DESIGN AND IMPLEMENTATION OF AN AUTOMATIC SOLAR POWERED IRRIGATION SYSTEM

[1]Okpeki, U. K. and [2]Oyubu, A. O.
[1,2]Department of Electrical/Electronic Engineering, Delta State University, Abraka,
Oleh, Campus, Nigeria
Email: omakazeem@yahoo.com and akposweet@yahoo.com

ABSTRACT

Due to the increased global warming and climate change being experienced in our world today, local weather conditions have become so unpredictable and increasingly severe. This has resulted in a major setback to some agricultural practices especially farming. To overcome this constraint, irrigation comes to play; thus, the importance of irrigation to farming in the 21st century cannot be overemphasised. Again, because of the desire to produce food throughout the year for both consumption and export, dry season farming has become increasingly popular. This type of farming requires a managed system of irrigation. This paper shows the design and implementation of an automatic solar powered irrigation system that monitors and automatically manages the soil moisture level of a specified area using a soil moisture sensor to read soil moisture levels and a C language programmed microcontroller to read the sensor values and output level in a digital readout on an LCD as well as control the water pump that supplies water to the soil when moisture levels fall below the programmed threshold. The system was designed to be powered by a battery which is charged by a solar panel.

Keywords: Moisture sensor, Microcontroller, Solar Panel, Irrigation, Actuator.

1.0 INTRODUCTION

Irrigation is defined as the method by which a controlled amount of water is supplied to plants at regular intervals. Irrigation is used to assist in the growing of agricultural crops, maintenance of landscapes and re-vegetation of disturbed soils in dry areas and during periods of inadequate rainfall. Over the years, many farmers all over the world employ some form of irrigation system to supply water to their farms. These irrigation systems are usually manual and require regular human input and so much manpower for their continued operation; to overcome this, automatic irrigation systems were developed. Automated irrigation systems have an advantage in terms of precision over manual methods of irrigation thus conserving water and saving money in the long run. The current trend in irrigation is to shift from manual to automatic irrigation systems.

This work focuses on realizing a practical and cost effective way of automating the process of irrigation using a programmable microcontroller to monitor and maintain a desired level of soil humidity via an LCD display and moisture sensor. The microcontroller is connected to a relay circuit which would trigger a water pump connected to a reservoir to supply water once soil moisture levels fall below programmed values. The addition of a solar panel and a deep cycle battery ensure an uninterrupted supply of electrical power to the designed system so that its overall design goal is realized without interruption resulting absence of power to drive the system. This also makes the design implementable in off-grid locations as well as eliminate cost of purchasing/generating electricity.

2.0 LITERATURE REVIEW

Different researchers have approached the problem of designing and developing a cost effective irrigation system incorporating modern technological features for ease of maintenance and efficient operation while utilizing water economically for such activities. Miranda et al. (2005) proposed the design, development and deployment of a low cost solar-powered feedback controller for distributed irrigation control of fixed irrigation systems. Their specific tasks included the controller design (hardware and software), performance evaluation, and power optimization. The designed controller uses soil water potential (SWP) measurements to control the amount of water applied to each specific management zone, and measured system hydraulic pressure to communicate with other controllers.

Umair and Usman (2010) proposed the development of an optimal automatic irrigation scheduling algorithm using artificial neural networks. Their paper aims at overcoming the problem many irrigation scheduling techniques have; which are mainly based on monitoring the soil, crop and weather conditions. These variables are quite evasive and controlling the operation of irrigation system machinery based on ON/OFF operating conditions is sub-optimal. Their approach incorporating artificial neural networks (ANN) based controller extensively dealt with the problems of sub-optimal scheduling of irrigation systems.

Ingale and Kasat (2012) proposed the design and development of microcontroller-based drip irrigation system. They monitored the changing conditions of humidity levels by weather patterns and soil types and scheduled irrigation activity and proper timing for water supply.

Hedley et al. (2012) proposed the design, development and deployment of wireless soil moisture sensor networks for irrigation scheduling. They incorporated within the design an advanced nutrient management system which aims at optimizing plant nutrient use and minimize deleterious environmental effects. Precision irrigation hardware allows irrigation and nutrient inputs to be varied to small defined management zones under the irrigator. The management zones are derived from data layers obtained from electromagnetic (EM) surveys and yield maps. Wireless soil moisture sensor networks (WSNs) are then positioned into these zones to monitor wetting and drying events for precision irrigation scheduling. Their research presents progress in developing a wireless sensor network (WSN) to inform software which initiates control actions for a variable rate irrigation system.

