Sustainable Design and Modular Assembly of Eco-Friendly Urban Vehicles

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Solar energy remains among the foremost renewable resources powering new advances in green transportation. This study presents the stepwise green engineering and modular assembly of an environmentally friendly urban car specifically targeted at meeting daily commuter needs within Noida Smart City, India. The focus herein is to optimize the entire commuter journey for reliability, cost, and usability—exclusively employing free, renewable solar inputs. System modeling covers full commuter range requirements under local operational constraints. The electrical subsystem features photovoltaic modules charging a lithium-ion battery array, with charge/discharge intelligently regulated by a microcontroller-based energy management system, ensuring system longevity and safety. Power is delivered by a high-torque brushless DC motor via a robust drive assembly, while vehicle controls, direction, and speed are governed by a custom-designed controller with regenerative braking integration. Special attention is given to material selection for chassis fabrication and low-embodied energy structural systems, emphasizing the use of recyclable composites and the minimization of lifecycle CO_2 output. The paper demonstrates the wiring and integration of all electronic and power modules into the underlying vehicle framework, outlining stepwise mechanical assembly and highlighting safety, comfort, and ergonomics. This research provides a comprehensive technical roadmap for translating green vehicle concepts into commercially viable, mass-assembled products for urban mobility. The described system addresses current limitations in solar vehicle engineering and presents detailed empirical results on energy flow, user acceptance, and cost-benefit for future transport infrastructure planning.

The quests for a constant, safe, clean, environmental-friendly fuel is never-ending. Carbon-based fuels, such as fossil fuels are unsustainable and hazardous to our environment. Some of the alternatives are renewable energy sources which include all fuel types and energy carriers, different from the fossil ones, such as the sun, wind, tides, hydropower and biomass. Amongst these elements, solar energy is preferred since it could provide the cleanest sustainable energy for the longest duration of time – the next few billion years. Photovoltaic production becomes double every two years, increasing by an average of 48 percent each year since 2002. Due to its

innumerable benefits in environmental, economic and social aspects PV systems have becomes the world's fastest growing energy technology. It can arguably be said that the only limitation to solar power as an energy source is our understanding of developing efficient and cost effective technology which can implement it. Nothing on earth is free of cost, but what if we could find a way to implement free rides? Indeed it would be wonderful if our cars could continue to run without us having to spend billions on fossil fuels every year and to deal with natural hazards that their combustion leave behind. If we could drive a solar-powered car, that auto dream would come true. Solar cars would harness energy from the sun via solar panels. A solar panel is a packaged, connected assembly of solar cells, also called photovoltaic cells which are solid state devices that can convert solar energy directly into electrical energy through quantum mechanical transitions. They are noiseless and pollution-free with no rotating parts and need minimum maintenance. The electricity thus generated would then fuel the battery that would run the car's motors. Therefore we would obtain an electrically driven vehicle that would travel on "free" energy with no harmful emissions, that can utilize its full power at all speeds, and would have very little maintenance cost. The earth is suffering as a result of the destruction wreaked upon it by humanity. Whether it is the pesticides contaminating the rivers, chemicals from factories polluting the seas or the exhaust fumes from vehicles and industries polluting the air, the systematic destruction of our different ecosystems all over the world has led to a dreadful mess. Our main focus is on the transportation industry which is the second largest source of pollution and health hazards. According to the World Air Quality Report, India ranked fifth among the most polluted countries in the world where the roads congested with vehicles bombard the countless hordes of people streaming past on the pavements with deafening noise and toxic exhaust fumes from burning fuel especially during peak office hours when cars stuck in traffic produce more and more harmful emissions. As a result thousands of people are becoming victims of heart and lung problems, depression, memory loss, asthma and even premature deaths. Fuel-based cars not only threaten the very air we breathe in but also the cost of running and maintaining them are huge and overbearing, and as the fossil fuels are gradually being depleted, the cost of these limited scare resources, the existing fuels' prices are continuously rising. Clearly, individuals need to become more aware of the consequences of their actions and can help protect the earth by using an alternative method of transport, perhaps the solar car, an eco-friendly, clean, inexpensive, compact car, independent of fossil fuels and toxic emissions. This electric vehicle may definitely be a major step in reducing traffic congestion, noise and vehicle emissions on the road. Solar cars would not contribute to global warming or to the production of CO_2.Thus this will reduce greenhouse gas emissions as CO_2 is the primary greenhouse gas and thereby lower human health risks. They will cost four times less than fuel-based cars since apart from the initial cost of the major components of installation for example the solar panels, charge and motor controllers,

