Design And Build of Energy Proportional Electric Folding Bike According to Rider Needs

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Design And Build of Energy Proportional Electric Folding Bike According to Rider Needs

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***Abstract*—The use of fuel-powered vehicles is not recommended because fossil fuels are running low, and these vehicles pose a major threat to the safety of many people. Foldable electric bicycles can be a solution to this problem. The purpose of this research is to design and build an energy-proportional electric folding bicycle according to the needs of the rider. The method of implementing this research is designing, manufacturing, assembly, function test, performance test, and evaluation stage. Based on the research that has been carried out until this progress report has been prepared, it can be concluded as follows: (1) The mechanical system and control system for electric folding bicycles can function properly according to the design; (2) The average accuracy percentage of the pedal-assist sensor is 98.25% (very good); (3) The electric folding bicycle has 6-speed grades which are set according to the needs; (4) The electric folding bicycle uses a 48V 350W Planetary Gear BLDC Motor and a 48V 10AH Lithium battery which can travel 80 km per full charge.**

Keywords: electric folding bike, energy proportional, sports, healthy, easy to use

I. INTRODUCTION

Bicycles are a means of transportation that has been known to mankind for a long time and has even been the backbone of a means of transportation both for transporting people and goods. Now the bicycle is just one part of the means of transportation for modern humans whose position has been displaced by motorized vehicles. Even though it's only a small one, the existence of bicycles until now still exists due to several reasons, namely that a bicycle is a practical vehicle with a small size, lightweight, and is driven by footing. This vehicle is very suitable for serving short distances such as children commuting to school, shopping mothers in the market. In addition, bicycles also have elements of recreation and sport at the same time. Cycling is a pleasure in itself, where the body does exercise and at the same time, the eyes become fresh with the view that is enjoyed along the way.

The development of technology and mobility today has encouraged people to innovate and create means of transportation that are energy-efficient, environmentally friendly, and can reduce dependence on fuel oil which will run out at any time. Currently, transportation using electricity as an alternative energy source from fuel oil has begun to emerge, including electric folding bicycles. There have been many companies producing electric folding bicycles, both domestically and abroad. Of the various types of electric folding bikes on the market, no one has used energy proportional technology. The technology used is still using the on / off system. This means that if the rider wants to activate the electric motor as the main drive, just press the switch and if the rider wants to deactivate it, just press the switch again.

Some problems are often experienced by electric bicycle enthusiasts, namely when going through an uphill road. If you fully use leg power, it requires extra power so that the rider will get tired easily, but if you use electric power it will be burdensome for the electric motor so that it can quickly break down. To answer this problem, it is necessary to research with the title Design of Energy Proportional Electric Folding Bike According to the Needs of the Rider.

The e-bike controller by using ATMEGA-32 also has been reported in[1]. The simulation power converter and charger of the e-bike have been presented in[2] and [3]. Design and Manufacturing Feasibility of a Novel Smart Electric Folding Bicycles in the Philippines has been discussed in[4]. The results of this study indicate that the final design of the folding frame includes bicycle components such as wheels, pedals, brakes, and electrical components. The folding bike frame can also be used as a regular bicycle. Compared to other commercially available folding bicycle frames, the DLSU electronic folding bike offers a compact and practical folding orientation. The foldable design, which is pending patent, uses standard 305 or 16-inch wheels, nearly half the diameter of a full-size bicycle. The smaller wheels allow for a more compact fold design. The design results are as shown in Figure 1.

The smart electronic folding bike has two electronic components: hardware and software. The electronic hardware components are the battery pack, controller, and cables. This affects the frame of the folding bike in both cycling and folding/rolling cart mode, and therefore the hardware design

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Figure 1. Novel Smart Electric Folding Bicycles in the Philippines

