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Report for B.Sc. Degree in Agricultural Engineering

Title: DESIGN AND DEVELOPMENT OF PROTOTYPE OF IOT SENSORS BASED SMART FARM IRRIGATION SYSTEM

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ABSTRACT

In the application of traditional irrigation methods, water saving is not considered. Due to the fact that the water is irrigated directly on the land, crops sometimes undergo increased stress from disparities in the soil moisture, consequently crop performance and output is reduced. This paper discusses an automated drip irrigation system designed to operate based on soil moisture content as detected by soil moisture sensors. The data from the sensors are analyzed and acted upon based on the software (code) loaded onto the microcontrollers. In this system, a microcontroller is assigned each row of crops. Each microcontroller obtains the mean soil moisture from an array of moisture sensors spread across the row. The resultant reading is wirelessly transmitted to and receiver by another microcontroller with the aid of nRF24L01 transceivers. A water reservoir tank of capacity 1000 liters elevated on a stanchion of height 2 meters above the ground is used to store and supply water at the required pressure via gravity to the drip irrigation system when required. The components, design, programming, working, and performance of the circuit are described in this article.

Keywords: Wireless communication, drip irrigation, Microcontroller, soil moisture sensors, nRF24L01 transceivers.

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CHAPTER 01: INTRODUCTION

Irrigation is the process of artificially supplying water to land or soil. It is used to aid in the growth and development of agricultural crops, revegetation of damaged soils in dry areas, maintenance of landscapes, and during periods of insufficient rainfall. Irrigation of crops is a significantly time-expending activity; to be done in a feasible amount of time, it also demands a huge amount of human resources. Conventionally, all Labour required in the irrigation process were carried out by humans. Also, the cost of labor is on the increase. As a result of this, if efforts are not invested into the optimization of these resources, additional money will be required by the same processes. In the application of traditional irrigation methods, water saving is not considered. Due to the fact that the water is irrigated directly on the land, crops sometimes undergo increased stress from disparities in the soil moisture, consequently crop performance and output is reduced. The absence of an appropriate water control system results in improper use and wastage of water. (G, Rakshita, R, A, & N P, 2019). Majority of farmers irrigate using manual means which can be said to be effective for small scale farming. But the larger the farmland, the greater the need for a more efficient and effective means of irrigation, hence, an automated irrigation system. Automated irrigation systems are one of the most efficient, effective and convenient technique of water optimization. The systems help in conserving water and reducing wastage, thereby enabling more land to be put under irrigation. Furthermore, a controlled irrigation will make possible all year-round farming of crops. Also, crops cultivated under controlled conditions have a tendency to be healthier. This means that more and better yields are harvested all throughout the year. A method for more efficient irrigation and uses of water is the use of soil moisture sensors to control the irrigation process. Soil moisture sensors can measure the soil water content, allowing us to detect when soil moisture drops below the required. This makes it possible to automatically turn on the irrigation when required. This maintains a well irrigated field whilst reducing water wastage. (Ogidan, Onile, & Adegboro, 2019). The communication module is a very sensitive and vital part, especially for large scale projects, of an automated irrigation system. It ensures that accurate real time data is wirelessly transmitted from the sensing modules and received by the actuating modules of the irrigation system. Most small-scale projects (10m2 or less) make use of Bluetooth as the communication device, especially because they are easy to operate and work with. Much larger project makes use of internet or Wi-Fi communication, using modules such as the ESP8266-01, NodeMCU, etc., thereby allowing for communication over long distances. (N., N., O., & C., 2015). This paper discusses an automated drip irrigation system designed to operate based on soil moisture content as detected by soil moisture sensors. The data from the sensors are analyzed and acted upon based on the software (code) loaded onto the microcontrollers. In this system, a microcontroller is assigned each row of crops. Each microcontroller obtains the mean soil moisture from an array of moisture sensors spread across the row. The resultant reading is wirelessly transmitted to a receiver by another microcontroller with the aid of nRF24L01 transceivers. This microcontroller programmed to maintain a predetermined soil moisture range as required for each type of crop. The nRF24L01 transceivers are used in this project because can operate over long ranges (up to 100m) and they achieve this without the need for internet. (Iersel & Chappell, 2009). NRF is a small size radio frequency wireless transceiver. It is a very useful component for wireless projects because it is user-friendly, affordable, has good range and low power consumption. The module operates on a permit-free 2.4G ISM band and reaches a data speed of up to 2Mbps. The module can use 125 different channels to have a network of 125 modems working independently in one place. Each channel may have up to six addresses, or each unit may communicate simultaneously with up to six other units. This creates the possibility of creating a medium-scale network without the need for internet or Wi-Fi. This module's power consumption during transmission is only around 12mA, which is lower than a single LED. The module's operating voltage is from 1.9 to 3.6V, but can still be connected to the 5V pin to an Arduino without using any logic level converters. (Purnima & Reddy, 2012). The automated irrigation system is designed to operate 24/7 and in order for this to be achieved there is a need for constant power supply. Hence, the system is also designed to run solar power which on the long-term is a sustainable and cost-effective solution using renewable energy. (Kansara, Zaveri, Shah, Delwadkar, & Jani, 2015). The system is powered by a battery that is powerful enough to power the system all through the evenings and night when there is no sunlight. The battery is then charged up with during the day using solar panels. This enables the entire automated irrigation system to run independently off-grid without the need for recurring power costs. This is a major advantage for the system which when used on even a larger scale can revolutionize the way we see irrigation farming, making it more efficient and environmentally friendly. The aim of this project was to design and construct a solar powered automated drip irrigation system based on the Arduino microcontroller and cheap wired soil moisture sensors, to automatically monitor soil humidity and moisture determine when the crops require watering by actuating solenoid valves open or close.