there would be no more recurring costs as solar energy is absolutely free. If the government and many transportation industries can take the initiative to provide the fund for the research and development of the technology to produce solar power and thus to the production of solar cars at a large scale, the use of this modern vehicle will benefit us all. The system architecture of the solar car is shown in Figure 1.

PROJECT OVERVIEW: The system architecture of the solar car is shown in Figure 1 and 2. According to the block diagram in Figure 1, the solar car system would consist of 10 main parts.

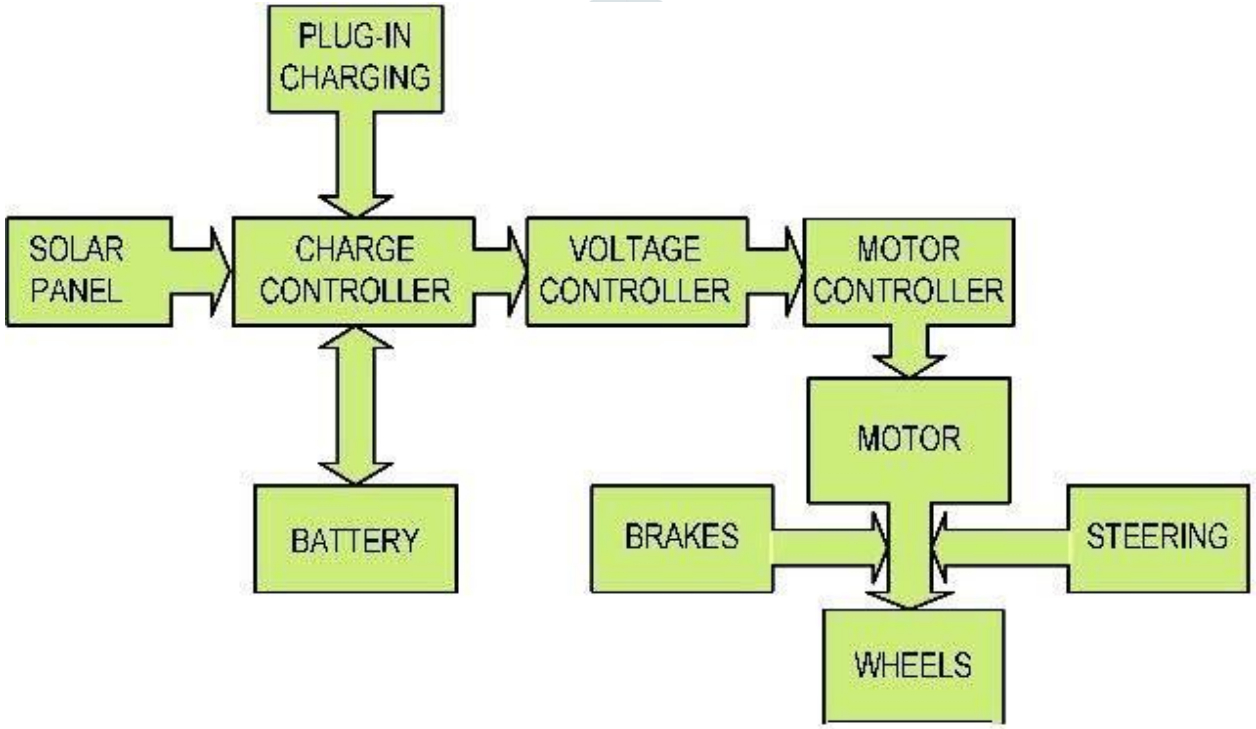


FIGURE 1: THE SYSTEM ARCHITECTURE OF THE SOLAR CAR.

