Design of solar powered electric vehicle

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Abstract. With the increased trends of industrialization and global economic growth leading to the everchanging petrol prices and other price hikes, private transport system has become a costly affair. All these problems can be addressed with innovation. One of the most feasible solutions is turning towards renewable energies to solve the issues i.e., increasing the use of renewable energies like solar power in the place of fossil fuels. Everyone’s dream of owning a commercially viable solar vehicle is slowly becoming a reality. Electric vehicles are now available at an affordable price. This opportunity is taken towards the design of a Solar powered two-wheeler. Designing a solar vehicle is a multidisciplinary subject that covers the broad and complex aspects from various subjects. In the designed vehicle, solar panel is used as the power source and developed voltage, stored in the battery, is used to drive the permanent magnet DC motor which drives the rear wheel of the vehicle.

Index Terms— PMDC motor, lead acid battery, solar panel, throttle, speed controller, charge controller, LED.

1. Introduction

The quests for an everlasting, safer, cleaner and an environmental-friendly fuel is never-ending. The carbon-based fuels, like the fossil fuels that are widely used nowadays are unsustainable and unsafe. They pose a serious threat to the environment. The best alternatives to these are renewable energy sources like the sun, wind, tides, hydropower and biomass. Amongst these elements, solar power is the most preferred since it could provide the cleanest sustainable energy for the longest duration of time – at least for the following few billion years. Photovoltaic production doubles every two years globally; it has increased by a mean of 48 percent annually ever since 2002. Thanks to its innumerable benefits with regards to the environmental, economic and social aspects, PV systems have become the world’s fastest-growing energy technology. It can be said that the sole limitation to alternative energy as an energy source is our understanding of
developing efficient and cost-effective technology which must be used for the implementation. Nothing on this planet comes free of cost, but what we could find the simplest way to implement free rides. Indeed it'd be wonderful if our two-wheelers could still run without us having to spend billions on fossil fuels each year and to pander to natural hazards that their combustion leave behind. If we could drive a solar-powered vehicle, that dream would come true. A solar vehicle would harness energy from the sun via solar panels. A solar panel is nothing but a packaged, and

connected assembly of solar cells also called the photovoltaic cells which are the solid-state devices that use quantum mechanical transitions to convert the available solar power directly into the needed electric power. They're noise-free and pollution-free with no rotating parts and requiring minimum maintenance. The electricity thus generated is used to run the vehicle’s motor by storing it in the battery. Thus, we get a vehicle driven electrically which travels on “free” energy with no harmful emissions, which could utilize its full power at all speeds and would have extremely little maintenance costs [1] – [2].

The planet Earth has awfully limited amount of energy resources which would soon become extinct. Fortunately, population models have suggested that the world's population will level out at two to three times the current numbers over the subsequent hundred years. The demands of the population increase as the total population count increases. The lingering question is whether the earth's resources will be sufficient to sustain the earth’s population with a high standard of living for all. Energy is the key issue in this. Nowadays, people dealing with natural resources like fuel, coal etc. face a tough time to stay at pace with the increasing demand. At one hand, there are more cars and motor vehicles, dominating the transport medium, while on the opposite hand these vehicles are being dominated by the fuel. As a result, the limited resources are being quashed by the producers and dealers to satisfy this need which is leading us to an uncertain future with the scarcity of fuel and minerals. So, it's clear that present trends in energy consumption, especially oil, can't be sustained for much longer. Also, these are the most contributing factors for global warming, environmental imbalances, depletion of the ozone layer, etc., which eventually challenges the survival of humans. The fossil fuels also play the antagonist role with regards to global warming. Therefore, under this circumstance, it's quite necessary to create a brand-new exploration of natural resources of energy and power. The question now is the need for exploration when the resources are right in front of our eyes. They are effective, less costly and specially, they are an endless source of energy. With greatly improved energy efficiency, a transition to the present energy based economy capable of sustaining the anticipated growth within the world economy is feasible. This effective source is —Solar Energy.

