Design of one-person car for urban commute in the new administrative capital

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Abstract–
Egypt is entering the 21th century with a new administrative capital MASA capital. The new capital should provide a pollution free environment for its inhabitants. This is to ensure that the new capital adheres to the latest sustainable development goals set by the United Nations. Therefore, the transportation system must include the state of the art design technologies to minimize vehicle weight while producing minimum to zero emissions. Moreover, the vehicle should comply with the road and crashworthiness safety standards. This poses a challenging design task, as these are conflicting objectives. Electric vehicles provide such an optimal solution for this conflict. In this paper, we present the design of a concept car for one person commuting inside the new capital. We succeeded in obtaining the primarily design of a lightweight electric vehicle that uses solar panels to recharge its batteries. It is capable of making 60Km daily at average speed of 50Km/h without recharging.

Keywords—friendly solar-powered electric vehicle, solar panels, MASA capital, administrative capital.

I. Introduction

Previously, we were depending on nonrenewable sources of energy (petroleum fuels) such as gasoline, diesel, natural gas…etc.

The problem of these fuels is that they will not last forever and we are already starting to run out of these petroleum fuels. In addition, these fuels have several problems that affect the environment as the exhaustion of petroleum fuels increase gas emissions and cause global warming. Transport is one of the largest sources of greenhouse gas emissions and fossil-fuels consumption.

Air pollutants from an automobile affect human health hardly so; we should look for an alternative for internal combustion engines vehicles. A solar energy is renewable and less harmful to the environment; it is gradually taking the place of fuels. So solar-powered electric vehicle is one of the solution because of pollutant free. Our solar-powered electric vehicle uses solar panel and batteries instead of using fossil fuels. So it can be considered as a fully eco-friendly vehicle. Solar-powered electric vehicles have many advantages as they provide less noise, less carbon dioxide emissions and saving energy. All these advantages make it useful and suitable for using it in the new administrative capital.

So, electric vehicles, which are powered by electricity, are considered as a promising solution to roadside air pollution and health damage. Lot of governments has established policies or goals to promote the deployment of EVs. For instance, the Swedish government has set a goal that 100% of the national energy used in vehicle fleets should be independent of fossil fuel by 2030 [1].

II. HISTORY OF SOLAR VEHICLES

In the late 1970's photovoltaic devices and electric vehicles were combined for the first time. Facing the pressure of the oil crisis, engineers and environmentalists started looking for an alternative source of energy and finally found solar as the best alternative. In order to create more coverage and examine interest in solar powered transportation, Hans Tholstrup organized a 1,865 mi (3,000 km) race across the Australian outback in 1987, better known as the World Solar Challenge (WSC), in which competitors were invited from industry research groups and top universities around the globe. General Motors (GM) with their Sunraycer vehicle won the event by a large margin, achieving speeds over 40mh [2]. In response to their success, GM came up with the US Department of Energy (DOE) to hold the GM Sunrayce in 1990 [3]. Approximately the same length as the WSC, Sunrayce is considered a more difficult race due to more varied terrain and climates as well as more challenging road surfaces and traffic blocking. USA conducted American Solar Challenge in 2001, then the North American Solar Challenge in 2005, which are now held every two years across different routes. A new record for the longest solar vehicle race, covering 2460 mi (3960 km) from Austin, Texas, USA to Calgary, Alberta, Canada was setup in the year 2005. Initially motivated by research, the building of solar vehicles is now referred to as "brain sport," developing dozens of new vehicles each year for the sole purpose of competition, not production. Solar vehicle competition enables engineers to research and develop new technologies. With the unique nature of the solar community and events, these technologies remain an available resource. Considerable improvements and attentive technologies of electric vehicles has been developed that can be applied to a broader range of automobiles to provide more efficient, effective and reasonable alternatives over combustion engine vehicle.

The objective of this competition is to promote the innovation of solar-powered cars. It is a design competition at its core, and every team/car that successfully crosses the finish line is considered successful. Teams from universities and enterprises participate. In 2015, 43 teams from 23 countries competed in the challenge.