Julie S. Chang presented a thesis on an Automatic Irrigation Management System in 2006. The system was designed to operate on a pre-programmed timing mechanism for the control mechanism. The system comprises a microcontroller unit and a timer system interconnected with the I2C protocol. Due to its timer system, it incorporates scheduling of irrigation activities.

This work shows the design and construction of an automatic irrigation system that will monitor soil moisture levels and trigger ‘ON’ an irrigation pump once soil moisture level falls below a pre-set lower limit and also trigger ‘OFF’ the irrigation pump once soil moisture level reaches the pre-set upper limit. This work also incorporates a solar panel and a deep cycle battery to ensure an uninterrupted power supply as well make the designed system operable in off-grid locations.

3.0 METHODOLOGY/SYSTEM DESIGN

The methodology employed in this work takes into account both the hardware section which consists essentially of all the component units such as the display, sensor, control, actuator, pump, and power supply units, and the software section which is essentially made up of an embedded ‘C’ language program containing sets of instructions that were transferred to a microcontroller, that functions to ensure that different actions are carried out accordingly.

The overall design is broken down into a functional block diagram where each block in the diagram represents a unit of the circuit that carries out a specific function. Figure 1.0 below shows the functional block diagram of the automatic solar powered irrigation system.

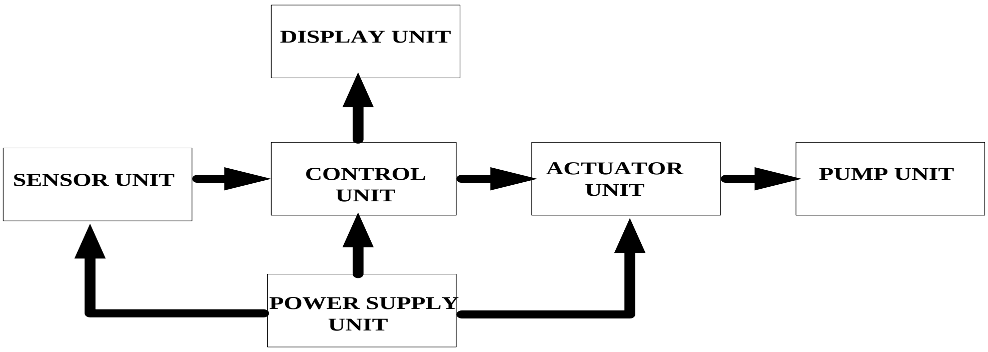

Figure 1: Functional Block Diagram of Automatic Solar Powered Irrigation System.

3.1 Power Supply Unit

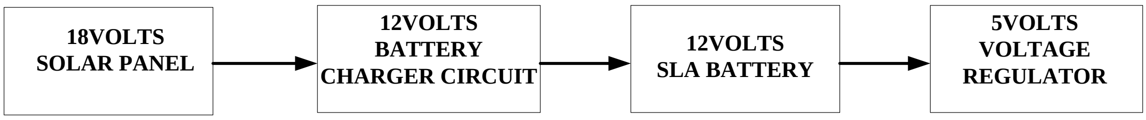

Figure 2: Block Diagram of Power Supply Unit.

The power supply unit of this was realized using these various components- a solar panel Diodes, LM317T voltage regulator, Capacitors, BC548 transistor, Resistors, LM7805CV voltage regulator. The various components were electrically linked to realize the power supply unit of the designed system.

3.1.1 Solar Panel

In this work the solar panel is required to a charge a 12 V 7.2Ah battery through a voltage regulator. By the battery specifications, a voltage in the range of 14.4 – 15 V is required to charge the battery for cycle use. Also a voltage regulator is required to stabilize the charging voltage and the voltage regulator has a forward voltage drop of 2 V. The diode used to protect the solar panel and voltage regulator from reverse voltages also has a voltage drop of 0.7 V

From calculation, using $V_{out} = V_{cyc} + V_{tf}$

Where V_{out} = Solar panel voltage, V_{cyc} = Battery cycle charge voltage and V_{tf} = Total forward Voltage drop, an 18 V solar panel was chosen. Electrical ratings of an 18V solar panel are shown in table 1.

Table 1: Electrical ratings of an 18V solar panel.

