Economically Designed Solar Car for Developing Countries (Pakistan)

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***Abstract*— Developing countries like Pakistan, Bangladesh, and Nigeria etc. are facing severe energy and economic crises. The use and awareness of renewable energy system is strongly recommended for economic evolution of these countries. Moreover, they are also facing the problem of dreadful shortage of natural fuel (petrol, diesel and CNG). In order to combat this, our aim is to design a vehicle that could make efficient use of renewable energy source e.g. (the solar energy) as a replacement of natural fuels. Through our model, we have tried to depict the scenario relating to the feasibility of this vehicle on small commercial level, extracting power from solar panel, replacement of IC engine by dc motor, control of motor via dc drive and various other supporting features have been added as the part of this vehicle which can be considered as cost effective (manufacturing). Our experimental work also shows that the large scale commercial production of solar vehicle in developing countries will overcome some part of energy and economic distress because it decreases the dependence on natural fuel due to effective utilization of renewable energy resources, saving environment from pollution and low running cost which could be considered as a great revolution in transport system.**

Keywords—Solar Vechicle; Basic Structure; Electric Powertrain; Automatic Doors Movement, Electronic Power Steering; Automatic Light System; Charge Level Indicator and DC Motor Assembly with its Drive.

I. Introduction

In this ever growing and evolving society, transportation sector is progressing heavily day by day. So, more efficient vehicles need to be developed which are cleaner and faster. As IC engine creates pollution, now more research is being concentrated on renewable energy resources like solar power, wind power and biofuel etc. Electric vehicles or solar vehicles are emerging as a popular transport alternative, these types of vehicles are environmental and eco friendly, cleaner and require less maintenance than gas-powered cars [1]. An electrically powered vehicle has essentially three major electrical components. These include energy source (usually a rechargeable battery bank), an inverter or, motor controller and an electric motor. In the case of a solar car, the energy source is typically a bank of batteries, which may be recharged by photovoltaic solar panels. The motor controller is typically a power electronics device which when supplied with the driver's input commands, controls the torque and speed of the electric motor. The electric motor converts the electrical energy [2] supplied by the motor controller to mechanical energy used to propel the vehicle, usually through a type of transmission. For a developing country like Pakistan which imports natural fuel [3], the ever growing demand of fuel is a burden to its economy. Solar vehicles can prove valuable in decreasing usage of fossil fuel. Pakistan hasn't utilized this unending resource of energy [3] yet, and is situated in the region that has one of the highest insolation as shown in the Figure 1.

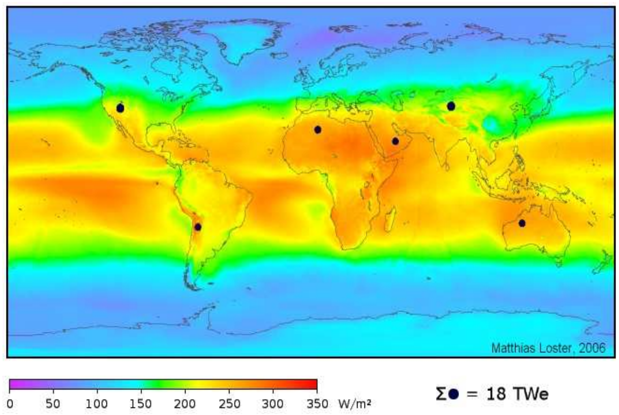

Figure 1. Average solar irradiance (W/m^2) for a horizontal surface

Most cities of Pakistan receive between 2,200 and 2,500 hours of sun [4]. Following are some motivational points that encouraged authors to design and implement economically designed solar electric vehicles for developing countries (e.g. Pakistan). Giving the concept of practical implementation of solar vehicle on commercial level in Pakistan, presenting an efficient solution to the acute shortage of natural fuels, zero running cost vehicle (approx) with even low purchasing cost if developed commercially, vehicle with zero emissions and 100% environment friendly. Almost zero maintenance cost as compared to the vehicles using IC engines which need heavy maintenance work. Furthermore, considerations like cost effectiveness, reliability also taken into account while designing process [6].

