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Studying performance evaluation of hybrid e-bike using solar photovoltaic system

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ABSTRACT

Hybrid e-bike system is a bicycle included electric hub motor used to aid propulsion. A solar package with main components is built with it. This study included the travelled distance divided by time under only the batteries and batteries with photovoltaic (PV) modules (at different hours during the day). A comparison between two methods is made and documented in this paper. The paper aims to captivate the fettle and experiences with the use of e-bike. Commuting distance per hour was approximately 6.8 km/h. The current limitations must not exceed (10.4 A) and the big challenge, no shading plops on solar panels due to rider. Finally, depending on the solar irradiance with time curve, hybrid e-bike gave longer travelled distance with respect to time as compared with the batteries case study.

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1. INTRODUCTION

The motivation reason to design solar e-bike is to surmount the quandary with pollution and the economy. E-bike is the best solve for the technical application in the word [1]. E-bike is a battery functioned cart that is low fending cost, less pollution and very economical. It is very attractive and alternative to both traditional automobiles and conventional e-bike which providing a fun, efficient, environmentally and convenient manner to travel [2]. Battery bank is coupled with the electric DC motor in the e-bike structure. Now days this cart is manufactured at a very large scale and the power is stocked in a rechargeable battery bank which drives the DC motor [3].

Solar e-bike is sophisticated to study the pollution caused by e-bike. For remote and rural areas where fuels are not plenteous to drive two wheelers so that it can run under solar energy in addition to the low driving cost [4]. Solar energy is used to drive the motor and it is a free of cost. It different from others carts. Solar panel will be charged the battery bank while e-bike is running [5]. When the energy is not availed a pedal operation is used. In present scenario, the petroleum products are reaching to the peak under mark-up number of automobiles [6]. These oil products are hazard of exhaustion and non-renewable sources. Over the past few years, the prices of crude oil have significantly high value without turning back [7]. The form hybrid infers to more than one energy supply which is used to power part or all carts motive [8]. Solar energy may be also used to sell power for controls, communications and other auxiliary functions, DC motor is used in this work. Hybrid e-bike is a project that can carry both cleaner technology as well as a lesser reliance on oil [9].

2. METHOD

The requires research method included the components, hardware description, solar irradiance curve and flowchart algorithm.

2.1. Components required

Figure 1 depicts a solar hybrid e-bike that consist of 24V. Table 1 represents types of companents used in the project. Solar panels, DC motor, and sealed lead acid battery was used to build up the e-bike.

Figure 1. Solar hybrid e-bike

Table 1. Components of hybrid e-bike

No.	Components
1	Solar panels
2	DC motor
3	Sealed lead acid battery
4	Speedometer
5	Manual control

2.2. Hardware description

The hardware components that have been used in this project are:

2.2.1. Solar modules

The e-bike appears to be powered by solar energy. Sunlight is converted to electricity by photovoltaic (PV) modules utilization PV effect [10]. There are two types of effects that solar modules can produce, one is PV and the other is photoelectric [11]. When using photoelectric effect, as soon as a metal is exposed to photons, it releases electrons that move to the conduction and valence bands, creating potential differences between the electrodes [12]. The solar e-bike is run by solar energy. With the assistance of a PV cell, the lead acid batteries are charged using solar energy [13]. Solar cells convert the sun light directly into electricity by using PV effect. Electromagnetic radiation is converted into electrical energy by the PV effect, which is then used to produce electricity [14]. Solar cells are manufactured as a module and connected in series or parallels to permit sunlight to pass and protecting the silicon's layers from the weather [15]. It is possible to obtain the desired voltage by connecting two small PV modules in series. Figure 2 represents solar modules. Table 2 illustrates the parameters of solar module.

Figure 2. Solar module

Table 2. Parameter solar panel

Parameter	Value
Max. voltage (V)	18.9
Max. current (A)	0.53
Max. power (W)	10
Short-circuit current (A)	0.56
Open-circuit voltage (V)	22.4
Normal operating cell temp. (℃)	-40 to 85
Dimention (mm)	360.300.28

2.2.2. Hub DC motor

A syllogistic DC motor has no brushes, which reduces the cost, fending, time, and efficiency of the motor. It is divided into two sections [16]. The fixed coils are represented on the inside, while the rotating magnet is represented on the outside. Many types of tiny magnetic field sensors set in the coils [17]. These sensors sense the position and direction of motor and called hall effect sensors. An extra electronic circuit must be added when using this type of motor. Figure 3 represents DC motor of the e-bike [18]. DC motor specifications are listed in Table 3.

