Design and Fabrication of a Solar Powered Toy Car

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***Abstract*— At present, solar vehicle is used as one of the cardinal energy saving vehicle where the application of renewable energy meets sustainable energy demand with reduction of fuel cost plus purification of atmosphere. In this vehicle, solar energy powers all or part of a vehicle's propulsion. For running a model car or toy car which is a miniature representation of an automobile, electric power is needed to run the car. As there lies shortage of electric power in Southeast Asian country, it has become a vital issue to initiate the use of renewable energy in developing countries like Bangladesh for reducing the demand of electricity. This paper deals with an attempt to investigate the energy recovery possibilities from the solar energy by using a solar panel which converts light energy from the sun into electrical power. That power is transmitted to the storage battery. The stored power of battery is used to run the car. Speed to weight ratio of toy car illustrates comparatively more flexible and simple than any other design when load is varying. Aerodynamic drag, weight, and rolling resistance all influence the car's design. Due to its simplicity and less bulkiness this design also reflects cost effectiveness and user friendliness.**

Keywords—battery; light weight vehicle; renewable energy; solar panel; toy car; wiper motor

I. INTRODUCTION

At present time, energy crisis has turned into a bulk throughout the world. Besides resources are decreasing with population increase. Also more energy is required to sustain the current human development. In 2012, world averaged energy demand is 17 TW and 85% of this comes from fossil fuels (coal, oil, and natural gas) For 2050 the demand will be as much as 30 TW [1]- [2]. The world energy demand vs. production difference has shown in figure 1.

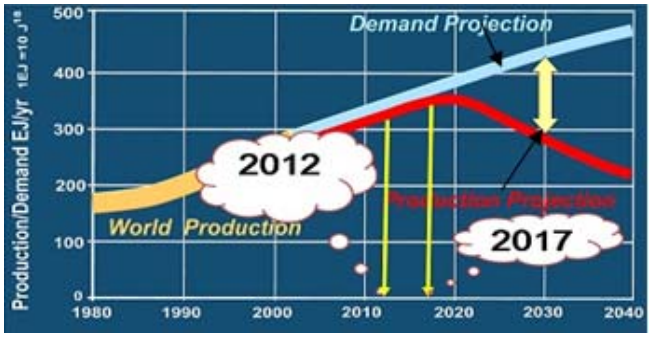

Figure. 1. World energy demand vs. production comparison

Burning more fossil fuels is not best solution for meeting future energy demand. By doing this normal condition of environment is diminishing gradually, beside world fossil fuel reserve is degrading significantly. To overcome this problem and taking account of healthy environment concern, clean and renewable sources of energy are the sound alternative of present and future energy crisis because renewable energy is regenerated after regular time cycle and constantly replenished, will never run out. There are different sources of renewable energy among which solar energy is the most available renewable energy source. Solar energy exerts energy from the sun in the form of solar diffusion for heat or to produce electricity [3]. It is found from a research that in many developing countries like Bangladesh, crisis of electric power is one of the major problems [4]. For terminating this crisis, to supersede the traditional energy source by the renewable energy source should give more priority and also utilize that energy to the machines and devices to decrease the pressure of the national grid. By taking account this problem in mind, an effort has given on designing and then fabricating a simple and low cost toy car by using solar power as its main impetus which can be afforded by all class of people. Many systems have been already designed around globe about toy car powered by solar energy. Many of these utilize monorystalline or polycrystalline silicon panels. Monocrystalline panels have a return electricity rate of anywhere from 14 to 18 percent [4]. Besides, Polycrystalline silicon panel has an electricity return rate of about 12 to 14 percent and less efficient than monocrystalline silicon solar panels. On the other hand, Monocrystalline panels are not economical for long term use. To overcome these shortcomings, this proposed system is mounted with amorphous silicon solar panels. These types of solar panels are comparatively powerful than other structure with crystalline silicon output, structure, and manufacture plus lowest electricity return rate than any type of solar panels having return rate of between 5 to 6 percent [4]-[5]. Also wheels and tyres of this system has been chosen in such a way that traction frictional force acting on it helps it to prevent from slipping while rolling along the road than other existing conventional toy car. Low weight of car is taken as important design consideration of proposed system for traveling at a constant speed. Reduced frontal area of the car and small openings design for wheel can be capable for overcome drag