II. Experimental Work (Economical and Appropriate Design)

A. Designing the structure of solar car.

Since the task of designing the vehicle was against the nature of our field so we had to take help from various other sources. The actual dimensions of the vehicle were decided keeping in account different factors as shown in Table 1.

a.	Size of the solar panel.
b.	Sufficient space for a person to sit and drive.
c.	Space for the other equipment like batteries and electronic circuitry.
d.	Proper aerodynamic arrangement to avoid air friction.

Table 1. Main designing factors

A Light weight hollow steel pipe based structure and metallic sheet is used as base which is supportable to bear a load up to 200 kg and solid steering shaft assembly to left right turn. Authors also used shock absorber for stability purpose with comfortable single man sitting arrangement. Next task after the design of the vehicle was to get the frame moving. For this purpose the wheels were to be attached with the frame. Four small size wheels were purchased along their axles. So the rear wheels were attached with a shaft made of solid iron and was welded with the main frame. Since the front wheels are mounted with the steering and there is no shaft on the front side so a different type of arrangement is made. Further, the vehicle contains mechanical braking arrangement on rear wheels as shown in figure 2.

Figure 2. Initial structure elaborations

In order to cover the main frame a fiber glass body is used. The front and rear of the vehicle is covered using fiber glass mounted on a light weight iron frame hence enhancing the beauty of our self designed vehicle. Further, aerodynamic assessment of this vehicle is out of scope of this paper , and it will be tried in next version of this project.

B. Electric PowerTrain of Solar Car

The basic Electric Power Train of proposed Solar Electric Vehicle is shown in Figure 3 [5].

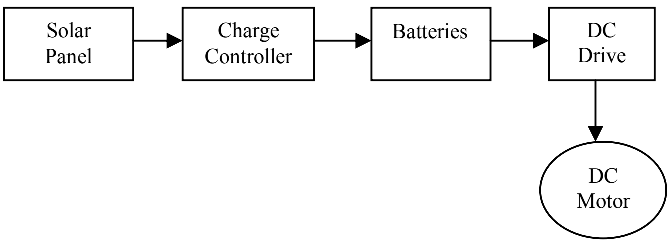

Figure 3. Block Diagram of Electric Power Train of Solar Electric Vehicle.

A 200 watt (24 Volts and 8 Amp) Polycrystalline solar panel have been purchased and fixed on the vehicle structure with a movable tilt angle setup. The panel connecting rods are capable of movement for the enhancement of the solar efficiency. Panel dimensions are 2.5 feet by 5 feet.

Figure 4. Polycrystalline Solar Panel

Two Lead Acid DC Batteries purchased and tested. Their Specifications as shown in Table 2.

a.	Voltage: 24V DC (two 12 Volts batteries in series).
b.	Current: 45 Amperes.
c.	Power Source: 1080 watts (approx).

Table 2. Electric power source ratings

The panel charge two lead acid batteries of 45 ampere and 12V which are further connected in series to run a 24 volt motor coupled to the shaft of the rear wheels, and battery charge cutter circuit designed and used along with high ampere rating diode to protect batteries from over charging and solar panel from reverse current respectively.

Further, the panel movement circuitry has been designed and tested [2]. This circuit would enable the 12 V DC motor to change the panel movement. The Relay Switching Circuit for this purpose has been shown in figure 5.

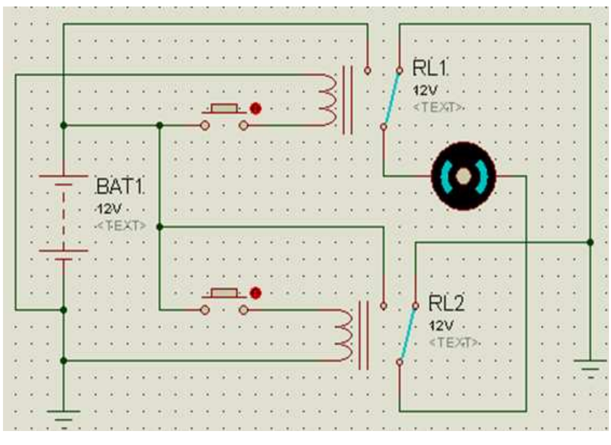

Figure 5. Proteus diagram of panel movement circuitry

Circuit for charging batteries from utility has been also designed and tested in the evening time, if one want to drive this solar car then charged batteries can be utilized. The soft and hardware design is shown in figure 6 and 7.

