Development of a light solar-powered electric vehicle

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Abstract–

The objective of this paper is to present a case study of designing a solar powered electric vehicle for use in surveillance and monitoring applications. The reason for using solar generated power is to investigate the role of renewable energy in powering electric vehicles. This is due to the increase in greenhouse gases due to fossil emissions and the fact that oil is unsustainable resource. Therefore, electric vehicles become an interesting choice due to their inherent advantages: quiet operation, zero operational emissions and comparatively lower maintenance costs. This when combined with using solar power can reduce/eliminate the need for charging an electric vehicle, which is an added advantage. In this paper, this concept has been applied through preliminary analysis of an electric golf cart. A summary of the overview of solar power technology was presented, focusing on the efforts in automotive applications. This was followed by a simple introduction to the main components of a solar powered electric vehicle. The experimental and theoretical work to convert an existing electric golf cart to a solar powered electric vehicle was described. Finally, a comparative analysis between initial vehicle and final one was introduced.

Keywords—solar-powered, electric vehicle, solar panels, photovoltaic, solar energy

I. INTRODUCTION

In recent years, greenhouse gas emissions and exhaustion of natural fossil resources have become serious global issue.
At the moment, we depend on energy made from the Earth`s sources such as: gasoline, diesel, natural gas...etc.
The problem with these nonrenewable sources of energy that they won`t last forever and we are already starting to run out, that`s why we should look for renewable sources of energy as we run out of these fossil fuels, especially in the field of automotive engineering, we should look for an alternative for internal combustion engines vehicles.
Internal combustion engines have several problems that affect the environment due to gas emission which come from these engines [1].
The air pollution that warming the earth as a result of pollutants from the automobiles, which is about 23% of the total air pollution due to the increase of internal combustion engine vehicles as shown in Fig.1.

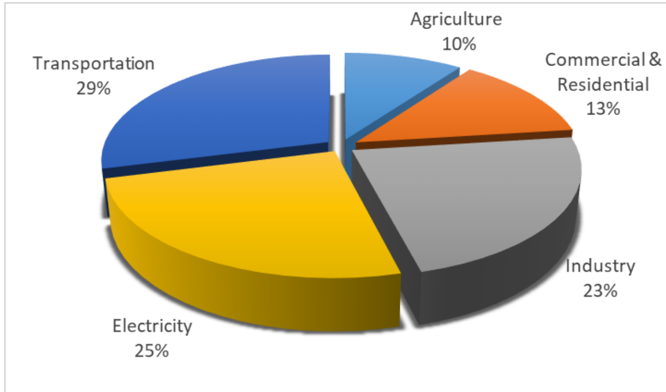


Fig.1 Different Sectors of CO_2 Emissions [2].

So solar-powered electric vehicle is one of the solutions because it is pollutant free.
Solar energy is one of the important sources of renewable energy as it solves the problem of pollution and reduces the emissions that have a bad effect on environment. Solar-powered electric vehicles have many advantages as they provide less noise, less carbon dioxide emissions and saving energy.
The problem with the renewable energy was that we were not able to store this energy. Things like wind and solar power only work when there are wind and sun around. They also cost a lot more money to install but now we can easily store this energy in batteries to use it at night and when needed.
Research and development on batteries have increased the battery capacity, made it able to store more energy, and increased the vehicle mileage.
Generally, the advantages of using solar power are:

- A clean energy.
- Renewable source of energy.
- They require little maintenance.
- They are reliable.
- They don`t produce any noise.
- Appropriate for remote locations.

The disadvantages of using solar power are:

- Relatively high initial cost to buy and install.
- Do not generate power at night.
- Currently, relatively low efficiency.

Research and development have been made on solar panels to make them more efficient and less expensive over years. The following figures show the reduction in cost and the increase in solar panels efficiency as shown in Fig.2.

