

# DESIGN OF SOLAR CHARGER AND TEMPERATURE SENSOR IN PHOTOVOLTAIC POWERED WATER PUMP SYSTEM FOR PLANT SPRAYING APPLICATION

K. Saleh<sup>1</sup>, M. Irwanto<sup>2,\*</sup>, H. Alam<sup>3</sup>, M. Masri<sup>4</sup>, Hafiz<sup>5</sup>

<sup>1,2,3,4</sup>Department of Electrical Engineering, Medan Institute of Technology, Medan, Indonesia

<sup>2,3,5</sup>School of Electrical System Engineering, Universiti Malaysia Perlis (UniMAP), Perlis, Malaysia

\*Corresponding Author: irwanto@unimap.edu.my, mirwanto@yahoo.com (M. Irwanto)

## ABSTRACT

*When the plants get exposed to the sun too much, it can cause damage to plant growth. This paper presents a photovoltaic powered water pump system. The system was created to overcome the temperature problem on growing plant because the nature temperature not stable. The system is intent to make life easier in care the plantation growth. With the temperature sensing and photovoltaic that can save more energy by recharge the battery from the power source of photovoltaic meanwhile the plant will growth smoothly. The system consists of photovoltaic panel, 12 V solar charger, battery 12 V, 5 V power supply, temperature sensor, controller of water and direct current (DC) water pump. By using photovoltaic panel as a source to generate the DC water pump and to recharge the battery, the energy can be save more compare to electricity. The energy created by the photovoltaic panel are depend on the weather either the day are cloudy, rainy or sunny.*

**Keywords:** Photovoltaic, solar charger, temperature sensor, DC water pump

## 1. INTRODUCTION

Negative temperature coefficient (NTC) thermistors have a long history in a wide range of temperature-related measurement and control applications due to their low cost, extreme sensitivity, fast thermal response, and wide variety of physical shapes and sizes. Typical applications include temperature measurement (sensing and control), liquid level sensing, fluid flow sensing (air sensors), gas analysis using thermistors in self-heat mode, time delay with a very wide range of delay times, voltage surge and inrush current limiting, temperature compensation, and voltage regulation [1]. There are basically two broad types, NTC-Negative Temperature Coefficient, used mostly in temperature sensing and PTC-Positive Temperature Coefficient, used mostly in electric current control [2].

Photovoltaic, or PV for short, is a technology that converts light directly into electricity. Photovoltaic is best known as a method for generating solar power by using solar cells packaged in photovoltaic modules, often electrically connected in multiples as solar photovoltaic arrays to convert energy from

the sun into electricity. To explain the photovoltaic solar panel more simply, photons from sunlight knock electrons into a higher state of energy, creating electricity [3].

Specially designed deep-cycle cells are much less susceptible to degradation due to cycling, and are required for applications where the batteries are regularly discharged, such as photovoltaic systems, electric vehicles (forklift, golf cart, electric cars and other) and uninterruptible power supplies. These batteries have thicker plates that can deliver less peak current, but can withstand frequent discharging. Lead-acid batteries are generally used in emergency lighting in case of power failure [4].

Low voltage DC pumps designed to operate on solar power are not designed like 220 V AC water pumps. A DC water pump is designed to pump using the absolute minimum of electrical power [5]. Unfortunately, this also usually means a very low flow rate, so having a storage tank or open trough is essential. Although the flow rate can be less than one gallon per minute (GPM) for the smaller pump sizes, this small flow will be fairly constant throughout the solar day. This low flow rate can

still provide over 350 gallons of water per day from all but the deepest well applications.

This paper presents a project that it is intended to make life easier in care the plantation growth. With the temperature sensing and photovoltaic that can save more energy by recharge the battery from the power source photovoltaic meanwhile the plant will growth smoothly. The use of photovoltaic as the power source for water pump is one of the most promising areas in photovoltaic applications. With the increased use of water pumping systems, more attention has been paid to their design and optimum utilization in order to achieve the most reliable and economical operation

## 2. METHODOLOGY

This section explains a method from the beginning of the project until the project has been done. It starts from understanding concept to the final stage of implementation circuit. The overall project is shown in Figure 1. It consists of photovoltaic panel, 12 V solar charger, battery 12 V, 5 V power supply, temperature sensor, controller of water and DC water pump.