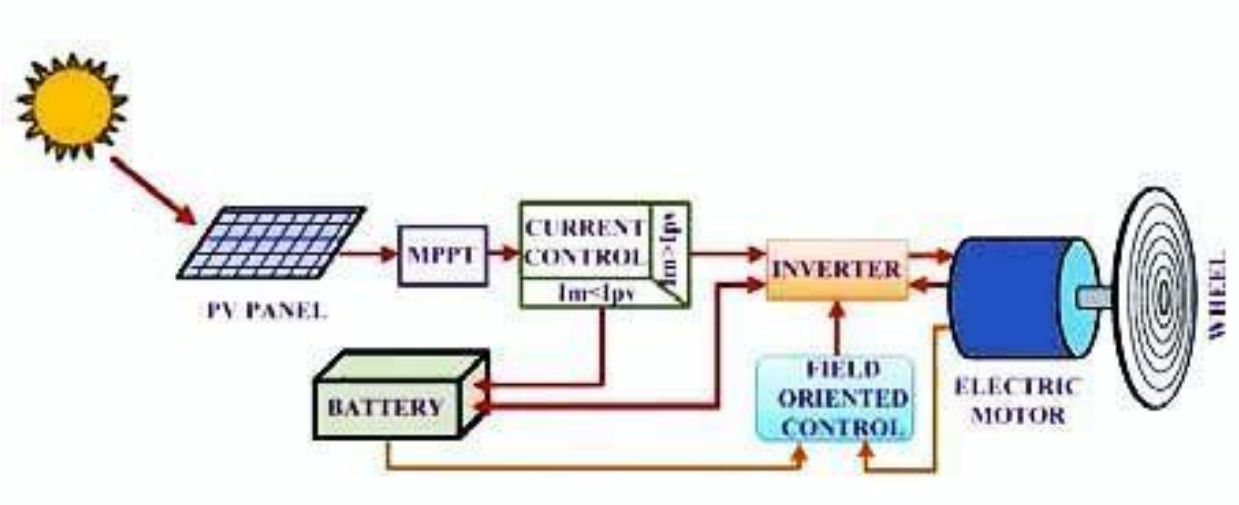


FIGURE 2: THE BLOCK DIAGRAM OF SOLAR ELECTRIC VEHICLE.

SOLAR PANEL: Solar cars are powered by the sun's energy ergo solar panels are the most important part of a solar car since they are solely responsible for collecting the sun's energy. The solar panels used in this project are mono crystalline and flexible. They can be mounted and fitted on top of the car or on the bonnet with ease owing to their thin semi-flexible nature.

FIGURE 3: TWO SEATER SOLAR CAR 'A DREAM TO REALITY'.

FIGURE 4: THE 50 W SEMI-FLEXIBLE SOLAR PANELS USED FOR THE ASSEMBLY OF ENVIRONMENTAL FRIENDLY CAR.

Solar panels have been around since the nineteenth century and since then till today people have been using them for a variety of applications at home, business, for transportation and even for agricultural use. Solar panels are still considered expensive and their performance needs to be verified without completely relying on the provided ratings by the company producing them. In the case of a solar car, the solar panels will be the ultimate supplier of energy for the whole car to function; for all intents and purposes it will be akin to the heart that pumps blood around the human body. Therefore, a thorough verification of the performance of the solar panels to be used for the solar car was carried out.

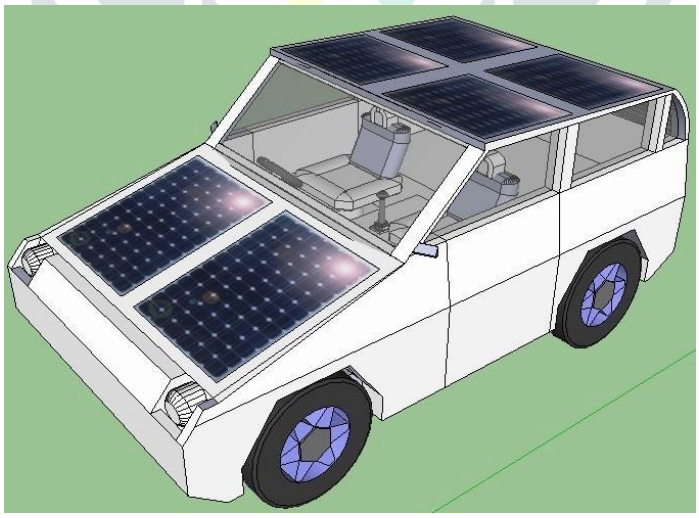


FIGURE 5: CONFIGURATION OF THE SETUP OF THE SOLAR PANELS ON THE CAR.

