Proceedings of the World Congress on Engineering 2017 Vol I
WCE 2017, July 5-7, 2017, London, U.K.

Smart Weather Station for Rural Agriculture using Meteorological Sensors and Solar Energy

Anthony U. Adoghe, Segun I. Popoola, Onyedika M. Chukwuedo, Abel E. Airoboman, Aderemi A. Atayero, *Members, IAENG*

***Abstract*—Access to short term weather forecasts is still limited in local communities of Africa. Unlike short term forecasts, seasonal forecasts based on global and regional climate models do not give localized and timely information relevant to farmers' needs. This paper presents a cost-effective, solar-powered automated weather station as a veritable system for weather forecasting that is relevant to solving agricultural decisions in rural communities. The developed system significantly reduced the cost of obtaining accurate, localized scientific weather information by interfacing various meteorological sensors to microcontrollers. On-site users can access the weather information via the LCD unit on the system while the data is sent to out-of-site user through Short Messaging Service (SMS) of mobile communication system. This approach will effectively ensure food security in arid and semi-arid African countries.**

***Index Terms*— automated weather station, meteorological sensors, rural agriculture, microcontroller**

I. Introduction

WEATHER monitoring and forecasting has a wide range of applications and offers numerous advantages to different fields. One of the relevant areas of application is the renewable energy generation. The power generation profile of renewable energy sources fluctuates because it depends, to a very large extent, on meteorological conditions. Therefore, weather forecasting becomes expedient to keep this variation under control for optimal system performance. For example, Global Horizontal Solar Irradiance (GHI) forecasting can be used to boost solar energy production of isolated power grids that are located on the island [1]. In addition, the accuracy of wind power prediction is greatly affected by the fluctuating and volatile nature of wind speeds and several other weather elements [2]. This unfavourable effect gives rise to a relatively weak grid for large scale wind power input to the system. Consequently, accurate weather forecasting will facilitate efficient management of the wind power grid and increase the revenues from the electricity market [3].

Seasonal weather forecast is most relevant to different agricultural decision problems [4]. This applies to crop production, animal farming, and food and forage processing. Meteorological content of the forecasts can be translated into agricultural parameters for tactical and strategic decisions. Farming operations can be planned based on local climate conditions [5]. Abrupt change in weather conditions has continue to limit agricultural production in sub-Saharan Africa in recent time. Continuous increase in temperature results in potential evaporation in the region [6].

Local farmers in rural areas of sub-Saharan Africa anticipate favourable weather conditions for agricultural practices based on ethno-meteorology [7, 8]. This form of weather forecasting involves intuitive observation of natural environment. Indigenous farmers solely rely on this technique to make adjustments in farming calendar and crop selection types in any given season [9]. To effectively handle the present challenge of food insecurity in arid and semi-arid African countries, the adoption of seasonal forecast is a vital element of climate change adaptation strategy [10].

Access to short term weather forecasts is still limited in local communities of Africa [4]. Therefore, efforts should be made to address this need. Unlike short term forecasts, seasonal forecasts based on global and regional climate models do not give localized and timely information relevant to farmers' needs [6]. In addition, available weather forecasts are not within the reach of local farmers living in rural communities. Consequently, local farmers have no contact with scientific weather information to predict future conditions.

Weather stations employ different meteorological sensors to monitor and report weather elements such as temperature, relative humidity, dew point, atmospheric pressure, wind direction and wind speed. The traditional approach to weather monitoring requires skilled labor for operation and demands regular maintenance. This will invariably increase the life cycle cost of the weather station. Also, the power grids in most of the countries of sub-Saharan Africa are unreliable. Power outages are peculiar to rural areas where most are not even connected to the grid [11]. With the advances in semiconductor technology, the cost of obtaining accurate, localized scientific weather information can be greatly reduced by interfacing various meteorological sensors to microcontrollers.

In this paper, the authors developed a cost-effective, solar-powered automated weather station using meteorological sensors, a microcontroller, a Liquid Crystal Display (LCD), and a GSM modem. The remainder of this work is organized as follows: Section II gives the materials and explains the methods employed; Section III presents the system implementation and testing procedures; Section IV

Manuscript received February 25, 2017; revised March 28, 2017.
A. U. Adoghe, S. I. Popoola, O. M. Chukwuedo, A. E. Airoboman, and AAA. Atayero,
Department of Electrical and Information Engineering, Covenant University, Ota, Nigeria.
{anthony.adoghe, abel.airoboman, atayero} @covenantuniversity.edu.ng, segunpopoola15@gmail.com

discussed and summarized the results obtained.

