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Solar Car

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Abstract: In modern days, one of the most used renewable sources to produces the energy is solar energy in order to solve the some problem of energy crisis and pollution done by the carbon compounds. Basically solar car is a single sitter car and the basic principle of the car is that when sun light strikes the solar cells of the solar array, due to photovoltaic effect it produces electric current which can travel to the batteries through the connections for storage and which helps to run the DC motor through DC motor controller which in turns run the rear wheel with the help of chain drive and makes the car run. Dynamos are installed in the wheels of the car which helps to charge the battery and run the motor when sufficient sunlight is not present.
Keywords: AC, BLDC, CV, DC, PV cell.

I. INTRODUCTION

The quest for safe and 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. 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. Solar car is a solar vehicle used for land transport. When sunlight i.e. photons strikes photovoltaic cells, they excite electrons and allow them to flow, creating an electrical current. Solar cars would harness energy from the sun via solar panels. They are noiseless and pollution free with no rotating parts and need minimum maintenance. In order to make the solar car more efficient during day as well as night time dynamos are fitted on all the four wheels which helps to fuel the battery when there is no sunlight. Dynamos help to convert the kinetic energy into electrical energy which can be stored in the batteries. The electricity thus generated from the solar panel and dynamos would then fuel the battery that would run the motors which in turn run the rear wheels of the car. 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.

II. LITERATURE SURVEY

This chapter reviews about the previously published articles and literatures, and by performing an online search for information related, which lays the foundation and basic for the further work. Fig. 2.1 shows the first electric vehicle which was developed in 1970's.

Fig. 2.1 First Solar Vehicle

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King [1], the first combination of photovoltaic devices and electric vehicles happened in the late 1970's. Pressured by the oil crisis, engineers and environmentalists began looking for alternative energy sources and eventually turned to solar. To generate more publicity and research interest in solar powered transportation, Hans Tholstrup organized a 1,865 mi (3,000km) race across the Australian outback in 1987 called the World Solar Challenge (WSC), competitors were invited from industry research groups and top universities around the globe. General Motors (GM) won the event by a large margin, achieving speeds over 40 mph with their Sunraycer vehicle. In response to their victory, GM teamed with the US Department of Energy (DOE) to hold the GM Sunrays in 1990. The various competitions were designed to promote exposure and interest in the vehicles and demonstrate a proof of concept for electric and solar vehicles.

Arnaud et al. [2], made the electric go-karts have the same dynamics as competition to petrol go-karts, with an honorable autonomy of 20-30 minutes. Similarly, the charging time is relatively short, less than an hour to charge a battery, suggested the designing and building an electric go-kart is a very good teaching project for students in electrical and mechanical engineering. Discussed about the resisting power depending on the vehicle speed, accelerating torque, types of motors and controllers used energy sources and chargers.

Alpesh et al. [3], tested the kart for its fuel economy under three conditions running fully on IC engine, running fully on electric motor & running on combination of both electric and IC-engine (hybrid) used an old DC starter motor of a car which has very high current consumption of the rate of 25 amperes at start-up because of high torque requirements during start up, but it gradually decreases to 10-12 amperes as it gains speed. So the battery drains out quickly reducing the overall efficiency. Instead of this to improve the DC brushless motor can be used which have low current consumption.

Ranjith et al. [4], solves the major problem of fuel and pollution in present days. Determine how feasible widespread change to hybrids would be in future with all information taken into account, concluded that hybrids have several advantages as fuel efficient, low pollution. Hybrid Solar Vehicles (HSV), derived by integration of Hybrid Electric Vehicles with photo-voltaic sources, may represent a valuable solution to face both energy saving and environmental issues particularly in urban driving.

Taha et al. [5], use of photovoltaic systems as auxiliary power generators in hybrid and electric vehicles. This technology provides an as yet unexploited possibility with the advantages of a new power source, which is light, noiseless, maintenance-free and continuously working. A notable reduction of air emissions can be achieved through a synergy of various technological breakthroughs, such as the method we present of introducing photovoltaic arrays and additional electrochemical energy storage capacity in vehicles. Solar cars are also considered as a case study in order to demonstrate the use of solar panels in electric cars.

Brian et al. [6], the surface of solar panels on a car is limited, with respect to most stationary applications. It is therefore important to maximize their power extraction, by analyzing and solving the problems that could reduce their efficiency. Part of these aspects is common to the stationary plants also, but some of them are quite specific of automotive applications.

