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Experimental Study on Solar Powered Hybrid Vehicle

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Abstract

In this paper a detailed study of a solar powered hybrid vehicle has been carried out. The sustainability and efficiency of electric vehicles (The E-Car) has been assessed as well. The factors that have been considered in this study are energy flow, the electric system design, mechanical features and overall weight and costs. This paper describes the effect of a solar panel area and orientation within this tropical region like Bangladesh. Also, the vehicle dimensions and electrical system components on vehicle performance, weight, and fuel savings have analyzed. It is seen that significant fuel-savings could be achieved by using solar & electric power in comparison to the traditional vehicle. A complete set of data are analyzed to examine the technical aspects of the hybrid car technology. The solar radiation data and sky clearance rate for various time period in Bangladesh have been shown using HOMER software analysis. Hybrid technology is highly prospective in the near future.

Keywords: *Energy, hybrid car, solid work, electrical design, voltage controller*.

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1. Introduction

In recent times geologists are highly concerned about reducing the use of fossil fuels as the demand is very high than the total deposit of natural gases. Researchers are working relentlessly to solve this problem and trying to find out the best alternative to fossil fuels. Using solar energy is one of the very few solutions they have found so far. As solar energy is renewable and less harmful to the environment, it is gradually taking the place of fuels. To make the optimum use of solar power we took the initiative to work on our project E car. Our solar power hybrid car uses solar panel, batteries and windmill instead of using fossil fuels. So it can be considered as a fully eco-friendly vehicle which is the crying need of present situation of the world. By considering these things we have made our E car which is more effective and efficient for commercial uses. Hopefully E car will be able to replace the fuel vehicles and will play a major role in creating a safe and sound environment.

2. Project Aim and Objective

Our objective is to design an efficient, cheaper and most of all an environment friendly car. The design consists of a generator as an additional power source which will be used only when power from solar cells is unavailable. Thus we aim at reducing the fuel consumption thus decreasing carbon emission for daily personal automobile uses. Less noise pollution is also expected as no Internal Combustion (IC) engine is used.

3. Design and Methodology

Power transmission system of our hybrid vehicle shows in Fig.1.

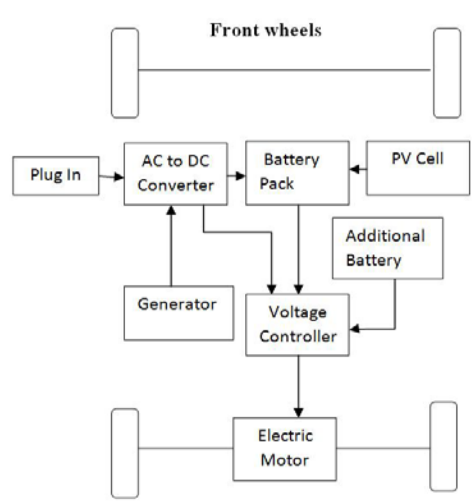

Fig.1: Transmission system of the vehicle

4. Mechanical Design

4.1. Full solid work Design

Length & width of the car is 102inch & 26inch respectively. Mild steel was used to build the chassis. We have used 1 inch by 2 inch dimensional mild steel. There are about 18 -20 welding joints in the chassis. Four leaf spring suspensions were used in the chassis. Distance from front wheel center to rear wheel center is about 54 inch & rear center to center distance is about 42 inch. Ground clearance is about 13 inch. 4 wheel of 22 inches diameter were used. Drum break was used in the system. For steering system we used power steering. Fig.5. shows the construction of our proposed car.

The front, sectional and additional solar panel views are given in the following figures:

