

Solar - Electric Commuting Trike with Manual Pedaling

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ABSTRACT

With dwindling petroleum resources and concerns about global climate, it is imperative to find better suited modes of commute for the future. In the United States, studies have shown that 50% of the travel on automobiles is within a 25 mile radius and a significant portion of the travel is made with a single passenger in the vehicle. Engineers across the globe are designing a variety of electrical/ solar powered bikes (ESB) and tri-cycles or trikes (EST). Although most of the designs are focused on fabrication of recreational vehicles, the trike is a significant advancement towards a perfect Zero Emission Vehicles (ZEVs). Therefore we targeted in our current study the design and fabrication of a commuting trike powered by a combination of solar, electrical energy with linear pedaling. The goal of our design is to manufacture a commuting vehicle which will be operable when one or both electrical/solar power is unavailable and yet it will allow the commuter to reach safely any end of the commuting path, i.e. office or home. In our assessment the cost of \$700-800 will make the trike an affordable transportation vehicle without compromising on the regulatory safety rules, comfort and speed levels as specified by the Federal regulations. Further work on the trike will be in the direction of optimizing the design and the creation of a commercial prototype.

Keywords: Solar, Vehicle, Electric, Manual, Pedaling.

1 INTRODUCTION

Ten years ago, in interviews from June 1997 to January 1998, Mr. Lee Iacocca has been discussing one of his latest ventures into the

world's transportation system - electric bicycles. Mr. Iacocca, former Chairman for Chrysler Corporation, has founded a company (Global Motors, Inc.) whose mission is to develop and market electric bicycles, scooters, and "neighborhood electric cars" [1]. Mr. Iacocca's approach is to introduce the average American to the concept of electric vehicles through "fun" vehicles. However, electric vehicles have historically made up only a minute portion of the vehicle makeup of the American highways and by-ways. The impact of this change may not be felt for some time, although there are already some positive findings. In one interview, Mr. Iacocca estimated one million electric bicycles per year will be bought in the United States [2]. If that estimate holds, and if an estimated one percent of these bicycles are solar powered, our nation's transportation infrastructure will be inundated. Currently, less than five percent of commuters in a metropolitan environment utilize bicycles as a normal means of commuting [3]. This number is also projected to increase. How will these bicycles interface with the automobile, our existing infrastructure and the evolving Intelligent Transportation System (ITS) [4].

Neighborhood Electric Vehicles (NEVs) [5] are classified as automobiles which weigh less than 1800 pounds when empty and are able to run at no more than 35 miles per hour (mph). They can be run on most of the city routes for short range commuting. With studies [6] indicating that almost half of the travels using conventional vehicles is within a 25 mile radius, it is imperative to address the modes of transport for this short range travels. And since the travel is over a short range, the vehicle must be quick and easy to operate, carry a fair amount of payload for the average house errands. A low cost vehicle

satisfying the above conditions might have a significant market potential. Current design is focused on development of the commercial product because the proof of concept was already done by our group.

One of the important considerations for successful manufacturing and marketing of solar-electrical vehicles is related to the existence of road infrastructure, whether special bike passes or hybrid combination of bicycle and conventional cars passes. Existing planned infrastructure for dedicated bicycle/pedestrian pathways would be able to support two-wheeled electric bicycles. The footprint of the two-wheeled electric bicycle is no larger than the standard two-wheeled bicycle. However, solar panel equipped cycles (tricycle or four wheeled) have an approximate 3.5' x 8' footprint. This means that a minimum safe lane width is approximately 6.5 feet (this allows room for drifting and obstacle avoidance). So the dimensions of our vehicle would be practical on conventional city roads across most of the US. Another important aspect to be taken into account is that many countries including the USA do not have fully dedicated routes for bikes or trikes in which case, the developed vehicle must be compliant with federal law and road worthy. Yet in some countries like Denmark, Holland, Germany and China do have the hybrid combination of passes for bikes and vehicles such as the EST together with conventional roads.

2 DESIGN CONCERNs

The design of the EST did address the major necessities during a travel. The following were the major concerns. (a) The capacity to carry about 350 pounds of payload including the driver and battery. (b) Operate on batteries and drive the vehicle by an electric motor. (c) Ability to recharge the battery at any available outlet. (d) Ability to recharge the battery using the solar cells when the vehicle is in motion and at rest. (e) An operating range of about 50-60 miles. (f) Ability to manually pedal the vehicle without any loss of speed, safety or comfort.

3 SYSTEM DESIGN

3.1 Design of the EST

Each of the above considerations is inter-related and therefore the design was undergoing a few iterations. The stability of the vehicle while running on straight segments or turning corners is better with the three wheel design and relieves the rider of the efforts to keep the balance. This ensures that the driver is free to focus on the distances between vehicles, on various objects on the road surface and on moving pedestrians. For our vehicle to be light and capable of carrying a payload of 350 pounds, we designed the chassis of the trike to be hollow square sections. The load distribution was calculated on each part of the trike using standard methods [6]. The external dimensions of the vehicle are 2.1m in length, 1.1m in width and 1.35m in height. The rider is seated at a height of 40cm from the ground. That ensures a low center of gravity and provides good stability.

The weather factor is rather important. In Wisconsin, for example, some cyclists use their bicycles all winter long, except in heavy snowstorms. In order to become a practical alternative for the urban commuter in all parts of the United States, the EST is designed to shield the operator (and possible passengers) from rain/snow fall, road spray, and blustering wind. Unlike motorcycles where heavy Plexiglas material can be used as a windshield, whatever material used on an EST must be lightweight and durable. To provide good aerodynamic flow of air over the front of the vehicle, the windshield is made of Polyethylene Terephthalate – Glycol modified (PETG). It does not shatter like glass but has transmissivity for visible light on a comparable scale to glass and Poly Carbonate (PC). Moreover, the material can be easily formed without heating to fit the contour of the front of the trike.