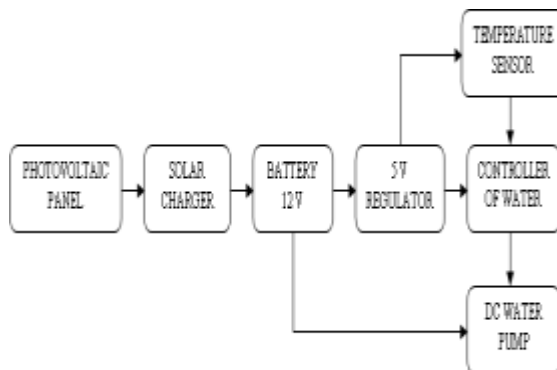


Figure 1. Block diagram of overall project

The function of photovoltaic panel is as a main direct current (DC) source. It converts solar energy become DC electrical energy. This energy is stored by the battery 12 using the solar charger controller. The temperature sensor and the controller of water are operated by the a voltage level of 5 V using the 5 V power supply. Both of temperature sensor and water controller have function to control the operation of the DC water pump at a required temperature level.

### 2.1. Solar Charger Controller

Solar charge controller circuit was created to charging the lead acid battery to the maximum level by using the photovoltaic panel as a source. Function of solar charge controller is to regulate the power flowing from a photovoltaic panel into a rechargeable battery. The power control circuitry of the SCC3 routes the operating current from the solar panel input through Q3 and IC3. When the solar panel voltage exceeds 12 V, zener diode ZD1 conducts and turns on Q3, providing power to IC3. IC3 produces a regulated 5 V power source. The 5 V is used to power the circuit's logic and as a reference voltage for comparing to the battery float voltage.

The float voltage comparator IC1a compares the battery voltage (divided by R1/VR1 and R3) to a reference voltage (divided by R5 and R6). The comparison point is offset by the thermistor TM1 for temperature compensation. The comparison point is also modified by the Equalize switch, S1 and R2. The output of IC1a goes high (+5 V) when the battery voltage is below the float voltage setting. The output goes low when the battery voltage is above the float voltage setting. This provides the charge/idle signal that controls the rest of the circuit.

The charge/idle signal is sent to IC2a and b, a pair of D-type flip-flops. The flip-flops are clocked by the IC1b phase-shift clock oscillator. The clocking causes the flip-flop output to produce a square wave charge/idle signal that is synchronized with the frequency of the clock oscillator. The two halves of IC2 operate in synchronization, IC2a is used to drive the current switching circuitry, IC2b is used to drive the charging state indicator LED either red (charging) or green (floating).

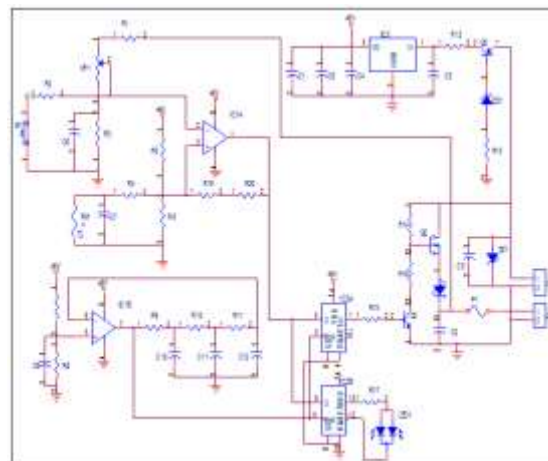


Figure 2. Schematic of solar charger controller



Figure 3. Circuit of solar charger controller in printed circuit board (PCB)

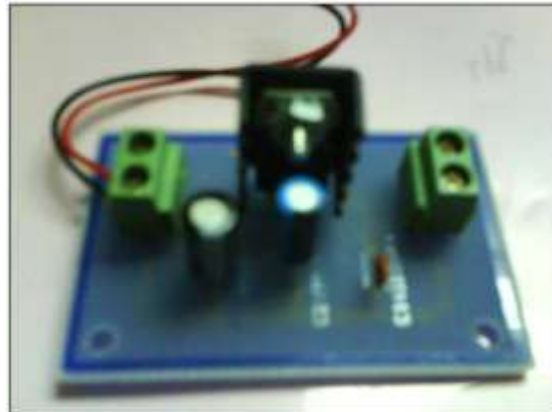


Figure 5. Circuit of 5 V power supply in printed circuit board (PCB)