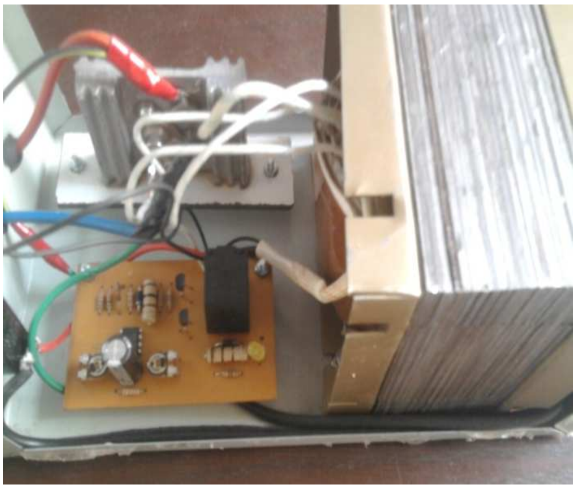

Figure 6. Battery charger along with over charging protection

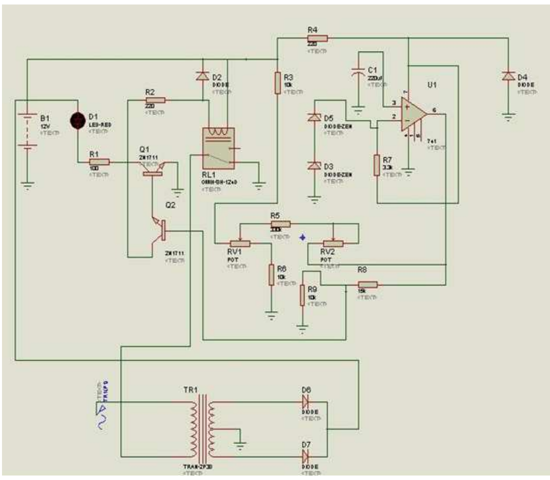

Figure 7. Proteus diagram of battery charger along with over charging protection

C. Automatic Door movement

For the automatic movement of doors a stepper circuit is employed. This circuit controls the door movement via stepper motors. Two 5A stepper motors have been employed for this purpose. The circuit contains two separate drives for these stepper motors controlled with a single microcontroller. Motor are mounted with the doors using a physical arrangement of chain and gear. One motor is given clockwise rotation while other is given counter clockwise rotation for moving the doors adjacent to each other with equal speed. The doors are made to slide on railing for smooth forward and backward movement as shown in figure 8 and 9.

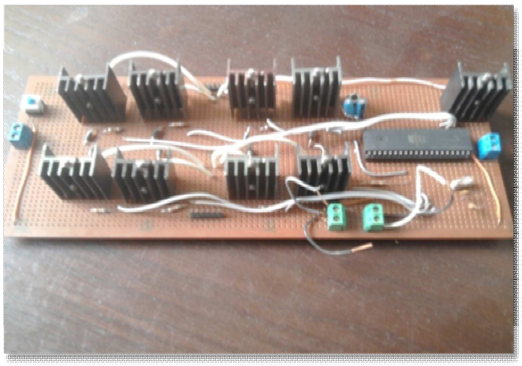

Figure 8. Stepper control circuit.

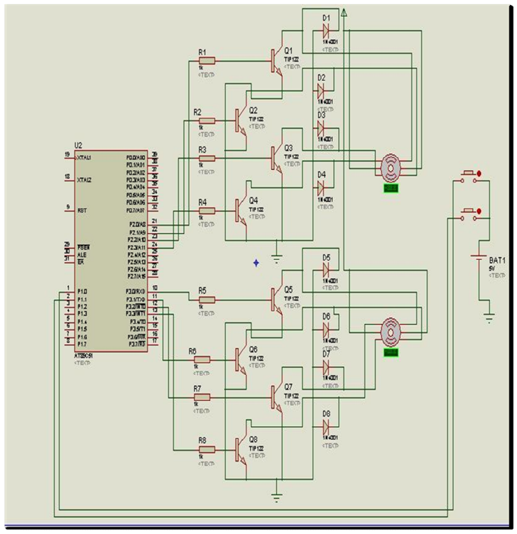

Figure 9. Proteus diagram of stepper drive

For controlling the panel and door movement by remote location, a commercial RF module can also be interfaced with these controlling circuits. This RF module can be aided with a remote to control the gadgets from a range of few meters.

