Dynamic Soil Moisture Control System for Irrigation Using GSM

Rabiu Aminu and Deepthi Raveendrababu Sugathakumari

Abstract—Agriculture plays a significant role in economic development for the African continent. For example, 45% of the Kenyan revenue is generated from Agriculture. In Africa, agricultural activities are primarily dependents on rain which is an insufficient source and thus the need for irrigation. In order to enhance water utilization efficiency and increase crops productivity, a new system called **Dynamic Soil Moisture Control System (DSMCS)** for irrigation using Global System for Mobile Communication (GSM) technology is introduced. The proposed system uses PIC16F877 microcontroller, dc motor, soil moisture and water level sensor to monitor any changes in the soil moisture content in the farm and water level in the irrigation tank. The GSM modem is configured using Attention (AT) commands to enable a real-time monitoring of the farm remotely. All the status of the farm are dynamically monitored using DSMCS and send to the farmer through short messages (SMS), which resolves the distance and range problem. From the results obtained, the proposed system ensures adequate irrigation to plants based on soil moisture content and thus minimized water wastage.

Keywords— DC motor, GSM modem, Microcontroller, Soil moisture sensor, SMS messages water level sensor.

I. INTRODUCTION

THE significant increasing demand for food has necessitated the rapid improvement in food production technology. The major source of income for most African countries is agriculture,[1], [2]. However, majority of these countries depend on rain for agricultural activities. This high dependency on rain reduces agricultural productivity in the continent. Only few farmers in the continent practice irrigation as an alternative way of supplying water to the crops. Most of these farmers use manual and traditional irrigation methods to provide water to their crops on regular basis. These include drip irrigation, ditch irrigation, sprinkler system etc. However, the manual and traditional irrigation techniques cannot ensure a stable supply of water to the crops, they consume time and are ineffective. Due to the lack of water management in the manual irrigation techniques, sometime the field become dry and sometime flooded with excess water. This might lead to the significant waste of water which is in the red alarm in countries like Kenya, Nigeria etc. Other resources such as man power, energy and time are also wasted in the process. Thus, the automated irrigation technique needs to be designed to bring an advanced of technology into the area of agriculture which plays a significant role in the economic development of the African continent. This technique used soil moisture sensor to detect the moisture content of the soil and sends signal to the microcontroller and accordingly irrigates crops. This paper presents a dynamic soil moisture control system (DSMCS) for irrigation using Global System for Mobile Communication (GSM). The main objective is to provide adequate water to crops and at the same time minimize the water wastage by monitoring soil moisture changes. Soil moisture sensor measures changes in the moisture level of the soil and sends signal to the microcontroller and accordingly communicates to the user through GSM network. Water level sensor is added to this project to monitor the amount of water in the irrigation tank and sends the information to the user.

The rest of the paper is organized as follows. Related works are summarized in section II. The working principle of the proposed system is described in section III, which includes the system block diagram, block diagram description, and components used. In section IV the system design is discussed. Experimental results are presented in section V. Finally, conclusion and recommendation are given in section VI.

II. RELATED WORKS

Over the years, several semi-automated and automated irrigation control systems have been proposed to address water wastage and increase crops productivity. The most widely used irrigation control systems use timers, controllers and switches to irrigate crops for a specific interval of time regardless of soil moisture content. ZigBee, Bluetooth and Wi-Fi are employed in this class of irrigation control systems. These systems have advantages over the manual irrigation techniques. The major drawbacks of these systems are limited range and lack of consideration for the soil moisture content of the farmland. However, soil moisture content has crucial impact on crops growth, reproduction and photosynthesis. Thus, getting information about soil moisture content accurately, effectively and timely plays an important role in guiding water saving irrigation [3]. The breakthrough of GSM technology and soil moisture sensors increased research interest in the area of remote control systems. With the use of GSM technology, the

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user and control system can communicate by sending and receiving Short Message Service (SMS) messages. Based on this technology many automated systems have been proposed, such as a remote monitoring through mobile phone using spoken commands [4], SMS controlled irrigation system with moisture sensor [5], internet based wireless home automation system for malfunctioning devices [6], a remotely controlled home automation system [7], etc.

