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Simulation and Fabrication of Hybrid Electric Bicycle with Multi Charging Mode

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Abstract

The use of electric vehicles actively contributes to environmental conservation. Lack of EV charging infrastructure is one of the most common challenges associated with the electric vehicles. The conventional method for the electric propulsion system deals with the single mode of charging techniques. The alternative battery charging techniques helps to enhance the usage of electric vehicles. In this work hybrid electric bicycle is designed with multi charging method. In addition to the conventional wall charger, a solar panel and dynamo is used to charge the battery. Increasing the performance and efficiency by means of BLDC motor. The entire propulsion system is connected with the PI controller which calculate the speed and relevant voltage needed for the drive. The performance of the proposed method is evaluated through simulation using MATLAB/ Simulink software.

Keywords: BLDC Motor, Lead Acid Battery, Dynamo, Solar panel, Accelerator, Sprocket.

1. Introduction

The current situation is such that there is a peak in the demand for petroleum products due to the growing number of automobiles. It is preferable to switch to alternative energy sources because petroleum products are nonrenewable and might eventually run out. The price

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of crude oil has risen dramatically in recent years, and there doesn't seem to be a way to stop it. There has also been an emphasis on the environment recently, and it appears that there is now a vital need for cleaner fuel options. The usage of electric power for transportation has increased because to the growing desire for pollution-free transportation, which has decreased the reliance on automobiles. Compared to a car, a hybrid electric bike is less expensive. Electric hybrid bicycles are not a novel idea, but their potential has not yet been fully investigated. The simulation and construction of an electric hybrid bicycle are the main goals of this research. The research is difficult since it involves changing the current mechanical system to one that uses electrical energy in addition to human pedaling. The term "hybrid" typically refers to a vehicle that is powered by a combination of energy sources. This concept uses human pedaling energy in addition to energy from an AC wall socket to charge a battery. A dynamo is installed in the back wheel to use the pedaling power. The bicycle's rear wheel is also equipped with a motor that is powered by the battery. In addition to encouraging cleaner technologies, the hybrid bicycle project reduces dependency on petroleum products. The average citizen of our nation can purchase this improved design at a reasonable cost. [1] outlines the electric power generated by solar arrays is primarily determined by factors such as temperature, insolation, and array voltage. The functioning and lifespan of batteries are influenced by battery voltage, state of charge (SOC), and charging current. Controlling the operating points therefore requires consideration of both battery factors and the maximum power operating points of the solar array. In order to modify the power extracted from the solar panel in a way that charges the battery in accordance with the conventional charging method, this study aims to propose an additional control in addition to the maximum power point tracking (MPPT) control. The power processing units found in appliances that are directly connected to photovoltaic systems can be utilized with the controller that was built in this way. [2] introduces a method to decrease city emissions by promoting bicycle usage and converting conventional bicycles into plug-in hybrid electric bicycles for short-distance commuters. The proposal suggests replacing motorized two-wheelers with converted plug-in hybrid electric bicycles for short-distance commuting. It outlines the sizing of the electric powertrain and conversion procedure. The study simulates a hybrid bicycle for sizing with specified parameters and offers results for reference. Additionally, it provides a detailed analysis of commuters based on distance and discusses the emission implications. The adoption of conversion is shown to significantly reduce emissions while also improving health and fitness. [3] examines various design methodologies for electric bicycles, focusing on three distinct areas: electrical, mechanical, and system level design. It examines the various ways that a wide range of problems can be solved in each of the above domains. The article provides a classification of the approaches to designing an electric bike after gathering the offered solutions and categorizing them according to domains, making it simple for a designer to find the data they need to begin working on their research. [4] By bridging the many energy sources that humanity has access to, this initiative seeks to provide an accurate picture. Travel is essential for humans to thrive in the modern, interconnected world we inhabit today. He should travel as little as possible in order to do this. This project describes how to operate an electric bike that powers the motor with battery power[5-7]. The design and construction of an electric bike, which uses electricity as its major energy source, are compromised in this project. When compared to a traditional car, the electrical power generated to power the bike can provide higher performance, lower emissions, and better fuel economy. To reduce noise pollution and air pollution. It minimizes fuel use and offers an environmentally friendly car. As a result, the vehicle's speed is likewise controlled in this instance by shifting between higher and lower gears. Similar to a gas-powered motorcycle, the speed can be changed [8-10].

