

Development of Aquaponic System using Solar Powered Control Pump

N. R. Mohamad¹, A. S. A .M. Soh², A. Salleh³, N. M. Z. Hashim⁴,
M. Z. A. Abd Aziz⁵, N. Sarimin⁶, A. Othman⁷, Z. A. Ghani⁸

^{1,2,3,4,5,6,7,8} Center for Telecommunication Research & Innovation (CeTRI), Faculty of Electronic & Computer Engineering, Universiti Teknikal Malaysia Melaka, Hang Tuah Jaya, 76100 Durian Tunggal, Melaka, Malaysia

Abstract : This paper describes the development of an aquaponic system using solar panel to control the water pump and air pump based on Peripheral Interface Controller (PIC) technology. Solar power is ideally can be used in Malaysia due to location factor and also give the benefit to the environment as renewable energy. It involves a combination of electrical, electronics and agriculture into one sustainable system which consists of a solar panel, inverter, water pump and air pump. The solar panel is the most cleanest ways to produce electricity. With the average output voltage is 12V while the maximum output voltage produce by the solar panel is 18 V. The voltage depends on light capture by solar panel. Weather can minimize the light capture by solar panel thus affect the overall performance. This project requires a substitution power grid with green energy from solar panel which an inverter is used to convert Direct Current (DC) to Alternate Current (AC) and to step up 12V to 110V or 240V. A microcontroller is used to control the operation of an aquaponic system for switching water pump, air pump, battery charge and discharge state. Based on observation, the output power from inverter has produced 65.55% efficiency and the average output voltage of the solar panel is 16.16 V.

Keywords: Aquaponic, Solar power, Inverter, PIC, Pump

I. INTRODUCTION

Aquaponics is a sustainable food production system that combines a aquaculture such as fish and combine with hydroponics in a symbiotic environment. In the aquaculture, effluents accumulate in the water, increasing toxicity for the fish. This water has led to a hydroponic system where the by products from the aquaculture are filtered out by the plants as vital nutrients, after which the cleansed water is recirculated back to the animals. The term aquaponics is a portmanteau of the terms aquaculture and hydroponic. Aquaponic systems vary in size from small indoor or outdoor units to large commercial units, using the same technology as shown in Fig. 1. The systems usually contain fresh water, but salt water systems are plausible depending on the type of aquatic animal and which plants. Aquaponics consists of two main parts, with the aquaculture part of raising aquatic animals and the hydroponics part of growing plants. The biofilter and hydroponic components can be combined by using plant support media such as gravel or sand that also functions as biofilter media. Raft hydroponics, which consists of floating sheets of polystyrene and net pots for plant support, can also provide sufficient biofiltration if the plant production area is large enough. Combining biofiltration with hydroponics is a desirable goal because eliminating the expense of a separate biofilter [1].

Nowadays the main sources of generating electricity such as oil, gas, nuclear power are more expensive than ever. Besides the price, the amount of non-renewable resources is decreasing and starting to run out while the demands of the world keep rising. If this situation still continues, it can cause a trouble to the world. Besides that, burning fossil can produce greenhouse gases and these gases can make a global warming becomes faster. In Malaysia, the majority of energy source is from oil. Since the world is consuming the energy sources, a precautionary step to protect the environment must be proceeded. A renewable energy is a good replacement for current energy source. Malaysia is suitable for producing energy through solar panel because it is located near the equator which is received average 12 hour day and night throughout the year. Thus, the solar panel is the ideal green energy for power aquaponics solar powered control pump because the project located in Malaysia.