Fig. 1. WSC Participants [4].

III. WORKING PRINCIPLE OF SOLAR VEHICLE SYSTEM

The detailed system architecture of the complete electric drive system of the solar car is shown in a block diagram in Fig. 3. The solar panels mounted on the roof of the car will collect energy from the sun and convert it to usable electrical energy that will be stored in a lead acid battery through a charge controller. The charge controller will ensure healthy life of the battery by preventing over charging and over discharging of the battery. The solar car will also have a provision of plug-in charge when there is not enough sunshine due to cloud, fog or rain. This provision for external plug in to charge the batteries from the conventional power supply will also allow the car to increase its capacity to drive for longer distance by putting additional batteries and charging from the power supply lines. The voltage controller will maintain a constant voltage at its output as is required by the motor, irrespective of the panel or the battery voltage level [5].

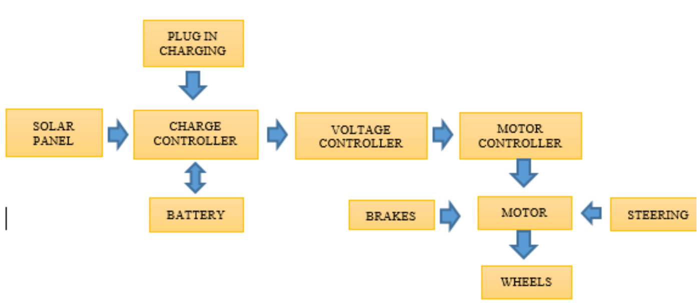


Fig. 2. Block Diagram of Solar Vehicle System

IV. CHARGING PROBLEMS

A. Solar Power

The problem with the solar power is that the power generated by the solar panel system is low, as the maximum efficiency of the available flexible solar panels in the market does not exceed 25%. Therefore, we selected the most efficient flexible solar panel in the market to make the most benefit of it, and we maximized the area on the roof of the vehicle as much as possible to increase the generated power and to increase the range of the vehicle.

Fig. 3. Selected Flexible Solar Panel

Company	Renogy
Model	RNG-175DB-H
Type	Flexible Monocrystalline
Power	175W
Dimension	59.2 × 26.5 × 0.08 in
Weight	6.2ibs
Price	$1.6/Watt

Table 1. Specifications of Flexible Solar Panel

B. Batteries

The challenge with the battery system is that we should select a battery system with lightweight and more efficiency and capacity. Therefore, we looked for the most suitable battery according to our requirement in the market and we selected the following one.

Model Number	48V160Ah
Application	Toys, Power Tools, Golf Carts, Electric Vehicles, Electric Power Systems
Place of Origin	China
Weight	38Kg
Nominal Capacity Per Ah	160
Standard Charging Current /A	32
Standard discharge Current /A	160
Maximum Charging Voltage /V	58.4
Cut-off discharge Voltage /V	46.4

Table 2. Specifications of the Selected Battery [6]

C. Vehicle Structure

The structure of the vehicle is very important as it should carry the load of the passenger and his cargo, and should be stiff enough to make the passenger and the vehicle safe if the vehicle make an accident or during maneuvering. The problem is that the structure should be light to increase the range of the vehicle. Therefore, the challenge was to make the structure from aluminum to be light as much as possible and it should be stiff.

The vehicle main chassis structure was made using hollow aluminum, and we made simulation on SOLIDWORKS to make sure that the vehicle structure will carry the load and will be stiff enough, and we got the following results.

