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Development of Automated Solar Watering System

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ABSTRACT

The main purpose of this project is to develop a Solar Watering System capable of performing irrigation or watering task automatically and is powered by Photovoltaic (PV) panels. A moisture sensor in the soil is used to check the need for irrigation in order to operate a pump powered by the PV system and lead acid battery. In addition to the input from moisture sensor, Timer function within the PIC18F4550 was also applied to prevent watering to many times per day. This ensures that the crop or plant in the field will not have growth problems due to overwatering. In order to increase energy harvesting from the sun radiation, sun tracker in the form of single axis was designed. Horizontal Single Axis Tracker (HSAT) was build based on the feedback from two Light Dependent Resistors (LDR) and an opaque sheet dividing them so that shadow will be casted on either one of them when the sun moves. The fully developed prototype has shown that the system able to reduce wastage and human intervention at minimum cost as the entire system runs only using solar energy. Therefore it can be said as a standalone unit which requires no additional devices or powers and requires minimal maintenance and attention.

Keywords: *Solar Watering, Photovoltaic, Programmable Interface Controller, Light Dependent Resistor, Solar tracker.*

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I. INTRODUCTION

A renewable energy source such as solar can be an excellent alternative and development of technology based on it can be used in areas where electrical power is difficult to obtain [1]. Solar energy is a free, inexhaustible resource that is environmental friendly and serves as an alternative to the increasing demand in energy usage throughout the world. According to latest figures published, the surface of the earth receives about124 exa (10^{18}) Watts or 3,850 zetta (10^{24}) Joules per year of solar power [2]. That amount of value is higher than all of energy generated in the earth.

Previous researches have shown that there are many controllers that have been used to control the watering system. Hemant Ingale *et. al.* [3], Shaik Ameer *et al.* [4] both used ATMEL microcontroller for their solar watering system to provide 12V DC output. Heman Ingale *et al*. introduced scheduling principle that aimed to modernize the agriculture industries at a mass scale with optimum expenditure that save manpower, water to improve production and eventually profit. The ATMEL microcontroller provides a highly flexible and cost effective solution to many embedded control applications [3].

Other similar works have been carried out by using controllers like arduino microcontroller [5][6], PLC[7], FPGA[8] and Data Acquisition System (DAQ) [9]as the main controller each with their own different complexity to achieve their automated watering using solar energy.

Apart from that PIC microcontroller were widely used in works carried out by several researchers. Mahir Dursun *et al*. [10] used PIC18F452 as part of his low-cost, low power requirements, integrated with custom circuits to achieve a cheap functional irrigation system. Digital signal PIC dsPIC30F4013 was used by Hakan *et al.* [11] to processes the data obtained from the calculations of current voltage and liquid levels. The two axes motor rotation of were controlled by the power obtained from the PV panel. Besides that Jia Uddin *et al.* [12] used PIC16F628 and water level sensor in paddy field to monitor the water level and control the water pump remotely through mobile phone.

It was shown from these works that PIC microcontrollers provide an affordable, easy to implement and well functional solar powered automatic irrigation system.

The price of solar power, together with batteries for storage, has continued to fall so that in many countries it is cheaper than ordinary fossil fuel electricity from the power grid [2]. This has encouraged the application of solar energy in various sectors including in the field of agriculture for the purpose of irrigation. Therefore, this project is to design and construct an automatic irrigation or watering system powered by Photovoltaic (PV) panels on a small level. The project constitutes of electrical part and mechanical part. The electrical part consists of

Photovoltaic panel, a device to store energy such as battery, and other required electronic components to form the circuitry for the controller whereas the mechanical part would be the relay and pump or device which enables the supplying of water to the field or crop.
Irrigation of time-based for the crops would also function well but with the disadvantage of wastage of water and causing over supply of water which can affect the productivity and growth of plants. Thus a mean to give input of when the plant requires water or in other words, the soil dryness level are to be implemented and it can be achieved with the use of soil moisture sensor. The control is made by means of a microcontroller which is the Programmable Interface Controller PIC18F4550 as it is affordable and easy to implement. The utilization of Automatic Solar watering system can reduce cost of agriculture, better alternative of energy source and solve many other problems in the field of agriculture

Component Used:
Soil Moisture Sensor Module
The two figures above indicate one type of soil moisture sensor module that is available in the market. It can also be made at home as shown by the circuit. However since the module has nickel coated on the two probes, it prevents corrosion and enables longer duration of application. The results also tend to be more precise and easier to be used compared to self-made soil moisture sensor. It consists of two prongs to be inserted in soil, an LM358 that acts as comparator, a pot to change the sensitivity of the sensor and a LED to indicate operation. The operation is similar as explained below for the three conditions of soil: dry, optimum and excess water.