2. Hybrid Systems

2.1 Introduction to Hybrid System

Road bikes, touring bikes, and mountain bikes are combined into a single type of bicycle known as a hybrid. Therefore, a 'hybrid bicycle referred as hybrid ' is capable of handling various riding situations and purposes is created—a general-purpose bike. Children, casual riders, inexperienced cyclists, and the general public will appreciate them for their stability, comfort, and ease of use. The flat, straight handlebars and upright seating position of mountain bikes, which many cyclists find comfortable and intuitive, are often borrowed by hybrid bikes. In order to ride on the road at a faster pace with less effort, hybrids also use the lighter weight, narrower wheels, and smoother tires of road bikes. Similar to touring bikes, hybrid bikes frequently feature rack and bag mounting locations. The advent of subcategories of hybrid bikes has satisfied a wide spectrum of riders. City, cross, and commuter bikes are categorized based on their design aims, such as comfort or fitness optimization.

2.2 Need for The Hybrid System

Hybrid energy, which combines two or more energy sources, is becoming more and more popular as renewable energy technologies progress. For example, optimized efficiency and balanced output can be achieved by combining geothermal with solar or wind and solar with batteries. Crucially, hybrid energy solutions may also be adjusted to the environment, with the ability to adjust to variations like shifting weather patterns and periods of greatest wind and solar energy production. Incorporating them with already-existing power producing systems allows businesses and communities to optimize their resources and guarantee a consistent flow of electricity. For developing nations, where the need for electricity is rapidly increasing, hybrid energy has significant promise. The predicted economic growth of the country will require a considerably larger and more efficient energy sector. Decentralized energy plays a significant role in the lack of grid access in many remote and rural locations, and hybrid systems provide the benefits of economies of scale, flexibility, and reliability. By implementing cutting-edge energy storage technology, this problem can be resolved. In order to maximize energy conversion efficiency, enable operators to fully utilize their resources, and guarantee stability and profitability, high-performing control and management systems are also required.

2.3 History of Hybrid Bicycle

The utility roadster constituted the majority of adult bicycles sold in the UK and many other countries of the British Empire from the early 20th century until the end of World War II. However, in the early 1970s, roadster popularity in Britain sharply declined as manufacturers shifted their focus to producing lightweight (23–30 lbs), reasonably priced derailleur sport bikes—essentially slightly modified racing bicycles from that era. This shift was driven by a surge in leisure cycling. The transition from road-only bicycles to all-terrain variants, such as the mountain bike, began in the 1980s among UK cyclists. The roadster's role as a utility bike was gradually supplanted by the mountain bike due to its robust frame and capacity for hauling loads. By 1990, when bicycle sales in the United Kingdom reached a record 2.8 million, nearly all of them were mountain and road/sport versions, rendering the roadster all but extinct. In contrast, the majority of Asian nations continue to produce and use roadsters on a large scale.

2.4 Methodology

There are two processes in this methodology

1. Development Process

2. Simulation Process

By splitting it into two processes we can easily understand the project needs. It is very easy for us to fabricate the vehicle. This methodology clearly shows the step by step procedure to complete the electric hybrid bicycle. The 250-watt PMBDC motor, operating at 24V and rated for 143A, achieves a speed of 2750 RPM. It was connected to a flywheel through a sprocket. The shaft from the flywheel was then connected to another sprocket on the opposite side with a housing. The drive from this second sprocket powers the multi-crank freewheels. These components were chosen to optimize power transmission efficiency while minimizing energy loss. The crank's drive directly connects to the rear wheel sprocket, enabling its movement. When the motor is activated, it draws power from two dry cell batteries connected in SERIES, providing an effective discharge of 24V and 7A. Due to the motor's initial high current demand during startup, batteries of that specification were employed. As the effective speed increases, the current draw decreases over time. The motor's torque is relatively low, requiring the rider to pedal the bicycle initially to achieve better torque. Once the pedals are turned, the ignition switch activates, and the bicycle becomes fully electric. After the battery is completely discharged, the rider may choose to pedal for travel. A dynamo connected to the rear wheel allows the rider to charge the battery if desired. However, the battery charges automatically, albeit at a slower rate.

