

**DESIGN OF A SOLAR PLUG-IN HYBRID VEHICLE**Shah Alam<sup>1</sup>, Mohammad Shah Fahad<sup>2</sup>, Shahnawaz Ahmad Quadri<sup>3</sup><sup>1</sup>Associate Professor Mechanical Engg section, J.M.I, New Delhi-25<sup>2,3</sup>Mechanical Engg section, J.M.I, New Delhi-2

**Abstract-** This report shows the design of a solar plug-in hybrid vehicle, a concept that could bring a change in modern day's vehicles while searching for a new and green technologies in fabrication of vehicles because of increased consciousness in the people for green and clean environment. These vehicles are powered by sun energy, as well as by employing conventional electrical energy charging system especially in cloudy days.

In this paper, our main goal is to determine the power required to drive the vehicle, so that we can select proper size and capacity of solar panel and power storage systems. The factors like road friction, air resistance, gradient resistance and acceleration resistance have been considered for the purpose of determining the required tractive effort. On the basis of these parameters we have obtained that the total required tractive effort to propel the vehicle is 210.22 N and the required Torque at the wheels is 73.57 N-m. To fulfill the requirement of vehicle power a motor of capacity 48V, 1500W is needed. Therefore to provide the electric supply to the motor, we need 4 Batteries connected in series of 12V, 250AH capacity each. To powered the vehicle we need 10 number of PV modules of 100Wp each. To modify the vehicle to work as a hybrid system, an on-board charger is installed to charge the battery directly from electricity along with solar panels.

**Keywords-** Solar panel, On-board charger, Battery Array, Tractive effort, Traction motor

**I. INTRODUCTION**

The main goal of modern automobile industries are to reduce the fuel consumption of vehicle and thereby reducing the carbon dioxide emission in the environment. Many options have been adopted to reduce the fuel cost and its consumption such as changing vehicle to run by LPG and CNG, but these options are also adding hydrocarbons, nitrogen oxide, Sulphur oxides and particulate matter in the environment, thus increasing pollution level. Therefore in modern days there is a need to change the energy source of vehicles. To run the cleaner vehicle solar energy is one of the best options because it's costless availability and zero polluting nature. All the solar based vehicles need batteries and the amount of energy carried by batteries are still smaller than I.C engine's vehicles.

A number of studies have been done in this field. Powell et.al[1] had done dynamic analysis on hybrid electric vehicles, Bambang et.al[2] had designed the small electric vehicle using MATLAB. Nikolay et.al[3] have simulated the cooling of solar cell installed on the surface of moving vehicle, Dusko et.al[4] have investigated the combined effect of P-V systems and plug-in electric vehicle, Pedro et.al[5] have modelled energy system with significant electric mobility and solar electricity.

**II. METHODOLOGY**

While designing the solar plug in hybrid vehicle, we have adopted following steps.

- i. In the second step we will calculate the total tractive effort and torque required at the wheels considering vehicle resistances such as rolling resistance, aerodynamic resistance, gradient resistance, acceleration resistance (neglecting acceleration forces of rotating components).
- ii. In the third step we will determine the rating of motor required based on the torque required at the wheels.
- iii. In the fourth step we will determine rating of the battery and number of the batteries required to propel the vehicle for a given period of time.
- iv. Finally, we will find the rating of PV modules and number of PV modules required to recharge the batteries.

**III. ANALYSIS OF RESISTANCES**

The various forces acting on a vehicles are as follows:

**A. Analysis of rolling resistance**

This force is expressed as

$$F_r = \frac{T_r}{r_{dyn}} = P f_r$$

Where  $T_r$  rolling resistance (Nm);  $P$  normal load acting on the centre of the rolling wheel (N);  $r_{dyn}$  dynamic radius of the tyre (m);  $f_r$  rolling resistance coefficient

Table 1-Rolling resistances at different road conditions

Conditions	Rolling resistance coefficient ( $f_r$ )
Car tire on smooth tarmac road	0.01
Car tire on concrete road	0.011
Car tire on a rolled gravel road	0.02
Tar macadam road	0.025
Truck tire on concrete or asphalt road	0.006-0.01

**B. Analysis of aerodynamic drag**

The aerodynamic drag is expressed as

$$F_w = K A_F V^2$$

Where,  $A_F$  Vehicle frontal area ( $m^2$ );  $V$  Vehicle speed ( $m/s$ );  $K$  Coefficient of friction of the body of vehicle.