II. Materials and Methods

The automated weather station consists of the thermometer, the anemometer, the wind vane, the Light Dependent Resistor (LDR), and the microcontroller. These components are interconnected as shown in Figure 1. The thermometer measures the temperature while the anemometer measures the wind speed. Also, the LDR is used to determine the intensity of the sunlight. The microcontroller acts as the central brain of the system; it converts the analogue signal input of the meteorological sensors into digital format. The sensors are connected directly to the Analog-to-Digital Converter embedded in the microcontroller. The weather element information are stored in the Erasable Programmable Read Only Memory (EPROM) available on the chip. EPROM has the ability to hold information when the power supply is interrupted. A GSM module is connected to the microcontroller to enable remote weather monitoring.

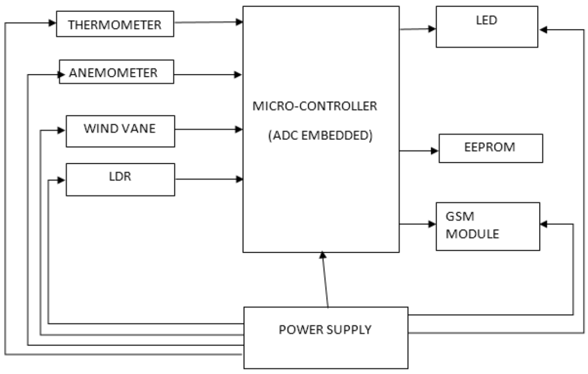


Figure 1: Block Diagram of Automated Weather Station

On-site users can access the weather information via the LCD unit on the system while the data is sent to out-of-site user through SMS of mobile communication system.

The temperature sensor used in this work is LM35. This device facilitates remote weather monitoring with high accuracy, low cost, and low power consumption. It operates within the voltage range of 4-30 V. A cup anemometer is made to rotate subject to the force of the wind. The speed of rotation is directly proportional to the measured wind speed. The three-cup rotor reed switch/magnet produces one pulse per rotation with a rotor diameter of 125 mm. The device can measure a wind speed of range 5-200 kilometer per hour.

The wind vane proposed for this work has eight switches, each connected to its own resistor. When the vane rotates, the magnet closes the switches in its path, leaving the rest open to allow the detection of the path of the wind. An external resistor is used to form a voltage divider, producing a voltage output that can be measured with the ADC.

The LDR circuit uses a voltage divider rule. A 10 kΩ variable resistor was connected to a 5 V supply. The voltage output of the circuit decreases with increasing light intensity. The sensor node voltage is always compared with the threshold voltage for different levels of light intensity corresponding to four different conditions: dawn, day, twilight and night. The LDR is designed to operate from 0.0495 V to 4.9 V. The lowest voltage limit of 0 V represents the brightest condition like daylight while the highest voltage limit of 5 V depicts the dark condition like midnight.

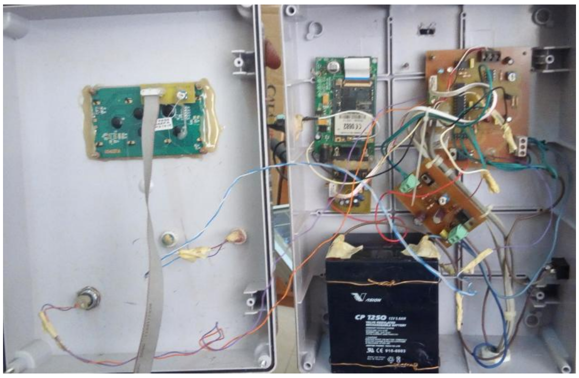


Figure 2: System Circuitry

The microcontroller PIC18F4520 was selected and programmed within the MPLAB Integrated Development Environment (IDE) using the assemby lanuage. The ICD2 was used to interface the microcontroller with the MPLAB. The PIC18F4520 was programmed serially to accumulate the data collected by the sensors for proper processing and logging. The GSM module requires Universal Synchronous and Asynchronous Receiver and Transmitter (USART) for functional communication. Hence, the choice of PIC18F4520.


