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Solar Bicycle Project

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ABSTRACT

This study sought to investigate the making of a sustainable solar-powered electric bicycle. The idea of sustainable development has gained significant traction over the last few decades. As reserves of coal, natural gas, and petroleum deplete, it is becoming ever more imminent to switch to renewable sources of energy. The objective of this study was to determine the reliability and cost efficiency of a solar-powered electric bicycle in daily life. This descriptive study involves a design making phase, a phase where spare parts are procured, a product development phase, and a testing phase.

The prototype bicycle now has a top speed of 35-40 km/h and can travel up to 40 kilometres in a single charge. The bicycle can be fully charged in 3 hours with the standard lithium ion battery and in about 5.5 hours via the attached solar panel.

This bicycle can be built at an approximate cost of USD 467 and is quite apt for warm environments such as the Middle East and Mid-Asia, where sunlight is abundantly available; in the United Arab Emirates, considering current electricity tariffs, the driving cost of the bicycle will be around USD 0.035 per every 40 kilometres.

Introduction

Our solar-powered bicycle is a product of the transition to sustainable sources of energy. A bicycle is already sustainable, however this project makes it more efficient and creates awareness amongst the masses. The idea to begin this project was influenced by existing socio-economic factors of bringing affordable and efficient transportation to large numbers of people. Considering a landscape such as rural India, where the land is covered mostly with steep hills, bicycles are the cheapest mode of transport but the rugged terrain is a major obstacle. It is from here where I got my inspiration to build the solar bike - by utilizing electricity and solar power, a bicycle can be effectively transformed and upgraded into a significantly more efficient version of its standard self. Subsequently, daily activities become much easier and less time-consuming.

Method

The solar bicycle includes standard parts found in any chain-wheeled bicycle and a few additional accessories such as:

- A solar charge controller
- A 24V-350W DC hub motor
- A 24V-18Ah lithium ion battery
- A 12V monocrystalline flexible solar panel
- A 3A lithium ion battery charger
- A charge indicator
- Brake lights

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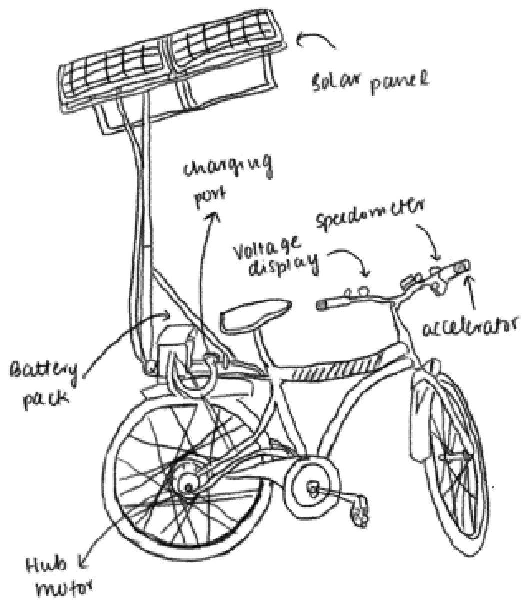

Figure 1.

The first step in the making of this bicycle was to buy any ordinary chain-wheeled bike that had room for equipment at the back. The DC hub motor was then installed into the wheel of the bicycle, after which the motor controller and the battery were placed into a box at the back. The controller comes with instructions on how to connect it within the setup. Accelerators were installed onto the handlebars. The solar panel was framed and mounted on a hollow, removable stick. Space for the insertion of the panel was allowed at the back. A speedometer was finally installed on the front handlebar to measure the instantaneous speed. The speedometer is linked with a Hall Effect Sensor that is attached into the front wheel of the bicycle. The bicycle now has a top speed of 35-40 km/h, and for each charge cycle it can travel up to 40 kilometres. The charging time is approximately 3 hours with the standard lithium ion battery present, and around 5-5.5 hours with the solar panel. There is also a display present on one of the handlebars which shows the voltage across the ends of the battery.

Rationale in components

Solar Charge Controller: this device is an integral part of the bicycle's machinery, and without it, the project would remain largely unfinished. The main purpose of this device is to make sure that the current coming from the solar panel remains at a level such that the optimum charging voltage is always achieved. Lithium ion batteries are highly unstable at extremely high or low voltages. Hence, a charge controller is used here to keep the terminal potential difference constant.

The solar charge controller used in this project is a Maximum Power Point Tracking (MPPT) solar charge controller. It is a DC to DC converter, and it converts DC current from the solar panel to a suitable voltage. The controller is also a 'boost' controller, i.e. it steps up the output voltage of the solar panel to make it suitable for the battery. This is necessary because the voltage of the battery is higher than that of the solar panel. This method of ''stepping up'' is done by an embedded MPPT algorithm. By using an MPPT charge controller, we also make sure that the maximum amount of current for a given power output is delivered to the battery without causing drastic voltage increases or drops.

