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DEVELOPMENT OF A GSM-BASED IRRIGATION CONTROL SYSTEM

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Abstract: This work presents a Global System for Mobile Communication (GSM) based irrigation control system which will be used to monitor soil conditions and control water usage in the farm. The proposed system will acquire soil moisture, temperature, humidity and pH from the farm and accordingly sends a Short Message Service (SMS) to the farmer through the GSM Module requesting for an action. If the response from the farmer is not forth coming due to network failure or other unforeseen circumstances after a given period of time, the system automatically turns ON/OFF the control pump depending on the situation of the farm. These sensors are embedded to a reliable microcontroller (ATmega 328 p) device which performs data acquisition and processing operations of the control system. Power supply plays an important role in this developed system, hence for this system; a robust solar power system (solar panel, charge controller and battery) is built to power the irrigation control system. Also as a constituent of functionality, a data logger was incorporated into the control system to store soil conditions of the farm. Several tests were carried out on the developed prototype; Moisture content of the soil, temperature, humidity and pH. The results from the tests conducted show that the system was able to effectively monitor soil conditions, control the pump (water usage) and also give the relationship between the moisture content of the soil, humidity, pH and temperature. The higher the temperature, the lower the moisture content and humidity of the soil and also, the lower the temperature the higher the soil moisture. The result obtained indicates that the soil moisture is at optimum with sensed values between 54% - 64% with temperature range of 26°C – 35°C. pH of the soil is at optimum level through the cause of this study with level ranging between 6.5 – 6.85 pH level signifying that the soil is moderately acidic and fertile.
Keywords: GSM module, SMS, Microcontroller, sensors, data logger, solar power, control pump.

1. INTRODUCTION

Traditional irrigation control systems are physically operated using artificial methods of opening and closing of irrigation ridges (Pavitra and Srinath, 2014). Irrigation system must be manageable in the sense that environmental conditions including soil type and temperature vary naturally from one place to another depending on the climatic condition of that environment (Anik *et al.,* Sengupta, 2014). These systems are graduallly modernized by semi-automated and automated systems by using advanced controllers and communication protocols to communicate with the farmer for efficient and effective control of the farm mechanism. Increase in population growth, urbanization and variations in nutritional demands of the inhabitants have led to high consumption of Agricultural produce (Uduma *et al.,* 2015). The use of sensor based irrigation system to monitor soil moisture, temperature , humidity and pH level of the soil, sends these signal to microcontroller for processsing and accordingly communicates (send real time data and also gives returning on time information of the soil condition) to the farmer through GSM communication protocol. This helps the farmer to monitor the soil condition of the farm. Data logging system is embedded to the system to store and retrieve information from the memory of the system accordingly whenever it is required. This work can be implemented for versed agricultural purposes.

Water is a scarce resource and significant amount of it is needed in agriculture through irrigation system. Regardless of challenges of water shortage, over-irrigation is a problem attributed to insufficient irrigation planning which is caused by lack of experience from the farmers and also flooding. Under irrigation is also attributed to deficiency of water to the irrigated area which is caused by improper scheduling of irrigation process.Excess amount of water in the farm due to over irrigation leads to leaching of soil nutrients which affects agricultural productivity and increase cost of production. Prior to the varying atmospheric conditions which vary from place to place inlargefarm lands, it becomes very difficult to uniformly and manually irrigate a largefarm landat the same time.