Figure 3: Automated Weather Station

The GSM module, SIM340C, is a quad-band GSM/GPRS modem that works on both 900 MHz and 1800 MHz frequency bands. It is used in this application for sending and receiving SMS. The module is powered by a 3.8 V DC supply and communicates with the PIC18F4520 using its serial port connected to the USART port of the microcontroller. Out of the 60 pins available on the GSM module, only 23 pins were used. The connection is clearly shown in Figure 4.

The LM35 has a sensitivity of 10 mV per degree Celsius. The output of LM35 was amplified using a LM324 single power supply operational amplifier (Op-Amp). The Op-Amp has a gain of 3, using a 10kΩ and a 20kΩ resistors while the LM35 has a 0.01 V rise in the output per degree rise in temperature. At this rate, it is capable of reading up to 500°C.

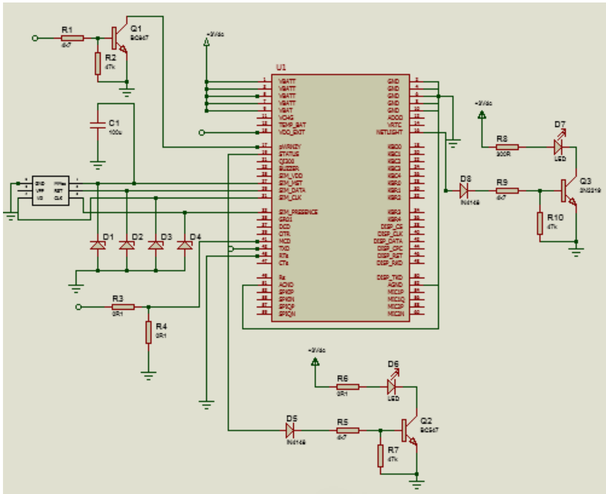


Figure 4: Microcontroller Circuit

III. Results and Discussions

The Hygro-Thermometer which displays its temperature in Celsius was used for standard test. At room temperature, it displays 29.6 degree Celsius while the module gives an output of 0.89, as indicated by the multi-meter. Based on the LM324 with a gain of 3.04, the temperature was given as 29.27 degree Celsius as shown in Figure 5-7.

Figure 5: Hygro-Thermometer Reading

The testing of the LDR was done in a controlled environment using fluorescent lighting as the light source and a black tape as a simulation of dark periods. The LDR shows a negative coefficient as the light voltage produced is inversely proportional to level of illumination. At room lighting level, 1.9 V was displayed on the multimeter while the multimeter read 4.97V in a very dark scenario.

The anemometer was taken to an open field where fast moving air could be felt. As the wind increases, more pulses are felt. The microcontroller codes were tested using PROTEUS 7 Professional software. The LCD unit used is a LMO16L. It has a good backlight for clear view of the readings in dark areas. Also, it has a contrast adjustment for user suitability. The complete system is shown in Figure 3.

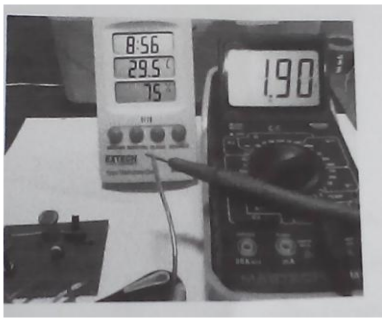


Figure 6: LDR Testing under Light Condition

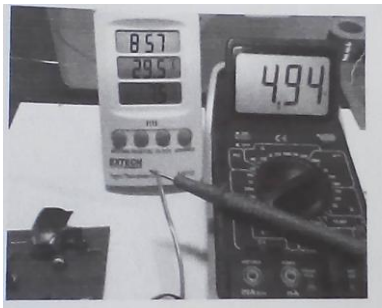


Figure 7: LDR Testing under Dark Condition

IV. Conclusion

This work set out to address the problem of availability and ease of access to short term weather information in local communities of Africa. A cost-effective, solar-powered automated weather station was designed and implemented using meteorological sensors, a microcontroller, a Liquid Crystal Display (LCD), and a GSM modem. The automated weather station utilized the thermometer, the anemometer, the wind vane, the Light Dependent Resistor (LDR) as meteorological sensors to measure weather elements relevant to agriculture. The data obtained from the environment through the sensors were collected, converted, and processed into usable format by the PIC18F4520 microcontroller. Information is accessible to on-site users through the LCD unit. Out-of-site users receives update on weather changes on their mobile phones via SMS. Arid and semi-arid African countries can exploit this low-cost system to enhance food production in their rural communities.