CHAPTER 02: REVIEW OF LITERATURE

In "A novel methodology for the monitoring of the agricultural production process based on wireless sensor networks", Díaz, Pérez, Mateos, Marinescu, & Guerra mentioned about 'WSN' will provide suitable means for the farmers in the development of agriculture and also will help them to invest more and gain more profit.

In "A review of wireless sensors and networks' applications in agriculture", Aqeel-ur- Rehman, Abbasi, Islam, & Shaikh mentioned about agriculture field sensor in WSN senses the temperature, soil and humidity which are essential to maintain the fertility of soil.

In "Wireless sensor networks: a survey", Akyildiz, W. Su, Y. Sankarasubramaniam, & E. Cayirci mentioned that Hybrid sensor network is a wireless network which is designed to communicate with the soil.

In "An Overview and Assessment of Wireless Technologies and Coexistence of ZigBee, Bluetooth and Wi-Fi Devices", R. Challoo, A. Oladeinde, N. Yilmazer, S. Ozcelik, & L. Challoo mentioned that ZigBee is a wireless communication device which operates under same frequency and transmits data to and from the sensing element and also compares the value.

In "Cross-layer network formation for energy-efficient IEEE 802.15.4/ZigBee Wireless Sensor Networks", Cuomo, Abbagnale, & Cipollone mentioned that IEEE 80215.4/ZigBee wireless sensor network which coordinates the whole network and optimized the power consumption using a PAN coordinator.

In "On the design of beacon based wireless sensor network for agricultural emergency monitoring systems monitoring systems", Kim, Yang, Kang, & Kim mentioned that Beacon based wireless sensor network for agricultural energy monitoring system provide real time agricultural monitoring.

In "Web Based Service to Monitor Automatic Irrigation System for the Agriculture Field Using Sensors", Rani & S.Kamalesh mentioned that Audrina microcontroller with grove moisture sensor and water flow sensor is used for automatic irrigation system. Moisture content of soil is sensed by Audrino microcontroller and data is transmitted using ZigBee protocol. When the moisture level reaches the pre-set level, flow of water in the pipe adjusted accordingly. All the information such as flow, water pressure, moisture content etc. updated in the database along with time by which one can check the status of moisture level and motor running time on display and also on mobile via GSM.