Moreover, the solar controller prevents reverse power flow (RPF). This occurs when the voltage in the fully charged battery is higher than that of the solar panel. Battery overcharging is also effectively reduced via a 3-step charging system, which includes bulk charging, absorption charging, and float charging.

Some solar charge controllers can also be connected to the DC load, which in this case in the motor. This is done to prevent the load from drawing any more current when the battery's voltage drops too low.

BLDC Hub Motor: a DC motor uses the interaction between electromagnetic fields to create a mechanical force. The motor creates a magnetic field in which a current carrying conductor develops torque and creates motion. The term "BLDC" stands for "brushless direct current," and in this case refers to a motor that functions on DC current without the help of mechanical brushes. Brushless motors are much more advantageous than brushed ones because the absence of physical brushes means less overall wear and tear of the system.

Commutation in BLDC motors is accomplished by separately energizing coils of wire that are located in the stator. The rotor is a permanent magnet with north and south ends. The coils are energized in such a way that the resulting magnetic field causes an attraction with the adjacent pole of the rotor. This results in a continued rotation, and after one full rotation, the polarity is switched.

One free end of each coil is also connected together to maximize the amount of torque delivered. This setup ensures that any momentarily unused coil is energized in such a way that it pushes the rotor in its direction of motion. The detection of the stator and rotor's position is done by a built-in electronic sensor, and the 24V motor controller decides which coils to energize. This way, torque output is maximized

Why this specific DC motor? If one was to look at all the electric bikes currently available in the market, it becomes evident that they all possess hub motors only. Note that the hub motors add relatively less weight to the system as compared to other motors. Moreover, this DC motor can be easily attached to the wheel of the bicycle for a smooth traveling experience

Lithium-Ion Battery: lithium ion batteries are batteries that use lithium compounds as the anode within cells. During electric discharge, lithium ions move from the anode to the cathode.

I have chosen the li-ion battery over lead-acid batteries (rechargeable batteries with sulphuric acid as the electrolyte), given the former's various practical advantages:

- It has a much larger energy density (lithium ion batteries can go up to 260 Wh/kg while lead acid batteries have a maximum of 90 Wh/kg)
- It can charge much more quickly (up to 3 times as fast depending on the size of the battery)
- It has a much longer life cycle (lithium ion batteries can be charged and recharged around 2500 times before they reach 80% of their original capacity, whereas lead acid batteries can only be done so around 200 to 250 times)
- It is more compact (on average it is 55% lighter than a lead acid battery)
- It has an extremely low self-discharge rate (at 2-5%)

Monocrystalline Solar Panel: solar panels can be of two types: monocrystalline and polycrystalline. Monocrystalline solar panels are made using only one silicon crystal and are much more efficient than polycrystalline solar panels. A few of the advantages of monocrystalline panels over polycrystalline panels include:

- Monocrystalline panels have a higher efficiency rate (18% efficiency) as compared to polycrystalline panels (15-16% efficiency)
- Monocrystalline panels generate more power per unit area (power density) due to their higher efficiency rate
- Empirically, it has been found that monocrystalline panels perform slightly better in low light conditions than polycrystalline panels.

However, monocrystalline panels are relatively more expensive than polycrystalline panels. Nonetheless, this panel was chosen mainly to ensure maximum productivity. The solar panel used here is also a flexible one, which makes it quite resistant to fall damage.

Cost of making the bicycle

· Hub Motor Kit – USD 110
· Lithium Ion Battery - USD 120
· Charger - USD 24
· Solar Panel - USD 66
· Bicycle - USD 105
· Speedometer - USD 3.

In addition, the welding work cost around USD 39 The total cost of these items comes to be approximately USD 467

Results and Discussion

The battery takes about 6 hours to charge with the solar panel, hence a total of 80 kilometres can be traversed in one day (if we were to consider that the sun is available for roughly 12 hours/day). The power capacity of the lithium-ion battery used is about 432 Wh (multiplying the current capacity and the voltage). In the UAE, the rate applied on an electric vehicle being charged with 1 unit of power is approximately 30 fils (0.082 USD). If we were to charge our 432 Wh lithium ion battery using an AC-to-DC charger, it would cost around 13 fils (0.035 USD). With this, a distance of 40 kilometres can be traversed with ease. Moreover, the mechanism of this bicycle has been designed in a failsafe manner when it comes to transport capability. If it were to start raining and clouds were to deeply line the sky, the portable charger that comes with this could keep one going. Nonetheless, if all fails, the pedals still work, and the bicycle can be used manually.

Figure 2.

Conclusion

In all, the bicycle has proven to be quite effective for running daily chores. In fact, chores get done at a much faster rate and with less energy utilized. With advancements in solar panel technology, the inclusion of small, compact, and lightweight panels can also be incorporated. In such a scenario, the bicycle is only to be made much more efficient. Since the current panel takes up quite some space, a smaller panel would allow for extra storage at the back. However, the panel must retain a high power output. This conflict poses problems to further developments and requires a creative engineering solution.

Acknowledgments

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