Smart Hydroponic System with Hybrid Power Source

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***Abstract*—Increasing energy demands and global environmental impacts contribute to the needs for renewable energy source utilization. The integration of a smart hydroponic system with hybrid photovoltaic energy is a proposed alternative application in order to minimize the utility grid usage. The hybrid energy system for small scale hydroponics farm is designed for terrace house with a limited space for gardening. This hybrid energy control system is developed using Arduino Uno and tested using Proteus 8 Professional. The results from this study show that the implementation of hybrid power source capable of reducing at least 45 % utility grid power consumption when the light intensity maintain very high for about 12 hours per day.**

***Index Terms*—Charging; Hybrid; Microcontroller; Renewable.**

I. INTRODUCTION

Recently, hydroponic has become a popular method of growing plants, especially in urban region due to the advantages over soil based planting. However, the terrace house tenant faces a problem to plant due to the limited (soil) space. Hydroponic garden is an alternative solution for the terrace house tenant because this planting method requires less space [1].

Hydroponic is a method of growing plants for high-quality crops using efficient use of water and fertilizer without using soil. One of the hydroponic techniques which is the Nutrient Film Technique (NFT) yields a high-quality agricultural product at a shorter period compared to other systems [2]. The NFT is based on continuous movement of a nutritious solution through the roots of the plants. This operation triggers rapid plant growth by supplying mineral elements and water continuously.

In addition, the conventional technique used is improper since the root of the plant is immersed in the medium, resulting to a lower quality plant and unpleasant smell. Alternatively, the flowing fluid can be applied to the system. This method can also prevent some other problems from occurring such as mosquito breeding and formation of precipitates. Besides, the current pumping system for the hydroponic garden is powered by household electricity, which leads to the increase of utility grid usage. However, hybrid power can be implemented in order to reduce electrical usage. Solar energy is a suitable sources because the monthly solar radiation in Malaysia is approximately around 400-600 MJ/m^2 with annual temperature ranges from 22 ℃ to 33 ℃ and the average daily temperature is about 26.5 ℃ [3].

This paper presents the development of smart hybrid energy system (solar photovoltaic/battery) for hydroponic application.

II. LITERATURE REVIEW

There are two topics that have been studied in this paper 1) the hybrid power system and 2) controller for agriculture based application. Hybrid system is a combination of energy system including renewable energy for an optimal output configuration [4]. The configuration can be a combination of conventional energy with renewable energy systems or the combination of more than one renewable energy systems such as PV/Grid, PV/ Battery, PV/Wind and others.

The presence of sunlight energy leads to the use of hybrid power generation. Babita [5] proposed for hybrid PV-wind power system. The result from this study shows that a battery bank is required in the hybrid system in order to draw maximum PV power and this hybrid system is suitable for low-power application. Kanzumba [6] studied the optimal power scheduling for a grid-connected PV-battery hybrid system. There are two studies in South Africa that have shown the importance of battery as a power storage during off-peak periods. A research of the charging control of the battery was suggested by Shi-cheng and Liang-yu in order to manage the efficiency and extend the life-span of the battery [7].

In addition, the other researchers have evaluated a smart wireless sensor network for monitoring agricultural environment using WiFi. The wireless sensors send the data wirelessly to the server. This system could be portably monitored by users [8]. In addition, a fuzzy control method using micro control unit (MCU) for smart home system has been proposed by [9]. This method is highly efficient and more cost-effective. Simon Siregar has designed automatic control system using Raspberry Pi microcontroller. This design could monitor and control various parameters in hydroponic system such as pH, temperature, water level, and light intensity [10].

From the previous study, the hybrid system have many advantages. Besides, the microcontroller-based controlling method shows that it is cost effective and user-friendly. However, the switching methods of the power source for hybrid energy selection is not discussed by other researchers.

III. METHODOLOGY

The methodology that has been carried out in this study is divided into A) Photovoltaic (PV) model; B) the selection of site location; C) system configuration; D) system operating principle; E) simulation study and D) experimental setup.

A. Photovoltaic (PV) model

The I-V relationship of the PV is expressed as Equation 1 below [12].

$$I = I_L - I_O\left[e^{\frac{V+IR_S}{a}} - 1\right] - \frac{V + IR_S}{R_{sh}} \qquad (1)$$

where I_L is the photocurrent (A), I_o the diode saturation current (A), $a=nkT/q$ modified ideality factor, n is the diode ideality factor, k the Boltzmann constant (1.38x $10^{=23} JK^{-1}$), q the electronic charge (1.602×10^{-19}C), T is the cell temperature (K), R_s the series resistance (Ω) and R_{sh} is the shunt resistance (Ω).