In “A wireless design of low-cost irrigation system using ZigBee technology”, Zhou, Yang, Wang, & Ying mentioned that the methodology for the establishment of large scale automatic irrigation system using ZigBee as a wireless technology with the optimum use of labors and water. Hardware architecture, software algorithm, portable controller and coordinator in ZigBee wireless sensor network etc. Are discussed here in detail.

CHAPTER 03: METHODOLOGY

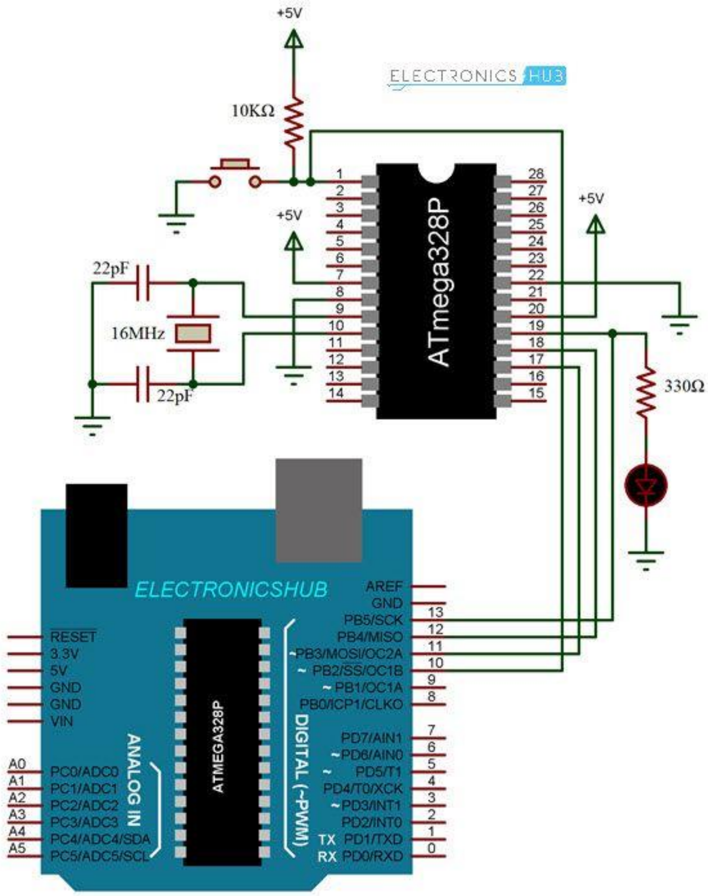
The various unit which are combine to form a complete systems are described step by step as follow:

3.1 Microcontroller:

Since the project's focus is on embedded hardware and software control, the microcontroller is the heart of the system. The microcontroller selected for this project must be able to read values from sensors through analog to digital convertor, send and receive signals from RF module and must be able to display them to LCD. Any 8-bit microcontroller can be chosen for this purpose. The ATMEGA328P was selected as it satisfies these requirements.

The Specification of microcontroller (ATMEGA328P) are:

- Program Memory Type: Flash
- Program Memory Size: 32
- CPU Speed (MIPS/DMIPS): 20
- SRAM (KB): 2,048
- Data EEPROM/HEF (bytes): 1,024
- Digital Communication Peripheral: 1-UART, 2-SPI, 1-I2C
- Capture/Compare/PWM Peripheral: 1 Input Capture, 1 CCP, 6PWM
- Timers/Counters: 2 x 8-bit, 1x 16 bit
- Number of Comparators: 1
- Temperature Range: -40 to 85deg
- Operating Voltage Range (V): 1.8 to 5.5V
- Pin Count: 32
- Low Power: Yes