D. Electronic Power Steering

For this purpose authors used the same Relay Switching Circuit like panel movement along with same 12 V DC Motor but welded the flywheel with car steering and used timing chain to couple with DC Motor.

E. Automatic Front and Rrear Light Systems (Day light sensor).

In this circuit authors used LDR with IC NE555, LED, and variable resistance of 47 KΩ etc.

F. Battery Charge Level Indicator

Authors also designed battery charge level indicator of the battery which would continuously indicate the power level of the batteries, the main component in this circuit was IC B1403N, Regulator 7805, LEDs which indicate charging of batteries.

G. DC Motor Assembling

The next challenge has been the selection of a perfect DC Motor to meet the load requirements. Since the dc motor that has been used in this vehicle has to pull a weight of approximately 150kg, so an appropriate motor was selected that could easily pull this weight. The rear wheels were to be mounted with the frame with the help of a shaft since the dc motor that had to pull the vehicle was to be coupled with this shaft. A motor fixing assembly was made on the rod that was used as a connection between the shaft and the main frame. This assembly was such that motor could be removed any time when required. The motor was to be coupled with the shaft using a chain and with flywheel. Flywheel was used to keep the shaft rotating when the dc motor was switched off thus reducing the stress on the gear and motor by freeing them. After the calculations of maximum load, authors decided that the following DC Motor would be enough to meet the load requirements as show in figure 10.

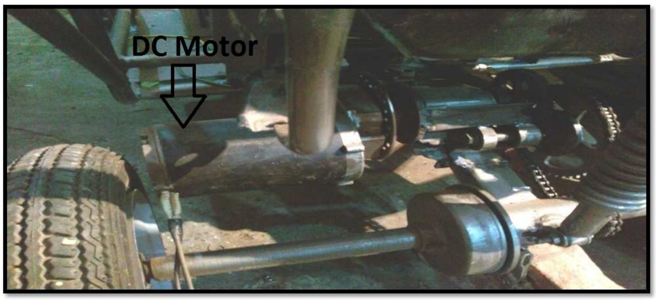

Figure 10. Assembly of DC Motor

a.	Permanent Magnet (1/2) horse power.
b.	Operating voltage = 24 volts.
c.	No load current = 9 Amp.
d.	Normal load current 20 – 35 Amp.
d.	Starting full load current = 100 Amp.
e.	Stall current = 150 Amp.
f.	Output RPM = 2000.
g.	RPM after gear = 200.

Table 3. Specifications of DC Motor

H. The DC drive used for vehicle (Motor Controller).

Since the motor used in the solar car had to pull a large weight so its current rating needs to be very high. Simple speed controllers of DC motors did not work with it since the surge current and the stall current ratings exceeded the maximum components ratings [2]. Frequent measurements showed that the surge current rose up to 100 Amp and the stall current sometimes exceeded 150 Amp. Something extraordinary that could bear such large surge of current was required to switch the flow of power to the DC motor in order to control the speed. Electronic components that are designed specially to be operated at high current rating are used in the drive circuit. TO220 package of FET's is used that is able to bear the DC current surge up to 160Amp and provides faster and efficient switching. Along with this package several limiting and protection circuits are made as a part of drive circuit. This includes the RC Snubber circuits for current and voltage limiting. These limiting circuits are also designed to work up to certain limit of current and give protection. Further current limiting features like soft start, slow acceleration and dynamic braking are used to limit the starting surge current to the motor, hence protecting both the motor and the drive circuit. Adjustment can be made for soft start using potentiometer by varying the start time according to the requirement as shown in figure 11.