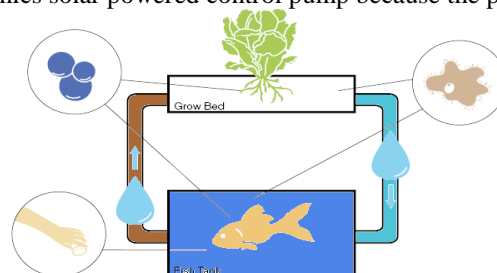


Fig. 1 Aquaponics System

Solar power is actually one of the cleanest methods of energy production known. But the main drawback of it is not widely used because of the cost of solar panel. Compared to electricity from coal-fired power plants, solar is more expensive. Typically solar panels produce the most energy during the middle of the day and somewhat less before and after that. Sun position is not static and keeps changing from east in the morning and moving to the west in the evening due to movement of the earth rotates clockwise. Since the position of the sun is not static, a moving motor required to follow the solar movement but in this experiment we placed the solar panel in static conditions and observed if the solar output on static condition is enough to power the system all the day. Also in cloudy areas with frequent rain are often not as well suited for solar panels because typical solar panels need direct sun to produce the most power. But as new panels can now use to diffuse light on cloudy days, the solar panel is still producing power. With prices going down steadily, more sites would be feasible that once were not. Another problem is shortages in materials for producing the solar panel because of shortage it can be hard for producers to meet demand capacity, thus pushing up the cost. The inverter is the essential part of the project because inverter converts a DC to AC current. AC is a sine waveform the problem of converting a DC to AC is to have a same waveform as AC. When converting a DC to AC there is a power loss in the inverter cause by component power dissipation. A complex inverter has a more power loss. Without the inverter, solar panel only can power DC equipment thus limit the usability of solar panel application. With the inverter, most of the existing electrical home appliance can be powered by solar panel and save the cost of without replacing or buying equipment that power by DC.

The project objectives are to power water and air pump using green energy via solar panels. Water pump required AC voltage and inverter is used for this application. This project focuses on using an inverter to instead replace the water pump with DC water pump because when replace grid power to solar panel energy, all the existing electrical appliances previously power of grid power voltage needs to be replaced with a DC appliance. This is not an appropriate solution for converting conventional grid power to green energy, it is wasted, costly and contribute to more greenhouse effect due to landfill full of garbage. By implementing inverter to the solar panel, the existing electrical equipment can be used as usual and benefits from energy produce by solar panel.

II. LITERATURE REVIEW

In the [2], the research is about the balanced renewable energy system. They found to produce an optimal sustainable energy system. Several components required to accomplish the mission. These include an efficient wind generator, solar panels and intelligent controller to manage energy storage. The main advantage of the system is to reduce cost of circuit for inverter and microcontroller. It provides states difficulty and solution for green energy to produce a constant energy throughout the day. However in this project, we focus on using only solar panel due to Malaysia climate have twelve constant twelve hour day and night throughout the year. Another source of green energy might be possible but more research needs to be done.

For the energy solution for developing communities [3], the World Bank estimates that roughly 1.6 billion people, one out of every four people on the planet, do not have regular access to electricity [4]. Based on the business as usual scenarios, the International Energy Agency predicts that 1.4 billion people will still lack access to electricity in 2030 [5]. In rural area without electricity, people use kerosene to light up their home during night time. Kerosene is dangerous. Families cannot afford a proper bottle and wick. They use fragile glass and rope for a wick. In 1998 there were 270 000 deaths from fire related burns in developing countries. In India 2.5 million people suffer burns each year mainly overturned kerosene lamps [3]. As the solar panel produces energy during daylight, the extra energy from solar panel is charging a battery and powered an air pump during night time. Tilt angles of solar panel need to be determined correctly to effectively capture sun energy.

The clear sky global solar irradiance on tilt angles of photovoltaic module was examined in Perlis, Malaysia. They found that Perlis is suitable for photovoltaic power generation due to big solar irradiance potential, its average is 1061 W/m² on January and its lowest is 995.38 W/m² on July [6]. They also found that the tilt angle for solar panels is an important to increase solar panel efficiency a series of calculation involve of angles, azimuth and several formulas required to get an ideal tilt angle for solar panel. Based on their research, it shows that northern region of Malaysia is suitable for producing green energy through solar panel. A series of research needs to be done at another place to validate another spot for green energy. The aquaponics system required an ideal solar panel tilt to harness the energy to power the motor pump and charge battery during sunlight. By using data from the journal, we have understood the ideal tilt angle, as well as the output power generates from solar panel. The energy produced by a solar panel is supplied to water pump and charging a battery during daylight. The inverter is used to convert DC voltage from solar panel into AC voltage. The motor pump is connected to the output of inverter as voltage becomes AC. In [7], the solar powered water pump problems, pitfalls and potential are discussed. They mentioned that 17 out of 90 inverters fail during testing. Thus makes reliable and efficient inverters are difficult. In the aquaponic system, the simple design of inverter is

needed which able to handle high power. During the test of inverter, it's concludes that the inverter is not efficient and reliable. Thus it is better to use a pump with voltage rated to the pump itself.