3. Development Process

3.1 Problem Identification

Governments prioritize conserving nature while maintaining transportation. Two-wheelers are popular but add to pollution. Traditional cycling demands more effort. Hence, we propose a substitute. Bicycles, especially for short trips, are preferable amid environmental concerns and fuel costs. Our project, "The Hybrid e-Bike," combines conventional cycling with electric motor support, promoting green energy

3.2 Selection of Components

3.2.1 Motor

A brushless DC motor (BLDC motor) is made up of windings in the rotor and permanent magnets in the stator. The commutator is attached to the ends of the winding coils. It has a DC voltage supply connected across the motor terminals.

Figure 3.2.1. BLDC Motor

Reversing the polarity of the voltage can change the direction of spinning. Permanent magnet poles interact with magnetic poles created in the rotor by the current flowing through the coils. The current flow needs to be reversed when the rotor OTN pole crosses the stator south pole in order to maintain the torque generation in the same direction. The sliding contacts are divided as a result. The term "commutator" refers to this segmented slip ring.

Motor Specifications - Power: 250W; Voltage: 24V; Current: 13.4A; RELATIVE SPEED: 275ORPM.

3.2.2 Controller

Here, we are using a controller to operate the electric bike setup. Certain components, including the brushed DC motor, are placed in this electric bicycle system. The controller needs both a battery and an input to control the various components of the electric bicycle system. This controller has several uses, including controlling the power supply, protecting against overcurrent and undervoltage, and operating a brushed DC motor. Several signals, including those for capacity detection, motor speed regulation, and current detection, are sent to the controller's pin in order to drive and operate brushless DC motors. 22 pins of the PIC16F72 controller's 28 pins are I/O pins are configured pin-to-pin by the user.

The reason this current detecting signal is used is that the motor's current increases when an electric bicycle is operating at a high load. Subsequently, the motor's winding and component will sustain damage.

Figure 3.2.2. Controller

3.2.3 Battery

Cost, longevity, energy density, and recharge cycle quantity were key factors in battery selection. Sealed lead acid batteries are preferred for their affordability and respectable energy density. We researched various electric bike designs and found that many use three 12V batteries, with capacities ranging from 7 to 20 amp hours. Our hybrid bicycle concept proposes the use of three 12V, 7-amp-hour Sealed Maintenance Free Batteries (SMFB), which are rechargeable lead acid batteries. The internal battery components are housed in a plastic case. The electrolyte in a lead acid battery loses a lot of its dissolved sulfuric acid (H_2S0_2) because the positive electrode uses lead oxide (PbO_2) plates and the negative electrode uses lead (Pb) plates.

Lead acid battery: - Rated voltage: 12V: Rated current: 7Ah; Number of batteries:2; Battery Rating 12 V* 14 Ah = 16

Figure 3.2.3. Battery

3.2.4 Solar panel

An additional power source for battery replenishment is provided by a solar panel positioned on the back of the bike, attached to the bicycle's controller charging port.

Solar panel specifications: - voltage: 12V; Current: 2.5A.

Figure 3.2.4. Solar Panel

3.3 Experimental Setup

"In this setup, the controller serves as the system's central control unit, managing all electrical components. The battery is connected in series with the controller, which also regulates power to the motor. The controller features a charging port for wall, dynamo, or solar charging. Additionally, components like battery indicators, ignition switches, and horns are connected to the controller. Power transmission is achieved through a chain drive system, which utilizes one or more roller chains to transfer power from the motor to the rear axle via sprockets and gears.

3.4 Working Principle

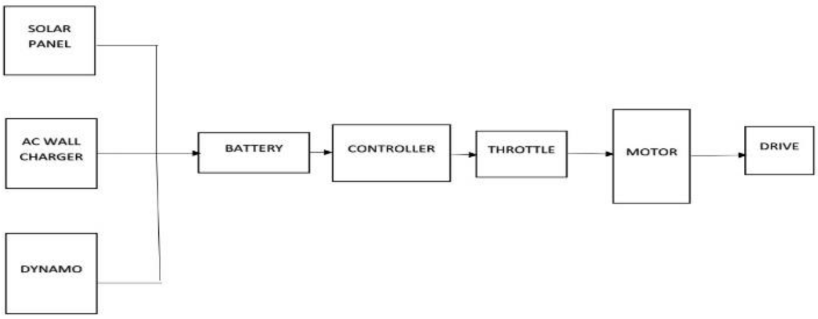

Figure 3.4. Working Principle

Table 1. Specification of Components

Motor Specifications	Power:250W, Voltage:24V,Current:13.4A Relative speed:2750RPM