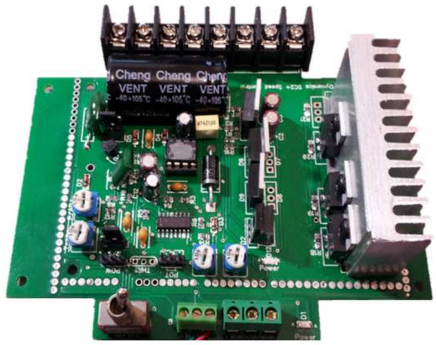

Figure 11. DC Drive circuit.

a.	12V-48V Input Voltage (Battery Bank) 12v-55V (Regulated Power Supply).
b.	0-100% Speed Regulation.
c.	Constant torque with Pulse Width Modulation (PWM).
d.	High Quality Industrial Design.
e.	Efficient High Voltage Regulator.
f.	On/Off Switch.
g.	3 Soft start settings (Off, Slow, Slower) ramps up to the desired speed once the controller is switched on.
h.	Max Current (Model Dependent) 25A, 50A
i.	High Speed Mosfet driver averaging 1.6uS opening/closing times.
j.	High Current 180A Mosfets with worlds lowest RDS On in TO-220!
k.	Low Battery Voltage cutout (for 12v, 24V, 36V).
l.	Over voltage Protected, ESD Protected!
m.	External connectors for Throttle or Potentiometer etc.

Table 4. Specifications of DC Drive

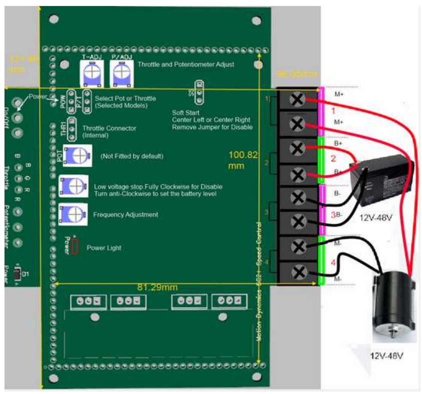

Figure 12. DC Drive connection diagram and component description.

I. Pictorial view of designed car

The final form of proposed vehicle in the limited budget is shown in figure 13.

Figure 13. The final structure of solar vehicle

III. RESULTS

- The batteries were charged by the solar panel in minimum 3.5 hrs (time may vary depending on ambient parameters). Once the batteries are fully charged the vehicle can easily cover a distance from 35 to 40 km with a speed of 40 km/h. This means that if the vehicle is run at maximum speed the batteries last for one hour. While, if the speed is slow battery time is increased. The external charging from utility is also available through a rectifier circuitry, charging the batteries in 1.25 hrs.
- Keeping in view the environmental aspects, the vehicle is best suitable in Pakistani environment. High intensity sun and longer days, especially in summer enhance the efficiency of the solar panel and its output ampere rating is increased.
- Compared with the IC engine, emissions from the solar vehicle are much lesser. The only addition to the atmosphere is the heat from the DC motor which is 98.5% less against IC engine.
- Further there are no additions of toxic gasses or pollutants as in gasoline engines that are the main cause of contaminating the Pakistani environment. In comparison the solar car is considered to be a zero emission vehicle since none of the toxic material and pollutants are added by it into the environment. Thus they can prove to be the most viable and sustainable energy vehicles in developing countries.
- Approximately zero running cost as compared with gasoline car and very little or no maintenance and are far more efficient than the IC engines that require tuning, oil change and suffer, decrease in efficiency due to knocking.

IV. CONCLUSION

Solar vehicles fill a perfect niche in the urban commute car market, where the range is short and the need for non-polluting cars is the greatest. With the total cost of only 950 US Dollars (approx), authors passionately developed this four wheel vehicle in Pakistan (a developing country) in 2012 and proved that Solar Car can be easily manufacture in anywhere. Overall this project is a depiction that solar cars can be commercialized in any developing country as a single person carrier. Moreover, it can be further extended for carrying 3 to 4 persons like a simple car which will be noise less, free of any running and maintenance cost and environment friendly.

Finally, through experimental work and results, authors are very confident that if this car manufacture commercially and promote in developing countries then it would overcome the dependence on natural fuel for transportation which would be very beneficial not only for developing countries (e.g. Pakistan) but also for humanity.

V. ACKNOLEDGEMENT

Authors would like to thank Dr. Malabika Basu for her excellent and useful remarks on this paper.

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