Figure 2. Design of Foldable E-Bike for Clean & Safe Travelling in Smart-Cities

Figure 3. Design of an electric bicycle using solar panels

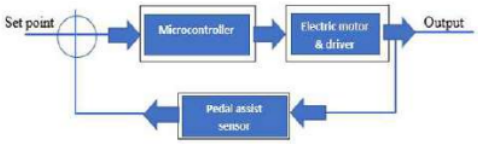

Figure 4. Block diagram of the electric folding bicycle hardware system

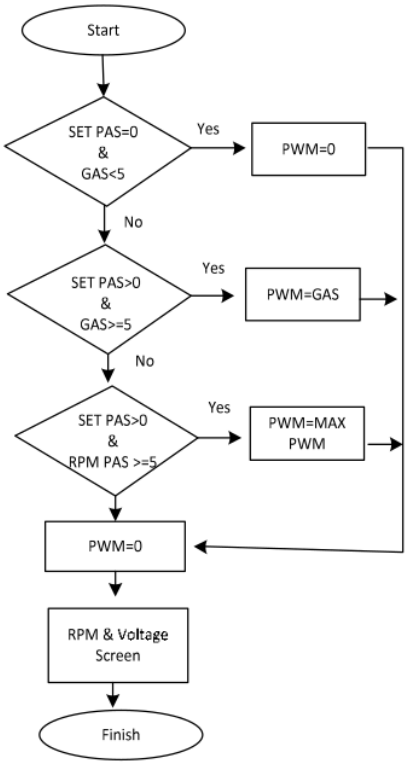

Figure 5. Flowchart of the electric folding bicycle software system

is considered in conjunction with the folding bike frame design. The mechanical and electrical components on this smart folding bicycle have several functions that make this folding bicycle electric and smart, but the electric power used is not proportional [4]

An Introduction to the Design of Foldable E-Bike for Clean & Safe Traveling in Smart-Cities with the design results as shown in Figure 2 [5]. The bike folds to 90x50x70cm and can run up to 24 miles on a single charge. It uses a Li-ion battery and is hidden in the frame, so it's nice to look at. This folding capability makes it compatible for use with public transport, users can use it to travel to the station and then fold & store it backpack when traveling from public transport. The weight of the bicycle is maintained in such a way that it is easy to carry on the shoulders without causing discomfort. These bicycles are ideal for traveling short distances (about 12 kilometers) [5]

The research is entitled "Designing an Electric Bike Using a DC Series Motor" has been reported in[6]. The results showed that the electric bicycle was designed using a drive system in the form of a 24 Volt, 350 Watt, 14.4 Ampere, 3000 rpm series DC motor. Electric bicycles use a 24 Volt permanent magnet DC generator with 29 Watt of power to convert all energy from the rotation of the bicycle wheels into electrical energy. The electrical energy storage medium on this electric bicycle uses 4 batteries with a voltage of 12 Volt - 7.1 Ah each. From the results of testing electric bicycles and all data, the output power is obtained to drive an electric bicycle with a load of 80.6 = 316.6954 Watt, a load of 85.6 kg = 303.7732 Watt, a load of 90.6 kg = 294.5672 Watt. The maximum speed of the bicycle without load is 78.53 m / s. The average speed of a bicycle with a load of 80.6 kg = 5.68

m / s, speed of a bicycle with a load of 85.6 kg = 5.13 m / s, speed of a bicycle with a load of 90.6 kg = 4.70 m / s [4].

The design of an Electric Bike Using Solar Panels as a Battery Charger has been explored in[7]. The design results show that to move an electric bicycle with a speed of 5.556 m / sec, assuming a 70 kg rider mass requires a motor power of 160.278 Watt and if using 40 WP solar panels and a battery capacity of 468 AH, the bicycle can cover a distance of 11.23 km. The design of the electric bicycle research results is shown in Figure 3.

II. METHOD

The hardware system in the process of designing an electric folding bicycle is done by designing a minimum system based on the block diagram in Figure 4.
The electric folding bicycle software system uses the Arduino 1.3.13 program based on the flowchart in Figure 5.

III. RESULT AND DISCUSSION

Based on the manufacturing and assembly process, an energy proportional electric folding bicycle has been realized as shown in Figure 6.
The mechanical system of the electric folding bike is functioning properly. This can be seen from the frame construction that can withstand the load of the rider and all the supporting components such as wheels, brakes, saddles, handlebar, transmission, gas handle, lights, bells, electric motors, batteries, control box. Mechanical system design analysis using 70 kg rider weight:
Vehicle system mass (Mtotal)
Mtotal = Bike weight + Rider Weight
= 20 kgf + 70 kgf = 90 kgf (N)
Mechanical Force Normal Style (FN) = 90 N
Static friction (FS) FS = FN x μS = 90 N x 0.7 = 63 N Kinetic friction (FK) FK = FN x μK = 90 N x 0.6 = 54 N
Torque The torque required to move the bicycle from rest must be more than:
T = (FN x Wheel radius): 2
T = (90 N x 0.25 m): 2
T = 11.25 Nm
For the bicycle to move, the foot pedal force (F) must be greater than:
F > T : Pedal radius
> 11.25 N : 0.2
> 56.25 N
After the bicycle has moved, the force (F) of the foot pedal must be greater than:
F > (FK x Pedal spokes) / Wheel spokes
> (54 N x 0.25 m) / 0.25 m
> 54 N

