

IoT-Based Watering Irrigation System Using Simulation Modelling

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Abstract

Managing water supply has become a pivotal task for farmers practising irrigation farming and for water utilities worldwide, especially as they try to run viable enterprises while coping with climate change, which increases the likelihood of drought in many regions. Manual irrigation wastes both water and labour because farmers must visit their fields regularly to decide when and how much to water. This study designs and simulates a low-cost, reliable and efficient Internet of Things (IoT)-based watering irrigation system that automates irrigation by monitoring the moisture content of the soil and the water level of the supply tank. The system was modelled with an Arduino Uno microcontroller, a soil moisture sensor module, an ultrasonic sensor module, a 20x4 liquid crystal display (LCD), 5 V relays driven by NPN transistors (2N2222) and a Global System for Mobile Communications (GSM) modem (SIM900D), using the Proteus Design Suite and the Arduino Integrated Development Environment (IDE). The watering pump is switched on when soil moisture falls below 85% and off when it exceeds this value, while the tank pump is controlled from the ultrasonic distance reading using a 65 cm threshold. The status of each pump is displayed on the LCD and sent to the person in charge by Short Message Service (SMS). Simulation results showed that the system responded correctly to changes in soil moisture and tank level and generated the corresponding SMS alerts, indicating that it can meet the water requirements of the field while reducing labour and water wastage.

Keywords: Internet of Things, Smart irrigation, Proteus Design Suite, Arduino Uno, Soil moisture sensor, GSM modem (SIM900D)

1. Introduction

The Internet of Things (IoT) is a system of interrelated computing devices, mechanical and digital machines, objects, animals or people that are provided with unique identifiers (UIDs) and the ability to transfer data over a network without requiring human-to-human or human-to-computer interaction (Rouse, 2019). Water is a vital and scarce resource in agriculture, and its optimal management is emerging as a key challenge. Watering is the most important cultural practice and one of the most labour-intensive tasks in daily greenhouse operation. Watering systems ease the burden of getting water to plants when they need it, and knowing when and how much to water are the two most important aspects of the watering process. Automatic plant watering systems were developed to make this work easier for the gardener. In developing nations, the economy depends heavily on agriculture, yet the available resources are not properly utilised for cultivation. This is mainly because of the unplanned use of water for irrigation. Although modern irrigation techniques such as drip and sprinkler irrigation exist, farmers still have to visit their farms regularly to water their crops; that is, irrigation remains manually controlled. These problems result in the wastage of human and agricultural resources as well as time. Hence, there is a need for an automatic irrigation

system, and the literature reports different techniques for implementing such systems (Ingale and Kasat, 2012). The aim of this study is to design and simulate a low-cost, reliable and efficient IoT-based watering irrigation system. The specific objectives are to: (i) design the architecture and control logic of a system that monitors soil moisture and tank water level; (ii) model and simulate the system using the Proteus Design Suite and the Arduino IDE; and (iii) notify the person in charge of the pump status in real time by SMS through a GSM modem.