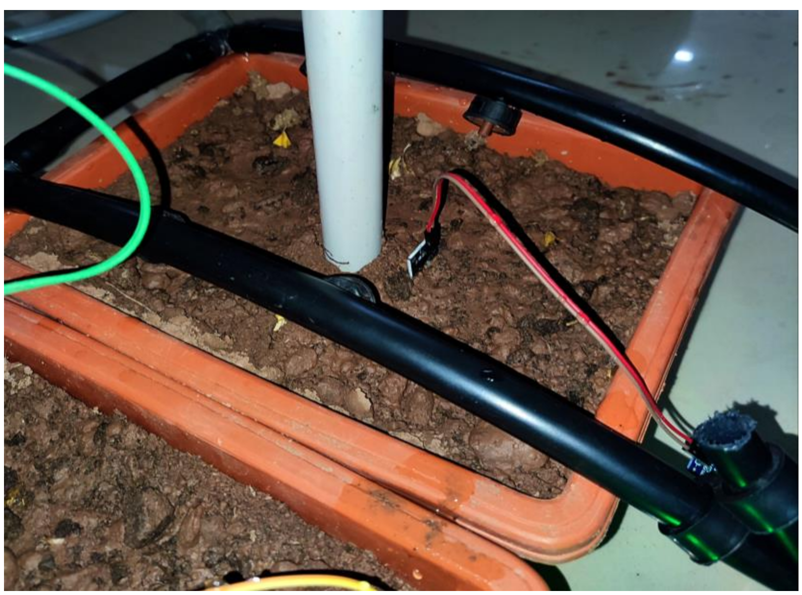
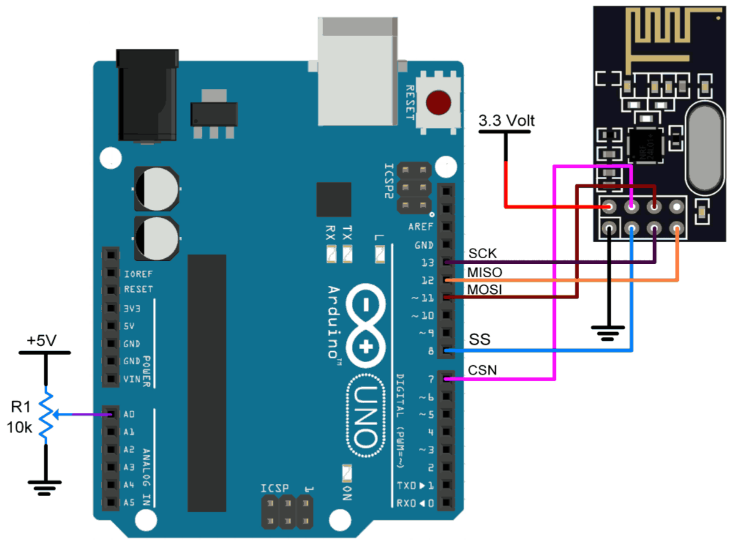


Figure 3.1: Installation of sensors and drip system in pot 1



3.2 NRF24L01 Transceivers:

This is essentially a low-cost, powerful but minimal energy requirement transmitting/receiving device which enables wireless communication over a long range for about 150 meters in the absence of barriers (for instance walls) and can be integrated with Arduino family controllers. The transceiver also allows networking between multiple modules for sending and receiving multiple packet data simultaneously.

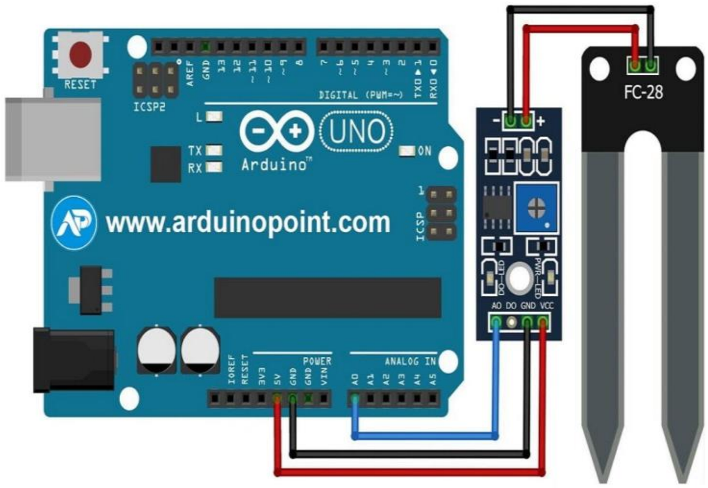
3.3 Moisture Sensor:

In this project, we use FC-28 Soil moisture sensor to measure the water content in the soil. In this sensor we are using 2 probes to be dipped into the soil as shown below. As per moisture we will get analog output variation from 0.60V-12V, input supplied voltage is 12V. Soil moisture levels can be expressed in terms of soil water content. A predefined moisture threshold is used as a reference to control the water pumping if needed. If the water level is less than a predefined value then our sensor will detect this and will inform the system to pump the water. On the other hand if it exceeds the threshold value and the water pump is ON then our system will switch OFF the water pump. This will allow efficient usage of water.