1.1 State of the Arts

Several scholars have studied the design and implementation of GSM based irrigation control systems. For example, the work of Subalakshmi *et al.* (2015) proposed a GSM based automated irrigation using soil moisture sensor, humidity and temperature sensors as the sensing unit. Their work is aimed at creating an avenue for easy and fast communication to the farmer for proper monitoring of the soil conditions from far locations. The system uses a PIC 16 microcontroller to automatically irrigate the farm and also send the sensed processed data to the farmer through the GSM module. In this system, the irrigation process depends on the preset values of the sensors. If the sensed data exceeds the set values, the microcontroller automatically activates the pump using the relay to effectively send water to the farm and also notify the farmer after irrigation. Limited sensors were discussed ignoring other methods for implementing intelligent sensors. Nilesh and Pagare (2015) proposed a GSM based advanced water deployment system for irrigation using a wireless sensor network and android mobile to automatically irrigate the farm. The system is aimed at deploying water to the farm using remote monitoring technology through GSM module to communicate the status of soil moisture, temperature, humidity at root zone to the farmer. Similarly, (Priyadharsini *et al.,* 2016) developed a GSM based irrigation system using mobile phone to remotely monitor and control pump through SMS. The system gives the farmer a simple interface to communicate with the control system through the farmers destination phone address. Embedded on the irrigation system is software support for TCP/IP, personal computer and modem for internet connection. However, the price of such system varies greatly depending on speed and bandwidth requirements. (Matenge, 2017) focused on soil moisture based irrigation test in a remotely monitored automated system which is aimed at monitoring the soil moisture content of the farm for proper scheduling of irrigation and also to avoid water wastage. The system is designed to measure plant growth using dielectric probe and tensiometers. Water wastages, nutrients deficit, leaching of nutrients which is caused by excess water in the farm are among the problems the system tends to overcome. Furthermore, (Ghute *et al.,* 2017) work focuses on a smart irrigation system using GSM module to overcome the challenges of water wastage by using smart irrigation technology. Readings of soil moisture and temperature were carried out and sent to the farmer for necessary action. The proposed system is designed in two modes, automatic and manual mode. In the manual mode, SMS is sent to the user notifying the user of the status of the farm and seek proper action to be taking. While in the automatic mode, the microcontroller automatically controls the pump and fan depending on the status of the sensing unit and also update the user on the status of the farm for proper planning. Their challenge here is that the system suffers from epileptic power from the battery system. Also, the work of (Manoj *et al.,* 2017) proposed a smart irrigation technology using Arduino which is usable to farmers and low cost for rural farmers. The work is designed to take data from the farm using soil moisture as their sensing unit and also to control the motor automatically without the farmer's intervention. Processing of data and subsequent communication to the farmeris done through the GSM/GPRS module and the actual irrigation system is based on Arduino controller. This system is focused only on one parameter. However, other relevant parameters like humidity and pH was not discussed. In addition, (Srishti, 2017) proposed an automated irrigation system the system use soil moisture sensors to monitor soil condition and control the desired water content of the soil through automation. Soil moisture information is updated to farmer's webpage using internet of things and microcontroller ATMEGA on Arduino uno controller. GSM and GPRS module is used to update farmer on the status of pump (on or off) and soil condition anytime the farmer request for update. Utilization of cost effective soil moisture and water level sensors to monitor soil condition and GSM module to communicate to the farmer helps the farmer to avoid water wastage during the irrigation process. (Deepak and Murtaza, 2014). From the literature reviewed, it can be interpreted that GSM based irrigation system plays an important role in Agriculture. However, in the reviewed work also, the sensing parameters were limited to specific types of sensors. Interfacing of the devices for specific amount of sensors have been discussed, but to serve as a constituent of functionality, an integrated system needs to be used for effective monitoring and controlling of wide section of farm parameters. GSM based irrigation system control will improve plant growth, increase production, regulate the amount of water required by the plant and control water wastage. It will automatically process and monitor the soil condition, temperature, humidity and pH as well as communicate action and events to the user for effective control of the farm.

MATERIALS AND METHOD

The GSM based irrigation control system monitors and control soil conditions in the farm. Figure 1 below shows the configuration of the entire system architecture of the GSM based irrigation control system. The control system encompasses four different sensor (soil moisture sensor, temperature sensor, pH sensor and humidity sensor) which is interfaced to the microcontroller to take data from the farm, ATmega 328 p microcontroller, GSM module which allows transfer of soil moisture, humidity, temperature and pH data from the sensors to the phone through the public mobile network, Liquid crystal display (LCD), DC motor and power supply unit (solar panel and battery). For optimum irrigation scheduling, the control system continuously sense parameters of the soil and act by watering the farm if it goes below the optimum level or shut down water supply if it reaches optimum level. Figure 3 below present the circuit diagram of the developed irrigation control system. The circuit diagram is designed using Proteus circuit simulation software and also the arrangement of the circuit and pin configuration is clearly shown in the figure 3 below. Sensors are connected to the ADC pins to enable data conversion from analog to digital data. Figure 2. below shows the flowchart of the designed methodology.