### 2.2. 5 V Power Supply

This 5 V Power Supply circuit was created because the controller of water pump and temperature sensor circuit only uses 5 V as its supply. The circuit is located before the temperature circuit and the input of both circuits which is controller of water pump and temperature sensor circuit will connect to the output of this circuit. This circuit can receive more than 5 V supply because it's has voltage regulator LM7805 which can regulated the supply to fixed 5 V at the output.

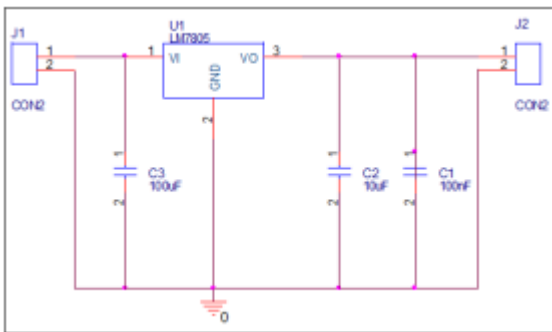


Figure 4. Schematic of 5 V power supply

Figure 4 shows the schematic circuit for 5 V power supply that has been designed. After designed the circuit and check no errors occur, convert the circuit into layout for PCB (Printed Circuit Board) printing. The complete circuit of 5 V power supply is shown in Figure 5.

### 2.3. Temperature Sensor

This circuit was designed to detect the temperature around the plant. Thermistor has been chosen as a temperature sensor to detect the temperature. When the supply is turned ON, the thermistor will automatically detect the temperature around it. The PIC12F675 has been programmed to read the temperature. Then the 74LS595 will receive the data from the PIC12F675 and convert the data from analog to digital then transfer the data to LCD screen. The LCD screen will show the temperature reading detected from the thermistor.

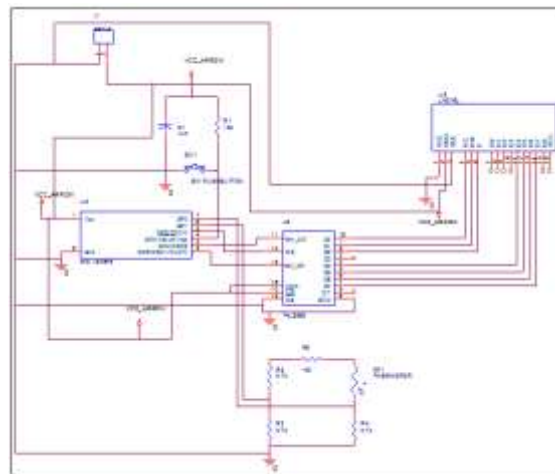


Figure 6. Schematic of temperature sensor

Figure 6 shows the schematic circuit of the temperature sensor that has been designed. After designed the circuit and check no errors occur, convert the circuit into layout for PCB (Printed Circuit Board) printing. Figure 7 shows the complete temperature sensor circuit unit.



Figure 7. Circuit of temperature sensor in printed circuit board (PCB)

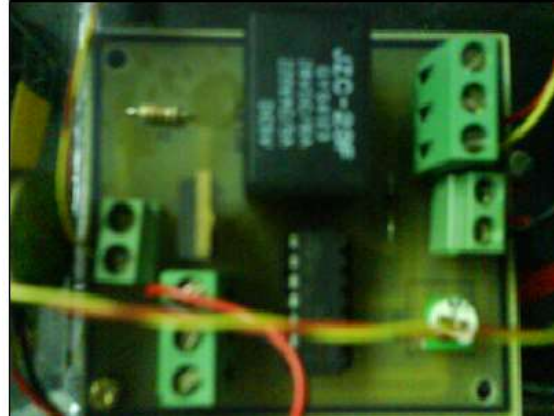


Figure 9. Circuit of water controller in printed circuit board (PCB)

