Development of a solar-powered electric bicycle in bike sharing transportation system

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Development of A Solar-Powered Electric Bicycle In Bikesharing Transportation System

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Abstract. The increasing mobility has directly led to deteriorating traffic conditions, extra fuel consumption, increasing automobile exhaust emissions, air pollution and lowering quality of life. Apart from being clean, cheap and equitable mode of transport for short-distance journeys, cycling can potentially offer solutions to the problem of urban mobility. Many cities have tried promoting cycling particularly through the implementation of bike-sharing. Apparently the fourth generation bikesharing system has been promoted utilizing electric bicycles which considered as a clean technology implementation. Utilization of solar power is probably the development keys in the fourth generation bikesharing system and will become the standard in bikesharing system in the future. Electric bikes use batteries as a source of energy, thus they require a battery charger system which powered from the solar cells energy. This research aims to design and implement electric bicycle battery charging system with solar energy sources using fuzzy logic algorithm. It is necessary to develop an electric bicycle battery charging system with solar energy sources using fuzzy logic algorithm. The study was conducted by means of experimental method which includes the design, manufacture and testing controller systems. The designed fuzzy algorithm have been planted in EEPROM microcontroller ATmega8535. The charging current was set at 1.2 Amperes and the full charged battery voltage was observed to be 40 Volts. The results showed a fuzzy logic controller was able to maintain the charging current of 1.2 Ampere with an error rate of less than 5% around the set point. The process of charging electric bike lead acid batteries from empty to fully charged was 5 hours. In conclusion, the development of solar-powered electric bicycle controlled using fuzzy logic controller can keep the battery charging current in solar-powered electric bicycle to remain stable. This shows that the fuzzy algorithm can be used as a controller in the process of charging for a solar electric bicycle.

1. Introduction

The world population has been progressively concentrating in the cities [1]. Cities around the world are undergoing rapid urbanization. Mobility in urban areas is one of the challenge that must be addressed and improved to get a better quality of life for the community [2]. The increasing mobility has strong correlation to the traffic conditions, extra fuel consumption, automobile exhaust emissions, air pollution, and quality of life. Urban mobility is a prevalent problem in many cities around the world. Issues on the urban mobility affects the quality of life and environmental sustainability are gaining importance in the world.

In recent years there have been over energy use and carbon emissions in the transportation sector, which then leads to an attempt to reduce the impact of transportation activities. In 2011 the transportation sector uses about 33% of the energy consumption in Europe [3]. So that the promotion of non-motorized modes of transportation received significant attention within the framework of sustainable urbanism and vision of eco-mobility [4].

Apart from being a clean, cheap and equitable mode of transport for short-distance journeys, cycling can potentially reduce traffic congestion. Cycling can be considered as one of the solution for urban mobility problems especially for short distance trips. Cycling offers many benefits to the problem of urban mobility. Cycling offers a fast, cheap and efficient transportation option for end-to-end short-distance trips, with smaller carbon than driving a car. Cycling can also encourage a modal shift from private car to public transport. To get these benefits, many cities have tried promoting cycling using different policies, particularly through the implementation of bike-sharing projects. [5].

Bike sharing scheme as an alternative transportation system has been growing rapidly throughout the world. Cities around the world have invested on bike sharing systems to improve their mobility and reduce the car dependency [6]. In recent years, bike-sharing has become popular in the world [7]. A bike-sharing system is a short-term rental scheme allowing bicycles to be collected and returned at any of self-serve stations. It represents a transportation alternative by complementing the urban public transportation. It enables commuters to flexibly use bicycles without incurring the cost and the trouble of owning and maintaining them. There has been rapid growth in bikesharing systems, and apparent success in attracting riders. In recent years, bikesharing systems have spread throughout the World. As of June 2014, public bikesharing programs existed on five continents, including 712 cities, operating approximately 806,200 bicycles at 37,500 stations [8]

Recently, many cities have implemented the third generation of public bikesharing systems. These new bikesharing systems overcome many of the operational problems associated with older bikesharing programs that operated with free or coin-deposit schemes. The third generation of bikesharing systems have docking stations to rent and return bicycles also use key smartcards for access to a bicycle. The technology improvements have enabled their success of bike sharing programs. In Europe, the deployment and expansion of the third generation bikesharing schemes in recent years have been implemented rapidly. The third generation is now approaching market saturation. At present, the fourth generation bikesharing system has been introduced which utilizes electric bicycles and clean technology implementations. Utilization of solar power is probably the key developments in the fourth generation bikesharing system and will become the standard in bikesharing system in the future [9]. The fourth generation bikesharing program uses a solar-powered electric bicycle as the main vehicle. Electric bikes use batteries as a source of energy and thus require a battery charging system with a source of energy from solar cells. Therefore, it is necessary to develop an efficient battery charging system. This work presents a novel method of a battery charging system using fuzzy algorithm.