The specifications of the FC-28 soil moisture sensor are as follows:

- Input Voltage: 3.3–5V
- Output Voltage: 0–4.2V

- Input Current: 35mA
- Output Signal: both analog and digital

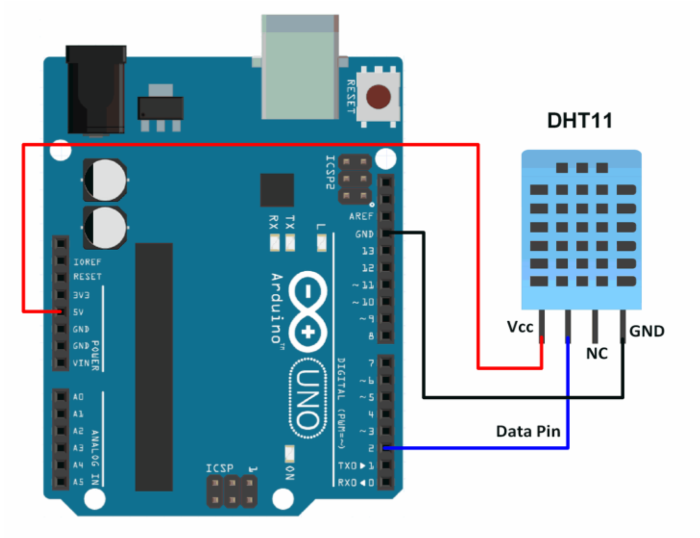


3.4 Temperature and Humidity Sensor:

The DHT11 is a basic, ultra-low-cost digital temperature and humidity sensor. It uses a capacitive humidity sensor and a thermistor to measure the surrounding air, and spits out a digital signal on the data pin (no analog input pins needed). It’s fairly simple to use, but requires careful timing to grab data. You can get new data from it once every 2 seconds.

The specifications of the DHT 11 temperature and humidity sensor are as follows:

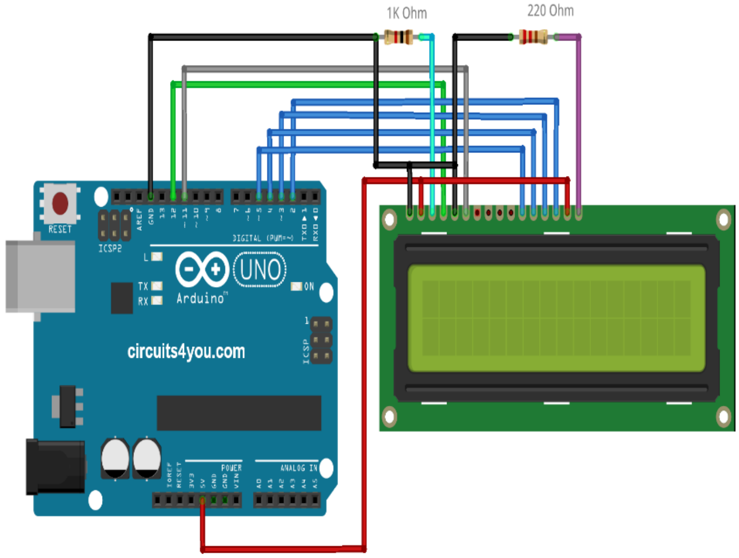
- Operating Voltage: 3.5V to 5.5V
- Operating current: 0.3mA (measuring) 60uA (standby)
- Output: Serial data
- Temperature Range: 0°C to 50°C
- Humidity Range: 20% to 90%
- Resolution: Temperature and Humidity both are 16-bit
- Accuracy: ±1°C and ±1%