2. Related Works

Sustaining agricultural productivity, guaranteeing food security and enhancing economic growth in the face of climate variability, a diminishing labour force and changing soil conditions require innovation in agriculture. Several techniques for automatic irrigation have therefore been reported in the literature. Suresh et al. (2014) proposed an agricultural environment monitoring system for collecting information about the field using wireless sensor network (WSN) technology. The system gathers environmental and soil information through WSN-based environmental and soil sensors, using moisture and temperature sensors that help to control the water level and temperature of the field, with GSM (Global System for Mobile Communications) as the communication medium. Siddagangaiah (2016) developed a plant monitoring system that monitors only the moisture, light and temperature of the plant. A moisture sensor measures the moisture of the soil, a temperature sensor measures the temperature of the plant and its immediate surroundings, and a light sensor captures light data. Nevon Projects (2015) presented a plant moisture monitoring system that continuously checks the moisture level of the soil. When the moisture level falls below the prescribed value, the system raises an audio-visual alarm: a light-emitting diode (LED) provides the visual alert and a buzzer provides the audible alert to the caretaker of the plant. With a simple combinational circuit and a sensor, the system helps to keep the plant healthy by maintaining the moisture level of its soil. When the caretaker waters the plant, the alarm stops and the monitoring cycle continues. Hashim et al. (2016) presented a smart agriculture monitoring system using an electronic device and an Android phone. The system helps farm owners to monitor and manage their plants in order to maximise yield and quality at different cultivation sites. Moisture and temperature readings from the sensors are stored in the cloud and presented through a mobile application that displays data for the selected zone and gives the user the option to water the plants. However, because the user must operate the application, it is less suitable for farmers who are not literate. Maheshwari and Sindha (2014) noted that advances in programmable logic controllers (PLCs), together with their reasonable cost, have made it possible to use them as stand-alone irrigation controllers. Their work aimed at autonomous irrigation systems that use a single climate measure and adjust the irrigation schedule to the observed conditions, leading to considerable savings in the amount of irrigation water. Such systems must also be dependable and easily deployable so that they can work under harsh outdoor conditions without supervision or regular checking. Since water availability is becoming one of the most valuable resources in agriculture, industry, the energy sector and public use, irrigation scheduling based on the soil-water-plant relationship can be used to determine the timing and quantity of water required by crops. Because less labour is available for such low-paid work, and because time and energy are wasted, automation of irrigation systems is required. Their paper therefore developed a cost-effective irrigation controller that adapts to daily weather conditions without the need for expensive sensors

or costly weather stations. An IoT-based smart irrigation system has also been proposed in which the automation of farming activities transforms agriculture from a manual and static practice into an intelligent and dynamic one, leading to higher production with less human supervision. The system monitors and maintains the required soil moisture content through automatic watering. An ATmega328P microcontroller on an Arduino Uno platform implements the control unit, and soil moisture sensors measure the exact moisture level in the soil. This value enables the system to apply an appropriate amount of water and avoid over-irrigation or under-irrigation.

3. Methodology

3.1 System Description

The water content is controlled using a soil moisture sensor, an ultrasonic sensor that measures the water level of the tank, a liquid crystal display (LCD) and a relay module. The soil moisture sensor works on the principle of resistance. When the resistance at the test pin is at its maximum, the sensor is either in dry soil or out of the soil, giving a moisture value of zero. When the resistance is zero, the circuit shows the maximum voltage across the voltmeter, indicating that the sensor is in wet soil with a high water content. In this system, the relay is automatically turned on when the soil is dry and automatically turned off when the soil water content is high. Ultrasonic distance measurement is based on the echo principle. When sound waves are transmitted into the environment, they return to the source as an echo after striking an obstacle, so the travel time to the target and back can be measured and converted into distance. In this system, this principle is used to switch the tank pump on automatically when the water level in the tank becomes low.

3.2 System Design

System design is the process of defining the architecture, components, modules, interfaces and data of a system to satisfy specified requirements; it can be seen as the application of systems theory to product development. In this stage, the specifications are translated into a design of the intended system, and the modules are defined together with their relationships to one another. The purpose of the design phase is to specify a system that meets the requirements gathered during the analysis phase.

3.3 Architectural Design

The architectural design describes the structure and behaviour of the system and the relationships among its components, as shown in Figure 1.