III. DESIGN METHODOLOGY

The design is based on software and hardware part. The software required to simulate the circuit using Multisim software, Microchip MPLAB IDE software used to perform the interface to Peripheral Interface Controller (PIC18F4550) and develop the layout of a printed board circuit using the Proteus software. PIC 18F4550 is ideal for low power and connectivity applications that benefit from the availability of three serial ports. Large amounts of RAM memory for buffering and enhanced flash program memory make it ideal for embedded control and monitoring applications that require periodic connection with a personal computer via USB for data upload or download and/or firmware updates [8]-[10]. The inverter circuit and microcontroller circuit are designed for the hardware part. Fig. 2 shows the development process of aquaponis system. During daylight time, solar panel captures energy from sun and converts to electrical energy to charge lead acid battery. Microcontrollers with LDR or photoresistor will choose which pump will be running depend on the LDR or Photo resistor output. If sun detects, the water pump is ON, air pump is OFF. A relay is used as a switch between microcontroller with the step up inverter, air pump and water pump due to high voltage. The voltage from lead acid 12 V DC is converted into 240 V AC using step up the inverter. However, in the night time the solar panel doesn't receive energy where air pump is ON and water pump is OFF. Lead acid battery continues supplying power to air pump until the next morning where the solar panel will charge lead acid battery.

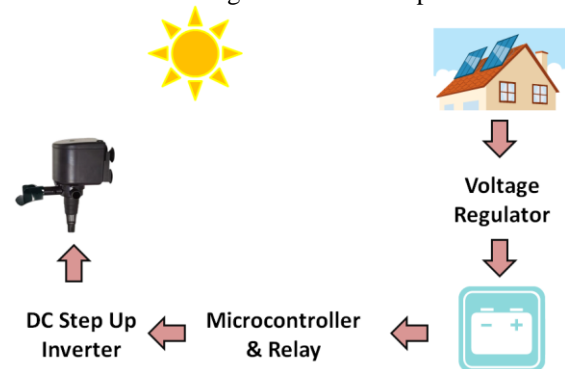


Fig. 2: Operation of aquaponic system during daylight.

The inverter can be designed using a 555 timer for low power application but in an aquaponic system need a higher power. The inverter circuit design consists of two parts which to convert from the AC signal to DC signal. The first part is to replace the 555 timer with a resistor, capacitor and transistor for switching frequency at 50 to 60 Hz and the second part is the positive and negative switching to emulate the AC voltage positive and negative voltage as shown in Fig. 3. At the end, the inverter is producing an output of 12 V based on the input with a higher current than using 555 timer inverter.

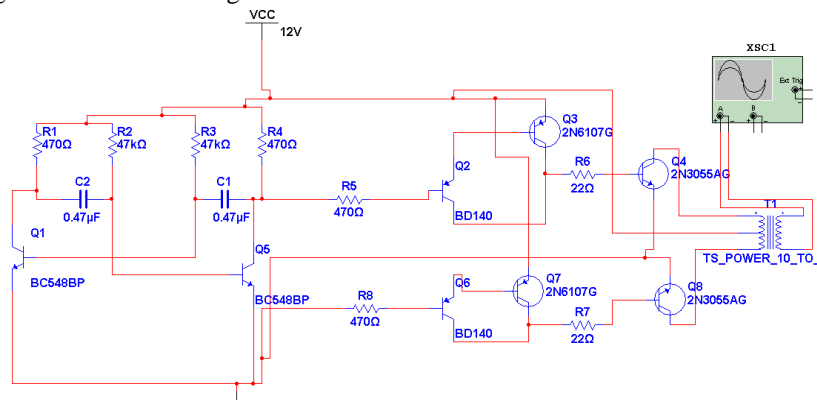


Fig. 3: Inverter Circuit

Fig. 4 shows the controller circuit in the aquaponic system. Controller circuit is used to control water and air pump via relay, charge and discharge battery and an input to activate the control condition. A voltage regulator is placed at controller circuit due to the input voltage supply by solar panel above 12V. A PIC 18F4550 microcontroller requires only 5V for operation thus voltage regulator 7805 is used to step down the voltage to 5V output. The operation of the controller is when daylight solar panel voltage is act as input “High” at pin RB0 and relay at RB1 and RB2 is being activated, the relay at RB1 is connected at water pump relay at

RB2 control the charging battery. When nighttime, solar panel output is zero, so the input for microcontroller is zero. The microcontroller output at RB1 and RB2 is low or zero. This condition both relays switch off and relay at RB1 is switch to air pump powered by battery. Relay at RB2 is not charging battery, the battery powered air pump throughout the night until daylight. In microcontroller circuit, there is a component it hasn't used such as photo resistor. Photo resistor act as a sun detector, but due to solar panel can be used as sun detector, when sunlight hit the panel, it produces electricity, and this electricity can be used as an input to the microcontroller.