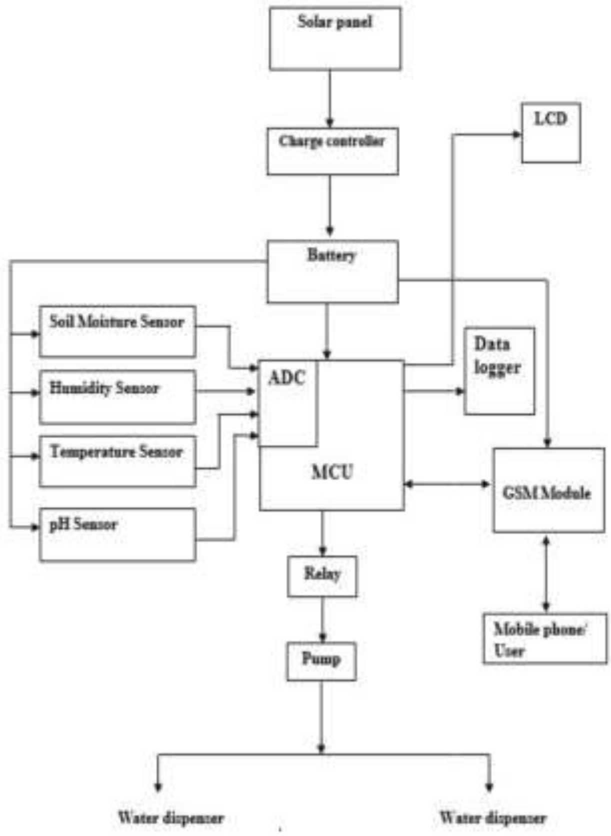

Figure 1: Block diagram of the GSM based irrigation control system

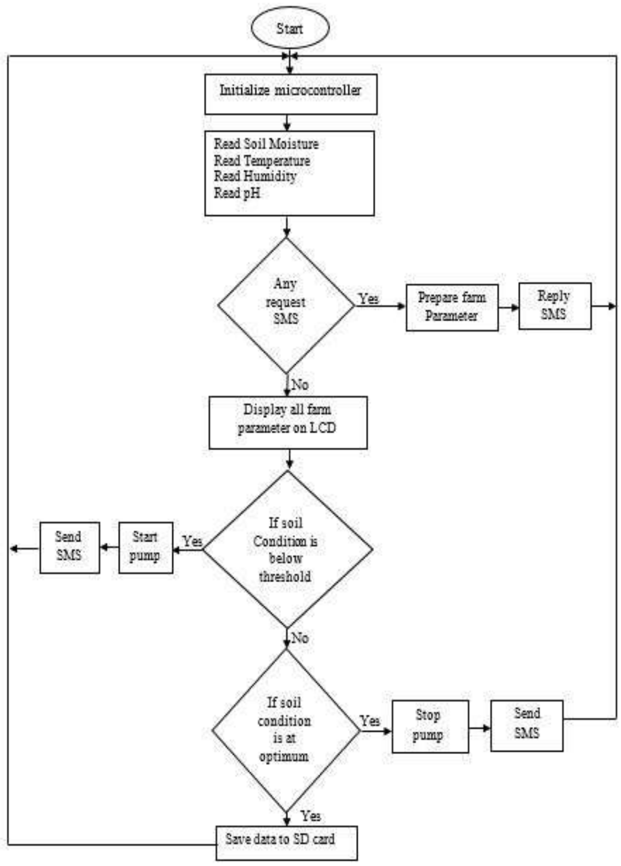

Figure 2: Flowchart of the control system

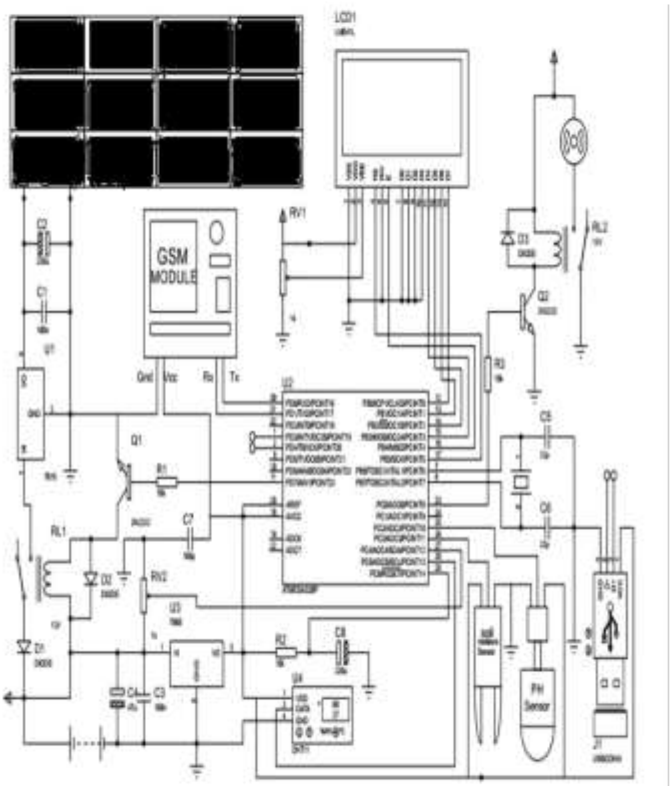

Figure 3: Circuit diagram of the GSM based irrigation control system

2.1 Soil Moisture sensor

Soil moisture sensor measures the volumetric water content of the soil and it is inserted close to the root of the plant based on its quality. Output analogue signal from the soil moisture sensor is fed to the microcontroller input and then the microcontroller converts this analogue signal to digital signal using the analogue to digital converter (ADC). Figure 4 below shows the control flow of the sensor which uses the microcontroller to monitor the soil moisture preset values. The control threshold for the soil moisture for this study is between 45% – 65%. Soil moisture above the threshold will lead to water wastages, over irrigation and leaching of nutrients. Also moisture level below the set threshold leads to under irrigation and decrease in crop yields.