Figure 3. DC motor of e-bike

2.2.3. Sealed lead acid battery

The battery is one of the most important components in the design and implementation of a solar vehicle [19]. The battery must be able to charge from the solar module in order to power and push the e-bike. The most crucial factor to consider is whether or not this battery is compatible with an e-bike [20]. The final decision falls to choose the best battery type that compatible with the e-bike. Figure 4 represents the battery type. Battery specifications are listed in Table 4.

Table 3. DC motor specifications

Value	Parameter
BFSWXB	Type
250	Rated power (W)
12-24	Rated voltage (V)

Table 4. Battery specifications

Value	Parameter
BFSWXB	Type
250	Rated power (W)
12-24	Rated voltage (V)

2.2.4. Speedometer

The speed/distance sensor is installed on the front fork of the e-bike with the same side of the magnet, and the sensor is secured on the front fork using the tie of connection [21]. Adjust the magnet and sensor's relative positions, then plane them together and make the spacing between them 1 mm [22]. Don't install the sensor in the magnet's center. Speedometer was fixed on the right side of handle bar as shown in Figure 5.

Figure 4. Battery type

Figure 5. Speedometer

where: $Speed = \frac{distance}{time}$

Wheel circumference=circumference of a circle=2×radius×Pi

No. of cycle=distance/circumference

2.2.5. Revoshift

Set refers to a manner of controlling the speed of a motor and on the right side of the handle bar, so that it connected in the e-bike to decrease or increase the speed based on the situation [23]. Figure 6 illustrates the throttle (Revoshift).

2.2.6. Motor controller

An electronic motor controller is used to provide a fixed voltage for brushless DC motors (BLDCs) [24]. It consists of various types of which reinstructs to excite the mainly coils in order to rotate the rotor, this controller included a microprocessor, transistors, MOSFETs, and other components that provide overcurrent, under voltage, and overvoltage protection for the motor [25]. Figure 7 represents the electric motor controller, and its specifications (throttle parameters) are listed in the Table 5.

Figure 6. Throttle e-bike

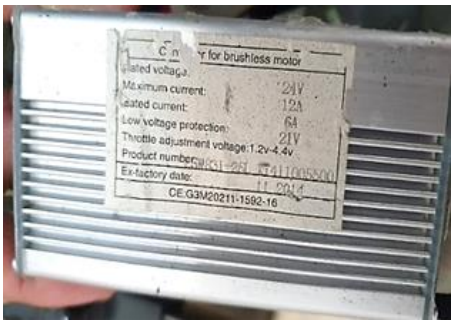


Figure 7. Electric motor controller

Table 5. Throttle parameters

Parameter	Value
24	Rated voltage (V)
12	Max. current (A)
6	Rated current (A)
21	Low voltage protection (V)
1.2-4.4	Throttle adjustment voltage (V)
L5W831-261,X1411005500	Product No.

2.2.7. Power mode

On the e-bike, there are more than one levels of electric assist available. Three power mode levels available in this e-bike [26]. In this work, the highest level (H-mode) is chosen in order to obtain actual results in less time [27]. Figure 8 shows the power mode's shape.

2.2.8. Blocking diode

Figure 9 depicts the shape of a blocking diode used to prevent reverse current after sunset and ensure that no discharge from the batteries occurs (no batteries charging losses) [28], [29].

Figure 8. Power mode

Figure 9. Blocking diode

3. SOLAR IRRADIANCE AND FLOWCHART OF HYBRID E-BIKE

The distribution of solar irradiance with time during July month is illustrated in Figure 10 [30]. International measurements of solar irradiance are taken on a horizontal surface, and the highest value of beam irradiance was indicated in July on a horizontal surface.