Figure 1: Assembly of the trike without the top canopy holding the solar panels.

3.2 Power Train

The power train consists of manual pedaling part and electric motor. The design of the electric motor provides adequate starting torque. A 24V DC motor is used. The motor is connected to the rear axle of the trike through a chain sprocket arrangement.

fatiguing effects from conventional pedaling. This effect can be quantified by the estimate of an eleven-fold ($45.1/4.19$) decrease in the aspects that cause isometric forces ("wasted forces") during pedaling. The design of the bicycle was based on measurements that would allow for speed over 20 mph at a normal pedaling cadence. On usual bikes, the normal pedaling rate is about 70 RPM. At that low rate, it is not possible to move as fast as with the electric drive. Pedaling the vehicle over slopes, the transmission system provides adequate torque. We designed the transmission system with chains, sprockets and internally geared hubs. An eight speed hub, Sturmey Archer XR-F8 with speed ratios of 0.67 to 1.35 and a five speed hub, SRAM P5 with speed ratios from 0.75 to 1.2 were used to provide both high torque at the lowest gear and high speed at the highest gear. The transmission also has sprockets in series to produce a speed reduction of 1.3 and 1.2.

3.3 Electrical System

A 24V Ni-MH battery of 32 Ah capacity is used.

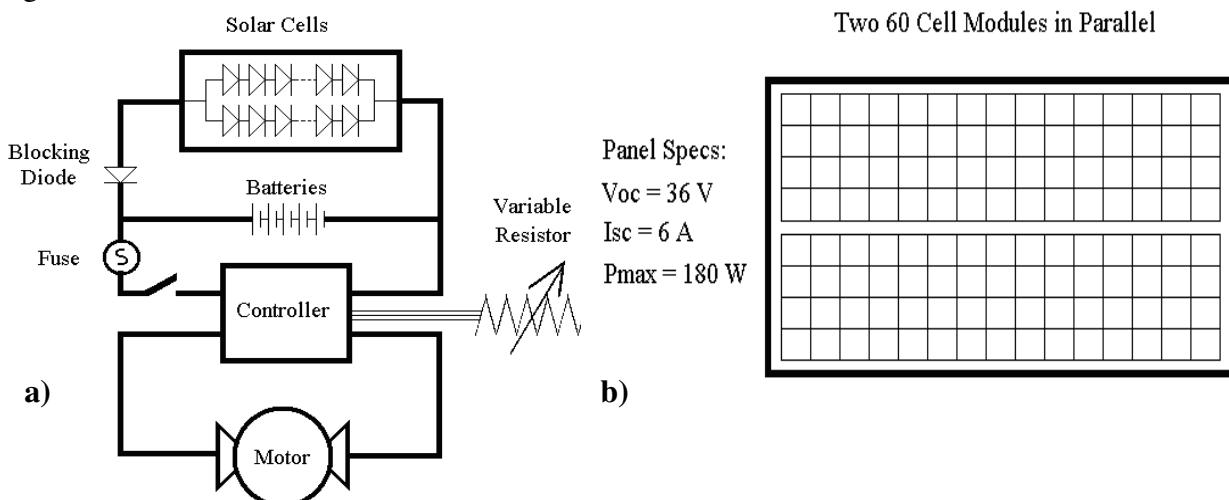


Figure 2: (a) Electrical circuit (b) Solar panels and their specifications.

One of our primary concerns was not to lose mobility if the batteries are completely empty. Thus a manual pedaling system is put in place. The trike features linear pedaling over the conventional rotational pedaling. This new pedaling mechanism relieves the rider of

The battery is positioned at the rear of the vehicle, behind the rider to ensure a safe position of the center of gravity. It is connected to the motor through a controller that optimizes the use of the power. A Battery Condition Monitor (BMC) is connected to the battery and placed on

the handle bars to inform the rider of the status of the battery. The battery can be recharged from standard power outlets at homes, offices or even at a convenience store.

Fig 2a, presents the electrical connections between the solar cells, batteries, controller and the motor. Fig 2b depicts the solar panels and their specifications. To charge the battery and to provide a dependable power source on sunny days, a Poly-Silicon solar panel is installed over the rider's head and forms the roof of the vehicle. To decrease the weight of the solar panel, a plastic substrate was used. The panel measures 1.92m x 0.92m and at peak operation, it can produce 36 V with 6 A of current. The panel is connected to the battery through an electronic current controller. We did not install a Maximum Power Point Tracker (MPPT), however the use of an MPPT will definitely yield better efficiency.

4 FEDERAL SAFETY STANDARDS

Although a variety of electrical bikes are present on the roads, the Federal Motor Carrier Safety Administration has formulated a set of standards for NEVs [7]. The standards formulate the most common specifications and safety features like headlamps, tail-lights, brake lights, direction signals, windshield, upper speed limit, tire pressure, passenger capacity and their testing procedures.

5 COST OF MANUFACTURING

Our prototype design is simplified and flexible what allows the manufacturing of the trike to be undertaken at sophisticated fabrication facilities of US and European countries as well as of developing countries. In our assessment the trike in commercial production, will cost about US \$ 400-600. This cost is affordable and should help market proliferation in developing countries. In future design there is room for improvement by using better batteries with higher power densities, lighter gear hubs and materials for the chassis.

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