force at high speed and makes it unique than other available toy car in some extents. Moreover, in maximum developing countries like Bangladesh, there is no such toy industry which can produce toy cars by their own. All of them are imported from other different countries. The design of these cars is a bit complex and their spare parts are not always available in everywhere. These toy cars are also of excessive weight. On the other hand, the price of these cars is above the purchase limit of maximum customer with lower economic condition. In this paper, an endeavor has been made to make a toy car which is simple in design, cost effective, light weight and solar energy is used to run this car.

II. SYSTEM DESCRIPTION

The flow chart of working method of total system is shown in figure 2. The main component of a solar car is its solar array, consisting of photovoltaic cells, which collect the energy from the sun and converts it into usable electrical energy. The energy from the solar panel is passed to the battery for storage through an electric connection by using wires. Then the stored power is passed to the motor, causing the drive shaft to turn. The drive shaft causes the wheel to spin. The spinning wheel moves the car forward. At low light conditions or after dark, the consumed power rate is designed low than it can be replenished too quickly. Storage batteries are mounted into the design to allow this model to operate without direct sunlight, but the weight of these battery systems really adds to a solar car's total weight. The system is designed to bear these loads with considerable amount of efficiency. The system requires a fair amount of small times to recharge the batteries. Since these batteries can be recharged many times further, then cumulative total service life exceeds that of primary batteries by a wide extends. Thus assists the consumer tremendous savings in the long run. Moreover, only a fraction of the solid waste is generated by the batteries which make the system total environmentally friendly.

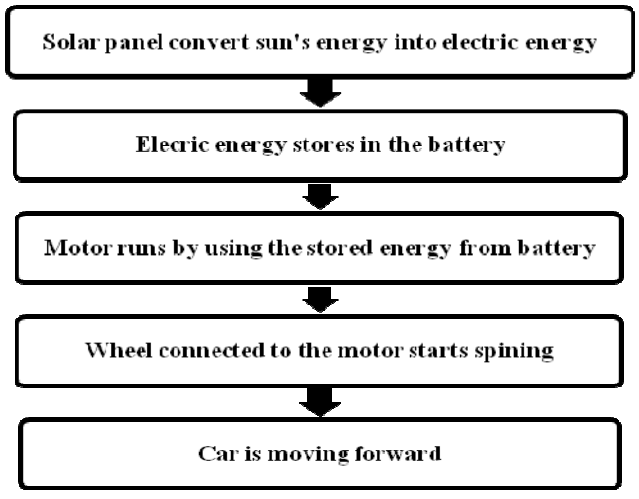

Figure. 2. Flow chart of working principle of toy car

III. FORCES AND POWER OF TOY CAR

Two forces mainly act for operating the toy car. They are drag force and frictional force. Drag is a mechanical force which opposes the motion of any object through the air. It is generated by every internal and external part of any object. Drag creates when there are interaction and contact of a solid body with a fluid which can be gas or liquid [6] . Contact with fluid is the inevitable condition of existing drag. Moreover, if there is no motion, there is no drag. So, difference in velocity is another necessary condition. It is a vector quantity that means it has both magnitude and direction. It acts in the opposite direction to the motion of vehicle. One of the important factors that affect the magnitude of drag is skin friction. It is the friction between molecules of air and solid surface of the vehicle. Again, another important factor which is considered for calculating drag is shape of the object or vehicle which is called Form drag. The local velocity and pressure are changed by flow of air around the body [7]-[8] . It is known to all that pressure is a measure of the momentum of the gas molecules and a small change in momentum produces a force. For this reason, a varying pressure distribution will produce a force on the body. For this work, drag force caused by the shape of the body is taken into consideration only. The formula for calculating drag force is

$$F_d = \tfrac{1}{2} \times C_d \times A \times \rho \times v^2 \qquad (1)$$

Here, F_d = Drag force; C_d= Drag coefficient; A= Projected frontal area; v = Velocity of the car; ρ = Density of air = 1.2 kg/m³ [9].