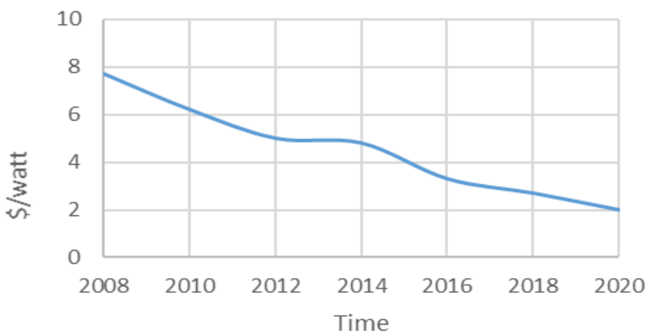
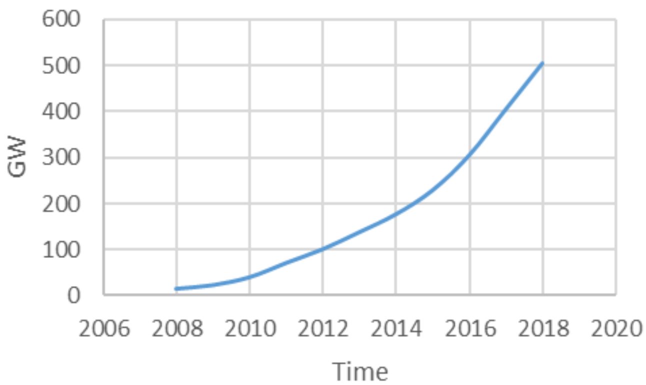


Fig.2 (a) Cost of Solar Energy [3].



(b) Growth of Solar PV (in GW) [4].

Electric vehicles paved their way into public use as early as the middle of the 19th century.

In 1970, the first hybrid type of photovoltaic devices and electric vehicles were manufactured. To generate more publicity and research interest in solar powered transportation, Hans Tholstrup organized a 1.865 miles (3000 km) race across the Australian outback in 1987 as shown in Fig.3. 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 vehicle. In 2005, a longer (3960 km) race was organized from Austin, Texas, USA to Calgary, Alberta, Canada.

Fig.3 WSC Track in Australia [5].

II. WORKING PRINCIPLE

A solar-powered electric vehicle gets the energy it needs to move by using photovoltaic (PV) effect to convert sunlight into electricity. A solar vehicle absorbs the sunlight and convert it to electricity by a device called a solar cell. PV modules consists of a number of interconnected solar cells encapsulated into a single, long-lasting and stable unit. The purpose of encapsulating a set of electricity-connected solar cell is to protect them and their inter-connecting wires from the environment in which they are used.

Fig.4 shows that the electricity is used to drive the electric motor and the excess electricity is stored in a battery to be used when needed or at night.

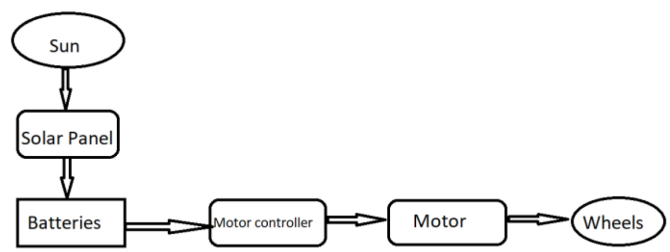


Fig.4 Working Principle of Solar-Powered EV [4].

III. SYSTEM COMPONENTS

A solar panel consists of a layer of silicon cells as shown in Fig.5, a metal frame, a glass casting and various wiring to allow current to flow from the silicon cells. Silicon is a non-metal with conductive properties that allow it to absorb and convert sunlight into electricity. When light interacts with a silicon cell, it causes electrons to be set into motion, this movement of electrons creates a flow of electric current through the panel`s wire. Wires feed this direct current (DC) electricity to a solar inverter to be converted to alternating current (AC) electricity.

A. Solar Panel

Fig.5 Solar Panel [4].

B. Power Tracker

Fig.6 Power Tracker [4].

The role of power tracker is to convert solar array voltage into system voltage. It sends the remaining energy to the battery.

C. Batteries

It stores the excess amount of electricity to be used at night. Therefore, the battery capacity should be high to increase the amount of stored energy and to increase the covered distance by vehicle.