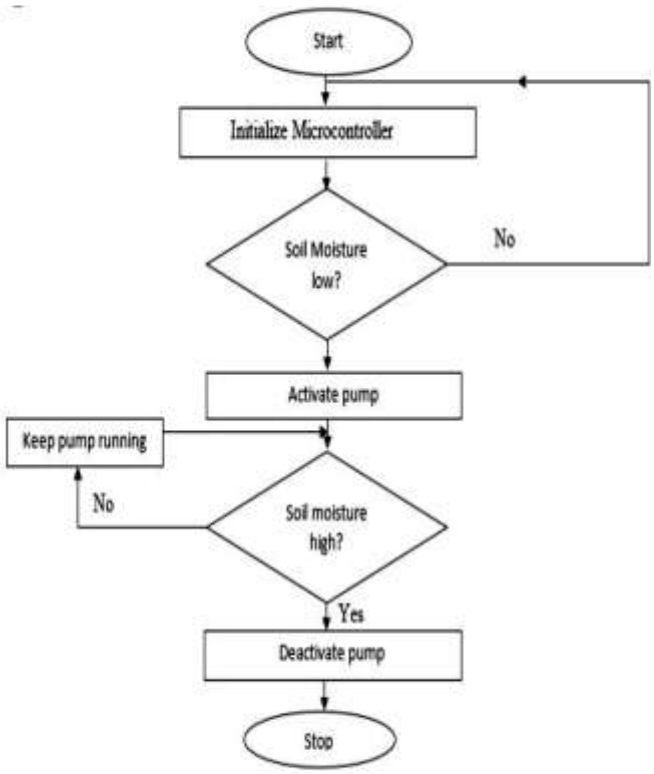

Figure 4: Flowchart of the soil moisture sensing

2.2 Temperature and Humidity sensor

DHT11 is a low cost digital device which measures the temperature and humidity of the soil. The availability of air is measured using capacitive humidity and thermistor which is converted to digital signal. Dht11 has four pins VCC connected to the power supply, data pin for data transfer, ground and an extra pin not connected to the module. A resistor is incorporated to the device between the VCC and Data pin to strengthen the pull up signal on the data line. Figure 5 below present a flowchart for dht11 sensor used by the microcontroller to effectively take readings from the farm. Microcontroller is embedded to with the dht 11 to monitor the temperature and humidity of the soil, turn On/Off the control pump depending on the situation and accordingly notify the farmer through the GSM module. The control threshold of the temperature and humidity sensor is as follows: Temperature is optimum between 25˚C – 37˚C and Humidity is optimum between 50% – 85%