### 2.4. Controller of Water

Controller of water pump is one of the important parts for this project. The circuit was designed to control the water pump either it is in running condition or not running. This circuit use comparator LM324 to compare the voltage (V1 and V2) at the comparator. The thermistor 10 kΩ as a V1 and the potentiometer which has been set the level to 470 Ω as a V2 have been used. When the thermistor been heat from the sun, the resistance in the thermistor will decrease and the comparator LM324 will compare it with the potentiometer. If the  $V1 > V2$  then the water pump will not running. If the  $V1 < V2$ , the water pump will running. Relay 5V has been used for switching the on or off the water pump.

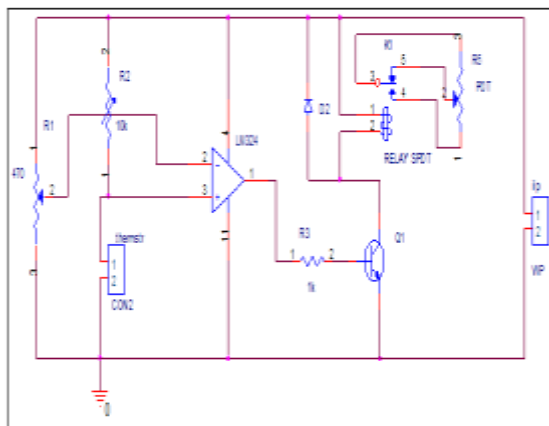


Figure 8. Schematic of water controller

After completely solder all component on the PCB for all circuit which are temperature sensor, controller of water pump, solar charge controller and 5 V power supply, need to combine together all the circuit and put the load which is DC water pump. Figure 10 shows the combination of all circuit with DC water pump.

### 2.5. Experimental Set up

The experimental set up is shown in Figure 10. It was tested in a corn plant area as shown in Figure 11.



Figure 10. Experimental set up





Figure 11. The system was spraying water in a corn plant area

After the hardware of the project has been complete, the temperature sensing for photovoltaic powered water pump system was tested to check the function, performance, and its efficiency. The steps and methods that were executed for the testing as below:

1. For temperature sensor, heat the thermistor and observe the reading of the temperature either it's fluctuate or not. The reading should detect the temperature around it before the thermistor is being heat. This is to confirm the temperature sensor function well.
2. Then, for controller of water pump, the relay should energize and the DC water pump will run when the thermistor was heat which means the resistance decrease while the temperature increases. When the temperature of thermistor reduces, the relay should de-energize and the DC water pump will not run.
3. Afterward, for solar charge controller, the supply should greater than 12 V. This is for the output of solar charger maintain well at 12 V. Check the voltage of the lead-acid battery with multimeter. Then, connect the battery together to the output of solar charge controller. In the mean time, make sure the photovoltaic panel voltage is over 12 V and connect to the input of solar charger controller. After a few minutes, check the voltage of the battery. If the voltage of the battery increase before the battery is connect to solar charge controller, that's mean, the solar charge controller function well.

4. 5 V power supply is just for regulate voltage to 5 V if the supply voltage is more than 5 V. This circuit was created because the temperature sensor and controller of water pump circuit only can operate with 5 V supply. If more than that, both circuits will damage. Give 12 V supply at the input of the circuit and check the output voltage of the circuit with multimeter. If the output gives the reading 5 V at the multimeter that confirm the circuit is in good condition.
5. After all circuits functioning well, take out all part to the open space where it has access to optimum sunlight ray without any blocking for accurate testing. Then, connect all parts together and the DC water pump will connect it to the sprinkle.
6. Before proceed to the next stage, check the voltage of photovoltaic panel and voltage of battery and record the voltage. This is for doing comparison before and after experiment.
7. This testing should do during the day from morning to evening to collect the data of solar radiation, temperature of photovoltaic panel, voltage of photovoltaic panel, voltage of battery, temperature sensing and condition of water pump either run or not run.
8. All the measurement data were logged and recorded using Microsoft Excel.

### 3. RESULTS AND DISCUSSION

This section will show the result and analysis for this project. The result from circuit (hardware) will be analyzed, so that the understanding on the correct design.