Hman [7], solar cell is an electronic device which can use photovoltaic effect to directly convert sunlight into electricity. Light shining the solar cell will produce both a voltage and a current to generate electric power. Photovoltaic energy conversion in solar cells consists of two essential steps. First, a material in which the absorption of light generates an electron-hole pair is required. The electron and hole are then separated by the structure of the device electrons to the negative electrode and holes to the positive electrode thus generating electrical power.

Kribus [8], primary material used in the modern collection of solar energy is silicon. Even though it takes 100 times more surface area of silicon than that of other solid-state materials to collect the same amount of energy, silicon was already developed and in mass production when solar energy collection technology was developed, and so it was the practical choice. However, any semiconductor is acceptable. The semiconductor is part of a panel called a photovoltaic, or solar cell. This cell absorbs sunlight and transfers it into electricity, typically with 15-20% efficiency. The true principle of this study centers not on the inner processes involved in the energy transfer, but rather on the efficiency of the solar cell. The purpose of solar panels and solar energy collection is for the output of power, measured in watts.

Letendre et al. [9], in the last years increasing attention is being spent towards the applications of solar energy hybrid cars. But, while cars only fed by sun do not represent a practical alternative to cars for normal use, the concept of a hybrid electric car assisted by solar panels appears more realistic. The reasons for studying and developing a Hybrid Solar Vehicle can be the large usage of non renewable sources like fossil fuels and crude oil are mainly used to run the vehicles, the carbon dioxide generated by the combustion processes occurring in conventional thermal engines contributes to the greenhouse effects, global warming and climatic changes and the worldwide demand for personal mobility is rapidly growing as a consequence energy consumption and carbon dioxide emissions related to cars and transportation are increasing.

III. COMPONENTS SELECTION

The solar car is the combination of many components which in turn produces the required final finished product. The main components used are:

- Solar panel,
- Solar charge controller,
- Batteries,
- Dynamo,
- Steering system,
- Suspension system,
- Braking system,
- Motor controller,
- Motor,
- Wheels, etc.

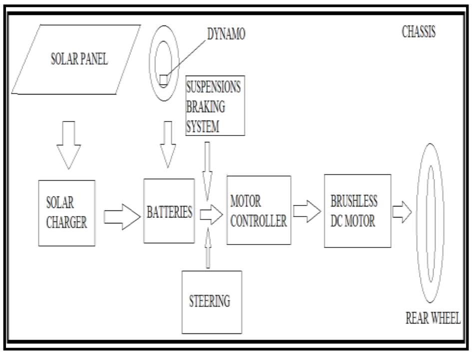

Fig. 3.1 System Architecture of Solar Car

Fig. 3.1 shows the system architecture of the solar car and the general description about the selection of the components are discussed below:

- **Solar Panel:** Solar panels today have become more efficient than they used to be before and are continuing to be increasingly efficient day by day. There are now different types of solar panels available, namely, monocrystalline silicon, polycrystalline silicon, and amorphous silicon thin film modules. Since solar cars have much less energy to work with to drive the car compared to say energy provided by internal combustion engines, it is important that this small energy is as efficiently utilized as possible. Also the lesser the space the solar panels take up over the body of the car the better it is. Therefore judging from the characteristics of three types of solar panels as described above it was most prudent to go with the mono crystalline type of solar panels but considering solar panel cost, durability, longevity, warranty, size and wattage, 375 watts polycrystalline solar panels was selected for model.
- **Batteries:** The battery to be used is a 12 V unsealed lead-acid re-chargeable battery. Despite having a very low energy-to-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.
- **Dynamo:** The dynamo in uses rotating coils of wire and magnetic fields to convert mechanical rotation into a pulsing direct electric current through Faraday's law of induction. A dynamo consists of a stationary structure, called the stator, which provides a constant magnetic field, and a set of rotating windings called the armature which turn within that field. The motion of the wire within the magnetic field causes the field to push on the electrons in the metal, creating an electric current in the wire. On small machines the constant magnetic field may be provided by one or more permanent magnets; larger machines have the constant magnetic field provided by one or more electromagnets, which are usually called field coils. The commutator is needed to produce direct current.
- **Steering System:** The rack and pinion steering mechanism system selected for the model because of lighter design and has fewer components. A rack and pinion assembly has two main components, the rack gear and the pinion gear, enclosed in aluminum housing. In a rack and pinion, the steering shaft is connected to the top of the pinion gear, which is held in the rack by a set of pinion bearings. The bottom of the pinion shaft has the pinion gear, which is meshed with the rack gear. The rack gear is a gear that has been flattened out with the teeth in a straight line. When the pinion gear turns, it moves the rack gear side-to-side. The rack

gear attaches to inner tie rods, which in turn connect to outer tie rods and hence the rotary motion from the steering wheel is turned into a linear motion to move the wheels.