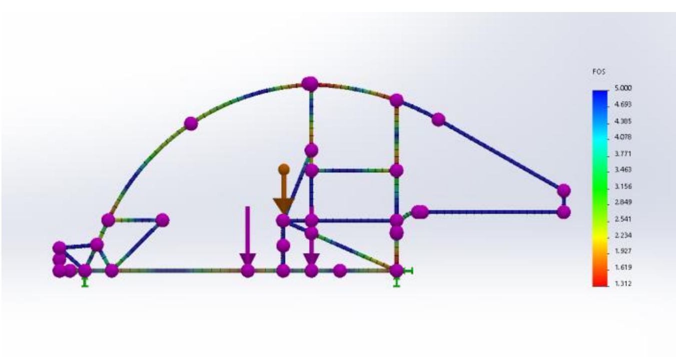


Fig. 4. Results for FOS

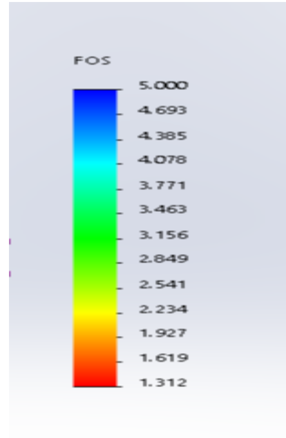


Fig. 5. Results for FOS

V. CALCULATIONS

A. The vehicle traction.

For simplicity, we assume that the vehicle is moving on level road with constant speed of 40 km/hr. (W=235 kg)
Assume that:

$f = .02$ $\rho = 1.225\ kg/m^3$ $F = 1.5\ m^2$ $C_d = .4$

$$P_f = G*f$$

$P_f = 260*9.81*.02 = 51$ (N)

$$P_V = (k*F*V^2)/13$$

$$K = .5*\rho*C_d$$

$K = .5*1.225*.4 = .245$

$P_V = (.245*1.5*60^2)/13 = 101.77$ (N)

$$P_\alpha = G*\sin(\theta)$$

$= 260*9.81*\sin(5) = 222.3$ (N)

$$P_{tot} = Pf + P_V + P_\alpha$$

$P_{tot} = 51 + 101.77 + 222.3 = 375$ (N)

$$\text{Needed power} = P_{tot} * V$$

Needed power = (375*60*5)/18=6250 (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.

For a 160 AH, 48 V battery and for 80% discharge, the Watt Hours is:

160*48*.8= 6144 WH.

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, and then multiply the result by .7 (for natural system losses).

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

175*2*7*.7= 1715 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= (1715+6144)/6250= 1.257 hrs.

A. The Covered Distance.

Range= 1.257*60 = 75.5 km.

The new design and components improvement besides the improvement on the aerodynamic shape and their effect on the covered distance of the vehicle are shown in the following figure:

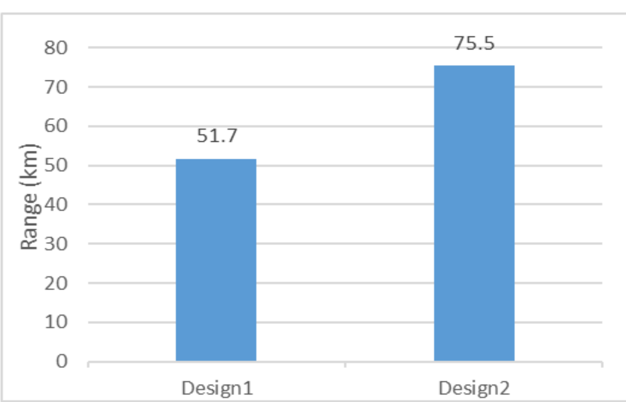


Fig. 6. Effect of Design Improvement on the Covered Distance

This figure shows that the range of the vehicle has increased by 46% after reducing the weight of the main chassis structure while keeping it safe and stiff, using new high efficiency and light battery and improving the aerodynamic shape of the vehicle.

Where...

- Design1… The vehicle with heavy structure, low efficient battery and high value of C_d.

- Design2… The new design improvement.

The difference between first and second design in addition to the improvement that had made will be illustrated in the following table.