To find out the performance of electric folding bikes on road conditions, it is necessary to conduct a performance test with the results that can be seen in Table 1 . Based on the results of testing the performance of electric folding bikes on flat roads as shown in Figure6. it shows good results with the following description.

Figure 6. Performance test on flat roads

TABLE 1. THE PERFORMANCE TEST RESULTS FOR ELECTRIC FOLDING BICYCLES ON FLAT ROADS

Setting PWM	Speed (km/hours)			
	No Weight	Weight 45 kg	Weight 60 kg	Weight 82 kg
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	4.5	1.2	0	0
12	8.3	6.5	5.4	4.5
13	12.5	9.6	7.8	6.5
14	15.7	12.3	10.1	8.5
15	18.3	14.6	12.2	10.5
16	20.6	16.9	14.6	12.8
17	22.4	18.9	16.8	15.1
18	23.9	20.7	18.5	16.9
19	25.1	22.1	20.1	18.4
20	26	23.4	21.7	20.3
21	27.3	24.9	23.3	22.1
22	28.9	26.7	25.2	24.3
23	30.1	27.9	26.5	25.6
24	31.4	29.3	28.1	26.9
25	31.4	29.3	28	26.9

- If the PWM is set with a value of 1 to 10, then at no-load conditions or with a load of 45kg, 60kg, 82kg, it will not result in wheel speed (the wheels are not moving).
- If the PWM is set with a value of 11, at no-load conditions it can produce a wheel speed of 4.5 km/hour, under 45kg load conditions it produces 1.2 km/hour, under 60kg and 82kg load conditions it doesn't produce wheel speed (the wheels don't move).

Figure 7. Performance test on uphill road

TABLE 2. THE PERFORMANCE TEST RESULTS FOR ELECTRIC FOLDING BICYCLES ON UPHILL ROADS

Setting PWM	Speed (km/hour)			
	No Weight	Weight 45 kg	Weight 60 kg	Weight 82 kg
1	0	0	0	0
2	0	0	0	0
3	0	0	0	0
4	0	0	0	0
5	0	0	0	0
6	0	0	0	0
7	0	0	0	0
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	4.2	0	0	4.2
12	6.9	4.3	0	6.9
13	8.4	6.2	4.8	8.4
14	10.8	8.9	7.1	10.8
15	13.1	10.5	8.7	13.1
16	14.9	12.6	10.3	14.9
17	16.4	14.3	12.1	16.4
18	17.1	15.7	13.3	17.1
19	17.7	16.4	14.2	17.7
20	19.6	17.8	16.3	19.6
21	20.9	18.9	17.1	20.9
22	22.2	20.2	17.9	22.2
23	23.7	21.4	18.6	23.7
24	24.4	22.5	20.1	24.4
25	25.1	23.4	21.3	25.1

- If the PWM is set with a value of 12, at no-load conditions it can produce a wheel speed of 8.3 km/hour, at 45kg load conditions it produces 6.5 km/hour, under 60kg load conditions it produces 5.4 km/hour, and at 82kg load conditions it produces 4.5 km/hour.
- If the PWM is set with a value of 15, at no-load conditions it can produce a speed of 18.3 km/hour, at 45kg load conditions it produces 14.6 km/hour, under 60kg load

TABLE 3. THE RESULTS OF THE ELECTRIC FOLDING BICYCLE PERFORMANCE TEST ON VARIOUS ROAD CONDITIONS USING 100% POWER FROM AN ELECTRIC MOTOR

Rider Weight	Speed (km/hour)		
	Up	Flat	Down
45 kg	25.1	29.3	40.3
60 kg	23.4	28.0	38.8
82 kg	21.1	26.9	37.2