Although, several irrigation control systems have been developed in the past years, most of them are semi-automated and do not use soil moisture sensor. Few automated irrigation systems that used moisture sensor can be found in [8], [9], [10], [11], and [12]. In general, GSM based automated irrigation control system has three important parts. The soil moisture sensor, which senses any change in the moisture level of the farm and sends the information to the control unit. The second part is the control unit. The microcontroller is the most widely used device for this purpose. It is the brain of the system, programmed to receive information from the sensing unit and communicates with the user. The microcontroller sends commands to different components of the system, handles real time data and takes timely decisions. The third part is the GSM modem, which is interfaced with the microcontroller using set of Attention (AT) commands. This device receives information from the microcontroller and sends it to the user's mobile phone through wireless communication.

To increase productivity and minimize water wastage numerous improved automated irrigation control systems have been presented recently. In [13], [14], and [15], a low cost automatic irrigation control system is introduced based on microcontroller and GSM technology. In [16], an automatic irrigation control system for smart city using Programmable Logic Controller (PLC) and Supervisory Control and Data Acquisition System (SCADA) is proposed. The system employed SCADA and fuzzy system to reduce the level of water wastage in irrigation. Namala et.al [17], presented a smart irrigation with embedded system. The system is based on the concept of Raspberry and soil moisture sensor. A solar powered automatic irrigation system on sensing moisture content using Arduino and GSM modem is introduced in [18], this system used solar energy, soil moisture sensor, GSM, and Arduino to supply adequate water to plants. In [19], Banumathi et.al presented an android based automatic irrigation system using Bayesian network with SMS voice alert. The system used Wireless Sensor Network (WSN), Arduino, and General Packet Radio Service (GPRS) module to provide water to the farms based on water level conditions. In [20], [21], an automatic irrigation systems based on Internet of Things (IoT) are proposed to minimize water wastage and human intervention in the irrigation process. Lastly, Kumar et.al [22] developed an automatic solar powered drip irrigation system using Wireless Sensor Network Technology (WSNT) by integrating Solar Photovoltaic System (SPV), Arduino microcontroller, soil moisture sensor, mobile Bluetooth, water tank, pump etc. The intension is to ensure uniform watering at right time without manual intervention and thus enhance quality and quantity of agricultural yields.

III. PROPOSED SYSTEM

Fig.1 shows the overall block diagram of Dynamic soil moisture control system for irrigation. The block diagram consists of three important parts: GSM modem, Microcontroller, and soil moisture sensor.

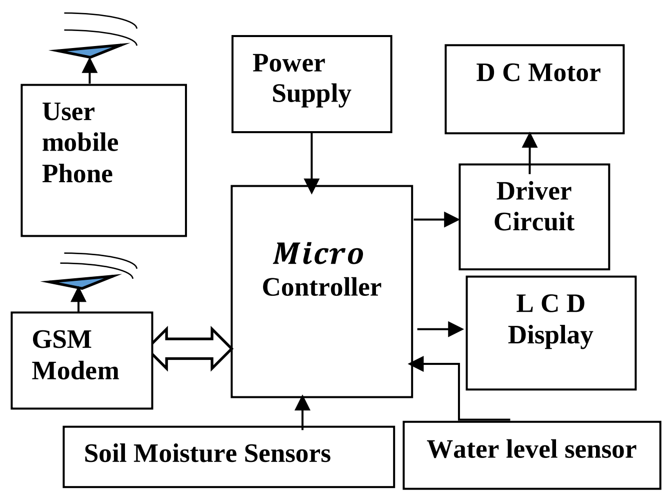

Fig.1: System block diagram

A. *Block diagram description*

The Dynamic soil moisture control system for irrigation block diagram comprises of microcontroller circuit, which acts as the central processing unit of the system. It is also interfaced with GSM modem, Liquid Crystal Display (LCD), moisture sensor and motor driver. Microcontroller is programmed with an embedded C- code to send commands to different components of the system and receives input data from soil moisture sensor and GSM modem. Through LCD a user can know the status of the field such as soil moisture content in the farmland, motor speed, and the amount of water in the tank. The GSM modem is used to describe protocols for digital cellular networks and interfaced with microcontroller to receive and send messages which indirectly control the entire system. GSM modem is controlled by a set of AT commands. Soil moisture sensor is as associated with the farm field to detect the moisture content of the soil. The data received from the sensor is sent to the microcontroller, which sends SMS messages to the user according to the received data. Water level sensor is added to this project to indicate the amount of water in the irrigation tank. The entire system is driven by 240V AC power supply.