B. Selection of site location

In this research work, Arau, Perlis was selected as a site location. This is because Perlis, Malaysia is located at 6.462°N, 100.351°E with 12 hours of daily sunlight [11]. The selected area is capable to harvest solar energy during daytime.

C. System configuration

This system consisted of hybrid energy system unit, solar charge controller, power controller box, lead acid battery and DC load (DC water pump). The block diagram of the design is presented in Figure 1. The hybrid energy system unit is a couple of PV system and utility grid. This power source was connected with a sealed lead acid battery. A sealed lead acid battery played an important role in this system since it supplied the power to the DC water pump. The battery was used in order to provide continuous power to the DC water pump.

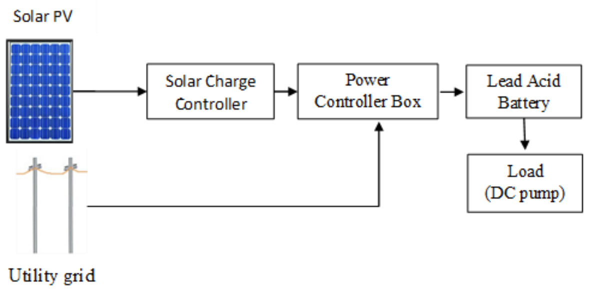


Figure 1: Block diagram of the proposed Hybrid Energy System

In addition, the Arduino microcontroller-based controller box was designed in this research work. The power controller switched the available power source based on the charging algorithm programmed in the microcontroller. The power controller also controlled the output current and voltage of the lead acid battery by connecting it with current and voltage sensor. The power controller considered the operating constrains of the lead acid battery including the minimum and maximum State of Charge (SOC) and Depth of Discharge (DOD).

D. System operating principle

The Arduino-based charging control algorithms was designed based on condition in Table 1. The selection of solar power and utility grid were varied depending on the battery voltage,V_B and solar voltage, V_S. Firstly, the system monitored the battery voltage. If V_B , was greater than the maximum voltage, V_{MAX} the pump would be running directly using the battery although the battery was not charging. When the voltage level dropped below V_{MAX} , the battery would start charging using solar energy or utility grid depending on the availability of solar power. The solar power acted as a primary power supply of the battery charging system. If the V_S was greater than 12V the battery would be charged using solar. Otherwise, the battery charging power source were shifted to the utility grid. The determination of battery threshold based on the specification provided by manufacturer.

Table 1
The Arduino-based charging control algorithms

Condition	Battery Voltage	Solar Voltage	Charging Status	Charging Power
Rule 1	$V_B \geq V_{MAX}$	$V_S \geq 12V$	Not charging	-
Rule 2	$V_B \leq V_{MAX}$	$V_S \geq 12V$	Charging	Solar
Rule 3	$V_B \leq V_{MAX}$	$V_S \leq 12V$	Charging	Utility grid

E. Simulation study

The simulation study was done using Proteus 8 Professional software. This simulation study demonstrated the working principle of the Arduino-based power controller. Figure 2 illustrates the circuit diagram of the system. The voltage sensor is presented by using voltage divider principle during simulation study. The Arduino code was programmed in the virtual Arduino in Proteus. The simulation parameter in Table 3 was used during simulation study.

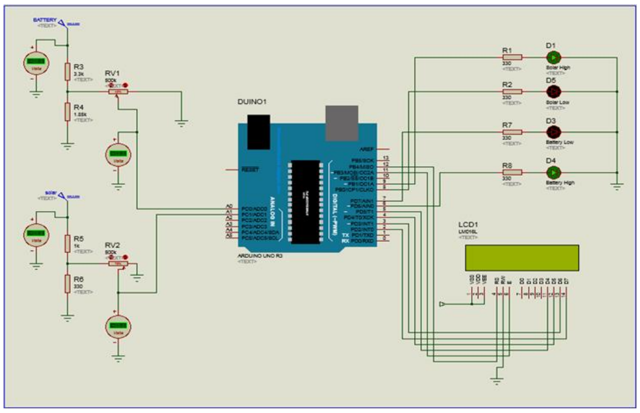


Figure 2: System circuit diagram

Table 2
Proteus 8 Professional simulation parameter

Simulation parameter	
V_{MAX}	13.0V
V_S	12.0V

F. Experimental Setup

The overall system was experimentally set up as in Figure 3. This system used a 20W polycrystalline solar panel based on the specification as shown in Table 2 and a 12V, 7.2 Ah sealed lead acid battery. The 12V battery (which can reach 13.8V when fully charged) was sufficient to power up a microcontroller and a DC water pump. This smart hydroponics system was integrated with hybrid power sources for battery charging purposed to ensure the continuous power for DC water pump.