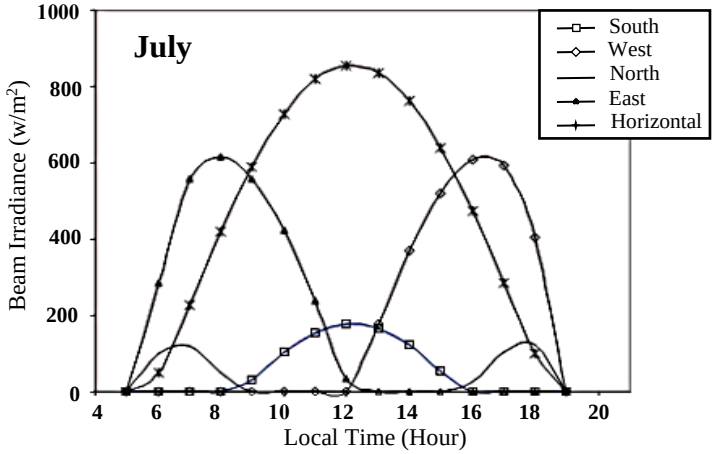


Figure 10. Solar irradiance vs time during July

Hybrid system includes two different ways for charging the batteries bank: wall charger and solar PV charger as shown in Figure 11. This flowchart illustrates the charging process according to both directions. If the battery bank is fully charged, the controller will send a signal to the motor hub, causing the E-bike to move via throttle commands.

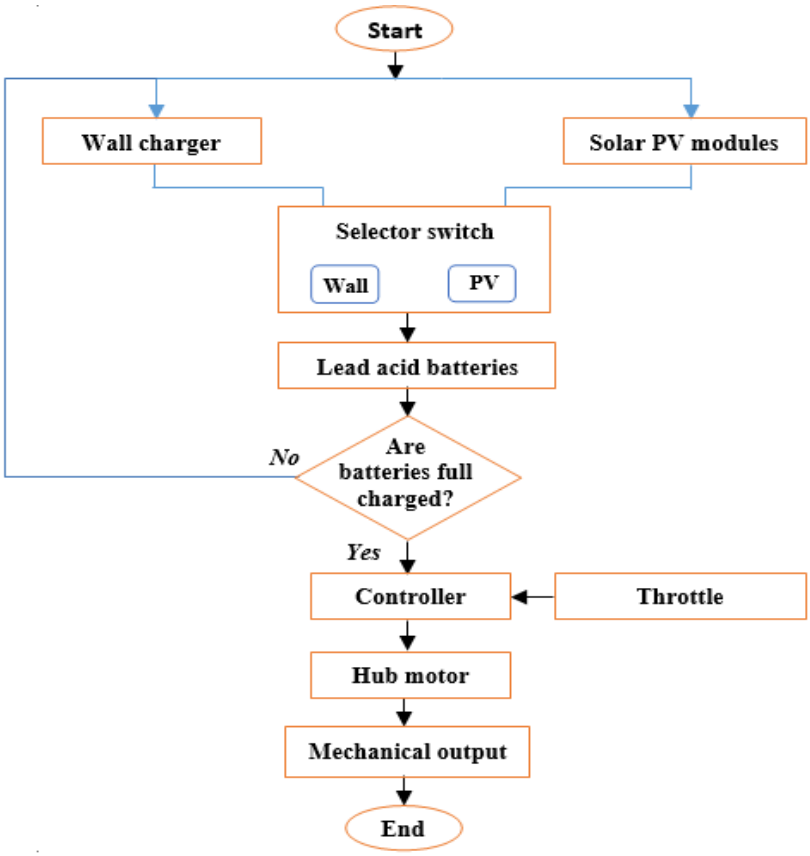


Figure 11. Flowchart of hybrid e-bike

4. RESULTS AND DISCUSSION

4.1. Without solar modules (with batteries)

The (km/h) difference between two readings of speedometer on e-bike by using only batteries was illustrated in Figure 12(a) before setting off and in Figure 12(b) after setting off, the result shown in Table 6.

(a) (b)