This work focuses on designing a solar powered two-wheeler vehicle aiming to tackle the issues that are related to pollution and shortage of fuel. When a solar powered vehicle is considered, it removes the burden of vehicle maintenance of the shoulders while ensuring both the safety and comfort for drivers as well as passengers Delhi, the capital city of India is one of the most heavily polluted cities in India. Recent study shows that pollution caused by the road dust and vehicles account for about 50% of total pollution of the city. Numerous solutions were proposed to face this which mainly includes afforestation and restriction on the usage of the vehicles [3] – [7].

2. Existing System

In the existing systems, solar photon energy is used as the fuel. This solar photon energy is transformed into electrical energy by employing a solar panel. This solar energy is used to power the electric vehicle. In a case that was studied, a regular IC engine scooter has been modified. This scooter’s engine has been replaced by with a 48 V, 0.33 Hp DC hub motor. This hub motor powered by a 48 V, 7.5 Ah Lead acid battery bank. Potentiometric method has been used for the purpose of speed control. A single 75 W solar panel is used to charge the battery. The following is observed in the existing system:
• The maximum speed attained at the end of the accelerating period is 45 kmph.
• The starting acceleration is 6.25 km/s².
• Distance covered is 3 km.
• Total time of the run is 280 s.
• The average speed is 36.3 km.

3. Proposed System

The proposed system exhibits a better performance because of the following reasons:
• The use of two 22,000 mAh batteries which provide a longer lifetime.
• The hub motors are replaced by a permanent magnet DC motor. The use of PMDC motors has its own significance. The absence of field windings in the PMDC motors eliminates the field circuit copper losses. This in turn increases their efficiency.

The output of the proposed system of the solar powered vehicle are as follows:
• The maximum speed attained at the end of the accelerating period is 50 kmph.
• The starting acceleration is 10 kmphps.
• Distance covered is above 5 km depending on the speed and acceleration.
• Total time of the run is above 600 s.
• Average speed is 45 km.

3.1 Solar Panel

Solar panels have been in use since the nineteenth century and since then till today people have been employing them for a variety of applications at home, business, for transportation and even for agricultural use. Solar panels are considered expensive even today, and their performance needs to be verified without blindly trusting the ratings provided by their producers. When a solar powered car is taken into consideration, the solar panels act as the ultimate energy supplier for the whole vehicle to function. Hence, a complete verification of the performance of the solar panels that has be used for the solar vehicle must be carried out. The sun emits its radiated energy in the form of light photons which is then converted into electrical energy by the solar panels. Solar panels are made up of silicon-based semiconductor materials and when the radiation comes in contact with the silicon atoms, the photons are absorbed separating the electrons from the rest of the atoms. There generated electrons take care of creating the electric current and their transportation. The generated electricity is then stored in the batteries that are to be used later.

3.2 Battery

The battery that is to be used is a 24V unsealed Lead acid battery. Lead–acid batteries were invented by the French physicist Gaston Planté in 1859. These are the oldest type of the rechargeable batteries available. Despite their extremely low energy-to-weight ratio and a low energy-to-volume ratio, their ability to supply high surge currents means that the cells can maintain a relatively large power-to-weight ratio. All these features of the batteries and their low cost, make them attractive for use in motor vehicles thus providing the high current required by the motors.
As the used permanent magnet DC motor requires a 24 V and a capacity of 42 Ah, two 12 V 42 Ah Lead acid batteries are connected in series thus providing supply to the motor. Due to the internal electrochemical mechanism of lead-acid batteries, charging is carried out in 3 distinct stages rather than through a continuous fixed voltage/current supply to the battery. Each of these stages varies with the amount of voltage/current that needs to be supplied to the battery. The charge controller will detect voltage from the battery prior to the charging process. After reading the output from the battery the charge controller will determine which stage has to be employed to properly charge it.