Fig.7 Battery [4].

D. Controller

The motor controller adjusts the amount of energy that flow to the motor to correspond to the throttle.

E. DC Motor

A DC motor converts direct current electrical power into mechanical power. Fig.8 shows the motor that we actually used.

Fig.8 DC Motor

IV. Design Activities

A. Taking the dimensions

We took the dimensions of the old vehicle.

B. Weight measuring

We measured the weight of the old vehicle and calculated the C.G point.

Fig.9 Golf Car

C. Drawing the vehicle model in SOLIDWORKS.

We drew a model for the vehicle in SOLIDWORKS to simulate the real one.

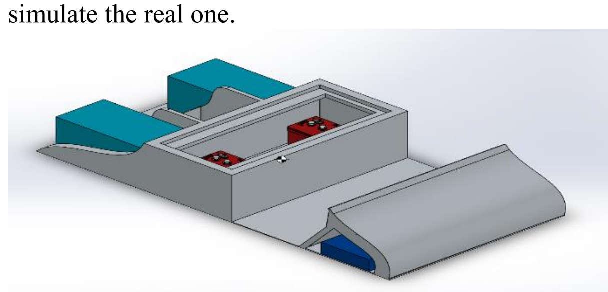
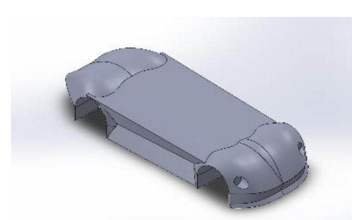


Fig.10 Old Simulation

D. The new body design iteration.

We drew the model of the new body on the old chassis taking into consideration the dimensions of the solar panels. The following figures shows our design iterations.

-Design Iterations.



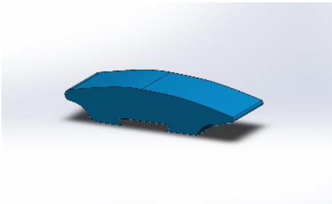


Fig.11. 1st design.

Fig.12. 2nd design.

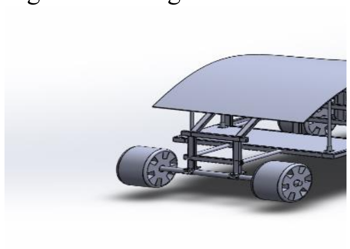


Fig.13 Final design for sheet fixation.

E. Solar Panels Fixation

We mounted four flexible monocrystalline solar panels on the body of the vehicle as they have the highest level of efficiency.

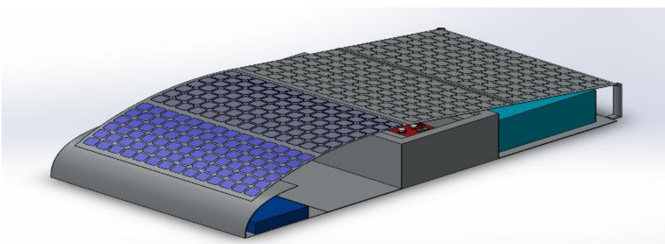


Fig.14 Solar panels fixed on the sheet.

V. CALCULATIONS.

A. The vehicle traction.

To actually calculate the resistance of the vehicle and the needed power, it should be according to specific driving cycle, but for simplicity we assume that the vehicle moves with a constant speed of 10 km/hr. (W=360 kg).

Assume that:

$$f = .02 \quad k = .4 \quad F = 1.8 \quad \theta = 5^{\circ}$$

$$Pf = G * f$$
$$= 360 * 9.8 * .02 = 71\,(N)$$

$$PV = (k * F * V\text{^}2)/13$$
$$= (.4 * 1.8 * 10\text{^}2)/13 = 5.5\,(N)$$

$$P\alpha = G * sin(\theta)$$
$$= 360 * 9.81 * sin(5) = 308\,(N)$$

$$Ptot = Pf + PV + P\alpha$$
$$= 360 + 71 + 308 = 385\,(N)$$

$$Needed\ power = Ptot * V$$
$$= (385 * 10 * 5)/18 = 1250\,(watt)$$

Where…

- P_f… Rolling resistance.
- G… vehicle weight.
- f … Coefficient of rolling resistance.
- P_V… Air drag resistance.
- k … Coefficient of air drag.
- F… Frontal area.
- V… Vehicle speed.
- P_α… Grade resistance.
- ɵ … Grade.