2. Literature Review

2.1 Bikesharing.

Bikesharing program is a bike user community network which is distributed around town at low cost. Bicycles can be borrowed at any time at the nearest bike station and can be returned to a bike station to another so bikesharing program ideal for transport from point A to point B. To use a bicycle, a person must register as a member and use the card members, users simply swipe the card members to make the process bicycles [10]. Bike-sharing is a convenient and 'green' transportation mode, therefore, plays an important role as a complementary within comprehensive transportation system [11]. Bikesharing has the potential to play an important role in bridging some of the gaps in existing transportation networks, as well as encouraging individuals to use multiple transportation modes. [8]

At this time the fourth generation has began to appear that integrates with other modes of public transport and clean technology. Utilization of clean technologies including solar power will likely become the standard in the future bikesharing system. [9]. The author in [12] has suggested that the bike sharing system based on electric bicycles provide a high level compared with the conventional bike sharing system, while maintaining low environmental impact. An electric bicycle reduces the trip effort required and the travel time [13], though at a higher cost due to the additional requirement of electricity. E-bike sharing system are expected to contribute, among others [14] include:

- reduction of single occupancy journeys with car, and thus ease of traffic congestion,

- reduction of CO2 emissions from motorized traffic, and thus improvement of air quality,
- increased of physical activity levels and improvement of public health,
- improvement of accessibility and flexibility of mobility,
- improvement of road safety (particularly for cyclists), and
- enhancement of the profile and conditions of living in modern cities, supporting also local economies and tourism.

2.2 Fuzzy Logic.

A basic configuration of a fuzzy logic system consists of four main components, namely a fuzzyfication device, knowledge base, decision making and defuzzyfication logic devices. This fuzzy controller consists of two input variables and one output variable. The input variable consists of an error (Error, E) and the change of error (CE). The concept of fuzzy logic is used for the handling and processing of linguistic information. Since 1980 Fuzzy Logic Controllers (FLCs) has been successfully applied with success in many industries [15], for instance: the process control, image processing, motor control, the automatic train operation, comcorder outfocusing, servo motors control, aircraft control, setting spacecraft position and others.

Major factors in FLC are:

- The value of the inputs and outputs as well as the universe of discourse (universe discourse) input and output,
- Scaling factor input-output variables,
- Fuzzy membership function used in the preparation of fuzzy values for each variable input-output, and
- Rule base.

In this study, FLC planted in memory of the microcontroller ATmega8535 and membership functions to be stated in the charging current error in the microcontroller ATmega8535 expressed in Figure 1. Membership function delta error in the charging current ATmega8535 microcontroller expressed in Figure 2. PWM output membership function is expressed in Figure 3.

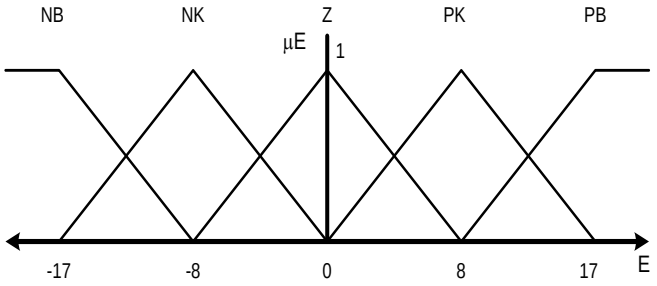

Figure 1. Membership Function error (E) Charging Current on the ATmega8535

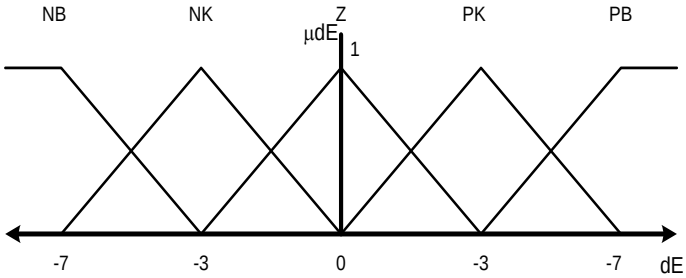

Figure 2. Membership function Delta Error (dE) Charging Current on the ATmega8535