Besides, frictional force of the car,

$$F_r = W \times C_{rr} \times 9.81 \qquad (2)$$

Here, W= Total weight of the car; C_{rr}= Rolling resistance of the wheel.

The formula for calculating the required power to oppose all resistive force acting on car is,

$$P = (F_{resistance})(v) \qquad (3)$$

Here, P= is the required power to overcome all resistance forces; v = is the velocity of the solar car

$F_{resistance}$= is the total resistance force which is equal to:

$$\sum F_{resistance} = F_d + F_r \qquad (4)$$

The generated power to operate the car comes from solar panel which is calculated from the following relation

$$\text{Power produced} = \text{Current} \times \text{Voltage} \qquad (5)$$

IV. DESIGN OF THE CAR

The following figure 3 has been depicted to illustrate the top view of the implemented car. The main components of the car includes solar panel, wiper motor, wheels, shaft, battery, wood for frame, steel pipe for steering, tin plate for seat, washers, screws, clamps, pins Insulated wire etc. The design is made simple for economical reason and for user friendly operation. The position of these parts in manufacturing the car has shown in the following top view figure.

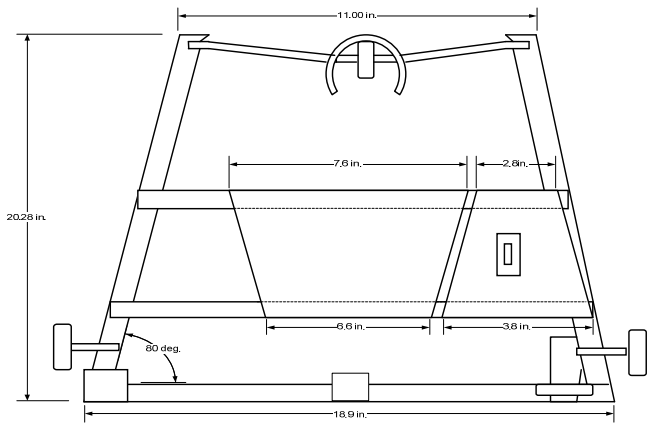

Figure. 3. Drawing of top view of the car

A. Solar Panel

The basic working principle of a solar panel is shown in figure 4 [10]. When sunlight shines on the cell, photons (light particles) bombard the upper surface. The photons carry their energy down through the cell. The photons give up their energy to electrons (in the lower, p-type layer). The electrons use this energy to jump across the barrier into the upper, n-type layer and escape out into the circuit.

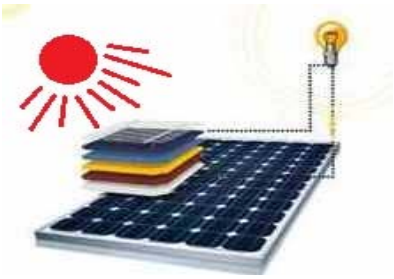

Figure. 4. Working principle of solar panel [11]

The alignment of solar panel for charging batteries of toy car is designed in such way that it will accept maximum amount of solar irridation. The generated power is used for overcome all resistive force. Since power is generated from renewable sources so it is free from genetaing smoke and fumes unlike convetional motor vehicles. The electrical ratings of the solar panel that has been used for this toy car are in the following table.