**C. Analysis of gradient resistance**

The grading resistance can be expressed as

$$F_g = M g \sin \alpha$$

Where,  $M$  Mass of vehicle ( $Kg$ );  $g$  acceleration constant ( $m/s^2$ );  $\alpha$  road angle (radians)

**D. Analysis of acceleration resistance**

Thus, acceleration resistance is calculated using the following formulae,

$$A_r = \frac{MgV_{max}}{gt_a}$$

Where,  $V_{max}$  maximum velocity of the vehicle;  $T_a$  acceleration time;

**IV. DESIGN DATA**

Weight of solar car = 400N

Weight of 1 passenger = 600N

Gross weight of the vehicle( $w$ ) = 1000N

Radius of rear wheel( $r_w$ ) = 0.35m

Desired maximum speed of the vehicle.

$$V_{max} = 25km/h = 6.95m/s$$

Desired acceleration time ( $t_a$ ) = 20seconds

Gradient ( $\alpha$ ) =  $6^\circ$

Coefficient of rolling resistance between tyre and road

$$(C_r) = 0.07$$

Coefficient of air resistance ( $k$ ) = 0.0032

Frontal area of vehicle = 1.824m<sup>2</sup>

## V. RESULTS AND DISCUSSION

### A. Vehicle parameters based on calculations

The total tractive effort ( $T_E$ ) is the addition of rolling resistance ( $R_R$ ), gradient resistance ( $G_R$ ), air resistance ( $A_R$ ) and acceleration force ( $F_A$ ). On the basis of calculation the following resistances are determined as:

Rolling resistance=70N

Gradient resistance=104.52N

Acceleration resistance=35.42N

Air resistance=0.2819N

Total tractive effort=210.22N

Torque transmitted to wheels=73.47N-m

power required to run the vehicle=1.436KW

### B. Selection of motor, battery and solar panel

**Table 2 Selection of various components**

Component	Make	Rating
Motor	Wuxi amthi electrical machinery co. ltd	48volt/1500watt DC motor
Battery	Motoma (Alibaba.com)	12volt/250-260 AH UPS battery solar gel deep discharge battery
Solar panel	Sukam	100Wp, ×10

On the basis of above analysis we can fabricate the solar plug-in hybrid vehicle. The solar powered cars can operate only for limited distances if there is no sun and only electric powered vehicles can run in urban areas where there is easy availability of electric power. It is not suitable for rural areas due to lack of electricity. Also purely electric vehicle indirectly contribute pollution because in India most of the thermal power plants are fossil fuel based. Therefore the design of solar plug-in hybrid vehicle can play vital role in the development of automobile industries whose main target is to minimize environmental pollution as well as making vehicle less dependent on fossil fuel.

## VI. CONCLUSION

The much work has been done in the field of solar powered battery electric vehicles but due to limited capacity of storage batteries the energy density of battery vehicle is much smaller than internal combustion engines based vehicles. Also the internal combustion engine based vehicles are much lighter. However the efficiency of electric vehicles are better than conventional fuels based engines.

The idea to develop solar plug-in hybrid vehicle can bring revolution in automobile industries

## REFERENCES

- [1] Powell, B.K., Bailey, K.E., Cikanek, S.R. "Dynamic modelling and control of hybrid electric vehicle power train systems", IEEE control systems, oct 1998
- [2] Bambang S.K., Soebagir, Mauridhi, H.P. "Development of small electric vehicle using MATLAB/Simulink", Int. Journal of computer applications, vol. 24,6, pp 19-23, 2011
- [3] Nikolay A. Vinnichenko, Alexander V., Uvarov., Tsun-Hsien wang, "Solar car aerodynamic design for optimal cooling and high efficiency", Solar Energy, vol. 103, pp 183-190, 2014
- [4] Dusko M., Tovilovic, Nikola L, J. Rajakovic, "The simultaneous impact of PV systems and plug-in electric vehicle on the daily load and voltage profiles and the harmonic voltage distortion in urban distribution system", Renewable Energy, vol. 76, pp 454-464, 2015
- [5] Pedro Nunes, Tiago Farias, Miguelc. Brito, "Enabling solar electricity with electric vehicle smart charging", Energy, vol. 87, pp 10-20, July 2015
- [6] Larminie, J., Lowry, J., Electric vehicle technology, John Wiley & sons, 2003