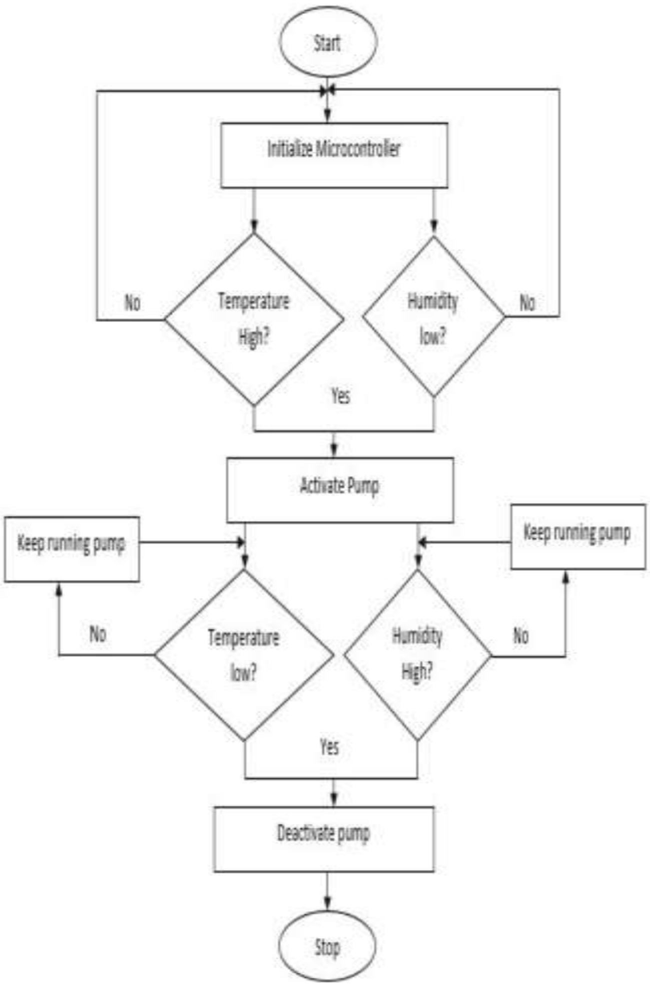

Figure 5: Flowchart of temperature and humidity sensing

2.3 pH sensor

pH plays a vital role in agriculture and is one of the variable considered in soil. It is the measure of the acidity and alkalinity of the soil (plant nutrients) and also influence the chemical formation of the nutrients. Figure 7 below shows the flowchart of the pH sensor incorporated to the control system and also use the microcontroller to send message to the farmer when pH becomes more alkaline or acidic and also suggest suitable solution. Optimum level of the pH is between 6.5 – 7.5 pH levels below or above the preset threshold will lead to stress and nutrient defect, cupping of leaves and stunted growth which affects crop yield. The pH sensor is interfaced with the microcontroller to monitor the acidic or alkaline nature of the soil and also sends notification to the farmer if it exceeds the pH range in the soil.

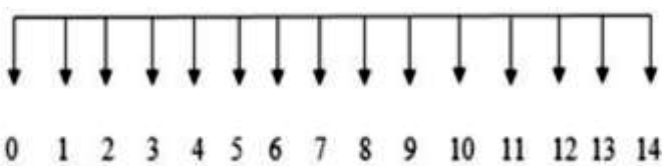

Figure 6: pH range (Marianne *et all*, 2016)

The pH neutral at is at 7 of the pH scale.

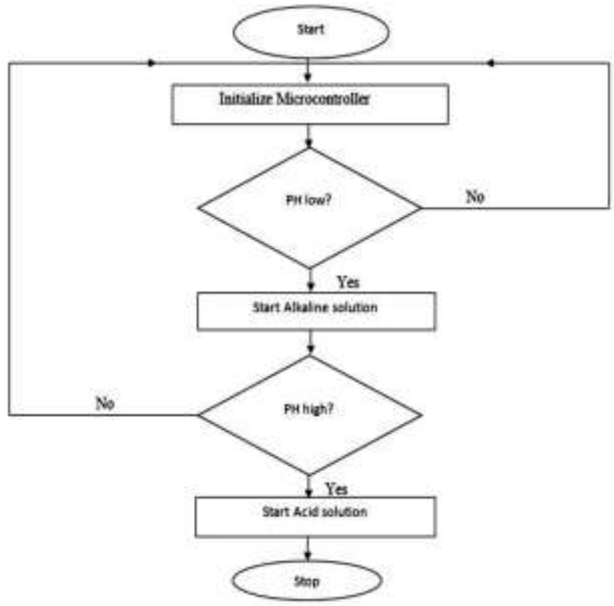

Figure 7: Flowchart of the pH sensing

2.4 GSM module SIM900

The GSM module SIM 900 is a quad-band device designed with a slot unit which accepts Subscribers Identity Module (SIM) and also, it is based on commands that starts with an Attention (AT) and ends with a character (CR). Communication with the user (mobile phone) and microcontroller is carried out through the UART port and can be interfaced directly to the microcontroller (ATmega3280) through three lines; transmitter (TX), receiver (RX) and Ground (GND).