TABLE I. ELECTRICAL RATING OF SOLAR PANEL

Parameters	Value
Peak Power at 16.4 (Min Pld)	10.0 W
Voltage (Vmp)	17.0 V
Current (Imp)	0.6 A
Open Circuit Voltage (Voc)	21.8 V
Short Circuit Current (Isc)	0.7 A
Minimum Bypass Diode	1 A
Maximum Series Fuse	2A

B. Wiper Motor

Wiper motors are generally used in windscreen wiper of motor vehicles. Wiper motors are designed for two speed operation [12]. The motor consists of three brushes namely; common, low speed and high speed. Two of the brushes will be supplied for different mode of operation. The torque is high but speed is low. Its speed is about 30 rpm. This type of motor is used for proposed system because it can carry more load than micro metal geared motor which are generally used in this types of toy car. For this system, a 12 volt DC wiper motor is used which is shown in figure 5. This motor combines two mechanical technologies for its operation. A combination of electric motor and worm gear reduction provides power to the wiper also a linkage used which converts the rotational output of the motor into the back-and-forth motion of the wipers. The worm gear reduction multiplies motor torque by about 50 times, while slowing the output speed of the electric motor by 50 times as well. The output of the gear reduction operates a linkage that moves the wipers back and forth.

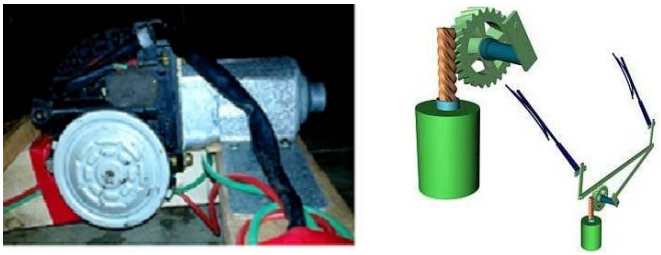

Figure. 5. Wiper Motor used in this car

C. Wheels

A wheel is a circular component that is intended to rotate on an axial bearing. Wheels, in conjunction with axles, allow heavy objects to be moved easily facilitating movement or transportation while supporting a load, or performing labor in machines. For this project, plastic wheels are used as these types of wheels are light in weight. The diameter and width of wheel that have been used here are of respectively 5 inch and 0.8 inch.

D. Frame

The frame of the car is made by wood because it is lighter than metal. This is a three wheeler car and its shape is triangular. Solar panel can be attached to the frame and directly connected to the motor when the car will run in a sunny day or the batteries can be charged previously by solar panel and then attach to the car.

E. Steering

Steel pipe is used for steering. A collar is welded with the axle of the front wheel. Then the steering is welded upon it. This arrangement is attached with the main frame of the car by using two flat bars whose one ends are welded with the steering and other ends are screwed with the wooden frame. It is shown in figure 6.

Figure. 6. Steering arrangement

F. *Switch Board*

There is a series connection among motor, battery and switch which is shown in figure 7. Motor's positive wire is connected to positive wire of battery-1. Negative wire of battery-1 is connected to battery-2's positive wire. Battery-2's negative wire is connected to one and of switch whereas another end of switch is connected to the negative wire of motor.

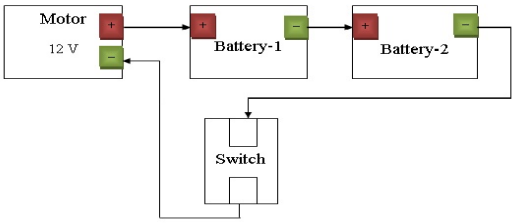

Figure. 7. Connection of motor and battery with switch

V. BATTERY AND STATE OF CHARGE WITH LOADS

Rechargeable alkaline battery popularly known as one types of secondary battery is used for solar car for its lowest cost rechargeable cells, a long shelf life and for moderate-power applications. Their cycle life is less than other secondary batteries, but having powerful cells with the added benefit of re-use after recharging. They can be reused 25 times or more, so to economical to the consumer. They give longer life per charge, hold power in storage and work far better than the old fashioned NiCd rechargeable batteries [13]. These packs can be charged properly for a dedicated charger have no memory problems, up to a seven-year shelf life and having lifetimes three times longer than a fully charged nickel cadmium rechargeable battery [13]. Absence of necessity to be fully drained before recharge and moderate to low current consumption, rechargeable alkaline batteries are taken as the best economical choice for this proposed solar toy car. Moreover they lack toxic ingredients, so friendly to environment. Storage capacity of batteries also has a relation with varying load on car. State of charge of batteries with different load for 30 minutes run has shown in the following table 2. The table represents when load increases, charge of batteries decreases with a slow rate. This relation can be shown graphically in figure 8.