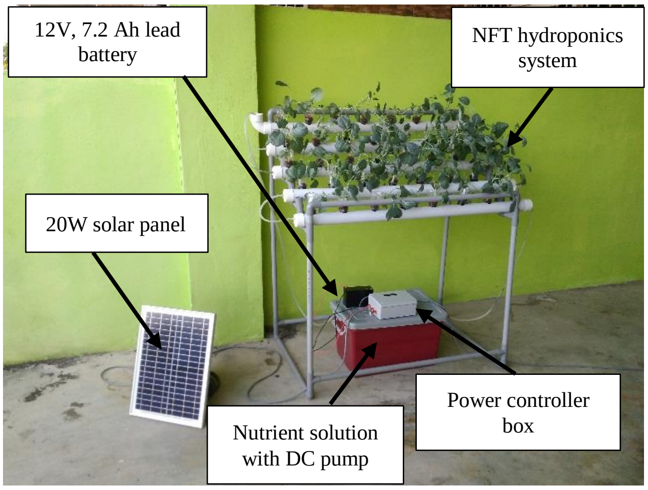


Figure 3: Experimental Setup

Table 3
Specifications

No.	Component	Specification	
1	Solar panel	Max Power (Pmax)	20 Wp
		Max Power Voltage (Vmp)	18.00 V
		Max Power Current (Imp)	1.12 A
		Open-circuit Voltage (Voc)	22.10 V
		Short-Circuit Voltage (Isc)	1.19 A
		Series Fuse Rating	10 A
2	Battery	Type	Lead Acid
		Nominal Voltage	12 V
		Capacity	7.2 Ah
3	Voltage Sensor	Input Voltage	0-25 VDC
		Voltage Resolution Range	0.02445-25VDC

The battery charging source is controlled by a power controller shown as in Figure 4. The power controller consisted of LCD display. The LCD display showed the reading of main parameter that was controlled by the power controller such as 1) the value of the current and voltage of the lead acid battery and 2) the solar voltage. This microcontroller based power controller used an Arduino UNO board which was programmed with Arduino IDE source. Besides, the current and voltage sensors were used in this study. The type of the current sensor used was ACS712 that can measure the current up to ±5A with output sensitivity of 185mV/A. The voltage sensor was capable of measuring DC voltage between 0 and 25VDC. This was based on potential voltage divider.

The Arduino board was connected to a relay module. This module acts as transmitter and receiver to send and receive signals from the microcontroller. The relay was activated by the electric current and performed an action to switch the available power source based on the Arduino command. The data and signal were measured and logged into the CoolTerm data logger which allowed portability.

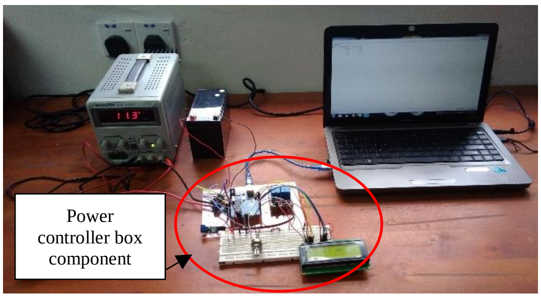


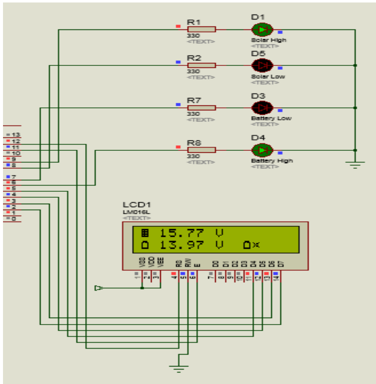
Figure 4: Power Controller Box Circuit Testing

IV. Results and Discussion

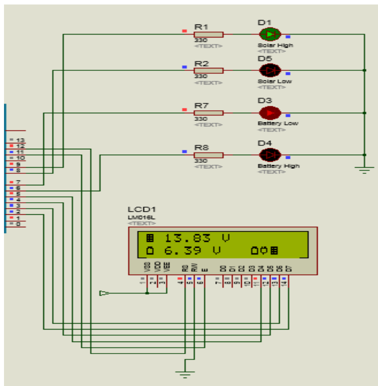
Simulation results shows that the proposed system successfully demonstrated the switching condition in order to optimize the performances of hybrid power sources. The simulation output for each condition was presented in Table 4. The simulated working principle of the system was illustrated as shown in Figure 5(a-c).