ELECTRICAL RATINGS	
Peak Power (Pmax)	10W
Voltage (Vmp)	17.4V
Current (Imp)	0.57A
Open circuit voltage (Voc)	21.6V

Short Circuit Current (Isc)	0.63A

3.1.2 Protection Diode

The protection diode is used to protect the solar panel from damage due to reverse voltages, it also protects the voltage regulator and capacitor from reverse connection of the solar panel. The solar panel chosen has an open circuit voltage of 21.6 V and a short circuit current of 0.63 A. Thus a 1N4001 diode was chosen with a maximum voltage rating of 50 V and a maximum current rating of 1 A.

3.1.3 Voltage Regulator

Two voltage regulators were used in this work, while one uses an LM317T to supply 14.4 V to charge the battery and power the water pump, the other uses a 7805 to supply 5v to drive the moisture sensor, the LCD and the microcontroller.

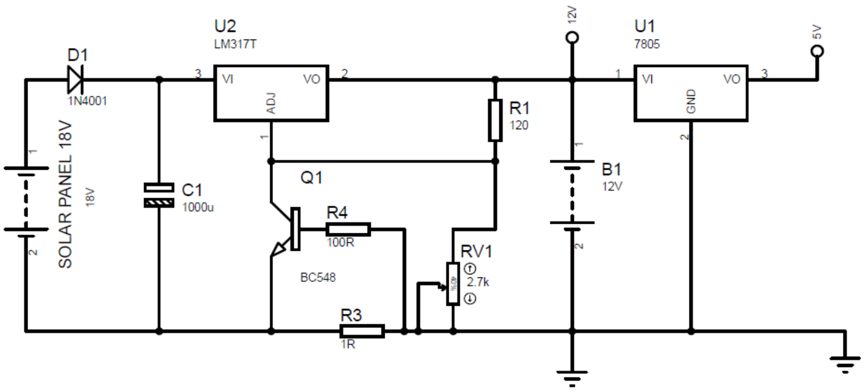

Figure 3: Power Supply Unit Circuit Diagram

3.2 Sensor Unit

The sensor unit of this work which is essentially a moisture sensor, is the unit that measures the environmental variable under consideration (soil moisture level) and converts this measurement into a format that can be read by the control unit. The soil moisture sensor is a groove shaped device that is inserted into the soil to be monitored. It operates by measuring the degree of resistance of the soil and from that the moisture level of the soil can be calculated. It outputs an analog value ranging from 0 V (Wet soil/Water) to 4.5 V (Wet soil/Water), or a digital value ranging from 0 – 950.

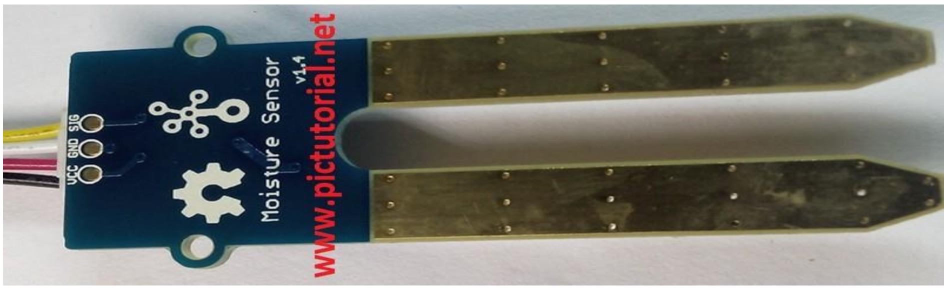

Figure 4: Soil Moisture Sensor

3.3 Control Unit

The control unit which can be said to be the brain of the system is essentially a 40 pin PIC16F877A microcontroller. It receives input and makes decisions based on this input, activating selected outputs and sending data to the display unit to indicate the status of the system and its environment. The control unit receives input from the sensor unit and acts upon this input. In this work the control unit receives the soil moisture level as an analog input from the sensor unit and converts it to a digital value.