TABLE II. STATE OF CHARGE WITH DIFFERENT LOAD

Load	Charge
No external load	11.72 V
0.5 kg	11.08 V
1.0 kg	10.48 V
1.5 kg	9.86 V
2.0 kg	9.22 V
2.5 kg	8.61 V
3.0 kg	7.98 V

The following figure 8 shows the decreasing rate of the battery charge with the increase of the load. But this charge decreasing rate is comparatively low.

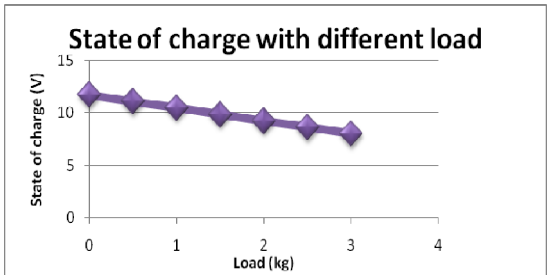

Figure. 8. Graph showing the state of charge with different load

VI. INTEGRATION OF ALL PARTS

Since it is a playing thing for children, maximum effort has been given for making the car as simple as possible. This toy car is made with least number of joints to reduce friction. As the solar panel is very heavy, so the batteries are charged separately and then attach it in the car frame to connect with motor. Different views of the car are shown in figure 9 and figure 10.

Figure. 9. Side view of the car

Figure. 10. Top view of the car

VII. RESULT AND PERFORMANCE ANALYSIS

After experiment the car needs about 15% of the total energy to moving its body, rolling resistance represents about 25% and air drag is about 60%. Drag force waxes with speed during the car runs, for slower speed, where air drag on car can be assumed at minimum but frictional force is increasingly large. The system is capable is capable to overcome all obstacle forces.

A. Drag force

For this car, $C_d = 0.338$ (assuming),
$A = 0.1206$ Meters square,
$v = 0.398$ Meters per second
Substituting these values from (1),

$$F_d = (0.5\times0.338\times0.1206\times1.2\times0.398^2) \text{ Newton}$$
$$= 7.79\times10^{-3} \text{ Newton}$$

B. Frictional force

Here, W= 4.6 Kilogram
$C_{rr} = 0.3$ (assuming)
From (2), frictional force of the car,
$F_r = 4.6\times 0.3 \times 9.81$ Newton
= 13.54 Newton

C. Power required

From the equation (4), the required power can calculate

$$\sum F_{\text{resistance}} = (7.79\times10^{-3}+13.54) \text{ Newton}$$
$$= 13.5478 \text{ Newton}$$

Substituting this in (3),

$$P = \{(7.79\times10^{-3}+13.54) \times 0.398\} \text{ Watt}$$
$$= 5.39 \text{ Watt}$$

D. Power produced

Maximum power this solar panel can produce is 10 Watt
From (5) the storage capacity of a battery is,
Power= (4.5 Ah) × (6V)
= 27 Watt
Total storage capacity of both 2 battery is (27+27) = 54 Watt

E. Performance evaluation

The velocity of car depends upon weight on the car.

TABLE III. VELOCITY IN DIFFERENT LOAD

Load (Kg)	Velocity (Km/hr)
No external load	1.47
0.5	1.43
1.0	1.38
1.5	1.30
2.0	1.23
2.5	1.18
3.0	1.12

But the table shows when load increases significantly velocity drops not at high rate which is one of main advantage of proposed system. Since velocity to load ratio decreases not so fast for proposed toy car so it can be regarded as best proto model for designing larger one. This relation can be shown graphically in figure 11. For the velocity control, PID control scheme can be used [14]. For a smart power management, PID and integrated intelligent control can be used in future research like hybrid electric vehicle to get best performance of this car [15]-[16].