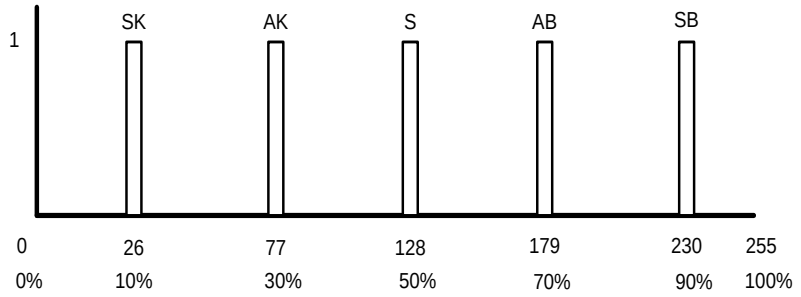

Figure 3. Membership Function PWM Output ATmega8535

A phase of fuzzy rules set needs to consider the form of the system response that may occur as shown in Figure 4. From this figure there are 25 possibilities for error and delta error combinations. The y axis represents the current set point of 1.2 A with an error of ± 1 A while delta-error taken ± 0.4 A. The designed fuzzy rule is shown in Table 1. Decision methods (inference) used by the fuzzy controller fuzzy logic is MAX-MIN method.

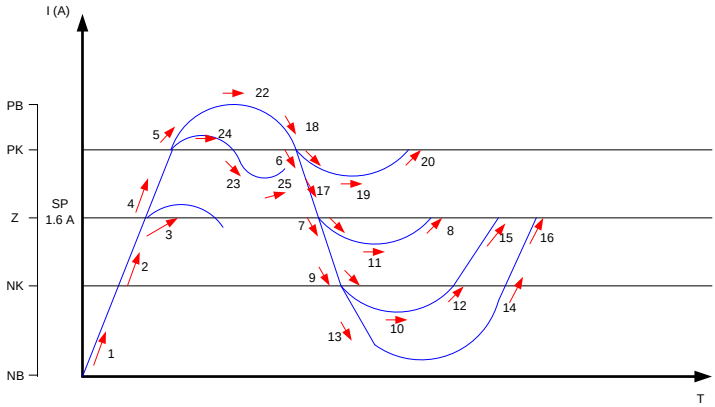

Figure 4. Various conditions may be on Response System

Table 1. Rule Set (consequent) Percentage Output

Error / d-Error	NB	NK	Z	PK	PB
NB	10	10	30	30	50
NK	10	30	30	80	90
Z	10	30	50	50	90
PK	50	50	80	50	50
PB	80	80	80	80	90

Defuzzification is the process for changing the fuzzy output into a crisp output. Defuzzification results that determine the amount of PWM is used to adjust the output voltage of the buck converter. Defuzzification method used in this paper was the center of gravity (COG).

2.3 Photovoltaic and Charging System.

Photovoltaic system (PV) is the equipment that is capable of converting solar energy into DC electrical energy. Solar cells become a source of the most important renewable system that offers many advantages such as it does not require fuel, produces no pollution, low maintenance costs and produces no noise. The solar cells system is a promising renewable energy source in many tropical countries, where the sun energy irradiation does not fluctuate too high throughout the year and radiates about 12 hours a day.

Solar energy received in one day (solar insolation or solar irradiation) can vary from 0:55 kWh / m (2 MJ/m) in a cool area until 5:55 kWh/m (20 MJ/m) in the tropics [16]. I-V characteristics of a solar cell is shown in Figure 5. From the characteristic curve can be seen that the solar cell is a current source, which generates a constant current for a variable output voltage [5].