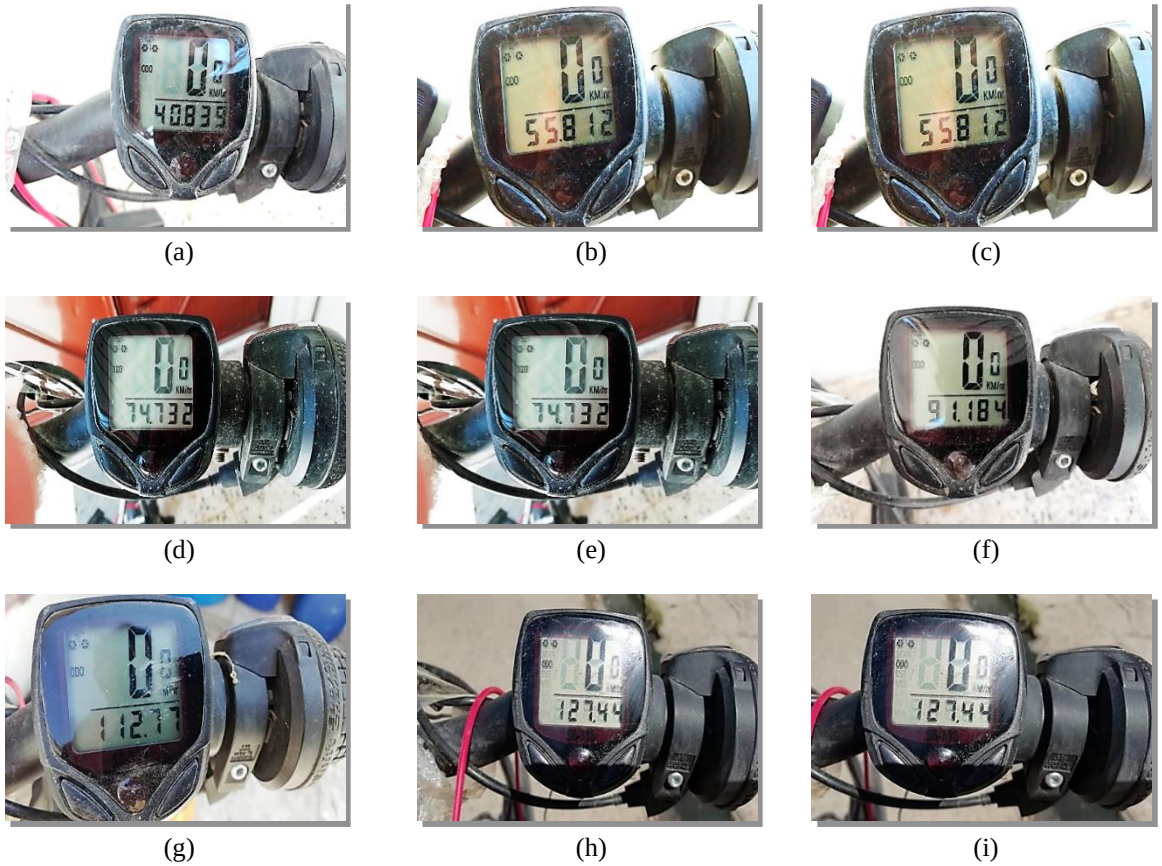
Figure 12. Speedometer (km/h) with only batteries (a) before setting off and (b) after setting off

Table 6. Km/h readings with only batteries

Traveled distance per hour (km/h)	After setting off (km/h)	Before setting off (km/h)
11.285	31.089	19.8

4.2. Under solar modules

The (km/h) difference between two readings of speedometer on e-bike under solar from the hour (11-12) a.m., (12-1) p.m and (1-2) p.m., (3-4) p.m., (4-5) p.m. and (5-6) p.m were illustrated in Figures 13(a) to 13(l). From Figure 13 the readings of km/h under solar radiation for all time periods can be listed in Table 7.



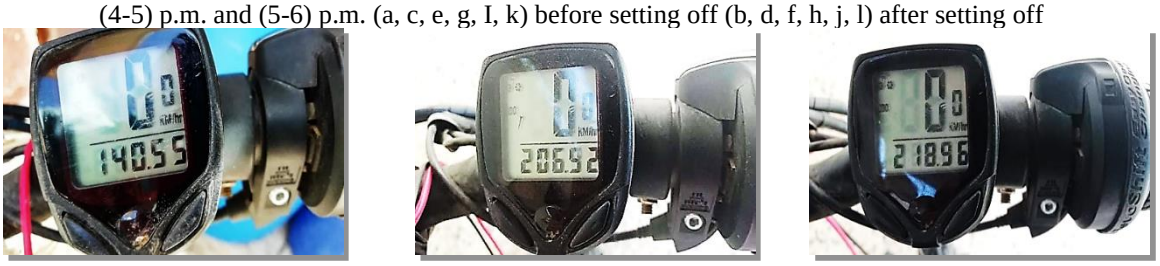
(a) (b) (c)

(d) (e) (f)

(g) (h) (i)

Figure 13. Speedometer (km/h) under solar from the hour (11-12) a.m., (12-1) p.m., (1-2) p.m., (3-4) p.m.,

(4-5) p.m. and (5-6) p.m. (a, c, e, g, I, k) before setting off (b, d, f, h, j, l) after setting off