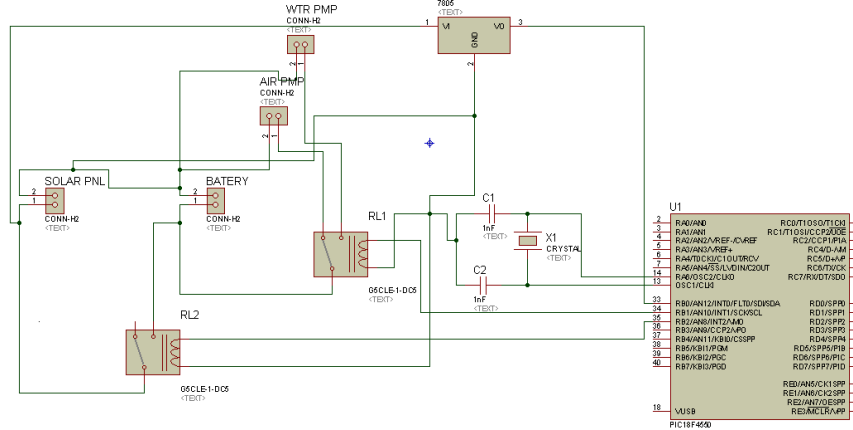


Fig. 4: Controller Circuit

IV. RESULTS AND ANALYSIS

Fig. 5 shows the waveform of the inverter circuit of the Multisim software and the performance of the circuit with three different inputs is summarized in Table 1. However the limitation of this circuit is the resistor at switching positive and negative polarity required a higher power resistor. A normal resistor used in normal electronic component which rated half watt or one watt is not enough to handle the high power switching, resistor. To eliminate the problem is replacing the resistor with same value but at higher rated power such as 5 watt sand block wire wound resistor.

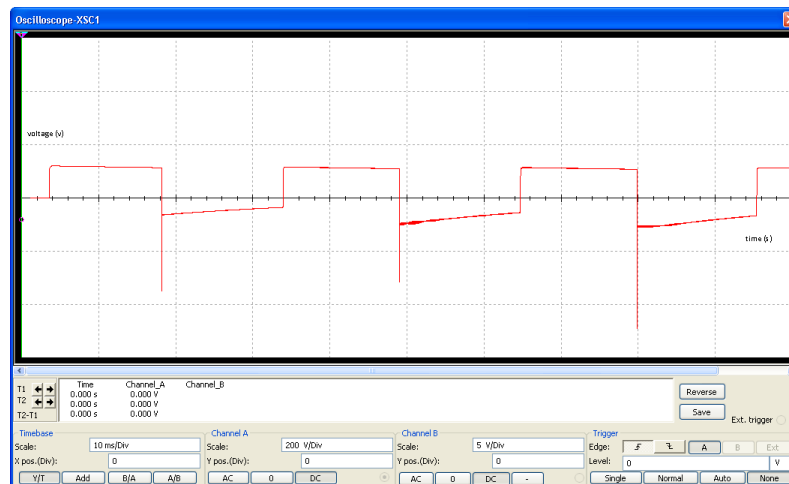


Fig. 5 Output of inverter circuit

Table 1 Performance of Inverter

Input (V)	Input (A)	Input Power (W)	Output (V)	Output (A)	Output Power (W)	Efficiency (%)
13.6	0.697	9.48	106	0.06	6.31	55.56
17.1	0.873	14.92	114	0.08	9.63	61.12
18.1	1.12	20.27	121	0.11	13.31	65.55

The overall aquaponic system is shown in Fig 6 which consists of microcontroller, battery, air pump and water pump. The total cost of this project is about RM 100.

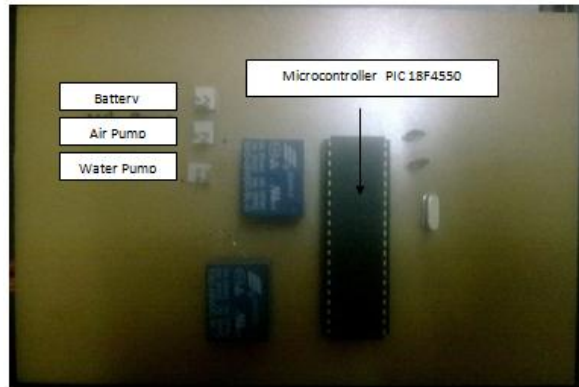


Fig. 6 Microcontroller Printed Circuit Board

The Fig. 6 shows the output voltage produced by solar panel between 8.00 a.m to 7.00 p.m on 21 May 2012. As the early morning at 8.00 am the output is 12.43V and gradually increase until reaches its peak output at 12 noon which is 18.49V. Then the voltage drop gradually to 7.00 p.m. The link between voltage and current, we can clearly see that ampere output for solar panel follow the gradually increasing and decreasing as the voltage line. This solar panel data is captured at Ayer Keroh, Melaka on 21 May 2012, the weather on that day is sunny, dry and hot.