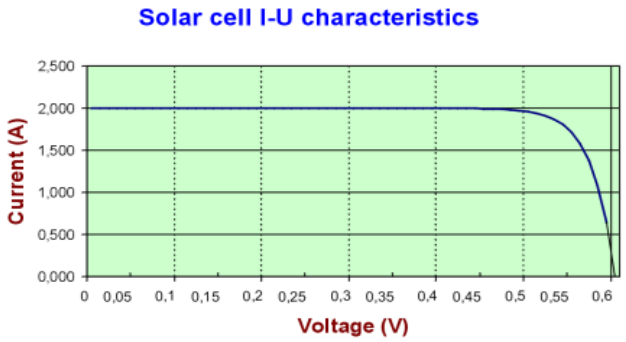

Figure 5. I-V Characteristic of Photovoltaic

The basic principles of Sustainable Tourism is optimally utilize environmental resources while maintaining the ecology and conservation, respect for cultural authenticity and communities and ensure the long term sustainability [6]. Environmental Carrying Capacity of natural attractions is the ability of natural attractions in the area and a certain time unit to accommodate the number of tourists [7]. Tourism carrying capacity has an important role in the management of the area because it was considered as a systematic, strategic policy tool in the planning process [8].

Management of protected areas as a tourist spot is one effort to build a sustainable management. Development of tourism in the conservation area occurred from mass tourism to an individual or small group tourism. The development of this travel pattern focuses on the experience with the motivation to get the expansion of life [9].

Physical carrying capacity is the maximum number of travellers who are physically fulfilled by the space provided at a certain time. The real carrying capacity was the number of visitors allowed to visit a tourist attraction with a correction factor derived from the characteristics of the object that is applied to the Physical carrying capacity [10]. The effective carrying capacity was the maximum number of visitors received at a tourist attraction, was obtained from the value of the real carrying capacity that related to the capacity menagemen attractions manager [8].

3. Methods

The electric bicycle batteries charging system proposed in this paper, as shown in Figure 6, consists of photovoltaic, boost converter, buck converter, microcontroller, current and voltage sensors, and battery. Photovoltaic converts solar energy into DC voltage and the buck converter generates an output voltage that is lower than the input voltage by the PWM pulse that is given to the IGBT switches. While the microcontroller has a function as PWM generator for generating a PWM signal by adjusting the duty cycle. The output voltage is generated depending on the duty cycle of the PWM signal given to the IGBT. Current and voltage sensors will detect current and voltage that flow to the power storage. Fuzzy Logic Controller (FLC) role controls the value of the PWM signal. FLC inputs are error voltage, delta error voltage, error current, and the delta error current. These inputs are used to determine the amount of PWM value. If the battery is full, microcontroller will disconnect the power storage from buck converter. On the other hand, there is a boost converter that serves as a charger circuit for electric bicycles. Boost converter circuit produces a higher voltage than the input voltage from the power storage so that current can flow from the power storage to the electric bicycle batteries.

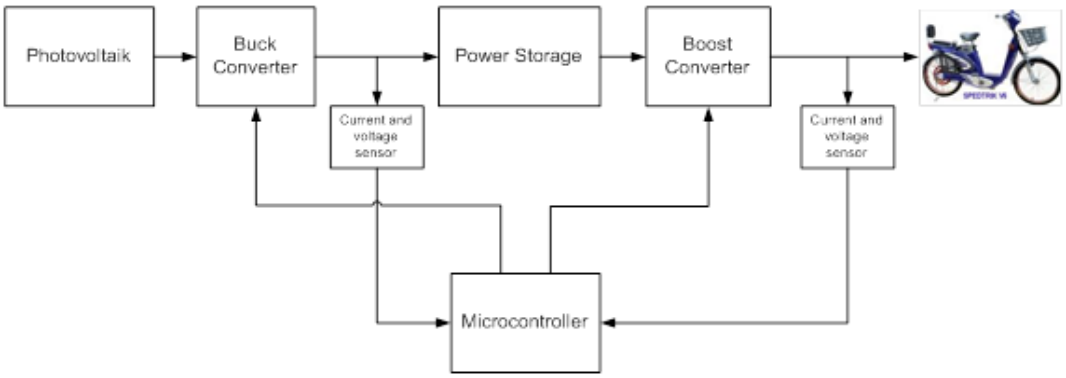

Figure 6. System Block Diagram

Buck converter is a DC to DC converter which provides a lower output voltage than the input voltage. Buck converter circuit on a bike sharing system connects the photovoltaic to the power storage, as shown in Figure 2. The buck converter consists of inductor (L), IGBT as a switch, diode and capacitor as filter. The working principle buck converter is as follows, during the interval when the IGBT is on, the diode in Figure 7 become reverse biased and the photovoltaic provides energy to the power storage as well as to the inductor. During the interval when the IGBT is off, the inductor current flows through the diode, transferring some of its energy to the power storage.