B. Battery capacity.

Battery capacity is measured in Amp Hours (200 AH). To convert it to Watt Hours is should be multiplied by the battery voltage (48 V), then multiply the result by .7 (for 70 % discharge).

$$For\ a\ 200\ AH, 48\ V\ battery\ the\ Watt\ Hours\ is:$$

$$200 * 48 * .7 = 6720\ WH.$$

This mean that the battery can supply 2400 W for 1 Hour or 1200 W for 2 Hours, i.e., for more energy, the battery discharges fast.

C. Solar panel generation over a period.

The power generation rating of a solar panel is also given in Watts (175 W). To calculate the energy, it can supply to the battery, multiply Watts by the hours exposed to the sunshine, then multiply the result by .67 (for natural system losses).

For 4 solar panels each of (175 W) exposed to sunshine for 7 hours

$$175 * 4 * 7 * .67 = 3283\ WH.$$

This is the amount of energy that the solar panels can supply to the battery.

D. The operating time of the vehicle.

$$Operating\ time = (6720 + 3283)/1250 = 7.1\ hrs.$$

The new design and components improvement and their effect on the working time of the vehicle as shown in Fig.15.

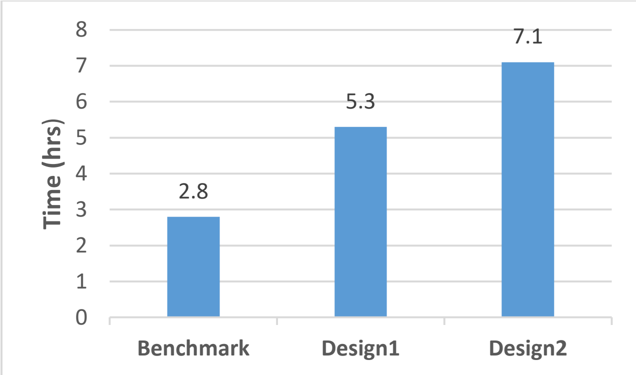


Fig. 15. Effect of new batteries and solar system on operating time.

This figure shows that the operating time has increased by 153.5% after using new light batteries and solar system and after developing the vehicle to be unmanned.

Where...
- Benchmark… The old vehicle.
- Design1… The vehicle with new battery system.
- Design2… The unmanned vehicle with new battery and solar systems.

The effect of new design on the vehicle weight is shown in Fig.16.

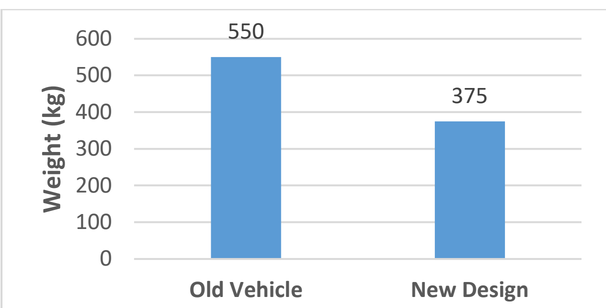


Fig. 16. Effect of the reduction in weight

VI. CONCLUSION

The objective of this paper was to develop an unmanned solar-powered electric vehicle for surveillance and reconnaissance purposes. A case study was presented based on a golf cart that is currently available at the automotive department in the military technical college. Its specifications were measured and used as a benchmark. Several design iterations were taken for continuously improving the efficiency of the cart in terms of weight and operation time. A new design was reached that benefitted from covering the outer surface with flexible solar panels and replacing the old electric batteries with lighter and more efficient ones. This resulted in a 34 % increase in range.

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