B. *Materials*

The main materials needed for this study are described as follows:

1.1 Microcontroller

A microcontroller is a high integrated functional computer system-on-a-chip. It contains an integrated memory and programmable input/output peripherals. Microcontrollers often operate at a very low speed and consume relatively little power. Microcontroller is now available in different families such as Intel, Motorola, Peripheral Interface Controller (PIC), Atmel, and so on. The choice depends on the application and the company preferred. For this project PIC16F877 has been selected, because of its additional features such Universal Synchronous/Asynchronous Receiver/Transmitter (USART), Analogue to Digital (A/D) converters, Pulse with Modulation (PWM) module which are very vital for this project. The PIC16F877 is a high performance modified Harvard Reduced instruction set computer (RIC) chip manufactured by microchip technology. It has 40 pins, 8k flash of program Read Only Memory (ROM), 368 byte of Random Access memory (RAM) and 256 byte of nonvolatile EEPROM memory, 33 I/O pins, 8 multiplexed A/D converters with 10 bits of resolution, PWM generator, three inbuilt timers, UART internal interrupt facilities and so on. The ROM or code ROM is used for storing program and the RAM is used for storing data. Figure 3.6 shows the pin configuration of PIC16F877 microcontroller [23].

1.2 Soil moisture sensor

A soil moisture sensor is a two terminal Integrated Circuit(IC) which uses a simple principle of conduction between to wires in a medium. This IC consists of two wires one with the 5V supply and the other one was the ground. When there is water in the field, a medium being established between the wires and conduction will take place between the wires. The voltage at the microcontroller will go low indicating the wet condition of the field. In the wet condition the motor will be in off state. If there is no water in the field, there is no conduction between the wires and the voltage at the microcontroller will go high indicating the dry condition of the field and the motor will be in ON position

1.3 GSM modem

GSM modem is used in this project to provide a two way communication between the user and the irrigation system through SMS messages. It is interfaced through the serial port of the PIC16F877 microcontroller. A set of AT commands are sent to GSM modem through its serial port, which is triggered by the microcontroller during the instances at which the interaction between the system and user are required. For this project a GSM SIM900 is used because of its special features which are very important for this study. GSM modem SIM900 is a quad-band GSM/GPRS modem engine, works on the frequencies of 850MHz, 900MHz, 1800MHz and 1900MHz and is small in size. This modem has an inbuilt RS232 level converter circuitry which allows interfacing it to the PC serial port directly. The baud rate ranges from 9600-115200 which is configurable using AT commands. It has an internal Transfer Control Protocol/Internet Protocol (TCP/IP) which makes it easy to connect with internet via GPRS. SIM900 is suitable for sending and reading SMS messages, calling as well as transfer of data application in Machine to Machine (M2M) interface. In addition, it needs only three wires that are Transmitter, Receiver and Ground (TR, RX, and GND) to interface with microcontroller and host Personal Computer (PC) [24].

1.4 DC motor

The main criteria to be considered when selecting a motor are the torque and speed of the motor. Many different motors such as servomotors, stepper motor, dc motors with and without gears are available in the market. These different motors are used according to their applications and requirements. For example, if we want high torque and precise speed we need to use servo motors, if we want to only position and if high torques not required then stepper motors are used. The motor can be selected once we know the torque and speed required for our application. A 12V DC motor is used for this project. The speed of this motor is counted in terms of rotations of the shaft per minute which is represented as RPM. The speed of this motor can easily be controlled by PWM (pulse with modulation) technique. By increasing and decreasing the duty cycle, its speed can be reduced to any desirable figure. This concept where the speed of the motor is controlled by monitoring the driven voltage ON and OFF time is called PWM technique of DC motor speed control [25]. A DC motor uses a permanent magnet to generate the magnetic field in which the armature rotates. Therefore, it can easily be modelled by using electrical circuit.

IV. SYSTEM DESIGN

The system design is divided into software and hardware design.

A. *Software Design*

The software used for writing the embedded C-program for implementing this project is MikroC Pro for PIC. This software makes the programming easier and the program can easily be run, built, compiled and debugged. To avoid errors when debugging the codes, the family of the needed devices is selected before writing the codes. Here PIC16F family is selected, one attribute about this software is that it support any category of PIC and for this project PIC16F877 is specifically selected.