Table 4
Simulation Data

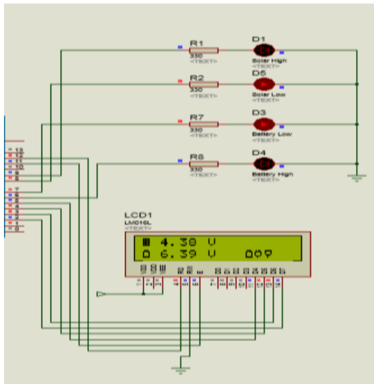
Figure	Condition	Battery Voltage	Solar Voltage	Charging Status
5(a)	Rule 1	13.73V	16.48V	Not Charging
5(b)	Rule 2	13.73V	7.75V	Not Charging
5(c)	Rule 3	8.18V	19.40V	Charging (solar)



(a)



(b)



(c)

Figure 5: (a) Simulation result Rule 1 (b) Simulation result Rule 2 (c) Simulation result Rule 3

There are three condition of charging power source such as utility grid, solar PV and also hybrid power sources were tested in the experiment study. The conventional hydroponic system used an AC water pump which directly generated from utility grid. In this research work, the DC water pump was used in order to reduce the utility grid power consumption. Figure 6 present the battery charging using utility grid. The result shows the lead acid battery charging using utility grid with and without 6W load took about 18 hours and 14 hours respectively for fully charging up to 3.08V.

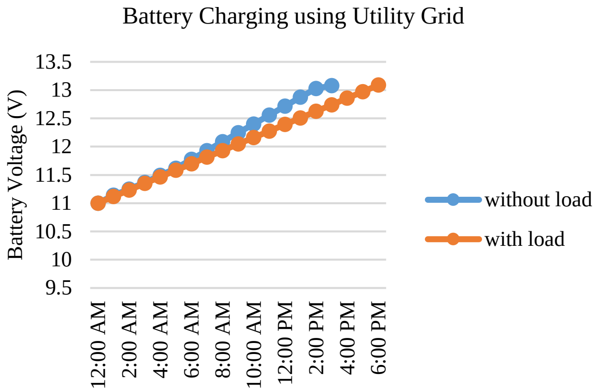


Figure 6: Battery charging using utility grid

Then, the charging method using solar PV alone also has been tested. The lead acid battery was charging from 7am to 7pm during clear day. During this period, the solar energy is available with fluctuate voltage. From the result as shown in Figure 7, the voltage different for charging with load is about 1.54V during 12hours time period. Besides, the battery capable to charge up 2.08V when the load is disconnected into system.