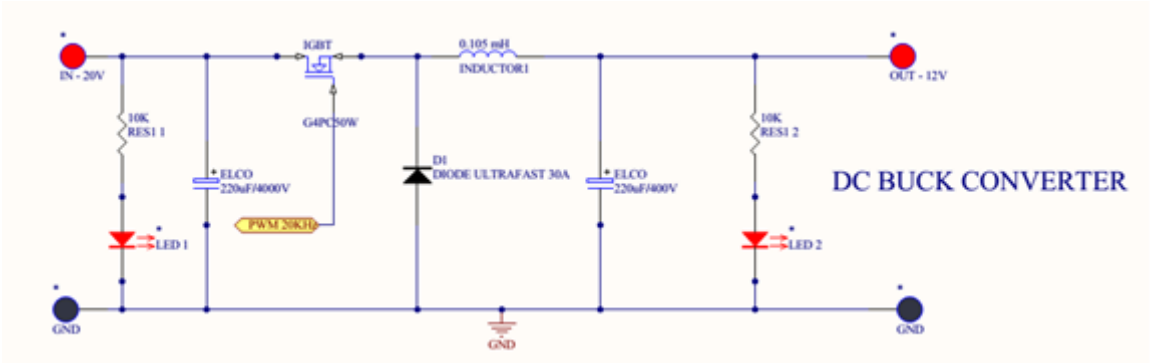

Figure. 7 Buck Converter for Bike Sharing

Boost converter is a DC to DC converter which provides a higher output voltage than the input voltage. Boost converter circuit on a bike sharing system is connecting the photovoltaic and battery, as shown in Figure 8 that consists of inductor (L), IGBT as a switch, diode and capacitor as filter. The workings of boost converter to raise the voltage is divided into two modes, the first mode when charging the inductor current (IGBT on) and the second mode is re-charging inductor (IGBT off).

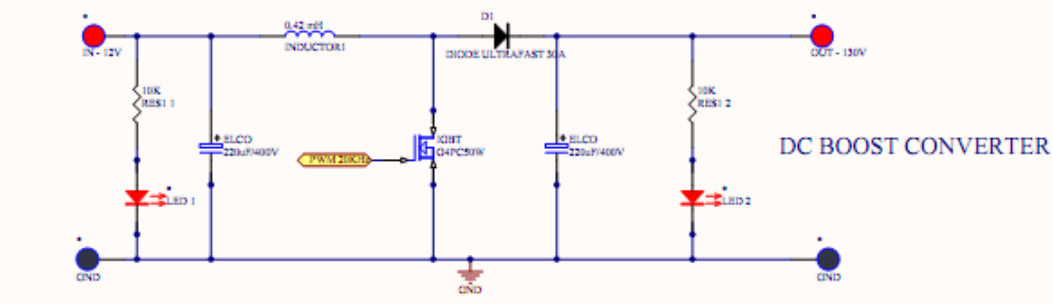

Figure. 8 Buck Converter for Bike Sharing

In the first mode, the inductor will be short circuited with the source. Because all of the current flowing through the switch to a negative source, the current flowing to the load can be ignored. Load voltage (Vb) will be zero when the charging process so that the inductor voltage (VL) will be equal to the voltage source (Vs) which can be expressed by

$$Vs = L\ \frac{dl}{dt} \tag{1}$$

Since switch is on and duty cycle is on, dt on eq (1) can be changed by ton and di = ΔI so that eq (1) can be expressed by

$$V_s = L\ \frac{\Delta I}{t_{on}} \tag{2}$$

When the switch is in the open position, the voltage source is coupled to the series inductor and load that it causes inductor in discharge state. In this condition, the inductor acts as a current source to supply the load. In this mode, the load is supplied from two sources, namely from the input source and the inductor discharge, the condition which causes the output voltage is always greater than the input voltage. The time span switch on and switch off will affect output voltage produced. If the phase switch on time then the longer the charging process, so that when the switch off voltage adders of the inductor becomes larger. The relationship between the input voltage and the output of the boost converter can be expressed.

$$V_R = Vs\frac{1}{(1-D)} \tag{3}$$

Boost converter is used to raise the voltage of the photovoltaic for battery charging. In this paper, bike sharing system using photovoltaic with 20Volts maximum output voltage range, input voltage 12 V 60Ah battery and a switching frequency of 20kHz. Inductor value used in this circuit depends on switching frequency (f), duty cycle (D) dan load resistance (R) that can be expressed by

$$L_{min} = \frac{D(1-D)^2R}{2f} \tag{4}$$

While capacitor value is determined by ripple (ΔV) that can be expressed by

$$C = \frac{D}{R(\%\Delta V)f} \tag{5}$$

.