The flowchart of the proposed system is depicted in Fig.2. The first step is to initialize the ports for LCD and motor as the outputs of the system, the PWM pin of the motor should also be initialized. The A/D converter port is declared for interfacing the moisture sensor and the serial port of the microcontroller is interfaced with GSM modem. When the system is in ON position, the soil moisture sensor will detect the soil moisture content and send the information to the microcontroller. The level of the moisture content will be displayed on LCD while at the same time sending a message to the farmer mobile phone about the status of the field (soil moisture is high or medium or low). Based on the received data, the farmer can send message to rotate the motor at the required speed. For example, the farmer can send message to rotate the motor at full speed if the field is dry, medium speed if the field has little moisture and to stop the rotation of the motor when the moisture is high. Since the process is continuous, after displaying the first outputs the microcontroller will continuously check the soil moisture content and send SMS message to the user to rotate the motor according to the received data. Anytime the soil moisture content changes, the system will communicate to the farmer instantly.

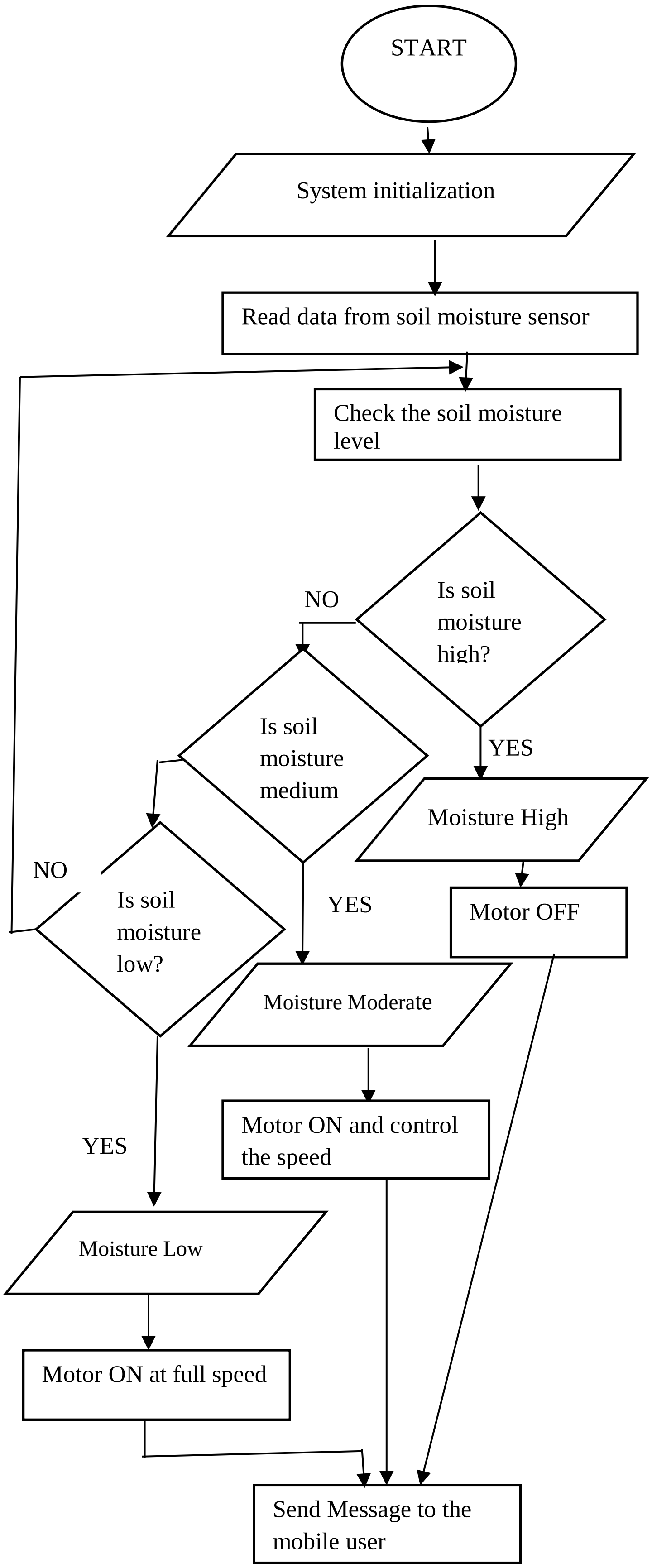

Fig.2: Flowchart of the proposed system

B. Hardware Design

The hardware implementation process involves schematic circuit design, breadboard testing, Printed Circuit Board (PCB) layout design, etching and finally system prototype testing.