Battery	Voltage:12V ,Current:7Ah,Battery rating 12V*14Ah=16
Solar Pannel	Voltage:12V, Current:2.5A

4. Simulation And Result

This chapter deals with the simulation of the electrical systems of a hybrid electric bicycle. The PV and dynamo are the input sources that generate the signal to drive the BLDC motor.

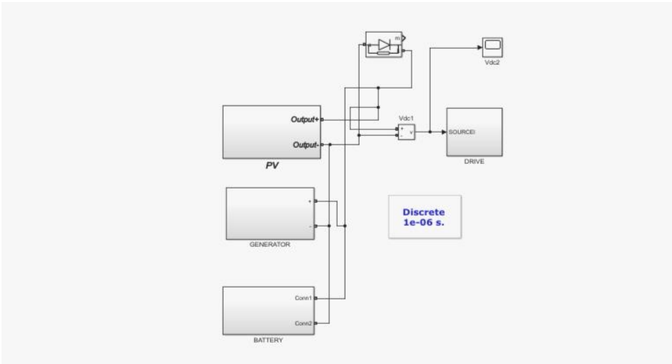

Figure 4. Simulation of Electrical System

4.1 Simulation of PV

A PV block is an irradiance block. It deals with the input, time, and amount of sunlight fell into the solar panel by means of irradiance. In current generator block, solar panel generates voltage and current. The photons were converted into electric signals. The boost converter's control block deals with the speed and movement of the photons.

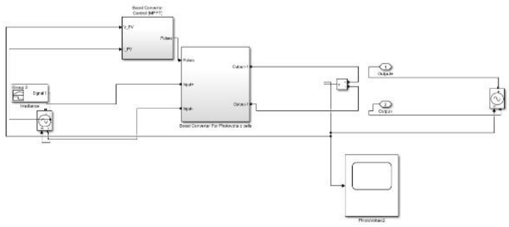

Figure 4.1. Simulation of PV

4.2.1 PV Input Irradiance

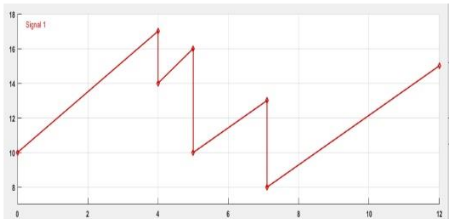

Figure 4.2.1. PV INPUT IRRADIANCE

4.2.2 PV Output Curve

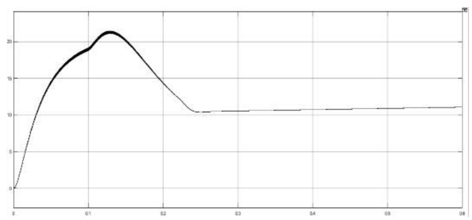

Figure 4.2.2. PV Output Curve

4.3 Simulation of Dynamo

The current generated from the dynamo is three phase AC. The conversion to DC is done by the rectifier. Here 4 N/m is an mechanical input which indicates the speed and power.