#### 3.1 Performance of Temperature Sensor

Thermistors are temperature sensitive resistors. All resistors vary with temperature, but thermistors are constructed of semiconductor material with a resistivity that is especially sensitive to temperature. However, unlike most other resistive devices, the resistance of a thermistor decreases with increasing temperature.

Saturday, on 30 January 2010 the data for this measurement was collect from 8:30 a.m until 2:30 p.m only because on 2:30 p.m onwards raining is

coming and the experiment cannot be continued and the data was recorded as indicated in Table 1

Table 1. Data collection of experiment

Hour	Solar Radiation (W/m <sup>2</sup> )	Temp. of PV (°C)	PV = DC Input (V)	DC Output = Battery (V)	Temp. Sensing (°C)	Water pump (Run / Not Run)
8:30 A.M	109.2	31.7	19.98	11.11	29.9	Not Run
9:00 A.M	121.1	31.3	19.92	11.11	30.08	Not Run
9:30 A.M	178.8	34.2	18.8	11.12	30.32	Not Run
10:00 A.M	233.2	41.3	19.68	11.14	31.01	Run
10:30 A.M	301.1	51.8	18.11	11.06	31.12	Run
11:00 A.M	382.1	52.1	18.1	11.89	31.22	Run
11:30 A.M	464.3	58.5	19.08	11.81	31.32	Run
12:00 P.M	767.2	57.1	19.01	11.81	31.15	Run
12:30 P.M	790.2	58.9	18.81	11.81	31.65	Run
1:00 P.M	430.1	58.3	18.11	11.81	31.75	Run
1:30 P.M	459.1	60.3	18.42	11.8	32.25	Run
2:00 P.M	179.4	49.3	18.48	11.82	30.43	Not Run
2:30 P.M	113.2	40.1	18.48	11.82	30.25	Not Run

Table 1 shows that from 8:30 a.m to 9:30 a.m the DC water pump are not run because the temperature area at that time are between 29.9 °C to 30.52 °C and the DC water pump will operate if the temperature circuit detect 31 °C. At the meantime, the battery was fully charged which is from 12.15 V to 12.32 V because the DC water pump is not run. At 10:00 a.m the DC water pumps start running because the temperature sensor at that time is 31.01 °C. The battery voltage also decreases from 12.32 V to 12.14 V because the DC water pump was operated and run about ± 5 minutes. Then the temperature sensor was reduced. This condition keeps running until 1:30 p.m. After that, on 2:00 p.m the solar radiation was reduce to 179.4 W/m<sup>2</sup> because the weather was cloudy and the DC water pump are not run. The reading of the temperature sensor at that time is 30.43 °C. Then, this experiment was stop because on 2:30 p.m onwards the rain was come.

### 3.2 Performance of Photovoltaic, Battery and Water Pump

Figure 12 shows the graph of solar radiation versus hour. The data was collect start from 8:30 a.m until 2:30 p.m only. From the graph can see the solar radiation increase when the hour increases until the peak time which is 790.2 (W/m<sup>2</sup>) on 12:30 p.m. Then the solar radiation decrease after the peak time until 1430 hour. This is because the weather was going rain and on 2:30 p.m the weather completely changes from sunny to rainy. The lowest reading of solar radiation is 109.2 (W/m<sup>2</sup>) which occurs on 8:30 a.m.

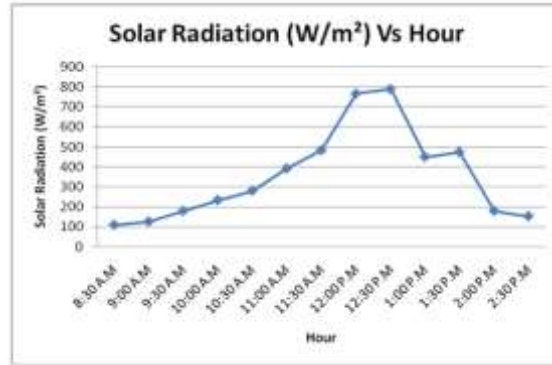


Figure 12. Graph of solar radiation versus hour

Figure 13 shows the graph for temperature of area versus hour. This temperature was measured by using the temperature sensor circuit. The sensor which is thermistor always measured the temperature when the supply is given. From the graph, the temperature of area start increase on 8:30 a.m which is 29.9 °C until 1:30 p.m which is 32.25 °C. Then the reading for temperature of area was drop until 30.25 °C on 2:30 p.m.