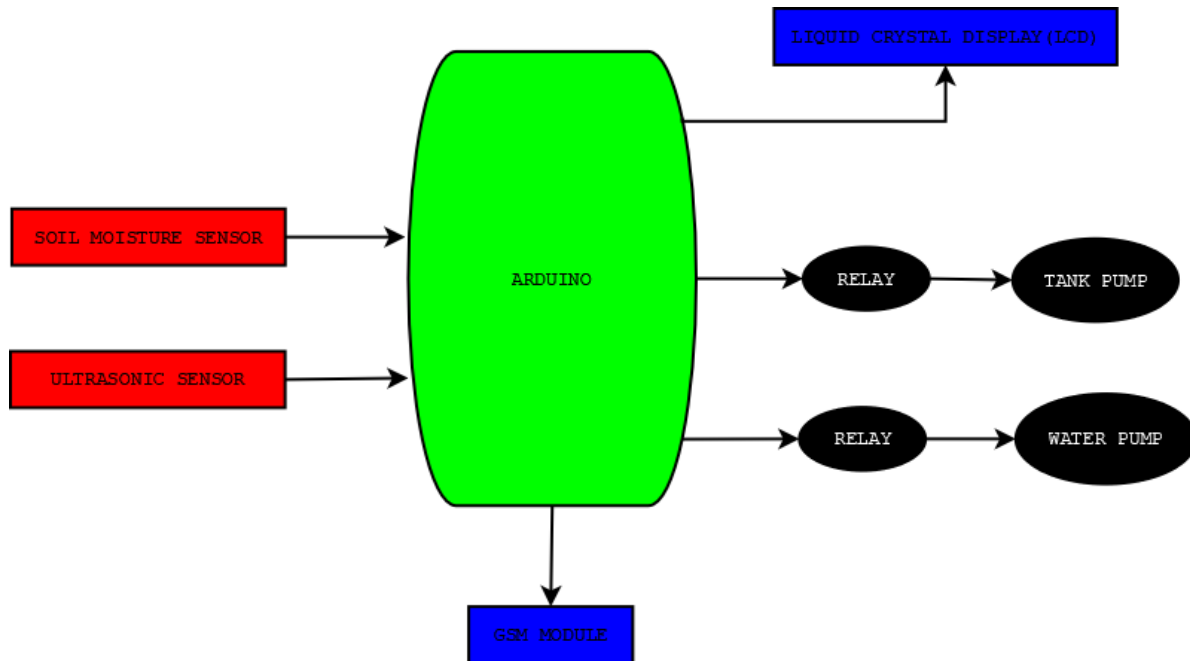


Figure 1: Block (Architectural) Diagram of the Watering Irrigation System

3.4 Logical Design

The logical design is an abstract representation of the data flows, inputs and outputs of the system. It is usually produced by modelling the actual system in an abstract, often graphical, form. The logical design of the watering irrigation system is presented as a flowchart in Figure 2.

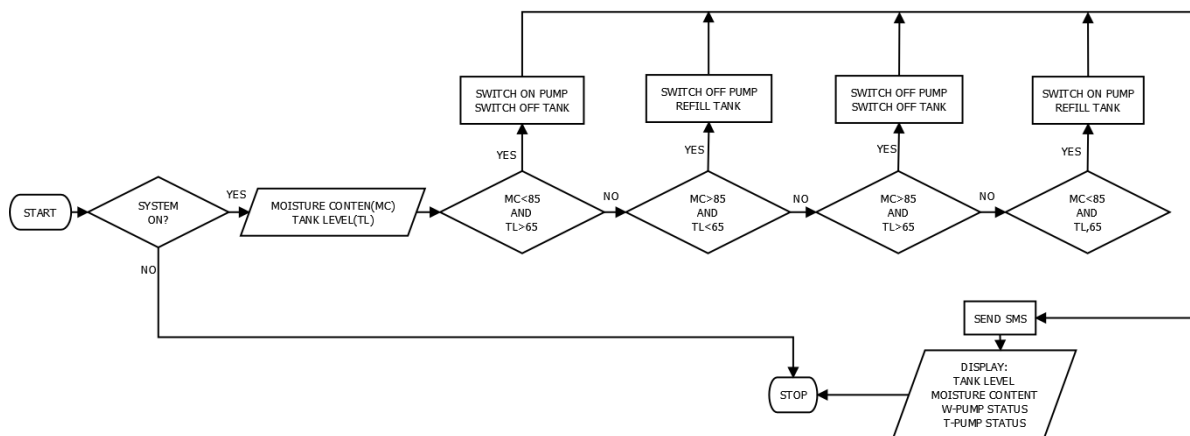


Figure 2: Flowchart of the Watering Irrigation System

3.5 Hardware Specifications

The hardware provides the platform that supports the software required to produce the working system. The hardware components used are:

- i. Arduino Uno
- ii. Soil moisture sensor

- iii. 20x4 LCD
- iv. NPN transistor (2N2222)
- v. GSM modem (SIM900D)
- vi. 5 V relay
- vii. Water pump

3.6 Software Specifications

System implementation involves coding, that is, using a formal programming language to convert the design from a paper prototype into a working prototype. The software used is:

- i. Proteus Design Suite
- ii. Arduino Integrated Development Environment (IDE)

4. Results and Discussion

Different tests were conducted to investigate, troubleshoot and test the sensors and modules. All devices were then connected to obtain the complete simulation circuit shown in Figure 3.

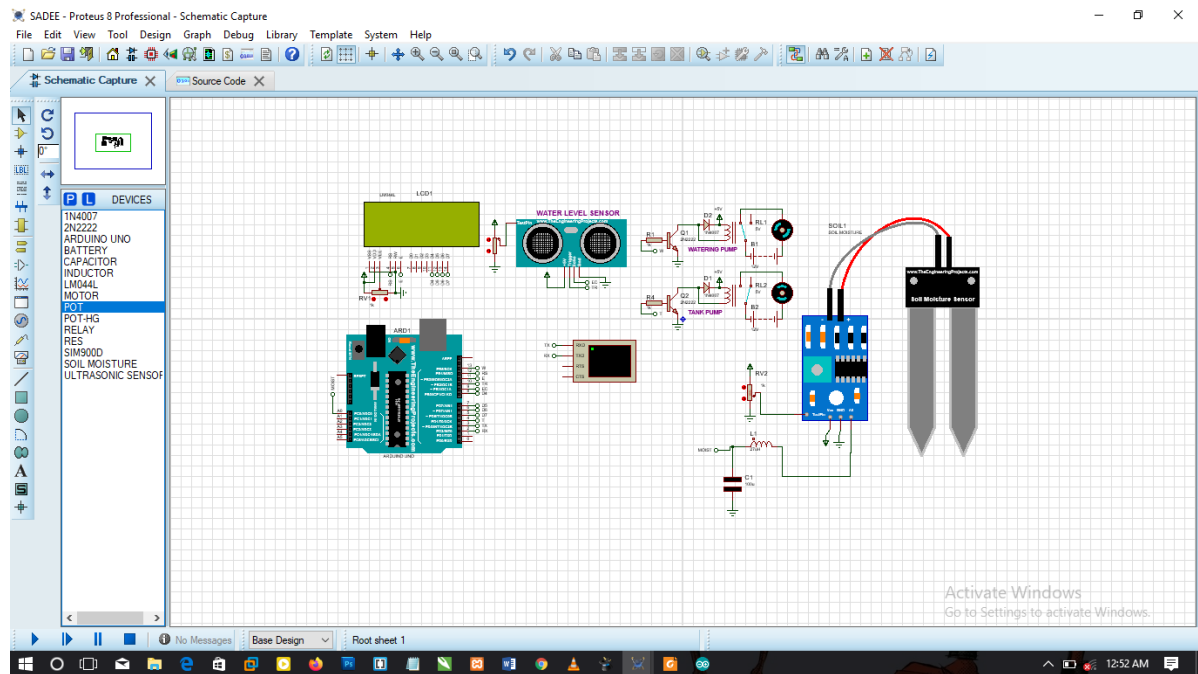


Figure 3: Connection of All Devices in the Watering Irrigation Circuit

The soil moisture sensor library was added to Proteus, and the sensor's hex file (SoilMoistureSensorTEP.HEX) was loaded into the soil moisture sensor model. The analog output pin of the sensor was connected to pin A0 of the microcontroller, with a DC voltmeter, a generic capacitor and an inductor (INDC3225X135) to ground on that line. The test pin was connected to a 1 k Ω variable resistor between GND and 5 V to vary the simulated soil moisture, while VCC was connected to +5 V and GND to ground.