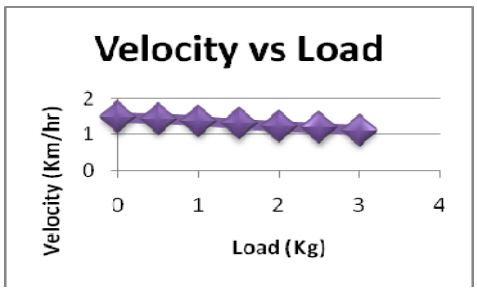

Figure. 11. Graph showing the change of velocity with load

F. Cost Analysis

To invest in a project, an investor first has to think how much time it would need to recover his investments. This proposed toy car is one of the best choices if he wants to be benefitted economically [17].
Let an investor wants to produce 40 this types of toy car initially. The making cost of each car is BDT 3000. So he has to invest BDT 1, 20,000 initially. Average profit of per month subtracting different costs such as workers salary, house rent etc is BDT 18000. Average maintenance cost per month is BDT 500. Let, the interest rate per year is i=14% ; Nominal interest rate for 12 months r=x; No. of compounding periods, m=12.
Therefore, $i= (1+r/m)^m-1$
So, $1.14=(1+x/12)^{12}$
And, x=1.09% / month
So the cash flow diagram is as follows in figure 12.

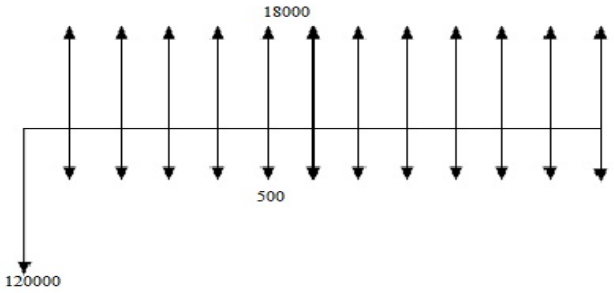

Figure. 12. Cash flow diagram

Therefore present worth after one month is
PW_1=18000(P/A, 1.09%, 1)-500(P/A, 1.09%, 1)
=17325
Present worth after 2 month is
PW_2=18000(P/A, 1.09%, 2)-500(P/A, 1.09%, 2)
=34434.75
Present worth after 6 month is
PW_6=18000(P/A, 1.09%, 6)-500(P/A, 1.09%,6)
=101412.5
Present worth after 8 month is
PW_8=18000(P/A, 1.09%, 8)-500(P/A, 1.09%,8)
=133910

So here we see that the capital will recover within 8 months.
Ratio of present worth to capital for 8 month is
= 133910/120000 = 1.12
For one year, we may calculate the benefit
B = 18000(P/A, 1.09%, 12) = 18000(11.191)
=201438 BDT
M&O cost=500(P/A, 1.09%, 12)
=500(11.191) =5595.5TK
Modified B/C ratio= (B-D-M&O cost)/C
= (201438-5595.5)/120000 = 1.63
The project is justified since B/C > 1

VIII. DISCUSSION

The proposed system handle only one motor which is connected to one of the rear wheels i.e. this car has one power wheel. Thick plastic or other lighter material can be used to make the car as lighter as possible. Despite several advantages, there is no control system for controlling the rpm of the motor, sometimes it creates problem during turning. Because during turning, the rpm of inner wheel must be lower than outer wheel. A controller should install to control the rpm of wheels while turning to overcome this problem. Also power tracker is not used with the battery. Moreover, the speed of the car can be increased by changing the car shape to airfoil. Because the value of drag coefficient is very small and this reduces the drag force. In this system, no power tracker is added to the battery. When the solar panel is charging the batteries, power tracker will help to protect the batteries being damaged by overcharging. A simple transmission system by using 2 meshing gears can also be installed for making the car more efficient.

IX. CONCLUSION

The proposed solar toy car runs efficiently using solar power effectively without any basic problem. In Bangladesh, there is no such a big toy company where engineers can work and apply their engineering knowledge to make innovative toys. As most of the toy cars are imported from abroad, their price is very high [18]. So, maximum middle class people cannot afford to buy these toys for their children. If these types of toy cars can produce industrially in Bangladesh by using local equipment, the cost will be low.

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