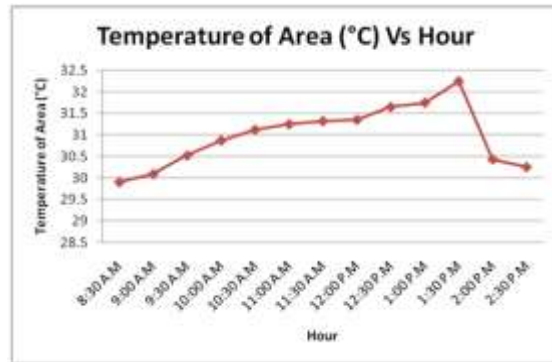


Figure 13. Graph of area temperature versus hour

Graph of temperature of photovoltaic panel versus hour was shown on Figure 14. The temperature of photovoltaic panel was measured by using temperature gun. On 8:30 a.m the temperature reading was 31.7 °C which is the lowest reading compare to the other. Then the reading for temperature of photovoltaic panel was increase until 60.3 °C on 1:30 p.m which is the highest reading. After that, the reading was decrease until 40.1 °C on 2:30 p.m because the weather becomes cloudy situated the rain is coming.

The DC water pump will operate when the temperature is above 31 °C. It can be shown in Figure 13. It means that the temperature circuit will operate in range 10.30 a.m until 1.30 p.m. The duration of DC water pump will operate is about ± 5 minutes to decrease the temperature at small area is decided by adjusting the variable resistor. By decreasing and increasing the value of variable resistor, the duration of DC water pump to operate will be long or short duration.

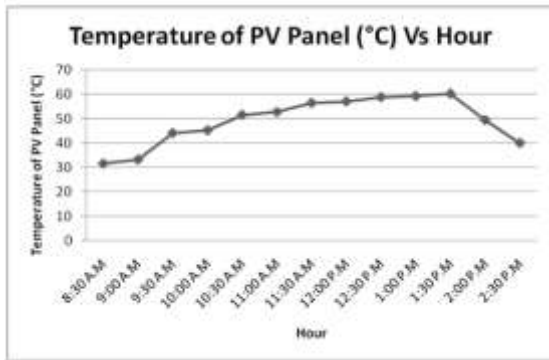


Figure 14. Graph of temperature of PV panel versus hour

Figure 15 shows the graph of voltage of photovoltaic panel versus hour. The reading was measured by using the multimeter and measured the voltage at the input of solar charge controller circuit. The reading of photovoltaic panel voltage was decrease when hour is increases. The highest reading was located on 8:30 a.m which is 19.98 V and the lowest reading was located on 2:30 p.m which is 18.49 V. On 10:00 a.m the voltage of photovoltaic panel drops instantly from 19.66 V to 18.42 V on 1:30 p.m. This is because at the period, the DC water pump was running continuously and make the current flow instantly to charging the battery. That's why the voltage of photovoltaic panel decreases. Then on 2:00 p.m to 2:30 p.m the voltage become maintain due to weather changes and DC water pump not running.

As indicated in Figure 12 to Figure 14 that the high of solar radiation occur at 11.30 a.m until 12.30 p.m. On that time, this temperature is high will effect of plant condition which is if the temperature on surface of plant is high, so the plant will die. To take care of the plant condition, needed reducing the temperature.

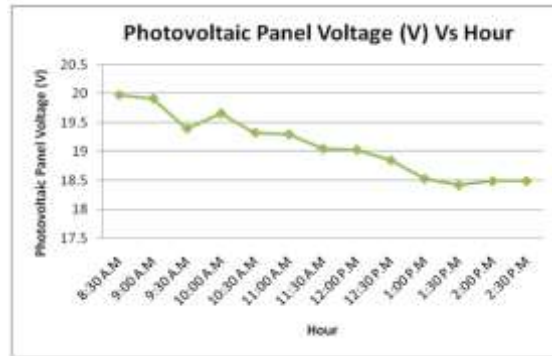


Figure 15. Graph of voltage of PV panel versus hour

Photovoltaic panel will give the voltage into battery and direct to thermistor circuit. It shows that the thermistor for circuit will operate using photovoltaic panel source hence will decrease it using battery supply and it can be shown in Figure 15.