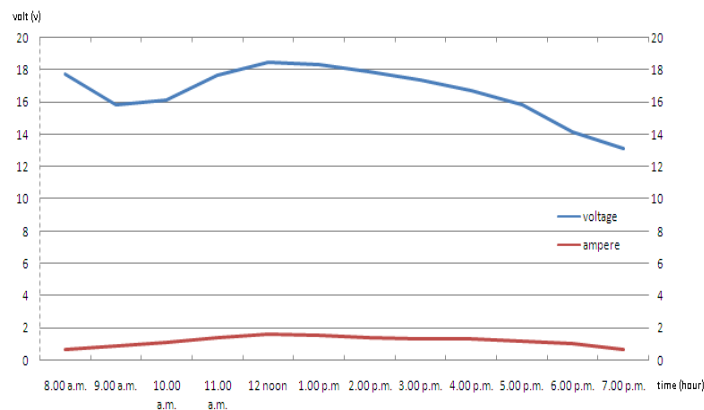


Fig. 6 Solar Panel Output vs Time

V. Conclusion

The low cost aquaponic solar power control pump was successfully developed using PIC technology. It a step towards green energy by replacing grid power with solar panels. The challenge of replacing grid power with a solar panel is to power existing equipment that already connects to the normal 240V AC. Solar panel produce average 12V with a DC voltage and this required an inverter to convert DC to AC and step the voltage to 110V or 240V. This project focuses on inverter to power a water pump or home appliances same as the power grid. The output power of solar panel is depending on the weather and sun angle towards the solar panel. The optimal solution to capture the sun's energy is by tracking the sun position and solar panel to move as the sun moved. The challenge of this research is to find out the air pump which the air pump normally used an AC voltage, but recently most of fish shops have sold a portable battery air pump. The portable battery air pump required a D type battery to operate which is a DC voltage, thus in this system the AC air pump can be replaced by a portable battery air pump with minor change needs to be done to implement the system. The portable battery air pump required a 2 cell D type battery 3V and the battery output rated at 12V. A voltage regulator to step down from 12V to 3V is needed. The improvement of this research can be done through using the high technology battery.

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REFERENCES

- [1] Michael P. Masser, Michael P. Masser and Thomas M. Losordo, *Recirculating Aquaculture Tank Production Systems: Aquaponics Integrating Fish and Plant Culture*, Southern Regional Aquaculture Center, Texas, 2006

- [2] Mitchell K, Rizk J, Nagrial M. , Balanced renewable energy system., *Proc. of power electronics and motion control conference. 2000*, 857-861.
- [3] R. Podmore, Ray Larsen, Henry Louie, and Brian Waldron, Affordable Energy Solutions for Developing Communities, *Prof of Power Engineering Society, IEEE General Meeting - PES*, 2011, pp.1-8
- [4] Thomas Friedman, *Hot, Flat and Crowded*, Allen Lane, 2008.
- [5] Dalberg Global Development Advisor, Solar Lighting for the Base of the Pyramid – Overview of an Emerging Market, *Lighting Africa Conference*, Nairobi, Kenya, 2010.
- [6] I. Daut, M. Irwanto, Y.M. Irwan, N. Gomesh, N. S. Ahmad, Clear Sky Global Solar Irradiance on Tilt Angles of Photovoltaic Module in Perlis, Northern Malaysia, *International Conference on Electrical, Control and Computer Engineering*, 2011.
- [7] Short T. D., Mueller M. A.; ‘Solar powered water pumps: problems, pitfalls and potential’, *International Conference on PEMD*, 2002, pp280–285.
- [8] N. M. Z. Hashim, A. F. Jaafar, Z. Zakaria, A. Salleh, and R. A. Hamzah, Smart Casing for Desktop Personal Computer, *International Journal Of Engineering And Computer Science (IJECS)*, 2(8), 2013, 2337–2342.
- [9] S. H. Husin, M. Y. N Hassan, N. M. Z. Hashim, Y. Yusop, A. Salleh, Remote Temperature Monitoring And Controlling, *International Journal For Advance Research In Engineering And Technology (IJARET)*, 1(9), 2013, 40-47.
- [10] Najmiah Radiah Mohamad, Chau Man Siang, Ahmad Sadhiqin Mohd Isara, Adie Mohd Khafe, Azahari Salleh, Nur Fatimah Azmi, Electromagnetic Levitator, *International Conference on Computer and Communication Engineering (ICCCE)*, 2012, 319-324.