The GSM modem (SIM900D) in Figure 3 was driven through the software serial statement `SoftwareSerial SIM900(2, 3);` in the Arduino code. Two relays were included and controlled by logic: when +5 V is applied, the relay is energised, and when GND is applied, it is de-energised. An NPN transistor was placed before each relay to amplify the current. When the logic state is 0 (ground), the transistor does not conduct and the supply cannot reach the relay; when logic 1 (+5 V) is applied to the base of the transistor, the relay circuit is completed and the relay is energised. In the circuit, the ultrasonic sensor measures the distance to the water surface, that is, the empty space above the water rather than the water level itself, and the level is shown on the LCD. Because of this, the system can be used with any water tank; the water level is obtained by subtracting the measured distance from the tank depth. When the distance is less than 65 cm, the Arduino switches on the tank pump by driving its relay, the LCD shows “T-PUMP STATUS ON” and the person in charge of the tank receives the SMS “TANK PUMP IS ON”. When the distance is greater than 65 cm, the Arduino switches off the relay, the LCD shows “T-PUMP STATUS OFF” and the SMS “TANK PUMP IS OFF” is sent to the farmer. Similarly, the soil moisture sensor measures the water content of the soil as a percentage. If the moisture content is less than 85%, the watering pump is switched on, the LCD shows “W-PUMP STATUS ON” and the person in charge receives the SMS “WATERING PUMP IS ON”. If the moisture content is greater than 85%, the watering pump is switched off, the LCD shows “W-PUMP STATUS OFF” and the SMS “WATERING PUMP IS OFF” is sent. The compiled program was loaded into the microcontroller in Proteus, and the simulation was run to obtain the outputs shown in Figures 4 and 5.