(j) (k) (l)

Figure 13. Speedometer (km/h) under solar from the hour (11-12) a.m., (12-1) p.m., (1-2) p.m., (3-4) p.m., (4-5) p.m. and (5-6) p.m. (a, c, e, g, I, k) before setting off (b, d, f, h, j, l) after setting off *(continue)*

Table 7. Km/h readings under solar radiation

Time	Before setting off (km/h)	After setting off (km/h)	Traveled distance per hour (km/h)
(11-12)	40.839	55.812	14.973
(12-1)	55.812	74.732	18.92
(1-2)	74.732	91.184	16.45
(3-4)	112.17	127.44	14.67
(4-5)	127.44	140.55	13.11
(5-6)	206.52	218.96	12.04

The relationship between the difference values (km) for each period and the time is expressed as the histogram shown in Figure 14, based on the above results that were measured under sunlight.

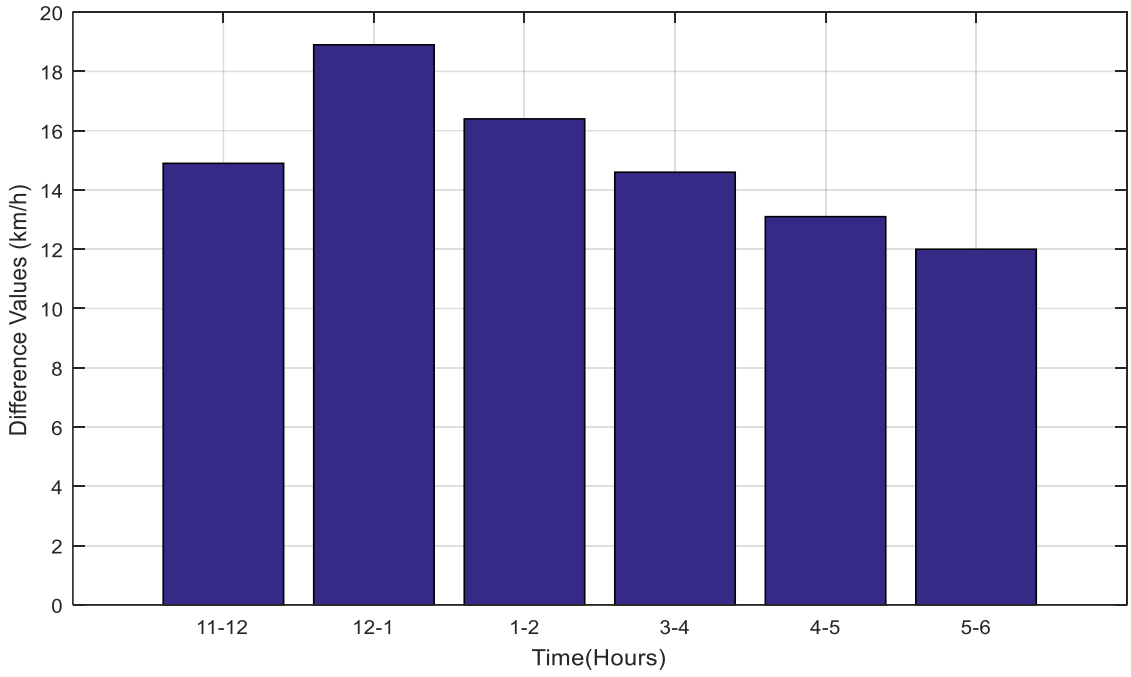


Figure 14. Histogram for difference speedometer values (km/h) of each period with respect to time

5. CONCLUSION

Hybrid e-bike solves many environmental issues and are considered a pollution-free mode of transportation and lessens reliance on fossil fuels. The least value in speed under solar gives an increase equal to (0.755 km/h) as compared with the battery only, the highest traveled distance divided by time is investigated at (12:00-1:00) p.m and the highest difference in speed under solar is (6.88 km/h). The difference value in speed between peak value under solar and the value under only batteries is (7.635 km/h)

and the maximum traveled distance divided by time value is obtained at 12:00-1:00 p.m. but the minimum value is obtained at batteries only, therefore the hybrid system based solar and batteries gives the highest travelling distance. This project comprises from two parts, software and hardware. The software part included controller program and the hardware part included hybrid e-bike with its components. The specifics about the project are using solar energy to recharge the batteries and using strong torque motor to drive the hybrid e-bike.

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