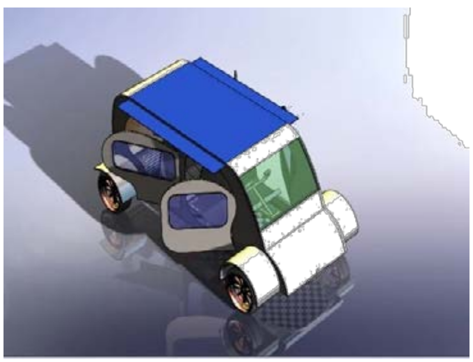

Fig.2: Isometric view

Fig.3: Sectional view

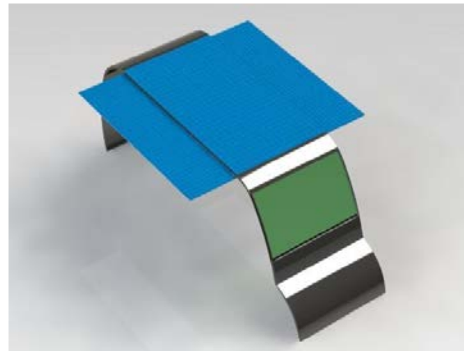

Fig.4: Solar panel while tray extended

5. Mechanical Parts Details

5.1. Leaf spring

Leaf spring is a normal suspension system. We have used it because it is cheaper than other suspension systems. It also can carry large amount of load. But at the same time it has some drawbacks. It is heavier and so increases the vehicle weight. It also produces unnecessary vibration which makes the vehicle uncomfortable.

5.2. Break

We have used only one pair of rear brakes. It is a pair of drum brakes which is controlled by foot paddle.

5.3. Steering system

Steering type is rack and pinion and minimum turning radius: 4.4 m (14.4 ft).

Fig. 5: Side view of the proposed model

5.4. **Load and torque**

The car chassis is made of 1.5/2 MS (mild steel). MS contains a maximum of 0.29% carbon and is used in almost any project. It has high toughness and also high strength so that it can carry a good amount of load. We also used differential gear instead of a chain-driven mechanism for better work of the rear wheels.

6. Electrical Design

6.1. Solar Panel

The amount of solar energy is impressive, the 89 pet watts of sunlight reaching the Earth's surface is almost 6,000 times more than the 15 terawatts of average electrical power consumed by humans. Most of the current PV panels, with multi-crystalline silicon technology, have efficiencies between 11% and 18%, while the use of mono-crystalline silicon allows increasing the conversion efficiency of about 4%. The amount of radiation theoretically incident on Earth surface is about 1360 W/m^2 (Quaschning, 2003) and only a fraction of this energy can be converted as electrical energy to be used for propulsion. Considering that the space available for PV panels on a normal car is limited.

In order to maximize the energy captured during parking mode, we can use horizontal panels (on roof and bonnet) with one tracking axis. Fig. 6 shows the power curve.

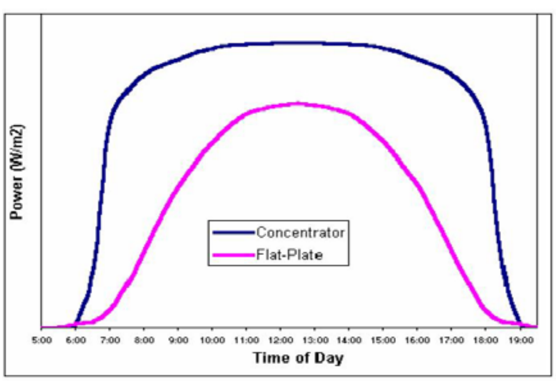

Fig .6: Power curve with respect to time of a day

The energy from PV panels can be obtained summing up the contribution from parking (p) and driving (d) periods. While in the former case it is reasonable to assume that the PV array has an unobstructed view of the sky.

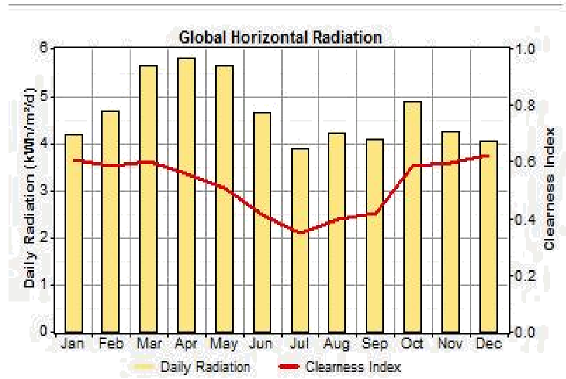

Fig.7: Power curve with respect to time of a day

This hypothesis could fail in most driving conditions. Therefore, the energy captured during driving can be reduced by a factor ¡1. In order to estimate the fraction of daily solar energy captured during driving hours (HD), it is assumed that the daily solar energy is distributed over sun hours (HS). A factor ¡1 is then introduced to account for further degradation due to charge and discharge processes in the battery for energy taken during parking. The net solar energy available for propulsion, stored during both parking and driving modes, can therefore be expressed as:

$$E_{s,p} = \eta_{PV} A_{PV} e_{sun} \frac{H_S - H_D}{H_S} \alpha \quad (1)$$

$$E_{s,d} = \eta_{PV} A_{PV} e_{sun} \frac{H_S - H_D}{H_S} \beta \quad (2)$$

Where e_{sun} is the average daily energy captured by solar panels in horizontal position. It has been assumed e_{sun} is equal to 4.6 KWH/day. Daily radiation and clearance index in HOMER analysis is given in Fig.7.