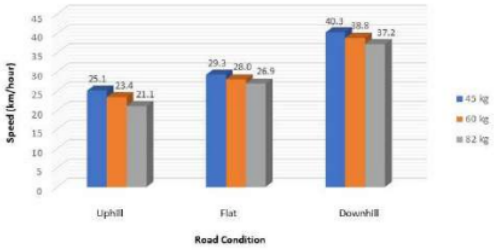

Figure 8 Graph of electric folding bicycle performance test on various road conditions using 100% electric motor power

- conditions it produces 12.2 km/hour and at 82kg load conditions it produces 10.5 km/hour.
- If the PWM is set with a value of 20, at no-load conditions it can produce a speed of 26 km/hour, at 45kg load conditions it produces 23.4 km/hour, under 60kg load conditions it produces 21.7 km/hour, and at 82kg load conditions it produces 20.3 km/hour.
- If the PWM is set with a value of 25, at no-load conditions it can produce a speed of 31.4 km/hour, at 45kg load conditions it produces 29.3 km/hour at 60kg load conditions it produces 28 km/hour and at 82kg load conditions it produces 26.9 km/hour.
- Bike speed is inversely related to the rider's weight.
- The average difference in bicycle speed for each 1 digit PWM change at no-load conditions is 2.07 km/hour, at 45 kg load is 1.90 km/hour, at 60 kg load is 1.89 km/hour and at 82 kg load conditions is 1.87 km/hour.

Based on testing the performance of electric folding bikes on uphill road conditions (see Figure7), the results are as follows.

- If the PWM is set with a value of 1 to 10, then all loads will not produce speed.
- If the PWM is set with a value of 11, at a load of 45kg it produces 4.2 km/hour, at a load of 60kg and 82kg it doesn't produce any speed.
- If the PWM is set with a value of 12, under 45kg load conditions it generates 6.9 km/ hour, under 60kg load conditions it produces 4.3 km hour and at 82kg load conditions it doesn't produce speed.
- If the PWM is set with a value of 15, at a load of 45kg it generates 13.1 km/hour, at a load of 60kg it produces 10.5 km/hour and at a load of 82kg it produces 8.7 km/hour.
- If the PWM is set with a value of 20, under load conditions 45kg it produces 19.6 km/hour, under load conditions of 60kg it produces 17.8 km/hour and under load conditions it produces 16.3 km/hour.
- If the PWM is set with a value of 25, at a load of 45kg it generates 25.1 km/hour, at a load of 60kg it produces

23.4 km/ hour and at a load of 82kg, it produces 21.3 km/hour.

- Bike speed is inversely related to the rider's weight.
- The average difference in bicycle speed for each 1 digit PWM change at 45 kg load is 1.49 km/hour, at 60 kg load is 1.47 km/hour and at 82 kg load condition is 1.38 km/hour.

Based on testing the performance of electric folding bikes on uphill, flat, and downhill road conditions using 100% electric motor power, the results are as follows.

- In uphill road conditions, the top speed is 25.1 km/hour with a rider's weight of 45 kg, while the lowest speed is 21.1 km/hour with a rider's weight of 82 kg.
- On flat road conditions, the top speed is 29.3 km/hour with a rider's weight of 45 kg, while the lowest speed is 26.9 km/hour with a rider's weight of 82 kg.
- In downhill road conditions, the top speed is 40.3 km/hour with a rider's weight of 45 kg, while the lowest speed is 37.2 km/hour with a rider's weight of 82 kg.
- Bicycle speed is inversely proportional to the rider's weight.

IV. Conclusion

Based on the research that has been done, it can be concluded such as: (1) The mechanical system and control system of the electric folding bike can function properly according to the design; (2) The average accuracy percentage of the pedal assist sensor is 98.25% (very good); (3) Electric folding bikes have 6 speed grades that are set as needed; (4) The electric folding bicycle uses a 48V 350W Planetary Gear BLDC Motor and a 48V 10AH Lithium battery that can travel 80 km per full charge; (5) If the PWM is set with a value of 15, at a load of 45kg it generates 13.1 km/hour, at a load of 60kg it produces 10.5 km/hour and at a load of 82kg it produces 8.7 km/hour; (6) If the PWM is set with a value of 20, under load conditions 45kg it produces 19.6 km/hour, under load conditions of 60kg it produces 17.8 km/hour and under load conditions it produces 16.3 km/hour; (7) If the PWM is set with a value of 25, at a load of 45kg it generates 25.1 km/hour, at a load of 60kg it produces 23.4 km/ hour and at a load of 82kg it produces 21.3 km/hour.

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