2.5 Microcontroller (Atmega 328 p)

The Atmega 328 p is one of the innovative 8-bit micrcontrollers built by Atmel, it uses a single clock cycle to execute powerful instructions and also it has a low power CMOS. It part of the ATmega family of microcontrollers and based on the AVR enhanced RISC architecture. It has 23 general purpose lines, 131 Powerful Instructions and a single clock cycle for executing instructions, 32 x 8 General Purpose Working Registers, Fully Static Operation and 20 MIPS throughput at 20MHz and On-chip 2-cycle Multiplier. The microcontroller is used to monitor the sensors, controls what is displayed on the LCD, communicate to the user through the GSM module and turn On/Off the pump.

2.6 Software

Proteus is a simulating software used for designing and simulating electrical circuits. It is famous for its graphic user interface (GUI) and easy to use. Proteus combines ARES PCB layout programs to run integrated and easy to use suite of tools and the ISIS 8 SP2 with advanced simulation schematic capture. It is a convenient software use to test embedded designs and programs. Also C-language program was used to program the threshold of the sensors on the microcontroller using ATMEL Studio Integrated Development Environment.

2.7 Power Supply

Power supply used in this work comprises of the solar panel which converts the solar radiation of the sun into DC output, a voltage regulator to maintain the output power at constant level, a diode to protect the solar panel from EMF and a battery for energy storage.

2.8 LCD

A 16*4 LCD was used for this work to be able to effectively display the four digital parameters measured from the sensors. It consumes small amount of power and it is more useful for battery based work. Polarization of light is the main phenomenon used. LCD is interfaced to the microcontroller to output the proceeds information of the sensors. It has 4 data bus, 2 control bus, Vcc, Ground and the contrast. A variable resistor is incorporated to the system to adjust the contrast of the LCD.

2.9 DC Pump

The 12 v dc pump is device used to convey water to the farm when the soil needs water and also it is an electro mechanical device which require an electromechanical switch (relay) to turn it On/Off. The 5 v output voltage from the microcontroller cannot turn a 12 v motor, in this case an electromechanical switch(a relay which is frequently open to give room for microcontroller to turn On/Off the pump) and electronic switch(transistor) is used together to activate or deactivate the pump when necessary.

2.10 System Data Logger

System data logging is the ability of an automated computer program to perform or record possible events which is monitored by the controlled embedded system in order to provide an assessment trail that can be utilized to recognize events of the system and to assess the problems. Logs are necessary in the case of systems that require little or no human interference to operate. The data logging system is incorporated into the control unit to store data from the sensors and also for retrieval when required. Microcontroller communicate actions to the data logger through a serial communication and a removable memory card is used to store data for easy retrieval.

3.0 RESULTS AND DISCUSSION

The control system is programmed to send sensed data from the sensor at an interval, data log the data received from the microcontroller and accordingly notify the farmer through the GSM module. Control pump is activated or deactivated if the soil condition is below and above the preset threshold on the microcontroller. Figures 8 and 9 below shows the construction stage of the control system and the final stage of the designed prototype tested in the farm. Figures 10-13 below present the sensed values of the sensors for the period of four days. From the calibrated data collected, soil moisture was kept between the ranges of 50% - 65% to maintain irrigation threshold for proper supply of water to the farm. Results obtained from the soil moisture sensor varies between the range of 54% - 64% thereby maintaining optimum water content availability to the plant and by doing this, it reduces over irrigation or under irrigation. Plants can only absorb pH (soil nutrients between 6.5-7.5 pH levels). The pH values obtained from the sensor ranges between 6.5 -7.0, signifying that the soil nutrient is at optimum level and need no application of acidic or alkaline solution to the soil. When pH level goes below or above the 6.5-7.5, it affects plant growth and reduce crop yield. The result obtained from the sensor temperature and humidity ranges between from 26˚C – 35˚C and relative humidity between 50% - 65%. From the result obtained, it shows that soil moisture is proportional to relative humidity and inversely proportional to the temperature i.e. the higher the temperature, the lower the soil moisture and relative humidity. Also, pH of the soil for the days under review is at optimum level since plants can only absorb nutrients between 6.5 and 7.5 range on a pH meter.