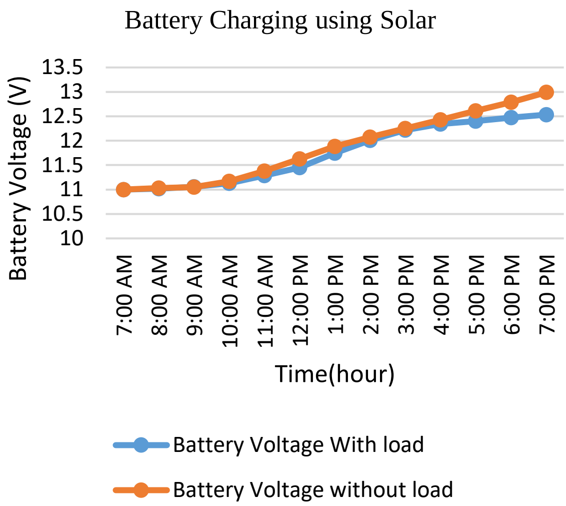


Figure 7: Battery charging using solar

The battery charging using hybrid power sources also has been tested. The results in Figure 8 are presenting the capability of performing battery charging for 1 complete cycle when the solar PV and utility grid is available. Observation shows that the battery is connected to the load and the hybrid power sources is connected to charge lead acid battery. The selection of the power source is depends on the availability of solar and grid. The battery is start charging at V_{MIN} =11V. In this case, the solar is available from 8am to 7pm. The battery is charging using utility grid before 8am. Then, the solar PV start charging the battery using solar at 8 am because the solar voltage is more than 12V. The battery voltage increments is about 1.54V during daytime. After 7pm, the microcontroller switches the relay to continue charging process until the battery is fully charge at 3.08V. The utility grid is used approximately about 4.5 hours for another 0.54V voltage increments. When battery is fully charge, the charging process will stop. The battery will discharge until 11.0 V before charging process take place.

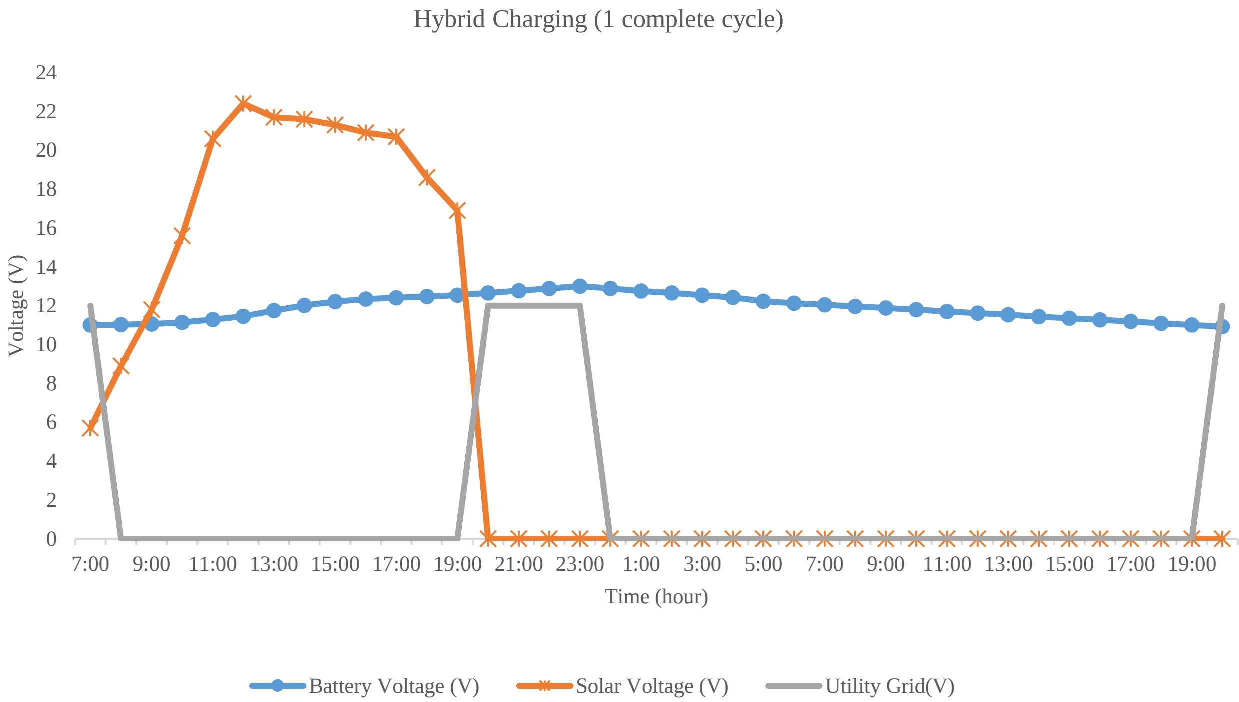


Figure 8: Battery charging using hybrid power sources

Results presented in the experimental study shows the ability of the microcontroller to sense and measure the voltage for the hybrid power sources and also the battery. The overall result demonstrated at least 45% of the electricity usage was reduce for one charging cycle (range between 11V to 3.08V) when the light intensity maintain very high for about 12 hours per day. This is because the electricity usage for battery charging can be reduce at least 11hours when the hybrid power sources is used.

V. Conclusion

In this paper, smart hydroponic with hybrid power sources was designed. The solar power coupled with utility grid as battery charging power supply was studied. The system was developed to overcome the shortage of power supply problem. The result from this study shows that the implementation of hybrid energy system can save 45% of electricity usage for the hydroponics system. The concept of this design can be applied to other DC based application.

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