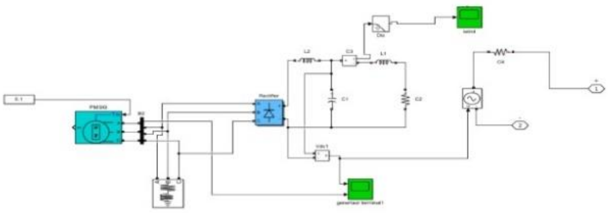

Figure 4.3. Simulation of Dynamo

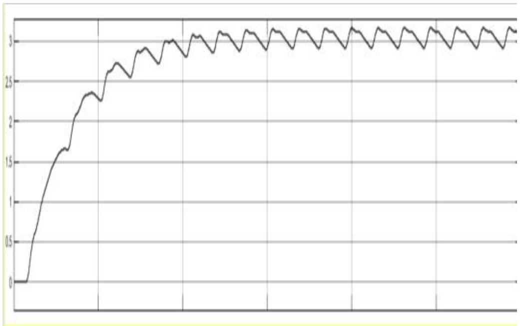

Figure 4.3.1. Dynamo Output Voltage

4.3.2 Dynamo Output Current Graph

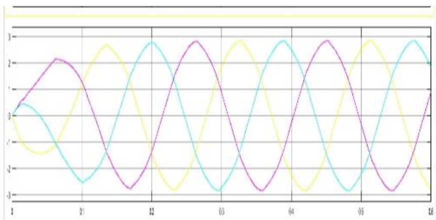

Figure 4.3.2. Dynamo Output Graph

4.4 Simulation of Motor

The expected RPM for the BLDC motor is 1500. It takes signal from the source and the solar panel. The signal provides the voltage information. The speed regulator regulates the signal from the various sources and sends it to PI controller. The PI controller convert the speed for the relevant voltage and generates signal.

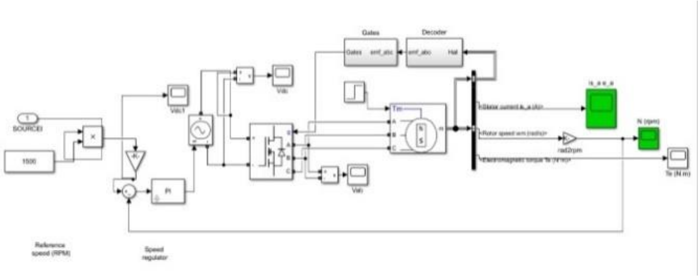

Figure 4.4. Simulation of Motor

4.4.1 Motor Output Current Graph

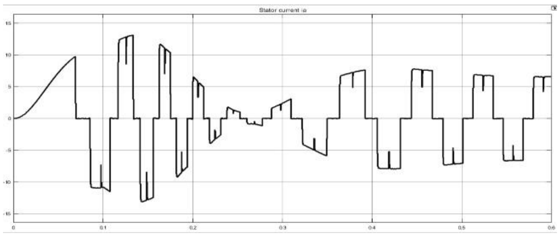

Figure 4.4.1. Motor Output Current

4.4.2 Motor Speed

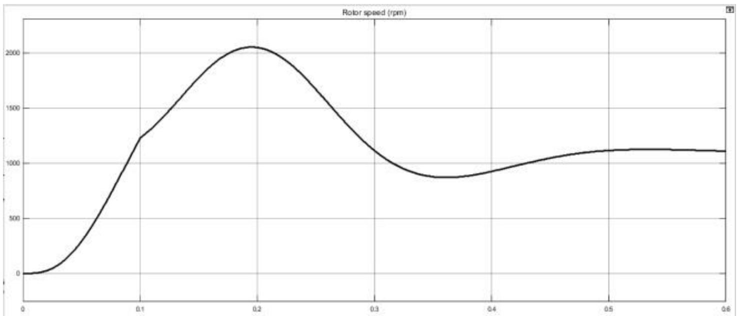

Figure 4.4.2. Motor Speed Graph

The output current and speed of the motor is obtained and shown in the fig 4.4.1 and 4.4.2

5. Conclusion and Future Scope

5 .1 Conclusion

Charging is the major complication in electric vehicles. Other than the conventional charging option, the other two ways of charging makes it more unique. The aesthetic outlooks and the robust design, provides more comfort for the riders. Both electrical and manual power are used for propulsion. So, the driver’s pedaling requirements is optional. Charging duration is 4 hours by conventional charger but it took quite longer for solar panel and dynamo. The unit cost is comparatively less than the available commercial e-cycles makes it less economical.

5.2 Future Scope

We can develop the proposed design methodology as a real-time hybrid electric bicycle. All we need is a normal bicycle and an electric propulsion system. We need to modify certain things on the selected bicycle, like adding an extra sprocket for another driving mode. Remove one of the conventional brakes in that cycle and replace it with an e-brake. We must make sure that the electronic components are precisely placed, and there should be no chance for any kind of damage for that. So, by following these principles accurately, we can easily develop a real-time hybrid electric bicycle, which will be carried out in the future work of this research.

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