3.3 PMDC Motor

A Permanent Magnet DC motor (PMDC motor) is built with a permanent magnet that creates the magnetic field needed for the operation of the DC motor. The use of PMDC motors has its own significance. These permanent magnet DC motors do not require the presence of field windings which in turn reduces their field circuit copper losses. This increases their efficiency. To satisfy the requirements, we use a 24V 42000 mAh permanent magnet DC motor, the speed of rotation of which is controlled by the throttle.

3.4 Throttle

The running speed of electric powered vehicles are adjusted under different riding situations with the help of a throttle. There are linear hall sensor integrated circuit and magnetic steel which are installed on the fixed part and rotating part of the throttle respectively. When the throttle is rotated, the movement of the magnetic steel will affect the magnetic field. The output voltage of the hall sensor will change accordingly.
The sensor transmits its output voltage signal to the controller, and then the software in the controller will analyze this signal to get the suitable PWM to drive the motor.

| SNO. | COMPONENT     | SPECIFICATION  |
|------|---------------|----------------|
| 1    | Solar Panel   | 20W            |
| 2    | Battery       | 12 V           |
| 3    | PMDC motor    | 2300rpm,3Nm    |
| 4    | Throttle Switch | 12V,24V,36V,48V |
| 5    | LED           | 15W            |
| 6    | LED back light | 5W             |
| 7    | Charger       | 60W            |

4. Vehicle Setup

The solar panel is connected to the battery through a charge controller which will regulate the supply to the battery. The battery is then connected to the throttle.

The throttle is used to provide supply to the permanent magnet Dc motor through speed regulator which consists of MOSFET to provide gate pulse to throttle. The rotor of the PMDC motor is connected using the pulley system to the wheel. A smaller pulley is connected to the rotor which is connected to the longer pulley attached to the wheel axis

4.1 Speed Controller

A speed controller is needed to control the power supplied to the motor. Most of the motors available these days have hall sensors that enable them run smoother. They also require a complex controller to dish out the power. The function of the speed controller is to make sure that everything runs smoothly. The throttle, the motor, the battery and other such components are connected to the controller. The voltage of the controller must match with the battery specifications. Also, with the increased amps of the controller, its size also increases making its components beefy thus making them expensive. Using a high-quality controller enables the quieter, smoother and the most efficient operation of the electric motor. The speed

Fig 3. Speed Controller
controller circuit is designed with four MOSFETs which provide the gate pulse required to rotate the motor with an increase of the throttle.

4.2 Charge Controller
The main objective of the charge controller is to act as a battery management system (BMS) regulating the charging and discharging of the battery. The charge controller circuit contains a voltage regulator circuit which provides a regulated output voltage corresponding to the input from the solar cell. The regulated output is conditioned such that the output voltage suffices to charge the battery available.

![Charge Controller Diagram]

Fig 4. Charge Controller

5. Design Consideration

5.1 Calculation of Angular Velocity Of Wheel

\[
\text{Angular Velocity} = \frac{\text{Linear velocity}}{\text{Radius of wheel}}
\]

\[
\text{Angular Speed} = 2 \pi \times \text{frequency}
\]

\[
\text{Frequency} = \frac{\text{Angular speed}}{2 \pi} \text{ rpm}
\]

5.2 Calculation of Peak Torque Required for Moving the Vehicle

\[
\text{Peak Torque} = (\text{Mass of the vehicle} + \text{Mass of the battery}) \times \text{Acceleration due to gravity} \times \text{Wheel Radius} \times \text{slope%}
\]

\[
\text{Power Required} = \text{Torque} \times \text{Angular Velocity}
\]

5.3 Calculation for Air Resistance

\[
\text{Air Resistance} = \frac{5}{100000} \times (\text{mass of vehicle}) \times (\text{average speed})^3
\]

5.4 Calculation for Rolling Resistance

\[
\text{Rolling Resistance} = 0.092 \times (\text{mass of vehicle}) \times (\text{average speed})
\]
5.5 Calculation for Continuous Power

\[ \text{Continuous Power} = \text{Air Resistance} + \text{Rolling Resistance} \]