References

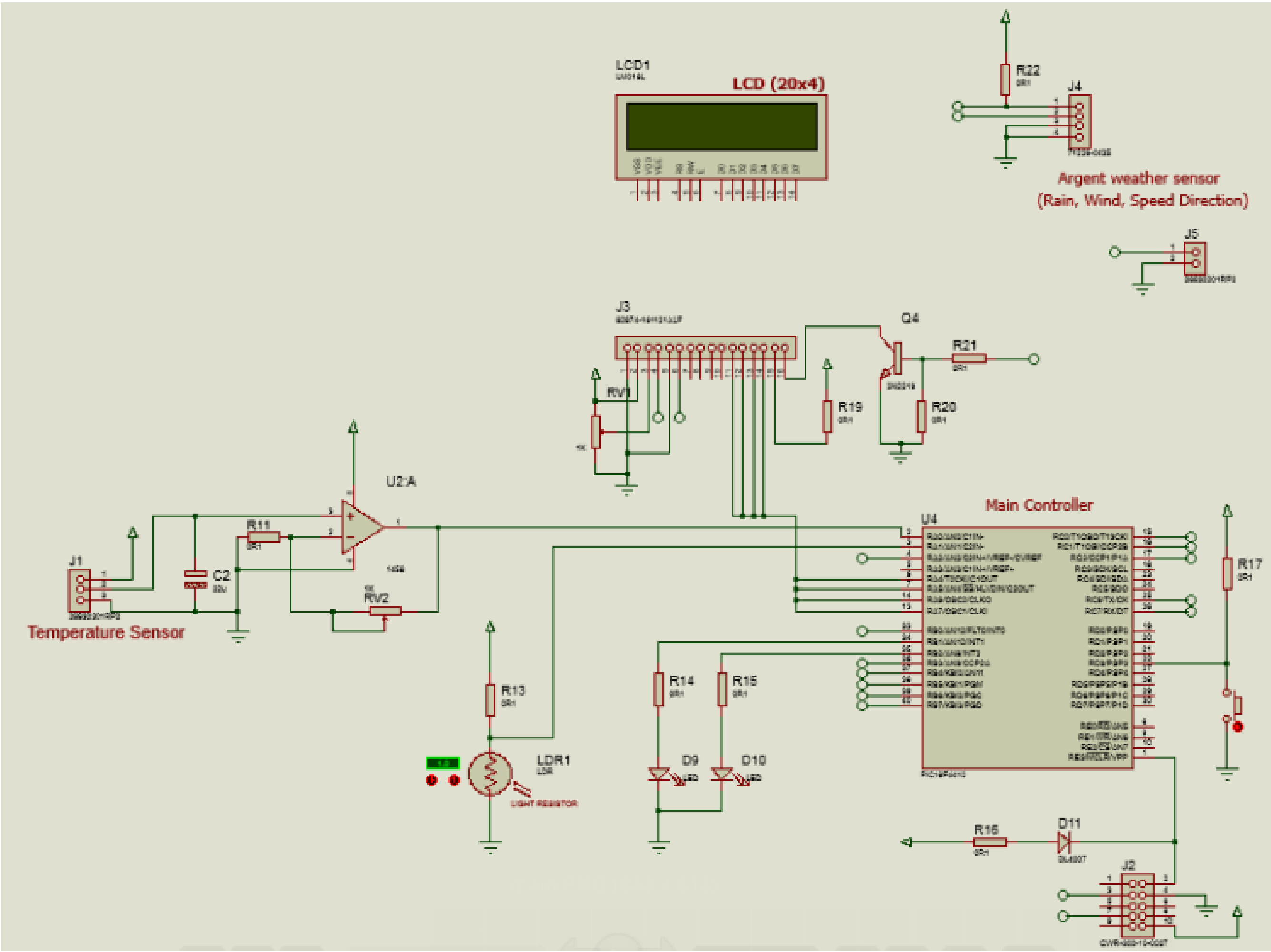
[1] L. Mazorra Aguiar, B. Pereira, P. Lauret, F. Díaz, M. David, Combining solar irradiance measurements, satellite-derived data and a numerical weather prediction model to improve intra-day solar forecasting, Renewable Energy, Volume 97, November 2016, Pages 599-610.