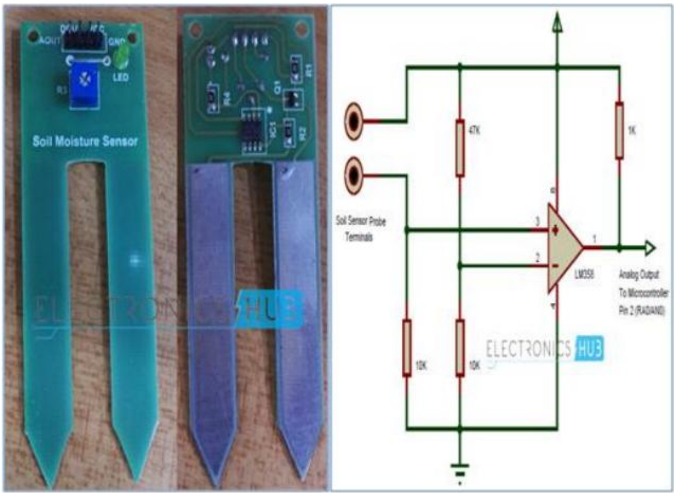

Figure 1: Soil Moisture Sensor Module [18].

Dry Condition:
Under dry soil condition, there is lack of water that provide conduction path for the current. The lack of conductivity causes reading taken from the probes to be less about 0-1.0V depending on the value of variable resistance tuned.

Humid condition:
The presence of sufficient water in soil spreads across the layers of soil due to capillary force and thus increases ratio of moisture. Since a better conduction path is available now, the electrical resistance drops. Voltage taken from the probes will be in the range of 1.0V- 3.3V depending on the potential divider value setting ahead.

Excess water condition:
Over water condition means water beyond the optimum level and drastic increase in the conductivity of soil which leads to further decrease in electrical resistance of soil. The voltage output will be expected to be higher than the optimum condition in the range of above 3.3V.

Horizontal Single Axis Tracker (HSAT)
Tracking mechanism for the PV panels will always result in better efficiency compared to fixed position PV panel as the solar radiation that incident upon the fixed panel will not be constant due to the suns movement across the sky. Tracker type can be divided to Single axis tracker and Dual-axis tracker. Single tracking then branches off to horizontal single axis tracker (HSAT), vertical single axis tracker (VSAT), tilted single axis

tracker (TSAT) and polar aligned single axis tracker (PSAT). Choosing between either one of the mechanism depends on many factors as below:

(i) Dual-axis comes at higher cost, greater complexity, and lower reliability due to more frequent maintenance than single axis.

(ii) Dual-axis has higher efficiency than single axis, however the difference is only small because of the additional part such as motor that consume the additional energy generated and also the extra maintenance.

(iii) Single axis offers lower cost and higher reliability since there are fewer things that can go wrong over the life of the system.

Considering multiple factors such as sun movement, long term use, economical benefit, maintenance, complexity and efficiency the single-axis tracker profits more and thus used in this project.

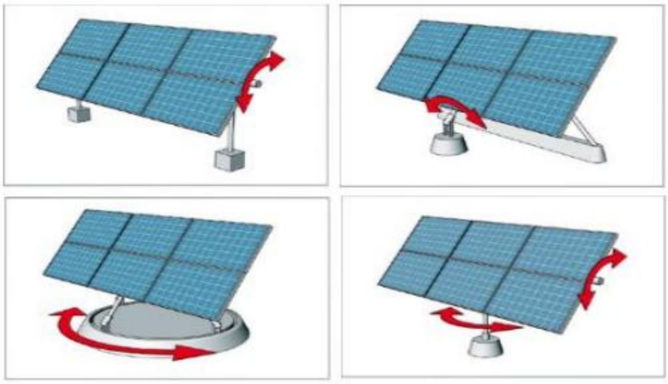

Figure 2: HSAT, VSAT, PSAT and Dual-axis.

II. METHODOLOGY

Designing and Simulation

The design was done with the ISIS & ARES tool within the Proteus Software Simulation. The software allows broad range of electronic devices to be utilized with the addition of correction and net listing for fabrication later on.