1.1 Simulations diagram

The overall simulation diagram of Dynamic soil moisture control system for irrigation using GSM is shown in Fig.3.

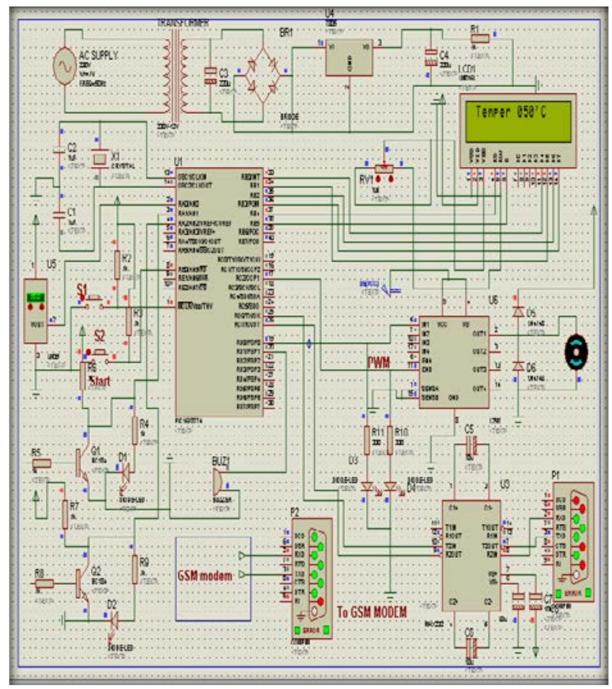

Fig.3: Overall system simulation diagram

1.2 AT commands testing

Before the breadboard testing, it is important to test the GSM modem to see if it can send and receive SMS message. In this project the test is carried out by connecting the GSM modem with computer via RS232 cable and hyper terminal software is used for verifying its functionality as shown in the Fig.4.

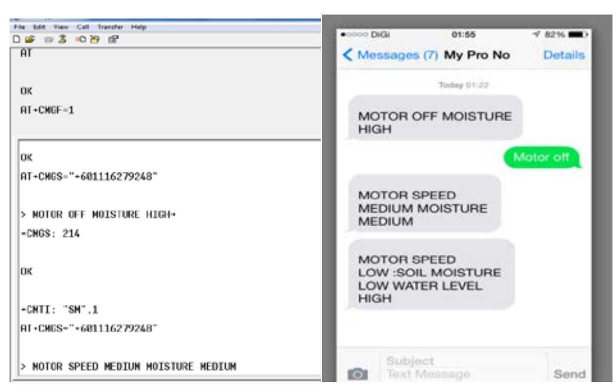

Fig.4: AT commands testing

1.2 Breadboard testing

It is important before the PCB design, to build the circuit on the breadboard to test how the circuit behaves prior to the implementation. Fig.5 shows the breadboard connection of the system.

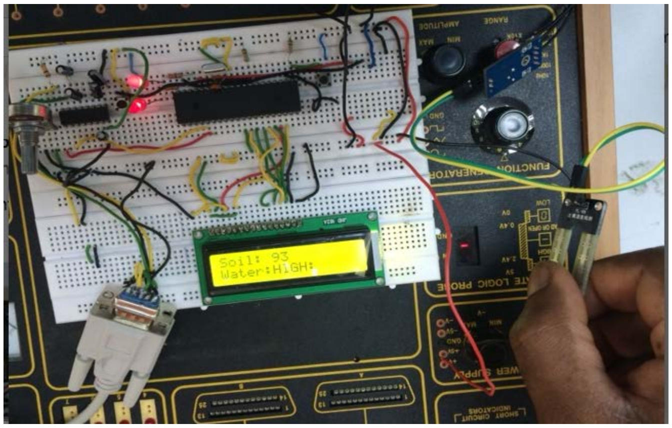

Fig.5: Breadboard connection of the system

V. EXPERIMENTAL RESULTS AND DISCUSSION

Experiment is conducted to determine the relationship between the analogue voltage, duty cycle and speed of the DC motor. The data is collected at various speed levels and corresponding voltage readings were measured using multimeter. The hardware performance is tested at various soil moisture levels. The motor speed is also recorded at high speed, medium speed and low speed.

A. Microcontroller input and output voltage

Fig.6 and Fig.7 show the voltage regulator input and output voltage measured using multimeter.