HOW SOLAR PANELS WORK: The sun gives off radiated energy in the form of light photons which is converted into electrical energy by the solar panels. Solar panels are composed of silicon based semiconductors and when the radiation comes in contact with the silicon atoms, the photons are absorbed and the electrons are separated from the rest of the atoms. These free electrons are responsible for carrying and creating an electrical current. The electricity generated is most usually stored in batteries to be used later.

BATTERIES: The solar panels will collect energy from the sun and convert it into usable electrical energy, which in turn will be stored in the lead acid batteries to be supplied to the motor when necessary.

BATTERY TESTING: A performance test for efficiency and fill factor of the panels were made to ensure that they are functioning as intended.

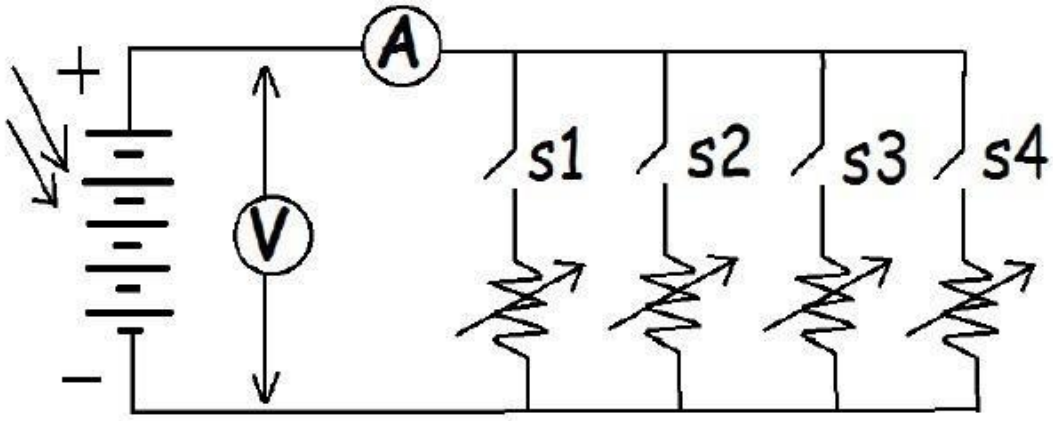


FIGURE 6: CIRCUIT SETUP FOR TESTING OF THE SOLAR PANEL USED FOR THE ASSEMBLY OF ENVIRONMENTAL FRIENDLY CAR.

The test was conducted on a bright, sunny day with the panels positioned in such a way as to get the most amount of sun. Additionally, the manual for the exact voltage and current ratings of the panels as set by the manufacturer was checked for consistency. The full test was carried out within duration of 15 minutes so as not to incur too much discrepancy in solar intensity. The 5 solar panels were connected in series with a resistor network of four rheostats of 150 ohms each and an ammeter. A voltmeter was connected parallel across the solar panel network. Then by varying the resistance of the load different values of voltages and corresponding current readings were obtained. The following graphs were than plotted using the data.