Programming

The core segment of this project is the program inside the PIC18F4550 that will carry out the task of Horizontal single axis tracking (HSAT) and automatic irrigation based on the feedback from the moisture sensor module and the pair of LDRs. To create the code, the programmer tool PIC C compiler was utilized, although there is a broad selection of software that can be used such as the MPLAB. Once the programme has been tested through the simulation at Proteus ISIS circuit, the hex file generated can be infused in the PIC microcontroller. Prior to the step above, the PIC must have been inserted with the driver software for it to communicate through the USB to the computer. This action is done using PIC programmer or PICkit. Since the microcontroller IC was enforced through the bootloader rather than with the attached PIC module that is available for purchase at store as a set, the initial step of inserting driver was all that is required for the bootloader to interface with external peripheral devices such as sensors.

Proteus Software Simulation (ISIS)

(i) Solar Charge Controller

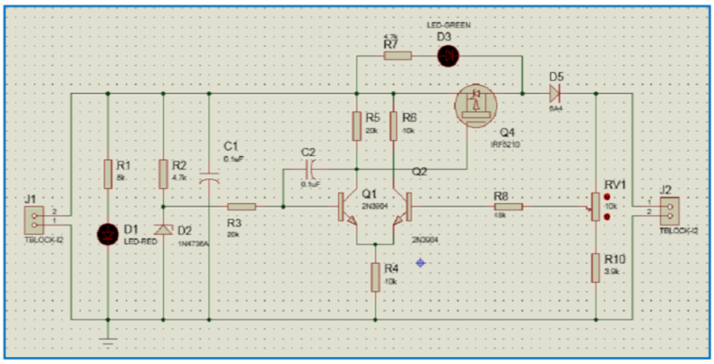

Figure 3: Solar Charge Controller ISIS Schematic.

The terminal block J1 is the input port to PV panel whereas the J2 is the output port leading to the lead acid battery to be charged.

(ii) PIC Bootloader Circuit

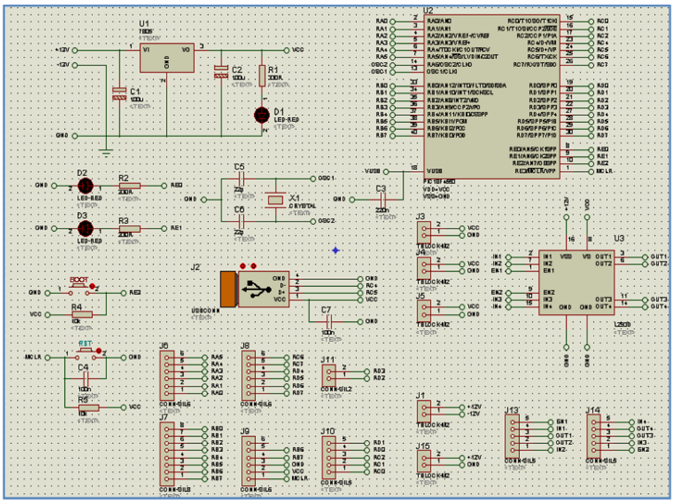

Figure 4: PIC Bootloader ISIS Schematic.

The PIC bootloader consist of numerous ports for each of the declared pins. It also includes other peripheral devices that need to be coupled with the PIC for it to be working such as the LM7805 regulator, boot & reset button, Universal serial bus (USB) port and crystal oscillator to provide clock. Instead of wire-connection, the terminal component was used as this simplifies the connection and prevents error from short circuit or wrong wiring. It is extremely vital to make sure the preliminary ISIS software is error free as the conversion to ARES will solely depend on the setting fixed at ISIS circuit.

Proteus Software Simulation (ARES)

