Solar Challenge" in which our exploratory vehicle was granted with the prize of best utilization of photovoltaic solar vitality in the "Solar Road" classification. Potential upgrades for the vehicle will be proposed in future works, thinking about the zero-discharge and the fuse of new advancements as primary rules.

ACKNOWLEDGEMENTS

The authors would like to acknowledge the authorities and personnel of the Faculty of Engineering (Universidad Nacional del Centro de la Provincia de Buenos Aires), the Buenos Aires Province Scientific Research Commission (CIC), and the Olavarria City Municipality, for the financial support. Likewise, a special acknowledgement is also extended to companies and institutions that demonstrated their commitment with this project.
REFERENCE