5.6 Calculation for Continuous Speed

\[ \text{Continuous Speed} = \frac{(\text{Average speed} \times 60)}{(2 \times \pi \times \text{radius of wheel})} \]

5.7 Calculation for Continuous Torque Required

\[ \text{Continuous Torque} = \frac{(\text{Continuous power} \times 60)}{(2 \times \pi \times \text{continuous speed})} \]

5.8 Battery

5.8.1 Energy Stored in Battery

\[ \text{Energy Stored} = \text{Capacity} \times \text{Voltage} \]

5.8.2 Discharging Time of Battery

\[ \text{Discharge time of battery (without power loss)} = \frac{\text{Energy stored in battery}}{\text{power of load}} \]

5.8.3 Charging Time of Battery

\[ \text{Charging Time of battery (without power loss)} = \frac{\text{Energy stored in battery}}{\text{power of panel}} \]

6. Concluding Results

\[
\begin{align*}
\text{Angular velocity} & = 59.52 \text{ rad psm} \\
\text{Frequency} & = 568.37 \text{ rpm} \\
\text{Peak torque} & = 22.64 \text{ Nm} \\
\text{Power required} & = 1347.41 \text{ W} \\
\text{Air resistance} & = 108 \text{ W} \\
\text{Rolling resistance} & = 220.8 \text{ W} \\
\text{Continuous power} & = 328.8 \text{ W} \\
\text{Continuous speed} & = 378.94 \text{ rpm} \\
\text{Continuous torque} & = 8.29 \text{ Nm} \\
\text{Energy stored} & = 1008 \text{ Wh} \\
\text{Discharge time of battery} & = 90 \text{ minutes} \\
\text{Charging time of battery} & = 37.84 \text{ hrs}
\end{align*}
\]
7. Conclusion

The presented results as well as the design for a solar powered vehicle makes the usage of these vehicles feasible and practicable in developing countries. The solar powered electric vehicle using a PMDC motor is a good choice for the Indian market. The solar powered electric vehicle stands with higher safety, high performance as well as remains cost efficient. Use of charge controller and speed controller in the vehicle improves the efficacy of power system. The presented eco-friendly solar powered electric vehicle can be a good choice for future generations.

8. References

[1]. G.R. Chandra Mouli, P. Bauer and M. Zeman, “System design for a solar powered electric vehicle charging station for workplaces” Applied Energy, Vol 168, pp 434-443, 2016.
[2]. A. Inba Rexy and R. Seyezhai, “A comparative study of active power factor correction ac-dc converters for electric vehicle applications” ARPN Journal of Engineering and Applied Sciences, Vol. 8, No. 9, Sep 2013.
[3]. Gurkaynak Y, Khaligh A. Control and power management of a grid connected residential photovoltaic system with plug-in hybrid electric vehicle (PHEV) load. In: 2009 Twenty-fourth annual IEEE appl power electron conf expo, IEEE; 2009. p. 2086–91.
[4]. G. Maggeto and J. Van Mierlo, “Electric and electric hybrid vehicle technology: a survey,” in Proc. IEE Seminar on Electric, Hybrid and Fuel Cell Vehicles, 2000, 1/1-11.
[5]. Ke Bao, Shuhui Li and Huiying Zheng, " Battery Charge and Discharge Control for Energy Management in EV and Utility Integration" ,2012 IEEE
[6]. Victor del Razo, Hans-Arno Jacobsen, "Vehicle-Originating Signals for Real-Time Charging Control of Electric Vehicle Fleets", IEEE Transactions On Transportation Electrification, Vol. 1, No. 2, August 2015.
[7]. A. T. Radu, M. Eremia, L. Toma, “Promoting Battery Energy Storage Systems to Support Electric Vehicle Charging Strategies in Smart Grids”, Electric Vehicles International Conference (EV), Oct. 2017.