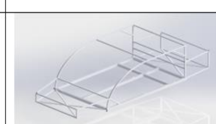
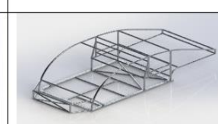
	Design1	Design2
Battery Weight	 W = 90 kg	 W = 38 kg
Structure Weight	 W = 50 kg	 W = 30 KG
C_d	↑	↓

Fig. 7. Difference between first and second Design

VI. IMPOVEMENT RESULTS

A. Effect of C_d value on the vehicle range

When we improved the aerodynamic shape of the vehicle the value of C_d is reduced and consequently the total resistance that results in increasing the range of the vehicle.
The following figure shows that changing the value of C_d has great effect on the covered distance.

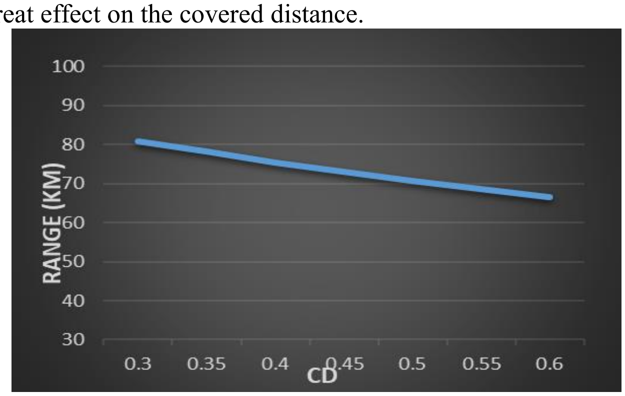


Fig. 8. Effect of C_d on the Vehicle Range

B. Effect of reduction in weight on the vehicle range

Our trials to reduce the total weight of the vehicle by reducing the weight of the structure and the weight of the battery has a good result in increasing the vehicle range as illustrated in the following figure.

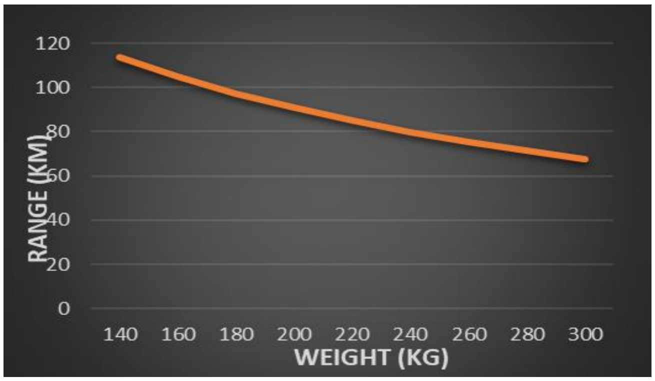


Fig. 9. Effect of Reduction of Weight on the Vehicle Range

VII. CONCLUSION

The main objective of this paper is to design a light Solar-Powered Electric Vehicle to use this vehicle in the new administrative capital and to achieve the utmost convenience level and a clear environment for high healthy criteria. In addition, the performance study after improving the first design is that the range of the vehicle is increased by about 46 %.

VII. Abbreviations and Acronyms

EVS: electric vehicles
PV: photovoltaic
GM: general motor

REFERENCES

[1] Xylia, M.; Silveira,S. On the road to fossil-free public transport: The case of Swedish bus fleets. Energy Policy 2017, 100, 397–412. [Cross Ref]

[2] R. J. King, “Photovoltaic applications for electric vehicles,” Conference Record of the Twenty First IEEE Photovoltaic Specialists Conference, vol. 2, pp. 21–25, 1990.

[3] ——, “Recent solar car technology developments including Australian world solar challenge results,” Conference Record of the Twenty Second IEEE Photovoltaic Specialists Conference, vol. 1, pp. 629–634, 1991.

[4] Barnard, R.W. and Kellogg, C. (1980) ‘Applications of Convolution Operators to Problems in Univalent Function Theory’, Michigan Mach, J., Vol.27, pp.81–94

[5] file:///G:/Concept%20Car/ahmed2014.pdf

[6] https://www.alibaba.com/product-detail/48v-48v-Lithium-Ion-Battery-For_1600247455462.html?spm=a2700.galleryofferlist.normal_offer.d_image.50294b71voXRHh&s=p&bypass=true