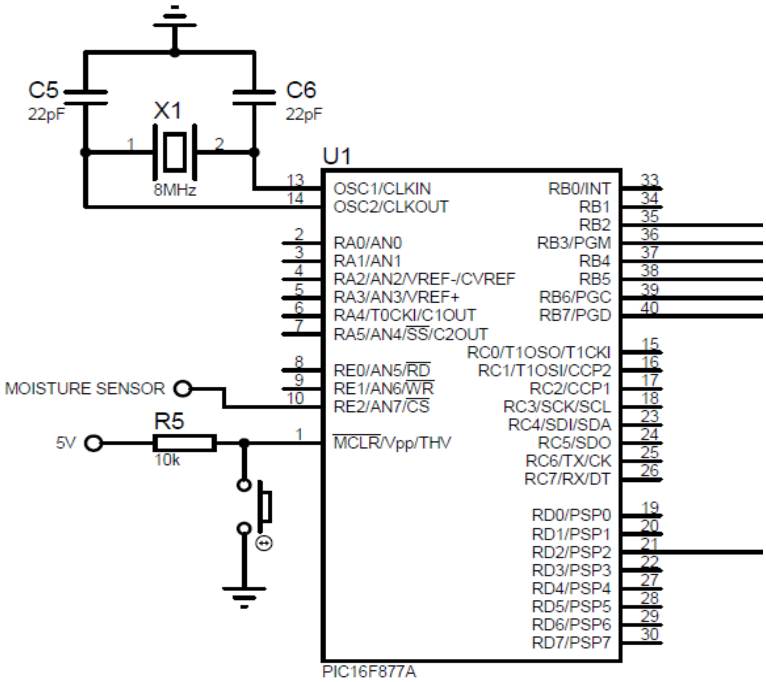

Figure 5: PIC16F877A.

3.4 Display Unit

The display unit is a 16X2 LCD display. It displays the current soil moisture level as well as the status of the water pump as either ON or OFF.

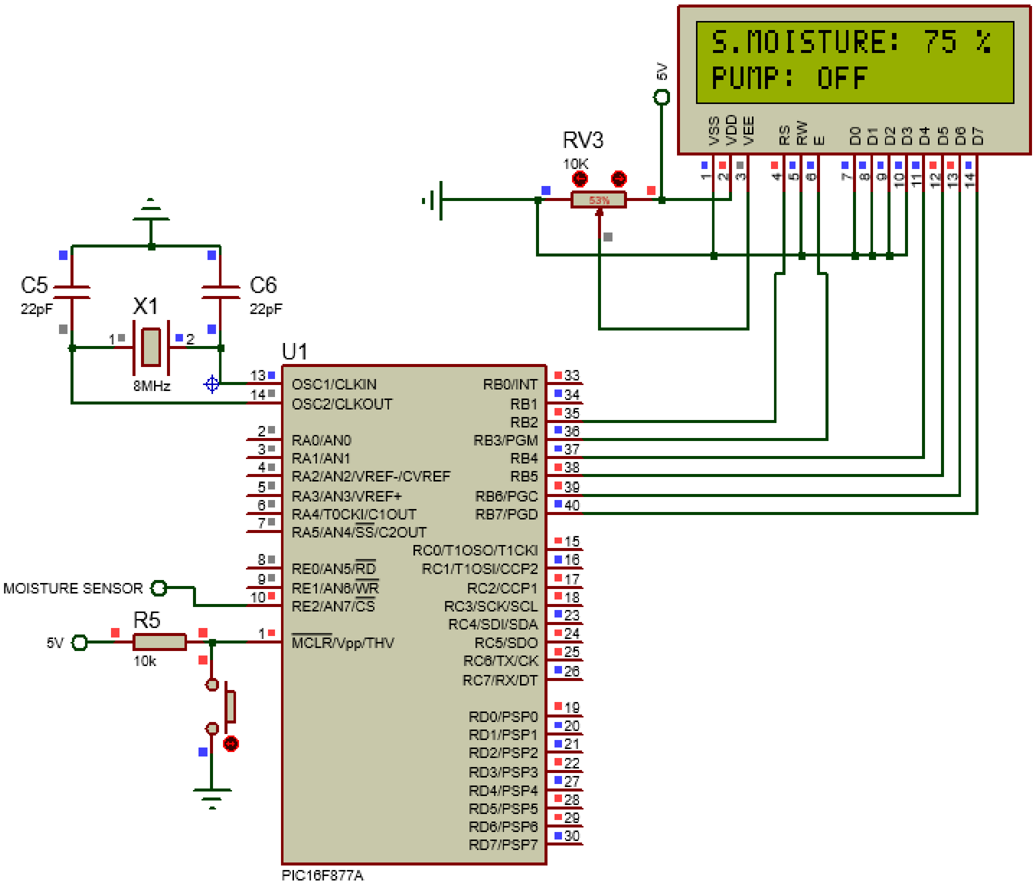

Figure 6: LCD interfaced with microcontroller (PIC16F877A).