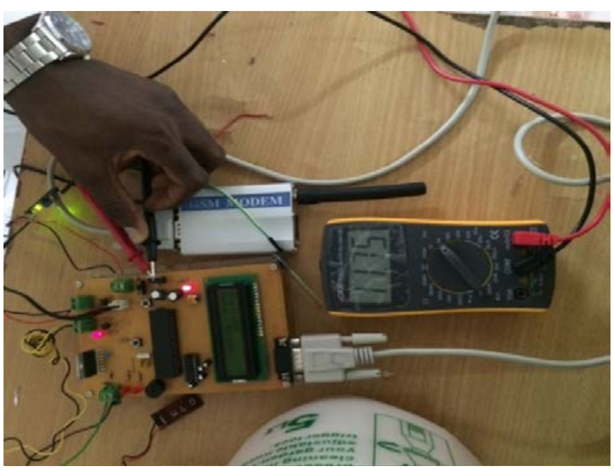

Fig.6: Voltage regulator input

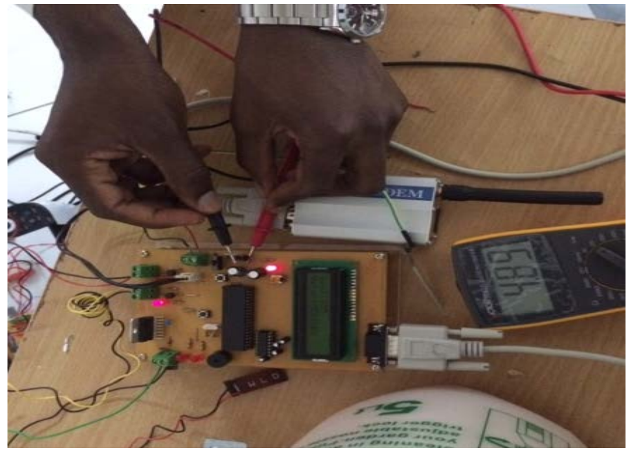

Fig.7: Voltage regulator output

Table 1: Voltage regulator LM7805 input and output

SNO	Parameter	Voltage (V)	Current (A)
1	Input	11.75	1.95
2	Output	4.89	0.3

As shown in table 1, the input current from the supply voltage is 1.95A and the corresponding output current is recorded to be 300mA. This means that the voltage regulator ensures 5V constant voltage is supplied to the microcontroller irrespective of the supply voltage fluctuation. The output current from the microcontroller is not enough to derive the dc motor. Thus, a motor driver is required to boost the current to the motor requirement.

B. DC motor driver input and output voltage

Since, the microcontroller output voltage cannot drive the dc motor due to the high current drawn by the motor when starting H-bridge driver is used. This will receive the microcontroller output as input and amplify the output current up to 2.2A which is enough to drive the motor as shown in the table 2.