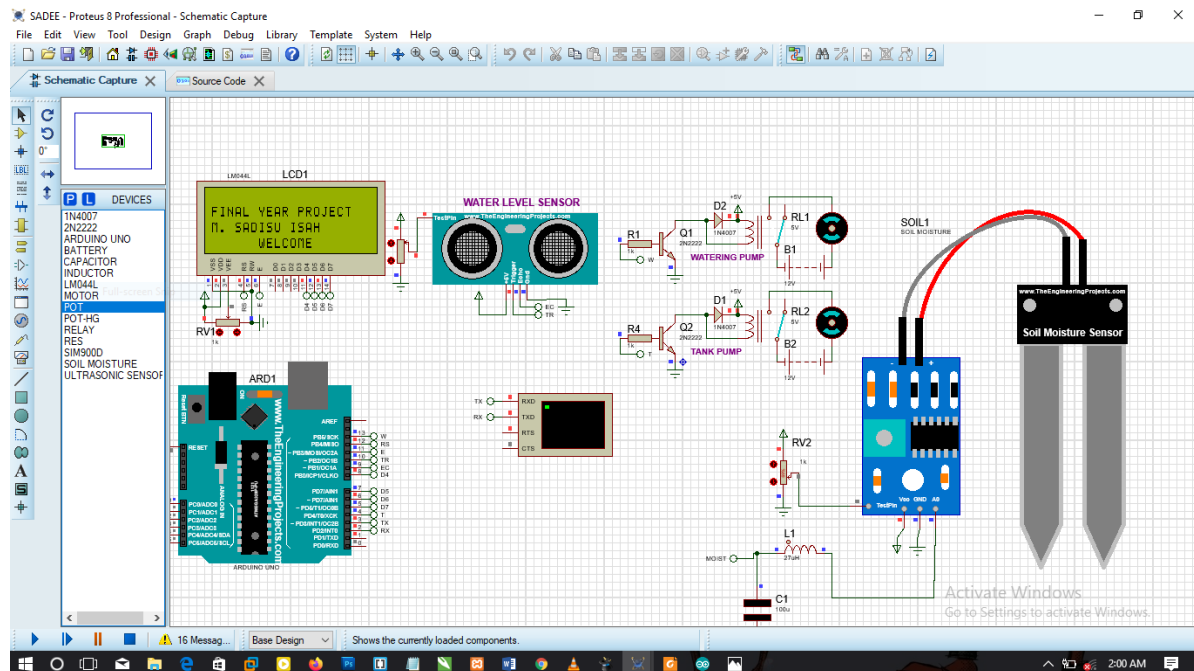


Figure 4: Running the Watering Irrigation System (State 1)

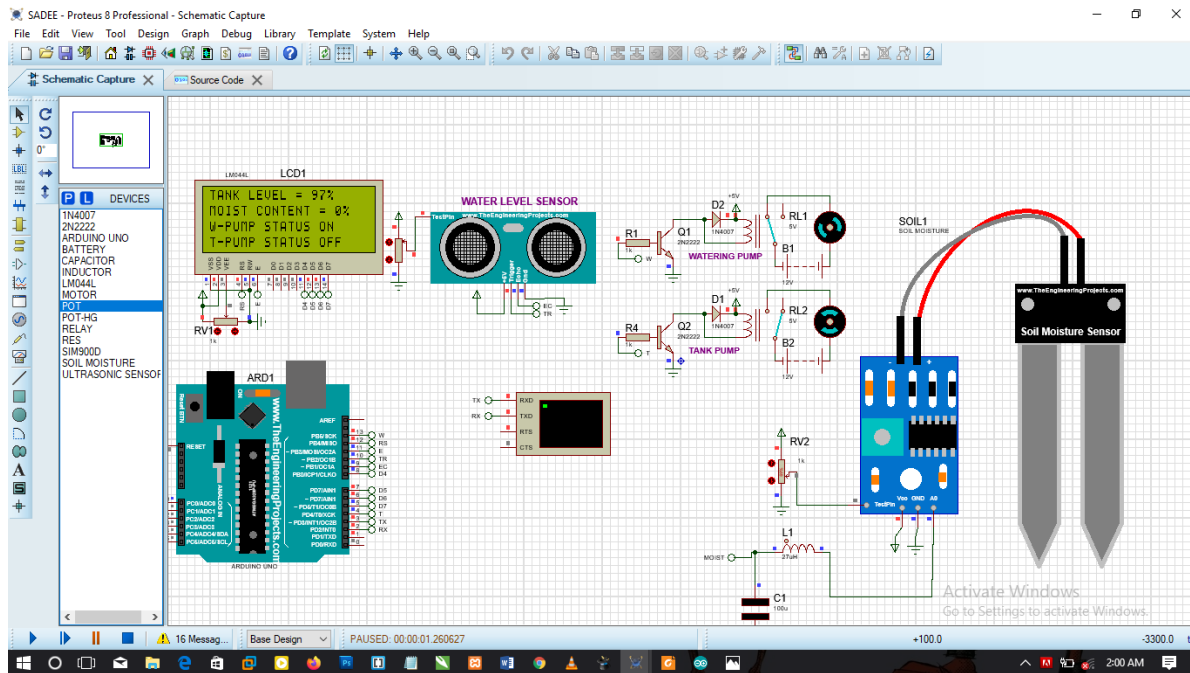


Figure 5: Running the Watering Irrigation System (State 2)

To display the SMS sent to the person in charge during simulation, a virtual terminal was used with AT commands, as shown in Figure 6.