3.5 Actuator Unit

The actuator unit can be likened to an amplifier that enables the control unit to trigger the pump unit with a small signal while keeping the control unit and the pump unit which operate at different voltages (5 V and 12 V respectively) electrically isolated.
The unit consist of a resistor, a transistor, switching diode and a relay.

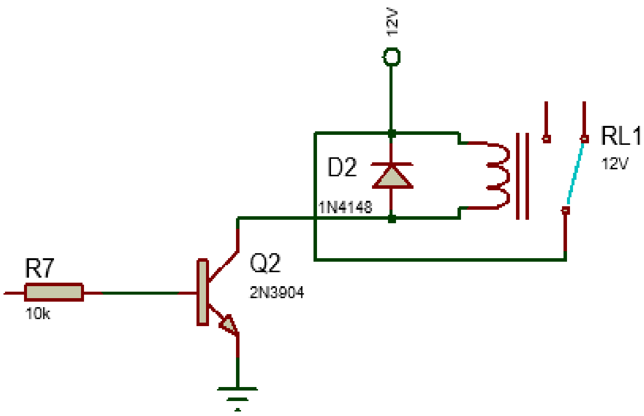

Figure 7: Actuator Unit

The pump unit is connected to the normally open contact of the relay, meaning by default it is switched OFF. The pump unit is switched on when the microcontroller sends a HIGH input to the base of transistor Q2 through R7, this causes Q2 to enter saturation and it begins to conduct. This causes a current to flow through the coil of the relay, triggering it and pulling the pole to the normally open contact thus activating the pump unit.

3.6 Pump Unit

The pump unit is essentially a submersible 12v dc pump that takes water from the reservoir and supplies it to the designated area.

3.7 Software Implementation

A source code was developed and transferred to the microcontroller to enable it receive analogue input from the sensor, perform calculations and using the result of these calculations, send output to the actuator and display the system's status on the LCD. Embedded "C" programming language was used in this work. The written codes enable communication between the microcontroller, sensor, LCD and water pump.

3.8 System Flow Chart

This is the flowchart used in this work to analyze, design and manage the process and program of this automatic solar irrigation system.