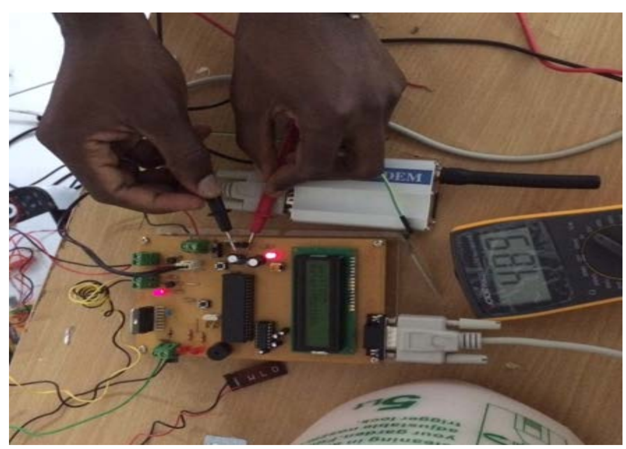

Fig.8: Motor driver input voltage

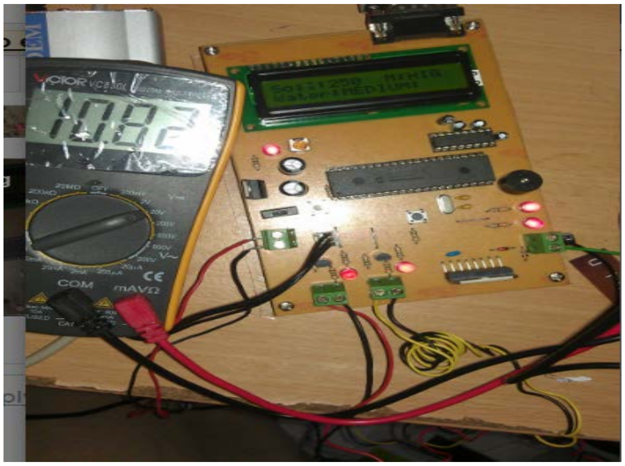

Fig.9: Motor driver output voltage

Table 2: DC motor driver input and output

S/NO	Parameters	Voltage (V)	Current (A)
1	Input	4.89	0.3
2	Output	10.82	1.53

As shown in table 2, whenever the output from the microcontroller is 0V the transistor inside the motor driver circuit will act as an open switch. The purpose is to set the driver output voltage to 10.82V. Similarly, if the output from the microcontroller is 4.89V the transistor acts as a closed switch hence 0V will appear across the driver circuit. This concept makes the motor driver to have enough current to drive the motor

C. Moisture level measurement with respect to voltage

The speed of the dc motor is measured using tachometer and the corresponding voltage at low, medium and high moisture level is recorded using voltmeter. The result is tabulated in the table 3.

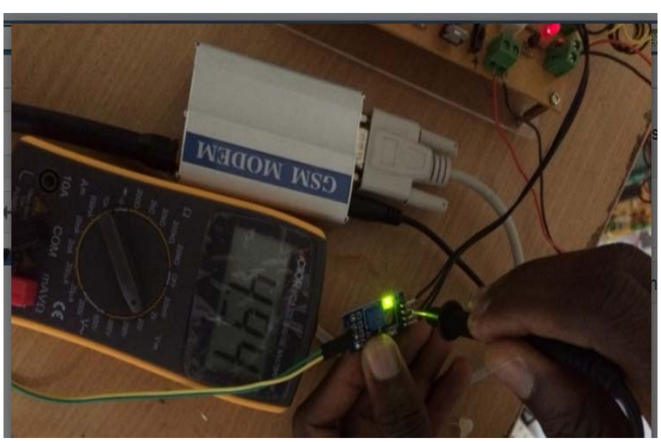

Fig.10: Voltage when soil moisture is high

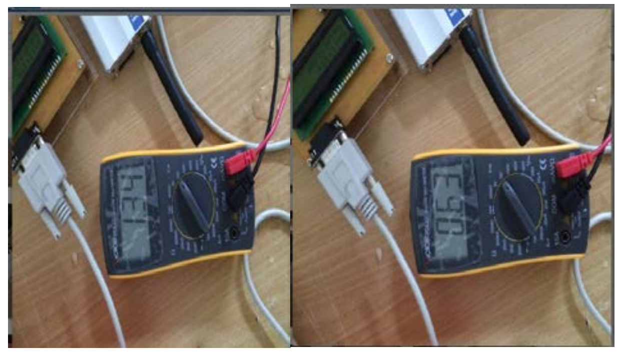

Fig.11: Voltage when soil moisture is medium and Low

Table 3: soil moisture level with voltage

S/NO	Parameters	Voltage (V)	Count Value	Status
1	High moisture	0-0.63	0-99	Moisture level high
2	Medium moisture	1.34-0.6	100-199	Moisture level Medium
3	Dried condition	4.94	200-255	Moisture level Low

A shown in Fig.10 and Fig.11, the soil moisture sensor shows a count value of 200-255 when the voltage is 4.94V, 100-199 for 1.34V and when the voltage is 0-0.63 the count value is between 0 -99 as recorded in table 3.

As shown in table 1 to table 3, the moisture level increases with decrease in voltage.

C. System prototype operation

The system prototype is depicted in Fig.13

Fig.12: System prototype

Fig.13 to Fig.15 shows the operation of the system under various conditions, Fig.13 shows the speed of the motor when the moisture is low. Fig.14 shows the motor speed when the soil moisture is medium while Fig.15 shows the speed when the moisture is high and the motor running at high speed.