- **Suspension System:** Suspension system is an assembly of springs, shock absorbers and linkages that connect a vehicle to its wheels. In a running vehicle, it is the suspension system that keeps the occupants comfortable and isolated from road noise, bumps, and vibrations. Suspension system also provides the vehicle excellent handling capabilities, allowing the driver to maintain control of the vehicle over rough terrain or in case of sudden stops.

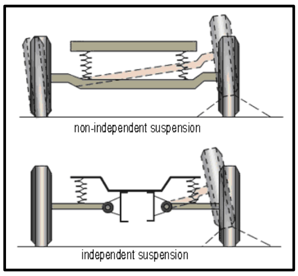

Fig. 3.2 Types of Suspension System

Different types of suspension systems as shown in Fig. 3.5 are being used in modern vehicles. Generally, the suspension systems can be divided into two groups: dependent suspension system and independent suspension system. Dependent type suspension system selected for our solar car because it has the advantages of simple structure, low cost, high strength and easy maintenance.

- **DC Motor:** After doing survey on every aspect of different types of DC motors, permanent magnet DC motor which is also known as Brushless Direct Current (BLDC) motor is a type of synchronous motor, where magnetic fields generated by both stator and rotate have the same frequency selected. The BLDC motor has a longer life since no brushes are needed. Apart from that, it has a high starting torque, high no-load speed and small energy losses. BLDC motor can be configured in 1-phase, 2-phase and 3-phase. 3-phase motors are the most popular among all the configurations. The structure of BLDC motor which is illustrated in Fig. 3.3.

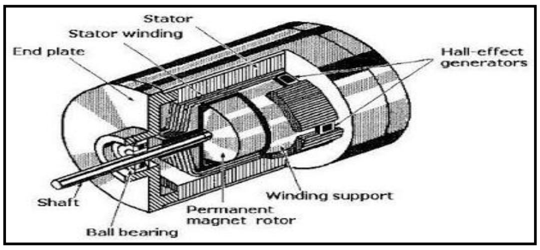

Fig. 3.3 BLDC Motor

- **Chassis Frame:** Design of the chassis was done on the basis of fixed type solar panel shown in Fig. 3.4. Another consideration is weight and stiffness. To make the car light in weight the body material should be as light as possible and material should be enough stiffer to carry the load. MS box (mild steel box) was used for building the body of the car. Typically, it is stiff and strong. Carbon steels do rust easily, but they can be easily painted or primed. They are cheap so they are the normal choice for most fabrications. Mild Steel can be easily cut or drilled to meet our requests. Mild Steel Rectangular Box Section is used for the fabrication of the model.


Fig. 3.4 Frame

IV. DESIGN AND CALCUALTION

Solar cars compared to internal combustion engine vehicles are simpler to construct and have few major components. The precise calculations of major components of the car are carried out at the design stage are discussed below;

4.1 Motor Rating

The speed and opposing forces are calculated as follows:

- Angular velocity (ω) = $\frac{v}{r}$ ……4.1

Where, r = radius of wheel = 0.1524 m

Linear velocity of vehicle (v) = 30 km/hr = 8.33m/sec

Therefore,

$\omega = \frac{8.33}{0.1524}$ = 54.68 rads/sec

Now, frequency of motor, $f = \frac{\omega}{2\pi} = \frac{54.68}{2\pi}$ = 8.702 rps = 522.16 rpm.

Hence, the speed of the BLDC motor needed is 522.16 rpm.

- Total opposing forces or total resistance (F_T) = Rolling resistance (F_R) + Aerodynamic drag force (F_A) + Force to accelerate the vehicle or Gradient resistance (F_G)

i.e. $F_T = F_R + F_A + F_G$

or, $F_T = \mu mg\cos\theta + \frac{1}{2}C_d\,\rho v^2 A + mg\sin\theta$ ………4.2

where,

m = mass of the vehicle = 350 kg

C_d = coefficient of drag = 0.35

ρ = density of air = 1.135 kg/ m^3

g = acceleration due to gravity = 9.81 m/sec^2

μ = coefficient of friction = 0.01

v = linear velocity = 8.33 m/sec

A = cross-sectional area of car = l × b = 2.7 × 1.04 = 2.808 m^2

l = length of car = 2.7 m

b = width of the car = 1.04 m

θ = inclination angle

T = torque required = $F_T \times r$ ……..4.3

P = power required to drive the motor = T × ω ………4.4

Case (i)

θ = 0°

$F_T = 0.01\times350\times9.81\cos0° + \frac{1}{2}\times0.35\times1.135\times8.33^2\times2.808 + 350\times9.81\sin0°$

F_T = 73.035 N

T = 73.035× 0.1524 = 11.13 N-m

P = 11.13× 54.68 = 608.617 watt.