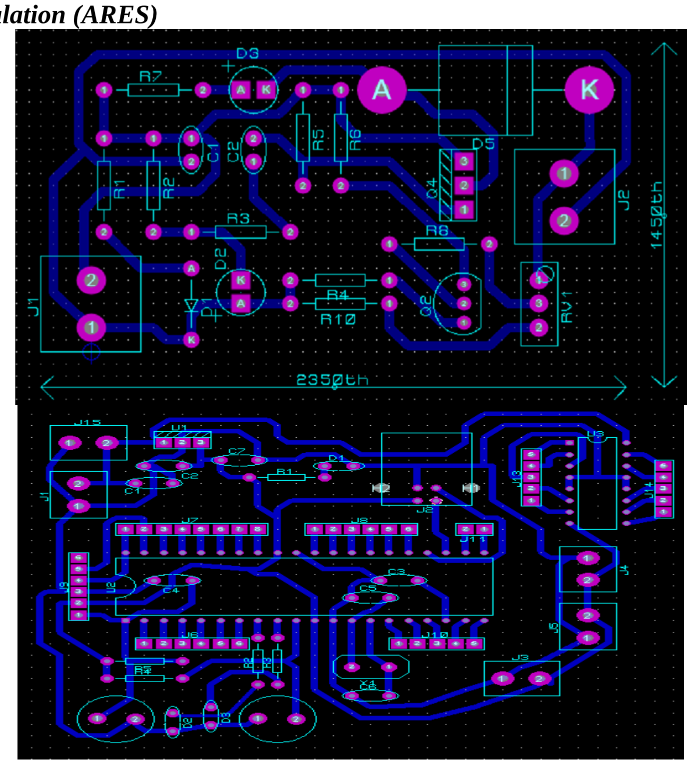

Figure 5: Charge Controller and PIC bootloader ARES schematic.

Circuit Prototype of Project

Charge controller prototype:

(i) Begins by the 6V shunt zener voltage reference formed by the combination of resister R2 and zener diode D2.

(ii) NPN transistor pair, Q1 and Q2 joins up as a differential amplifier that amplifies the variation between the voltage from variable resistor R6 and the reference voltage.
(iii) The output from collector of Q1 drives the P channel MOSFET Q4 gate terminal.
(iv) Assuming the feedback voltage rises at the arm of potentiometer, transistor Q2 will now turn "ON" even more or harder and siphons some of the emitter current away from Q1.
(v) Q1 collector current follows the emitter current. As a result, less voltage drops across R1 and reduces Vgs of Q4 thus turning if off.
(vi) The case of Q4 turning off is called cut-off that prevents the battery from overcharge and being damaged.
(vii) To obtain maximum charge in a 12V lead acid battery using this circuit, 1KΩ is connected to the output (terminal block J2) and the potentiometer is adjusted to set the control at 13-14V float charge voltage.

Figure 6 shows the charge controller prototype on a printed circuit board.

Figure 6: Charge Controller Prototype.

PIC Bootloader prototype:
The Programmable Interface Controller (PIC) can be used as a standalone IC with jumpers connecting to the pin terminals on a breadboard or on a PIC bootloader circuit. The bootloader circuit can also be purchased from the store and it has the complete port for USB, ICSP, I/O, 5V regulator, Boot & Reset button, resistors, capacitors and LEDs. However by purchasing from the store, the knowledge gained from designed the circuit in ISIS&ARES is completely neglected and thus fundamental concept on how the PIC works will not be learned. AS such, for this project the bootloader circuit was built from basic to the final step of soldering in the PCB board.
Another advantage of designing the bootloader is that other IC and additional components that might be required to perform the required task can be added directly to the circuit. This way it saves time and space as single circuit contains many traits. In this project DC motor was used to turn the platform according to the feedback from the two LDR sensors. To operate the DC motor, it is coupled with a L293D IC. The 5V output from the regulator was also linked to three terminal blocks. This is important as to provide power to the soil moisture module, LDR circuit and also the relay circuit. 12V from the input was additionally linked to another terminal block as well to serve as power source to the 12V DC water pump. Figure 7 shows the PIC Bootloader circuit.

Figure 7: PIC Bootloader circuit for this project.

Full prototype of the system is shown in Figure 8 below:

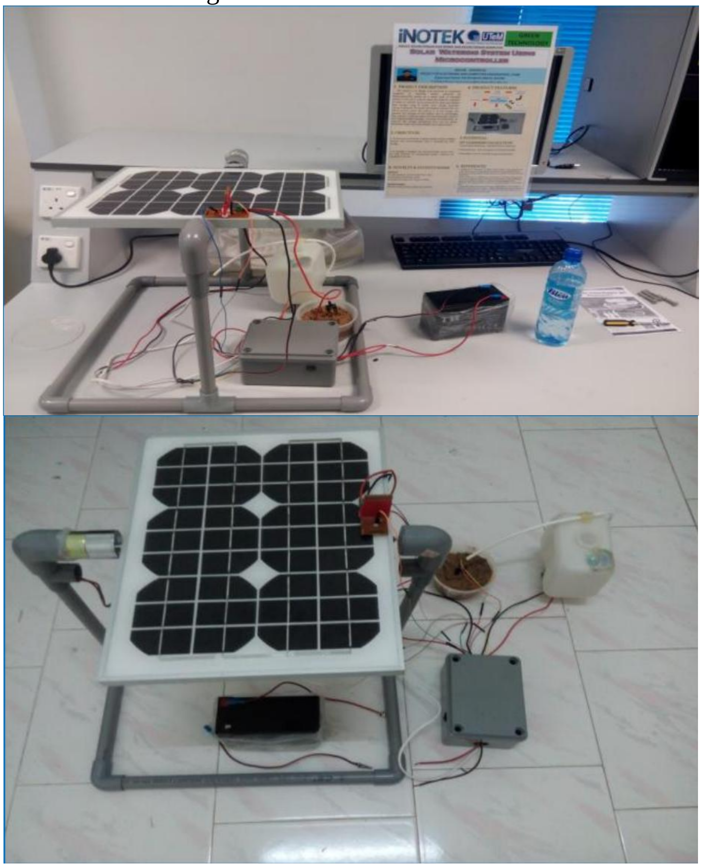

Figure 8: Full prototype testing.

III. RESULT

One of the main advantages of this system is in the capability of being self-powered. For that purpose the energy usage of all devices must be known, to calculate the duration at which the system can last. In reality application at field, it must be able to sustain long-term usage unless circuit error in which maintenance is needed. Otherwise the system must be able to operate for long term such half-year without a problem. The prototype that was created for the project is only for small scale and thus less sustainable. Table 2 shows the current consumption per second of the system.

Table 2: Current consumption per second of the system.

No	Equipment	Current draw/second active
1	PIC18F4550	220µA
2	L293D IC	100µA Max
3	Soil moisture sensor module	35mA Max
4	12V DC motor	600mA with load
5	12V DC motor pump	375mA with load
6	5 pin SPDT relay	30.60mA
7	LDR circuit	0.5mA
8	TOTAL CURRENT	1.3408A

The second important consideration on this system is the charging capability of the PV panel on the battery.

$$Peak - Hours\ Required = \frac{V_{batt}\, x Capacity_{batt}}{Power_{PV}}$$

$$= \frac{12Vx7Ah}{12W\ or (0.7Ax17V)} = 7 hours\ at\ full\ output$$

Hence 12W solar panel would take 7 hour of full output to fully charge the 12V 7Ah battery.

The third important consideration on this system is the capacity of the power storage system and how long it can last.

(i) Since 7A last for 1 hour, then 1.3408A which is the total current per second of system will last for X hours.

(ii) X = (7/13408) *60 = 313.25 minutes or 5.22 hours

≈ 5hours

For the current of 1.3408A usage per second, the battery will only last 5 hours but under the assumption that both the DC pump and motor was running continuously. In real application, the real run-time of both is as below for this project:

(i) 12V DC motor only triggers for 2-4 seconds every 3-4 hours from the duration of 6.00AM to 6.00PM.

(ii) 12V DC water pump trigger for 10-20 minutes every 4-5 hours from the duration of 6.00AM to 6.00PM.

Even with the real run-time as above, the battery charge would not last more than a few days to power up the system although it is being charged by the PV panel.

Simple solution to extend the battery life is by implementing larger capacity of energy storage device that can sustain the system much longer and establish the objective of self-powered.

IV. FUTURE WORK AND RECOMMENDATION

There are some recommendations that can be considered in the future work. Firstly, switching power supply with multiple batteries for charging and usage can be used during no-sun days or gloomy situation. Switching power supply will automatically switch from one battery to another if the first one is full. This way multiple batteries can be used and charged for use.

Secondly, real Time Clock (RTC) DS1307 IC may be integrated with PIC18F4550 so as to provide real-time facility to the system. By adding real time clock, the flexibility of the system can be further expanded.

Lastly, in order to reduce the power usage the controller may be integrated or set to low power consumption mode till the sensor gives reading below a certain threshold value. Optimization in low power mode to microcontroller whenever not in use can substantially reduce current usage and prolong the duration of battery depletion.

V. CONCLUSION

The Solar-Powered Automatic Irrigation System Using Microcontroller is designed to be a green technology which is capable of performing irrigation to the crop or area based on moisture level of soil and in combination with the Timer in PIC18F4550. This system optimizes the usage of water by reducing wastage and reduces human intervention plus saves cost as the entire system runs only using solar energy. Therefore it can be said as a standalone unit which requires no additional devices or powers to work with it. The system also requires minimal maintenance and attention. A secondary feature added was Horizontal Single Axis Tracker (HSAT) that increases the amount of energy harvested by the PV panel. This increases charge time of battery.

This project aimed at the agricultural sector and hopefully in the future technologies like this will be implemented worldwide.

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