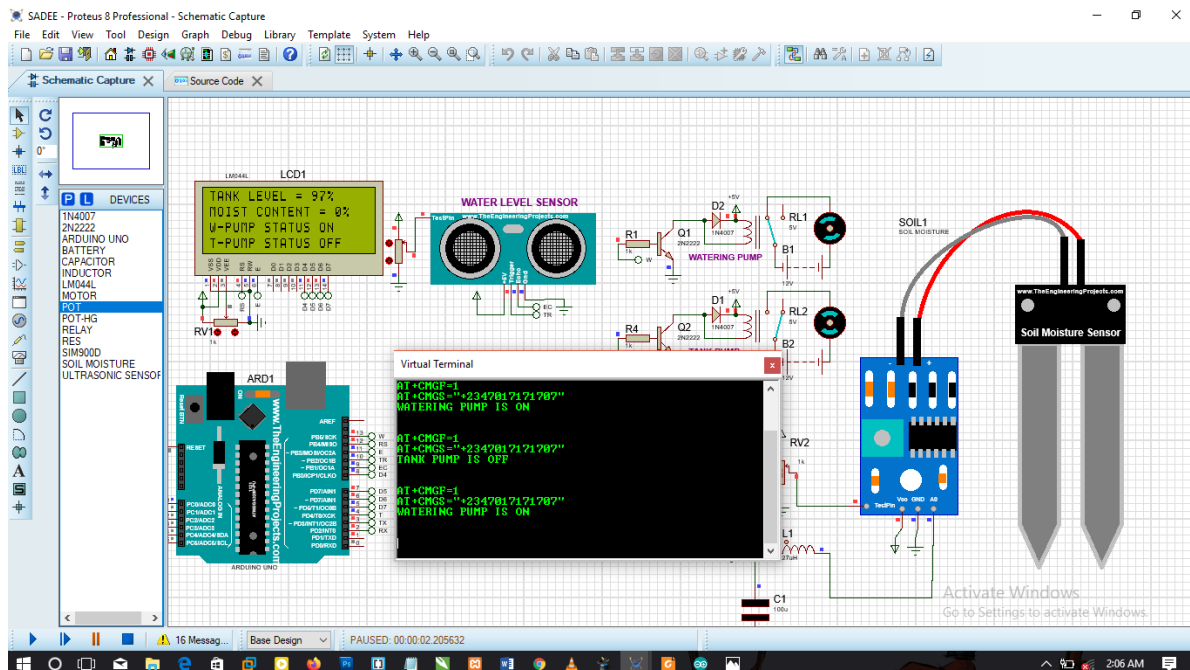


Figure 6: Simulation of Real-Time SMS Notification Using AT Commands

The simulation shows that both pumps respond to their sensor thresholds and that each change of state is reported on the LCD and by SMS. Compared with the alarm-based system of Nevon

Projects (2015), which only alerts a caretaker, and the application-based system of Hashim et al. (2016), which requires the user to trigger watering, the proposed system switches the pumps automatically and uses SMS, which works on basic mobile phones.

5. Conclusion

Advances in sensor network technology allow new hardware and software to be integrated, offering significant prospects for improving the irrigation sector. The watering irrigation system developed in this study uses a combination of soil moisture and ultrasonic sensors with relays to meet the watering requirements of the field. Irrigation is an important component of the economy of any developing nation, and for a long time irrigation has been carried out manually. The manual method has many drawbacks, is unreliable for irrigating large areas and directly affects the cost and quality of the final product. The proposed system aims to replace the conventional manual method of irrigation. Although the task of simulating the watering irrigation system appeared straightforward at the outset, interfacing the sensors with the controller proved demanding. All the stated objectives were achieved, and the simulation results indicate that the system can be applied in a real-time farming environment. The system is simple to install and makes decisions autonomously about the time, quantity and place of irrigation, which reduces the labour and time required to operate and manage irrigation and reduces water wastage. The concept can be scaled for use in agriculture, schools, hospitals and similar settings. Further improvements will require additional time, funding and effort, particularly to upgrade components for a physical deployment. It is recommended that future work implement the design as a hardware prototype and extend it with emerging IoT technologies for smart communities.

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