Graph of battery voltage versus hour is shown in Figure 16. The voltage was measured by using multimeter. Before start the experiment the battery was measured and the reading was 12.15 V. On 8:30 a.m the voltage of battery was maintain 12.15 V until 9:00 a.m because the photovoltaic panel not expose to the sun too much because the light from the sun not much and the DC water pump not running. Then, on 9:30 a.m the battery was fully charged which are 12.32 V and the water pump still not running. After that, the voltage of battery was decrease from 12.14 V on 10:00 a.m until 11.99 V on 11:00 a.m because the DC water pump keeps running non-stop. Then, on 11:30 a.m the voltage of the battery maintains 11.93 V until 1:30 a.m. This is because the time was in the peak which mean the photovoltaic panel exposed to the light of sun openly. After that, on 2:00 p.m until 2:30 p.m the voltage of battery increases constantly 12.02 V, because the DC water pump not running.

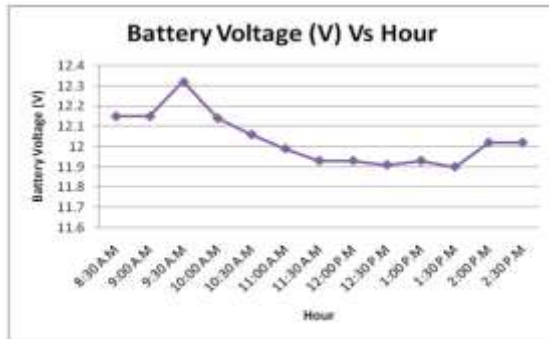


Figure 15. Graph of battery voltage versus hour

Battery source that used in this project is smaller usage for supply circuits in one time are shown in Figure 15. The power source of this project is depending on the 12 V lead – acid battery. If the battery is in good condition like maintain 12 V, this project will have no interrupt due to operating time. The photovoltaic panel is used for charging the 12 V lead – acid battery.

#### 4. Conclusion

According to result shown, the proposed solar charger controller and temperature sensor in photovoltaic powered DC water pump system can be applied to spray the plant, from the results can be summarized as below:

1. By using photovoltaic panel as a source to generate the DC water pump and to recharge the battery, the energy can be save more compare to electricity. The energy created by the photovoltaic panel are depend on the weather either the day are cloudy, rainy or sunny.
2. The solar charge controller presented in this paper can be used for charging lead- acid batteries with a photovoltaic panel. One single battery can be charged without any external

component, whereas several ones can be connected at the expense of only one additional resistor and diode per battery. The end of the charging process is determined without being influenced by the internal series resistance of the battery. This is achieved by a double verification of the battery voltage, once switch closed and once after disconnecting the battery from the photovoltaic panel.

3. The controller of water pump was designed to control the DC water pump either its running or not running. The DC water pump will operated by using the 12 V lead-acid battery. When the water pump is in running condition, the voltage of the battery will decrease due to DC water pump operated. The relay in the controller of water pump is act as switching either to on or off the DC water pump.

#### References

- [1] “Thermistor application notes,” *NTC Thermistor Theory*. [Online]. Available: [www.betatherm.com](http://www.betatherm.com)
- [2] Temperatures.com, Inc. (2002). Thermistor, <http://www.temperatures.com/thermistors.html>, 29 December 2009.
- [3] PVRESOURCES.COM, (2001). Photovoltaic Module, <http://www.pvresources.com/en/module.php>, 26 December 2009.
- [4] David Linden, Thomas B. Reddy, (2002). *Handbook of Batteries*, 3rd Edition. McGraw-Hill, New York.
- [5] Karassik, Igor J.; Messina, Joseph P.; Cooper, Paul; Heald, Charles C. (2001). *Pump Handbook* (3rd ed.). New York: McGraw-Hill.