4. Results

This research aims to design and implement electric bicycle battery charging system with solar energy sources using fuzzy logic algorithm. It is necessary to develop electric bicycle battery charging system with solar energy sources using fuzzy logic algorithm. The study was conducted by means of experimental method including the design, manufacture and testing controller systems. The designed fuzzy algorithm planted in EEPROM microcontroller ATmega8535.

The circuit was tested by applying fuzzy algorithm that has been designed to make charging electric bike. The charging process is displayed in a graph. The data of solar cell voltage (Vpv), the battery voltage (Vbat), and the charging current (Ibat) sent by the microcontroller to the computer via RS-232 communication cable. The results shown in Figure 8.

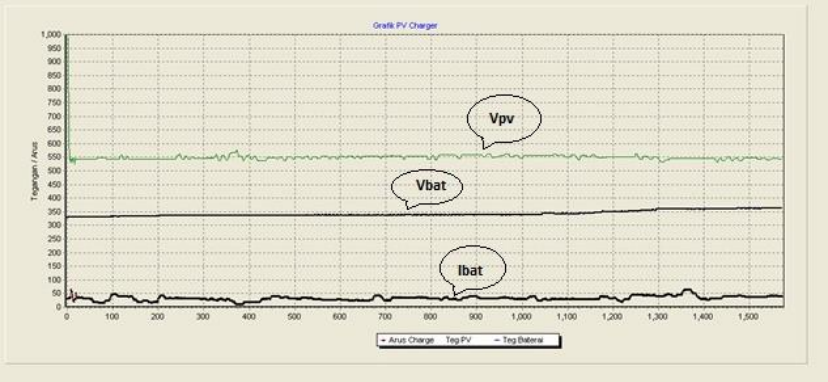

Figure. 9 Fuzzy Logic Controller Test

Based on the graph shown in Figure 9 the charging current is still unstable. This shows that the planning has been done is still not in accordance with the characteristics of the input and output, so it is still necessary to set the optimization rules and membership functions of input and output. After changing the triangular to the singleton output membership, membership input error, error delta, and set the rules obtained regulatory process flow chart as shown in Figure 9.

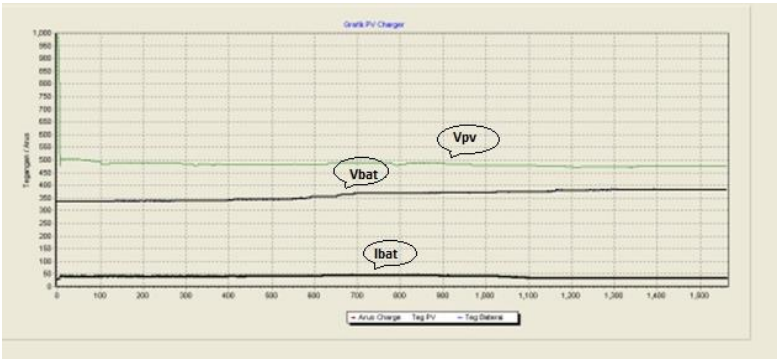

Figure 10. Optimization Results of Fuzzy Logic Controller Test

Figure 10 shows that the charging current is more stable when compared to the previous process. This shows that the fuzzy algorithm optimization results that have been made are in accordance with the characteristics of the system.

The charging current is set at 1.2 Amperes and when the full battery voltage of 40 Volts. The results showed a fuzzy logic controller is able to maintain the charging current of 1.2 Amperes with an error rate of less than 5% around set point. The process of charging electric bike lead acid batteries from empty to full takes times about 5 hours.

5. Conclusions

From the discussed results, it can be concluded that the development of solar-powered electric bicycle controlled using fuzzy logic controller can keep the battery charging current in solar-powered electric bicycle to remain stable. This shows that the fuzzy algorithm can be used as a controller in the process of charging in solar electric bikecycle. So, the solar-powered electric bicycle system developed can be applied to the program bikesharing to reduce traffic congestion which is a prevalent problem in many cities around the world.

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