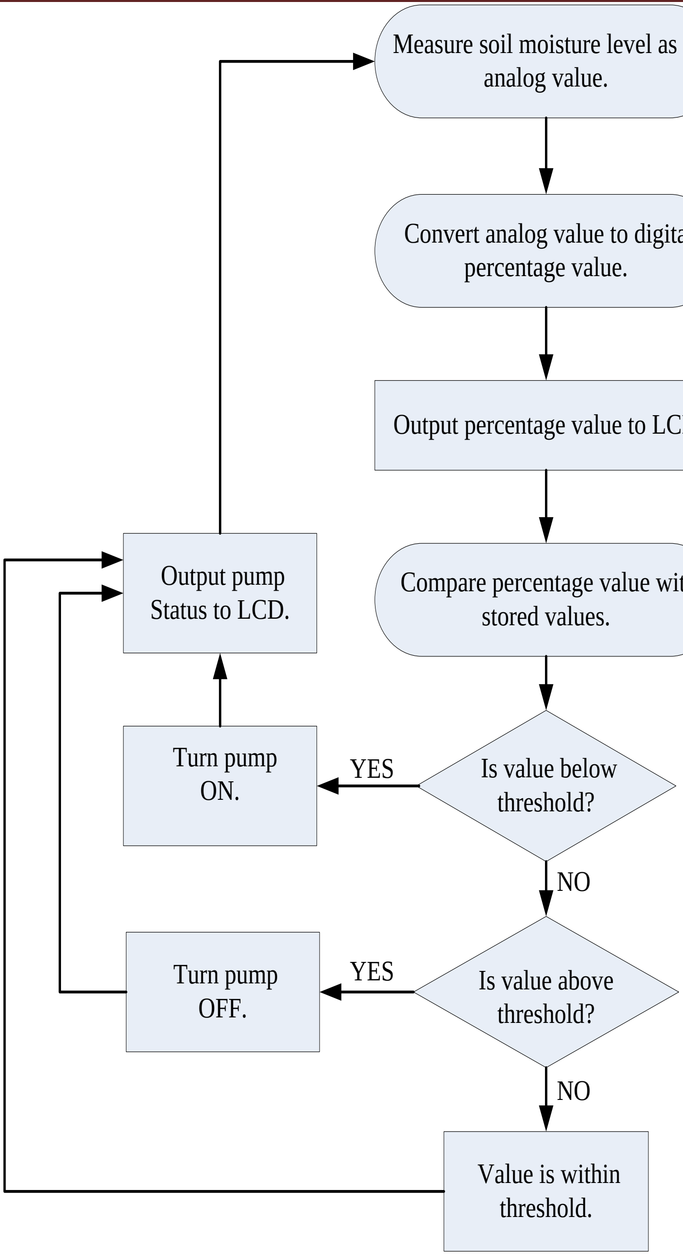

Figure 8: Flowchart of the System

3.9 Modus Operandi of the Designed System.

The system operates by using a solar panel to transform solar energy to electrical energy which charges the battery via a current limited 12 V battery charger circuit. The battery powers the microcontroller, LCD and soil moisture sensor through a 5 V voltage regulator. The soil moisture sensor measures the moisture level of the soil through its resistance (as moist soil is more conductive than dry soil), then sends this reading to the microcontroller as an analogue value. The microcontroller converts this analogue value to a digital value which is in the range of 0 to 1023, then converts this digital value to a percentage, this new value is equivalent to the soil moisture level expressed as a percentage. This percentage value is output to the LCD display. The microcontroller then takes further action depending on this value, if the percentage value of the soil moisture level is below the pre-set lower threshold the microcontroller sends a signal to trigger the actuator unit which in turn switches ON the water pump to supply water. If the value rises above the pre-set upper threshold the microcontroller cuts off the signal to the actuator unit which switches OFF the pump. The range between the upper and lower threshold is considered an optimum range and if the initial value is in this range no action is taken. The upper and lower threshold were included in the design in other to filter out transient oscillations in the soil moisture level which would otherwise cause the logic state of the system to switch rapidly. Such operation is undesirable and can lead to erratic behaviour of the system which can cause early system failure. The use of programmed thresholds eliminates this problem.

4.0 TEST AND RESULT

The design of this work consists of a software portion and a hardware portion. The software portion was first realized using mikroC PRO for PIC™ to develop the code for the project in embedded “C” programming language. The circuit was then designed in Proteus 8 Professional™ and the software was loaded into the circuit, then extensive simulation and testing was carried out to ensure the system perform without errors and at maximum efficiency. After simulating the system and modifying it as necessary, construction of the hardware portion commenced.

The overall circuit was broken into units and each unit was first tested on a breadboard before they were transferred to a Vero board and electrically linked by soldering after this several tests were carried out on the device to confirm the level of its performance and efficiency. Thereafter, it was confirmed that the system was functioning well and in line with overall design goal.