Figure 8: Control system during construction

Figure 9: Developed Prototype

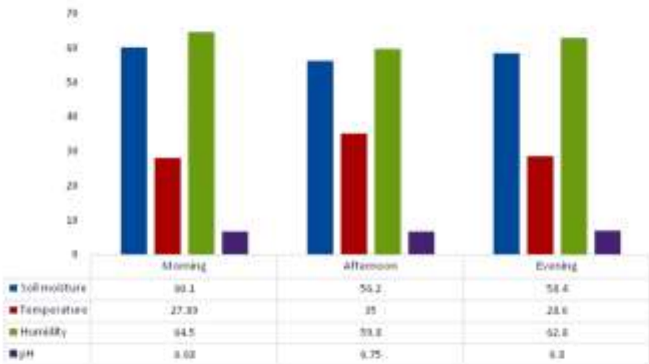

Figure 10: Result of day 1 data

Figure 11: Result of day 2 data

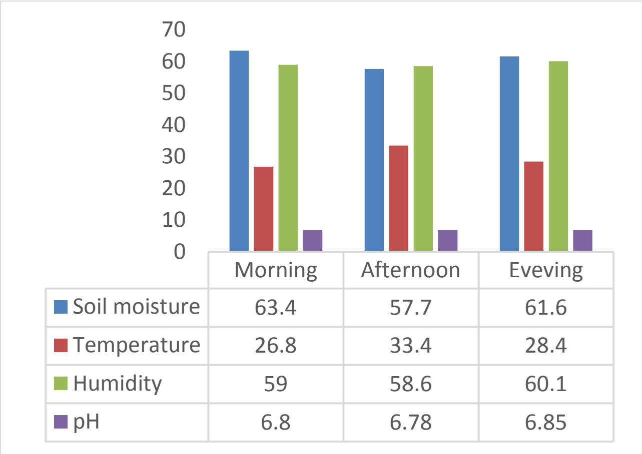

Figure 12: Result of day 3 data

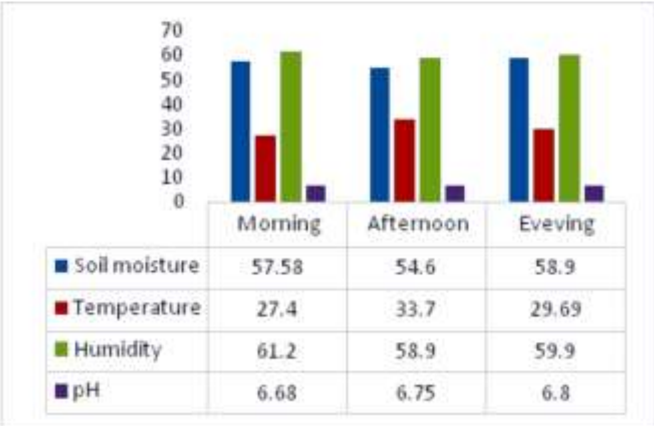

Figure 13: Result of day 4 data

CONCLUSION

A GSM based irrigation control system was achieved and fulfills the set objectives The system incorporates a soil moisture sensor, temperature sensor, humidity sensor, pH sensor, LCD, ATmega 328p microcontroller, SD card module, GSM module, pump and solar power system. C-language was used to write, develop and debug codes for ATmega328p using ATMEL Studio Integrated Development Environment (IDE) interface. The system is developed to read moisture content, temperature, humidity and pH levels of the soil and based on the code stored in the ATmega328p microcontroller's program memory, the control system communicates to the mobile phone through the GSM module. Processed data of the status of soil conditions from the sensor is displayed on the LCD. Data logging system is embedded in the control system to record and retrieve data. The result obtained indicates that the soil moisture is at optimum with sensed values between 54% - 64% with temperature range of 26°C – 35°C. pH of the soil is at optimum level through the cause of this study with level ranging between 6.5 – 6.85 pH level signifying that the soil is moderately acidic and fertile.

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