The energy required to drive the vehicle during the day Ed (kWh) can be computed as function of the average positive power P_{av}(kW) and driving hours HD:

$$E_d = \int_{H_D}^{\infty} P(t).dt \quad (3)$$

The instantaneous power is estimated starting from a given driving cycle, for assigned vehicle data, integrating a vehicle longitudinal dynamic model. Thus, required driving energy Ed depends on vehicle weight and vehicle cross section, which in turn depend on the sizing of the propulsion system components and on vehicle dimensions, related to solar panel area. The contribution of solar energy to the propulsion can be therefore determined as:

$$\lambda = \frac{E_{sun}}{E_d} \quad (4)$$

$$= \frac{E_{s,p} + E_{s,d}}{E_d} \quad (5)$$

Here we have used 150 watt four solar panels. So we can gain 54.54% (approx.) power from the solar panel [1].

6.2. **Electric Motor**

A PM motor does not have a field winding on the stator frame, instead relying on PMs to provide the magnetic field against which the rotor field interacts to produce torque. The development of low cost, high temperature magnets would lead to the widespread use of permanent magnet (PM) motors. PM motors have higher efficiency and need lower current to obtain the same torque as other machines. This would reduce the cost of power devices as well. This cost reduction is critical for market viability. The future technological challenges for the electric motors will be light weight, wide speed range, high efficiency, maximum torque and long life.

In our project we have used 1100W, 60V DC PM Motor. Maximum rated current is 22A. Its RPM is 3600. By using 3:1 gear ratio we decrease it in 1200 RPM. Motor torque calculation:

Generated torque:

$$T_g = \frac{P_w * 9.55}{n} \quad (6)$$

Where, T_g is the total torque, P_w is power of motor in Watt, n is rotation of motor in rpm

For our car:

$$T_g = \frac{1100 * 9.55}{1200}$$

$$= 8.75\ N - m \quad (7)$$

Required torque:

$$T_r = F * r \quad (8)$$

Here, T_r is required torque, F is required force and r is the radius of the wheel.

6.3. **Battery**

We have used 12V lead-acid battery. Five cell of this kind of battery are connected in series to make 60V. The whole battery pack is 130 AH. It takes 7-8 hour to recharge. According to our calculation the depth of discharge of battery is 75%. At low and extremely high temperature the efficiency of battery decreases. The battery Pack capacity in AH is-

$$B_{rc} = \frac{E_{C\,AH} * D_S}{DOD * \eta} \quad (9)$$

Where, DOD is battery depth of discharge, Ds is battery autonomy is Temperature Correction factor which is 0:9 and E_{CAH} is energy or load given in Ampere hour [2].

6.4. **Generator**

In our design we have used an 1100watt, 220V AC generator. The power is converted into 60V DC to operate the motor.

7. Control System

7.1. Charge Controller

To charge the battery pack efficiently we have used two charge controllers, one is solar charge controller and another is charge controller.

7.2. Voltage Controller

To control the speed of the motor we have used a voltage controller which will be connected with a paddle. In the basis of pressure on the paddle it will generate a pulse in the potentiometer which will control the provided voltage of the motor. Fig.8. shows the control module.