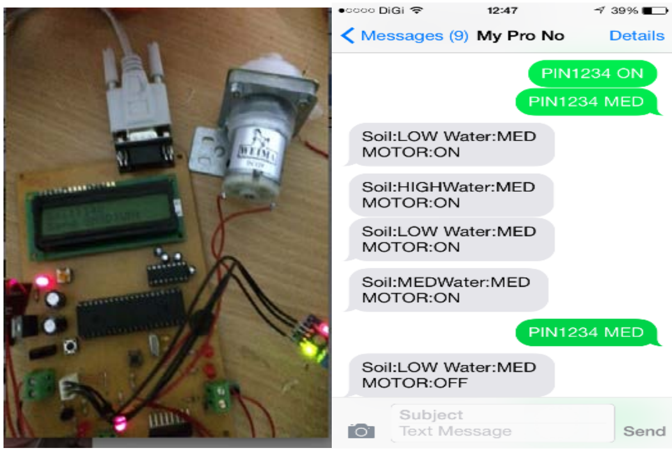

Fig.13: Moisture low motor running at High speed

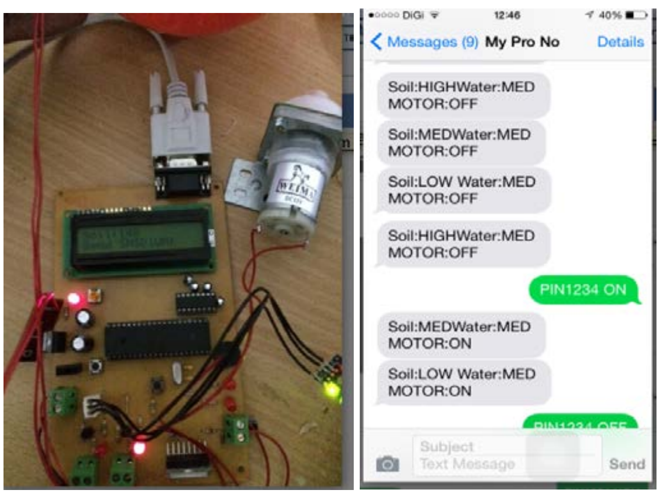

Fig.14: Moisture medium motor running at medium speed

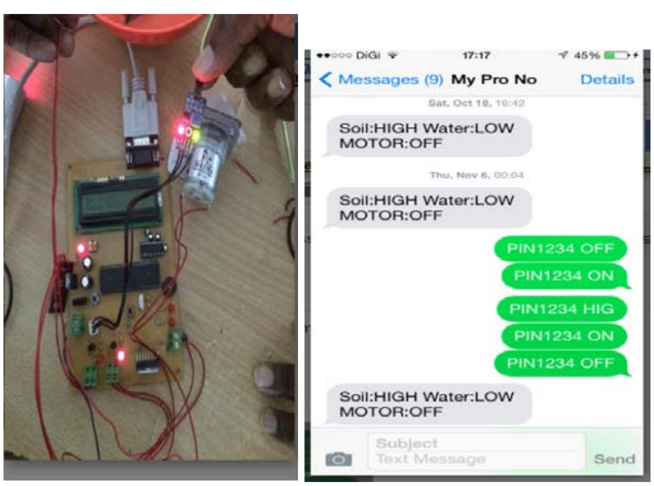

Fig.15: Moisture high motor running at low speed

VI. Conclusion

A Dynamic soil moisture control system for irrigation using GSM was successfully designed and implemented in this paper. The system notifies the user any changes in soil moisture content in the farmland and water level in the irrigation tank through SMS messages. The proposed DSMCS also provides feature to the farmer to select the speed at which the system should operate such as high, medium or low speed depends on the condition of the farm. Thus, the DSMCS proved that, the irrigation system can be controlled remotely and operated from far places. In addition, the developed system ensures effective irrigation to plants and thus minimized water wastage which is on red alarm in the African continent.

For future enhancement of this work, the system could be designed to use solar energy as its power supply which is one of the non-conventional energy sources, especially for some areas where the supply of electricity is not constant. Furthermore, instead of supplying water manually to the irrigation tank, the system can be modified in such a way that the irrigation water can be driven from the rain water harvesting (RWH) tanks installed on the farms. Moreover, the system can be enhanced so that the user can send an SMS message to the system to refill the irrigation tank when it is low. By rotating the motor to suck the water from the ground, this will save time and energy. The Dynamic soil moisture control system for irrigation using GSM could further be improved, so that if the water level reaches to the danger level, the motor will automatically start to ensure proper water in the farm field. The system could also be improved to use voice message so that even disabled community people especially those who lost their eyesight can operate the system.

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