Case (ii)

θ = 10°

$F_T = 0.01\times350\times9.81\cos10° + \frac{1}{2}\times0.35\times1.135\times8.33^2\times2.808 + 350\times9.81\sin10°$

F_T = 668.73 N

T = 668.73× 0.1524 = 101.91 N-m

P = 101.91× 54.68 = 5572.68 watt.

Hence, we can conclude that inclination of the road is directly proportional to power and torque required to drives the car. In our project 1000 watt motor is used to drive the car.

4.2 Battery

Capacity is the measurement of how much energy the battery can contain in Ampere hours. The capacity required will be dependent on the cars acceleration and speed as well as the total distance the car will overcome before the battery charge is depleted. In the design stage a rough estimation of the minimum battery capacity needed can be obtained. The capacity of the battery can be calculated as;

- Capacity of the battery = (load × time) / voltage of the battery ………4.5
  = (1000 watts × 1 hour) / 48volts
  = 20.83 Ah.

- Energy consumed by motor in 1 hour = power × time = 1000×1 = 1000 Wh
- Energy produced by solar panel for 1 hour = power × time = 375×1 = 375 Wh
- Energy stored in battery = capacity × voltage = 20.83×48 = 999.84 Wh
- Discharging time of battery**:** Considering battery to be fully charged
  Discharging time (without power loss) = (capacity × voltage)/power of load
  = (999.84)/1000
  = 0.99 hours
- Charging time of battery: Charging time from 0 to 100% without considering power loss = Energy stored in battery/power of panel = (999.84/375) = 2.66 Hours
- Charging time from 0 to 100% without considering power loss factor as 2.5 = 2.66×2.5 = 6.65Hours.

4.3 Capacity of Solar Panel

Total power of solar panel required to drive the solar car can be calculated as,
Total power of solar panel = [battery voltage × battery capacity × (1+ loss) × (1-state of charge)] ÷charge duration in hours ……..4.6
Assume,
State of charge = 0%
Losses = 25%
Charge duration in hours = 6 hours
Then, total power of solar panel = [48 × 20.83 × (1+0.25) × (1-0)] / 6 = 208.3 watts.

4.4 Center of Gravity Calculation

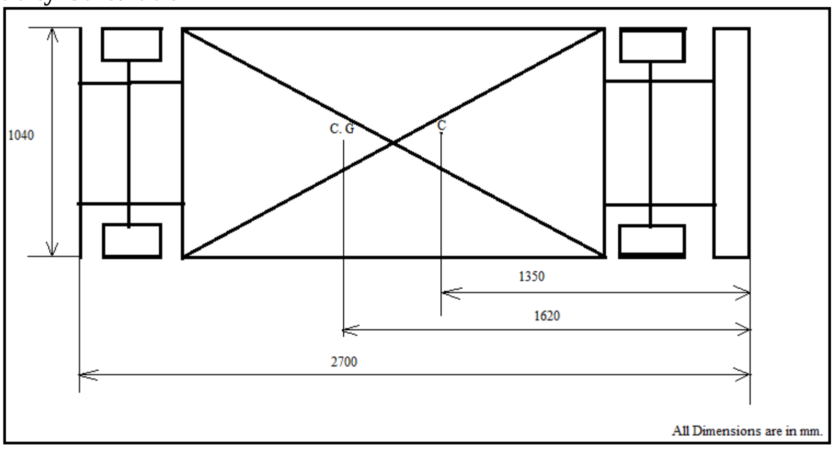

Fig 4.1 Centre of Gravity

Weight of the car (W) = 350 kg = 350 × 9.81 = 3433.5N
Weight Distribution: 40:60 (F: R)
Therefore,
Weight acts on the front side (WF) = 1373.4 N
Weight acts on the rear side (WR) = 2060.1 N
Total length of the vehicle (l) = 2.7 m
Total width of the vehicle (b) = 1.04 m
b = (WR x l) / W = (2060.1 × 2.7) / 3433.5 = 1.62 m from rear side of the car as shown in Fig. 4.1.
Centroid along the length of the vehicle = 2.7 / 2 = 1.35 m.
Centroid along the width of the vehicle = 1.04 / 2 = 0.52 m.

V. CONCLUSIONS

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 eco-friendly 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, it can be predict 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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