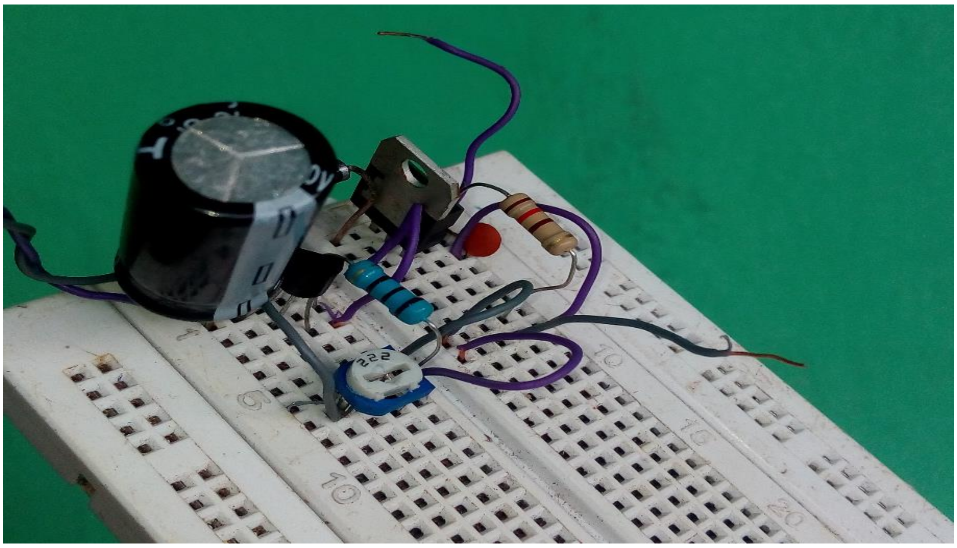

Figure 9.0: Power Supply Unit on Breadboard

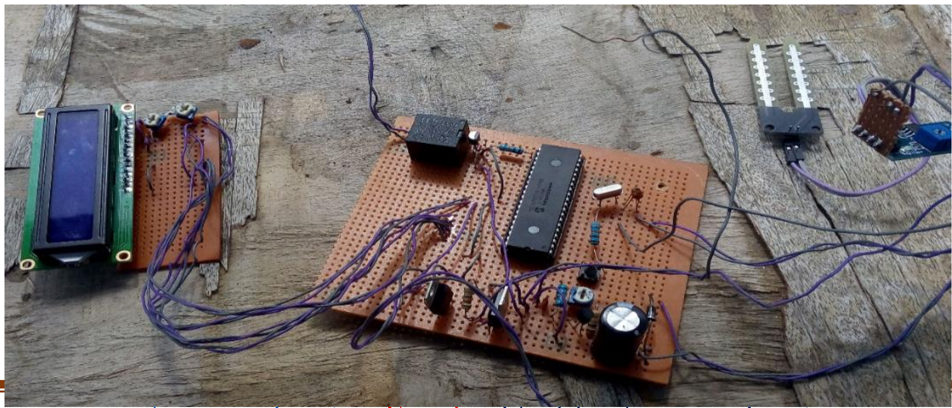

Figure 10: Complete Circuit on Vero Board

Figure 11: Testing the System

CONCLUSION

The design and implementation of an automatic solar powered irrigation system that monitors and automatically manages the soil moisture level of a specified area using a soil moisture sensor to read soil moisture levels and a 'C' language programmed microcontroller to read the sensor values and output level in a digital readout on an LCD as well as control the water pump that supplies water to the soil when moisture levels fall below the programmed threshold has been presented in this paper. The device is automated and can function without human intervention. Again; because the system is solar powered, it is suitable for use in off-grid locations as well as eliminate cost of purchasing/generating electricity.

REFERENCES

1. 7805 Voltage Regulator IC | 7805 Datasheet | Pin Diagram & Description-Engineers Garage http://www.engineersgarage.com/electronic-components/7805-voltage-regulator-ic
2. Automatic Irrigation Management System,(2011).www.edu/changj7/docs/proj-%20description.pdf
3. Divya, V. and Umamakeswari, A. (2013): "Smart Irrigation Technique Using Vocal Commands", International Journal of Engineering and Technology (IJET), ISSN: 0975-4024, Vol. 5, No. 1, pp. 385-390.
4. Dry season: Irrigation farming to the rescue - The Nation Nigeria http://thenationonlineng.net/dry-season-irrigation-farming rescue.
5. Guerbaoui, M.; El Afou, Y.; Ed-Dahhak, A.; Lachhab, A. and Bouchikhi, B. (2013): "PC-Based Automated Drip Irrigation System", International Journal of Engineering Science and Technology (IJEST) ISSN: 0975-5462 Vol. 5, No.01, pp. 221-225.
6. Hedley, Carolyn; Ekanayake, Jagath; and Roudier, Pierre (2012): "Wireless Soil Moisture Sensor Networks For Precision Irrigation Scheduling", www.massey.ac.nz/~flrc/workshops/12/Manuscripts/Hedley_2012.pdf
7. Ingale, H. T. and Kasat, N. N. (2012): "Automated Irrigation System", International Journal of Engineering Research and Development, Volume 4, Issue

11 (November 2012), pp. 51-54, e-ISSN: 2278-067X, p-ISSN : 2278-800X, www.ijerd.com

8. Irrigation https://en.wikipedia.org/wiki/Irrigation
9. Irrigation Practices in West Africa — Tomato Jos/West African Agribusiness http://www.tomatojos.net/irrigation-practices-in-west-africa/
10. LM317 – Wikipedia https://en.wikipedia.org/wiki/LM317
11. Miranda, F.R.; Yoder, R.E.; Wilkerson, J.B. and L.O. Odhiambo (2005): "An autonomous controller for site-specific management of fixed irrigation systems", Computers and Electronics in Agriculture Volume 48, pp. 183–197.
12. Umair, S. Muhammad and Usman, R. (2010): "Automation of Irrigation System Using ANN-based Controller", International Journal of Electrical & Computer Sciences IJECS-IJENS, Volume 10, No: 02, pp. 45-51.