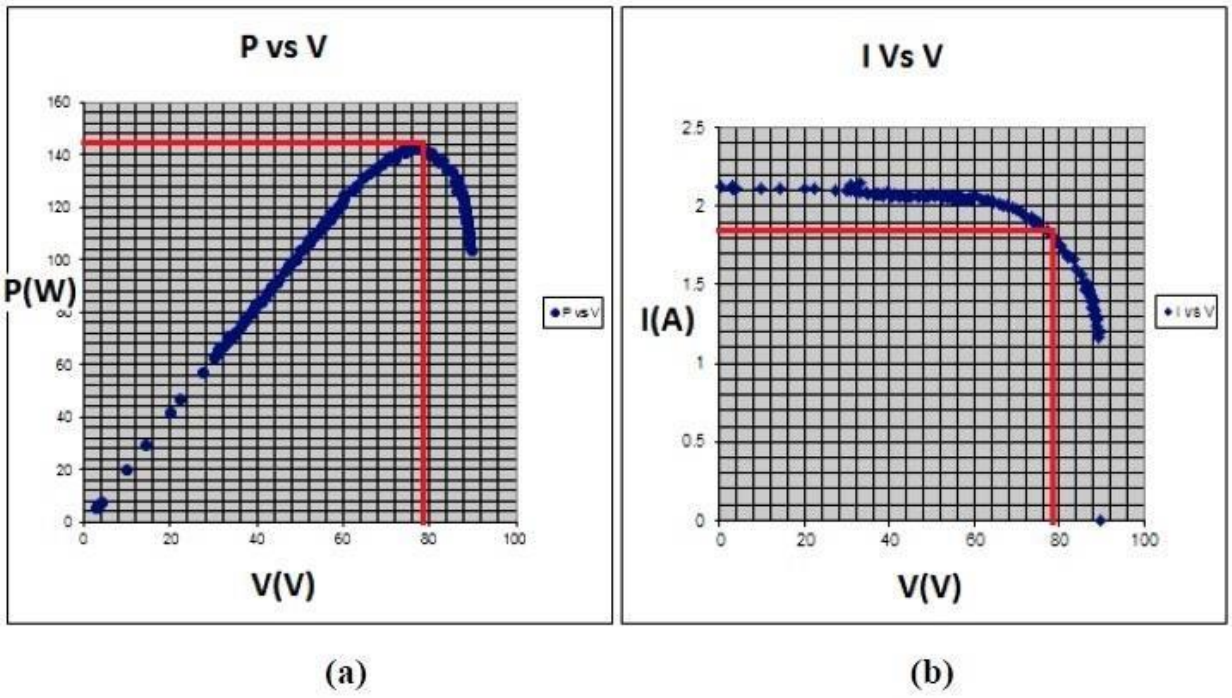
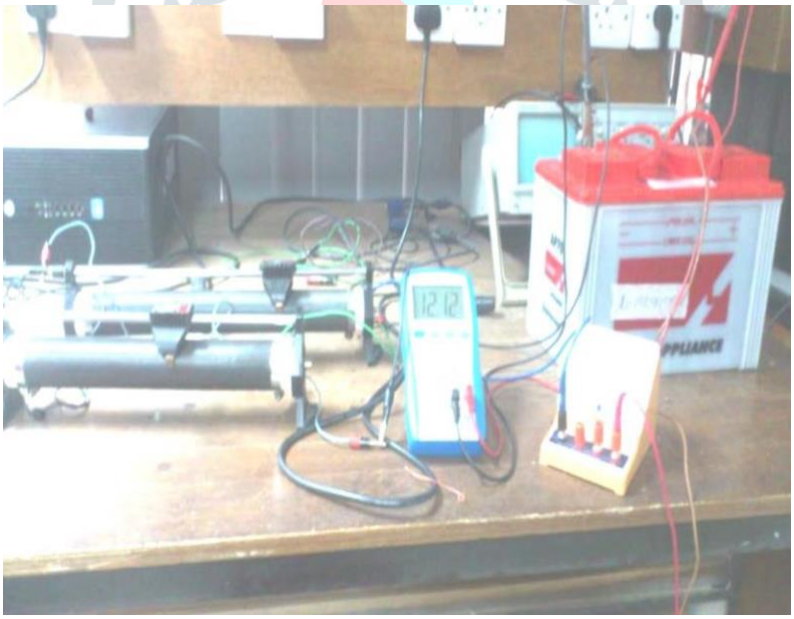


FIGURE 7: GRAPHS OF (A) POWER VS. TERMINAL VOLTAGE, (B) CURRENT VS. TERMINAL VOLTAGE FOR THE SOLAR PANEL.