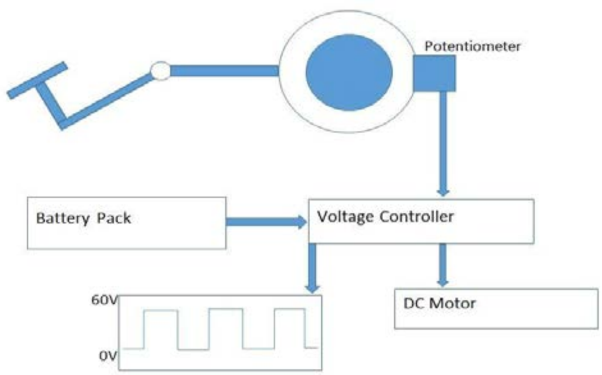

Fig.8: Control module of the proposed model

8. Solar Parking & Charging System and Station

8.1. Solar Parking System

Considering the maximum facilities we are offering a concept of building a parking system with photovoltaic (PV) panels. The PV panels can generate power that can be stored in battery throughout the day time when the car is in parked condition. For underground parking system, we can place PV panels on the roof top of the buildings providing the basement parking lot. The uses of solar panel will depend on the size of the parking lot. If the parking lot can make room for more vehicles then number solar panels can be increased. By using this system the pressure on the national grid can be reduced.

8.2. Solar Charging Station

This idea can be helpful in the case of long driving. The solar charging station can be built by using solar panels along with the CNG stations. The solar panels will store the energy in a battery during the day. If the batteries of the solar car runs out it can be replaced from any nearest charging station. Appropriate designing should be needed for better implementation of the solar parking lot as well as the charging stations using solar energy. Also further research can be done in this field to upgrade the charging system.

9. Features & Advantages of Our Proposed E-Car

In the recent years, comprehensive research work is going on for the development of solar powered electric vehicles. The most common problem for solar powered vehicle is that none of the solar panels are available that can provide required efficiency. Also, lack of solar radiation and sky clearance during rainy season and winter renders it unable to function properly. Keeping this in mind, our project was designed to mitigate these problems as much as possible. The new techniques adopted are described below.

9.1. Using Solar panels, Power Grid and Generator in a Hybrid System

The HOMER software analysis shows that during July-August time period the amount of solar radiation in our country is lowest, but at the same time the power generation almost consistently remains very high. The demand of electricity reduces too. In contrast during March-April, solar radiation is very high, though the power generation lessens to some extent. So in average, using the panel in the roof; we can get about 45% of the consumed power throughout the year. The backup generator is kept to ensure power supply when battery charge runs out in case of long drive. The DPD (depth of discharge) of the battery needs to be about 60%.

9.2. **Maximizing the Panel Area using Tray System**

As our E-Car is prevalently a solar hybrid, the area of the solar panel used is an important criterion to consider the sustainability of the vehicle. A 45 inch x 90 inch = 4050 sq inch panel is used on the roof of the vehicle to generate power from solar radiation. It is possible to generate double power by increasing the panel size twice. Two extra panels, each being half of the prime panel will be kept underneath, and they can be extended sideways like a tray to increase the panel surface two times the original area. This means the total area will be 8100 sq inch. It is to be mentioned here that this feature can only be used while the vehicle is parked. This extra power will be used to charge up the battery. Converting existing CNG stations into solar sheds: There are quite a lot of CNG stations in our country now, and if we install panels on the roof of these stations, they can be used as solar sheds to park and charge the vehicle. This way the dependency on the national grid will be further reduced.

Our E-car provides some facilities that benefit the mankind and pollution free environment. Since this is an eco-friendly car it hardly affects the environment hence pollution is reduced. The weight is significantly lower than the traditional vehicle. Also it provides comfortable driving experience with less noise and vibration. The car offers simple design and low manufacturing cost. Besides being cost-efficient the four-seated E Car can be popular to every walk of life. Wind energy can be used for back-up power generation. The average wind speed is 4.4kph in Bangladesh during the monsoon. So windmill can be used, when the solar energy is not sufficient. The back-up generator can be useful in both rainy and winter season.

10. **Conclusion**

This solar powered hybrid vehicle, designed by integrating battery powered motor and backup generator with photovoltaic panels, can represent a valuable solution for both energy saving and ecological problems, especially for urban usage. We have focused on the technological issues and challenges faced by grid-plugged hybrid electric vehicles in relation to components which can be used for design consideration and selection of electric motor and battery bank, controller circuits. Significant reduction of greenhouse gas emissions can be achieved through a simultaneous use of various technological aspects, such as the method we present of introducing photovoltaic arrays, battery storage capacity and use of generators in vehicles. This type of car does not create much pollution so it is beneficial for the environment. The cost of production is low and maintenance cost is minimal. Hence this car is very economical and environmental friendly than the conventional fuel driven cars.

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