[2] Qingli Dong, Yuhuan Sun, Peizhi Li, A novel forecasting model based on a hybrid processing strategy and an optimized local linear fuzzy neural network to make wind power forecasting: A case study of wind farms in China, Renewable Energy, Volume 102, Part A, March 2017, Pages 241-257.

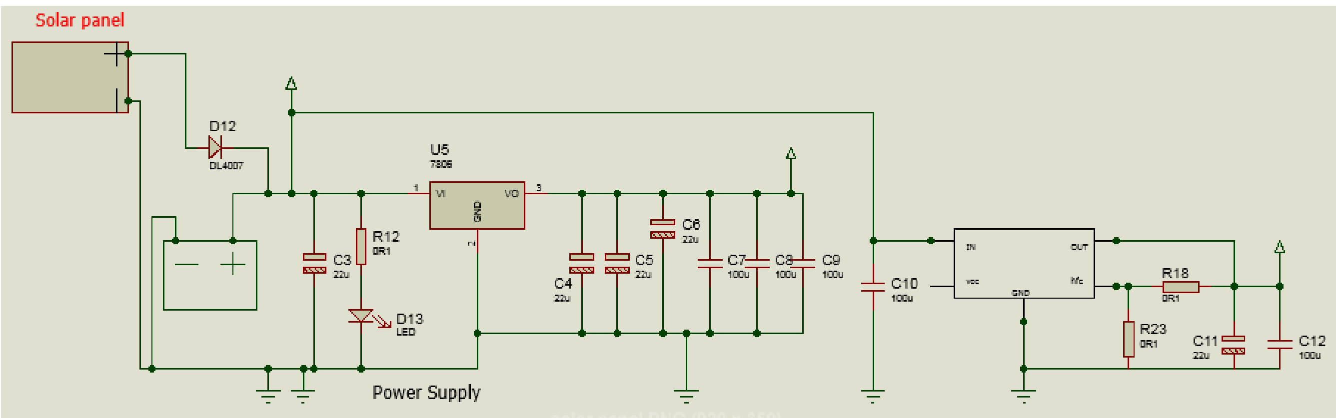
[3] Y. Feng, H. Lin, S.L. Ho, J. Yan, J. Dong, S. Fang, Y. Huang. Overview of wind power generation in China: status and development. Renew. Sustain. Energy Rev., 50 (2015), pp. 847–858.

[4] P. Calanca, Weather Forecasting Applications in Agriculture, In Encyclopedia of Agriculture and Food Systems, edited by Neal K. Van Alfen,, Academic Press, Oxford, 2014, Pages 437-449.
[5] S.A. Changnon. The past and future of climate-related services in the United States. J. Service Climatol. 1 (2007), pp. 1–7.
[6] Oluwatoyin Dare Kolawole, Piotr Wolski, Barbara Ngwenya, Gagoitseope Mmopelwa, Ethno-meteorology and scientific weather forecasting: Small farmers and scientists' perspectives on climate variability in the Okavango Delta, Botswana, Climate Risk Management, Volumes 4–5, 2014, Pages 43-58
[7] J. Gewald El Negro, el Nino, witchcraft and the absence of rain Pula: Bot. J. Afr. Stu., 16 (1) (2002), pp. 37–51.
[8] T.N. Huffman. A cultural proxy for drought: Ritual burning in the Iron Age of Southern Africa. J. Arch. Sci., 36 (2009), pp. 991–1005
[9] Ouma, G., 2009. Linking traditional and modern forecasting in western Kenya, Stories from the field (2009) On-line document: <http://idrc.org/minga/ev-148990-201-1-DO_TOPIC.html> (Accessed 11 November 2010).
[10] J.W. Hansen, S.J. Mason, L. Sun, A. Tall. Review of seasonal climate forecasting for agriculture in sub-Saharan Africa. Exp. Agric., 47 (2011), pp. 205–240
[11] S. O. Oyedepo, "On energy for sustainable development in Nigeria", Renewable and Sustainable Energy Reviews, Volume 16, Issue 5, June 2012, Pages 2583-2598.

APPENDIX A



APPENDIX B



ISBN: 978-988-14047-4-9
ISSN: 2078-0958 (Print); ISSN: 2078-0966 (Online)