The battery to be used is a 12 V unsealed lead-acid re-chargeable battery. Lead–acid batteries, invented in 1859 by French physicist Gaston Planté, are the oldest type of rechargeable battery. Despite having a very low energyto-weight ratio and a low energy-to-volume ratio, their ability to supply high surge currents means that the cells maintain a relatively large power-to-weight ratio. These features, along with their low cost, make them attractive for use in motor vehicles to provide the high current required by automobile motors. The battery test was carried out by first charged by connecting it in series with a controllable DC power supply and an ammeter, with a voltmeter across to measure the voltage. While charging data of current and voltages were recorded. For the discharging part, the battery was connected in series with a rheostat and ammeter with a voltmeter across to measure the voltage. Again, data of current and voltages were recorded. The arrangements are shown in Figure 8.

(a)



(b)

FIGURE 8: SETUP OF THE BATTERY FOR TESTING (a) CHARGING (b) DISCHARGING.

CHARGE CONTROLLER: The batteries are connected to a charge controller which will ensure healthy life of the batteries by preventing it from over charging and over discharging. A microcontroller inside the charge controller is programmed to detect the voltages at the battery terminal and/or the solar panel terminals and accordingly determine what charging current the battery needs to be supplied.

PLUG-IN CHARGING: A critical factor here is that the charge controller will be available with an additional input that can be used to charge the batteries from an AC power supply (simply by plugging in). Thus the solar car will have this plug-in charging system for use when there is not enough sunshine due to fog, cloud or rain. This provision for an external plug-in system to charge the batteries from the conventional AC power supply will allow the car to increase its overall utility.

MOTOR AND MOTOR CONTROLLER: The motor used is a DC-Series Excitation Motor which is rated at 1 kW, 60V, 23 A. This DC-series motor is sufficient to get the car up and running. The motor controller is designed to control the speed of rotation of the motor as well as the direction of its rotation. In other words, it determines the cars speed and forward / reverse direction of motion of the wheels.

STEERING, SUSPENSION, BRAKES, AND WHEELS: These four components make up the mechanical part of the solar car. Front wheel steering is used as it tends to be more stable and safe. The suspension used is sophisticated enough to allow the user a stable ride and to protect the car and panels from sudden shocks and blows. A drum braking system as in conventional cars is used to provide the safety features of the car while travelling. The wheel selection is dependent upon the rolling resistance which would determine how far the solar car can travel with the available energy. Since thicker wheels tend to have higher rolling resistance, thinner but strong wheels are opted for.

SCOPE OF THIS RESEARCH ARTICLE: The scope of the project involves designing and constructing a proto-type solar powered clean car that would be economical, reliable and environmentally friendly. The specifications of the motor driving the car is calculated based on the intended desired speed and acceleration to be achieved. This will in turn help calculate the battery capacity and solar panel wattage required to travel the desired maximum round trip distance within Sushant Golf City, Lucknow, India on solar power alone. A charge controller with the option of addition charging from AC lines, and a motor controller to control the speeding and direction of motion of the car is designed. The chassis of the car is constructed with key components such as suspension system, a rack and pinion steering system, drum braking system all put into place. Finally an aerodynamic outer body shape is planned.

CONCLUSION AND FUTURE DIRECTIONS: In order to cope with the increasing demands for fuel and the disastrous environment pollution due to driving carbon-based vehicles, it is quite necessary to switch to a new source of energy, i.e. the solar power which would be a cheap, efficient, limitless and of course an ecofriendly alternative. Solar-powered electric vehicles are safe with no volatile fuel or hot exhaust systems. They are zero emission vehicles, odorless, smokeless and noiseless. They require minimal maintenance, are more reliable with little or no moving parts and can be efficiently charged nearly anywhere. Needless to say it is very much cost efficient. Since solar cars can easily incorporate future technology, we hope that it would not be long before the majority of the worlds' people would switch to driving this modern vehicle and thereby bring about a positive change in their lives and the environment. This is just the beginning of a new technology and it is guaranteed that future developments will make solar cars the predominant mode of transportation over vehicles with internal combustion engines.

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