3.5 Liquid Crystal Display (LCD):

In this project, we are using a 16 x 2 LCD for displaying the values on the screen. It has 16 pins. It support 16 characters per rows and total no of rows are 2. It means that it can support up to 32 character at a time, which is sufficient for data display purpose. RS, R/W and Enable pins of LCD are connected with the receiving end microcontroller port pins. Data lines D0-D7 are connected to one of the output port of microcontroller. The basic connection of LCD is shown below in Fig.05. Here VDD (contrast voltage) is adjusted by using a variable resistor connected with it. It has following specifications;

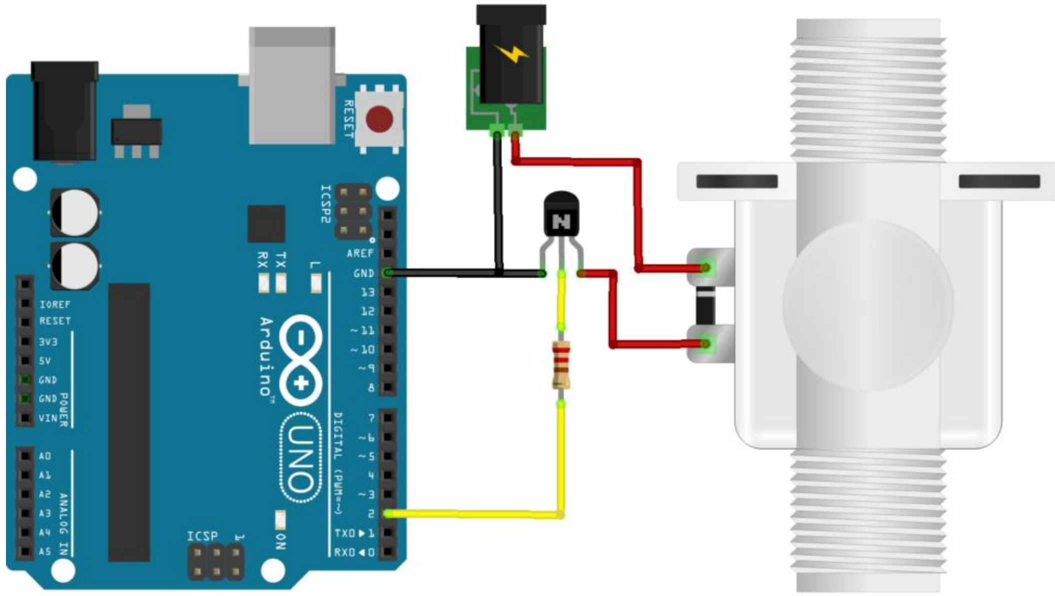
- Operating Voltage is 4.7V to 5.3V
- Current consumption is 1mA without backlight
- Alphanumeric LCD display module, meaning can display alphabets and numbers
- Consists of two rows and each row can print 16 characters.
- Each character is built by a 5×8 pixel box
- Can work on both 8-bit and 4-bit mode
- It can also display any custom generated characters
- Available in Green and Blue Backlight



Solenoid Valve:

In this project, we use 1 ½ inch Solenoid valve. This is an electromechanically actuated valve. It is initially in the closed position (i.e. normally closed), and when the circuit is live or current is allowed to flow, the valve opens allowing fluid to flow into a drip irrigation line. There are three solenoid valves for each sub- drip irrigation line. Specification of solenoid valve:

- Brand Name: Sanlixin
- Material: Brass
- Temperature of Media: High Temperature
- Pressure: High Pressure
- Power: Solenoid
- Media: Water
- Port Size: 1.5 inch



3.6 Relay Switches:

This is an electromagnetically operated device which can operate large voltage switches via smaller voltages. They are implemented where it is essential to operate a circuit by a low power signal. The relay is used to operate a device with a higher power rating. In this paper work relay issued for connecting the solenoid valve (24 Volts), water motor (230 Volts) and buzzer to a microcontroller. A single relay switch connection to microcontroller is shown below. A buzzer can also be connected by applying +12V at the common terminal of relay.

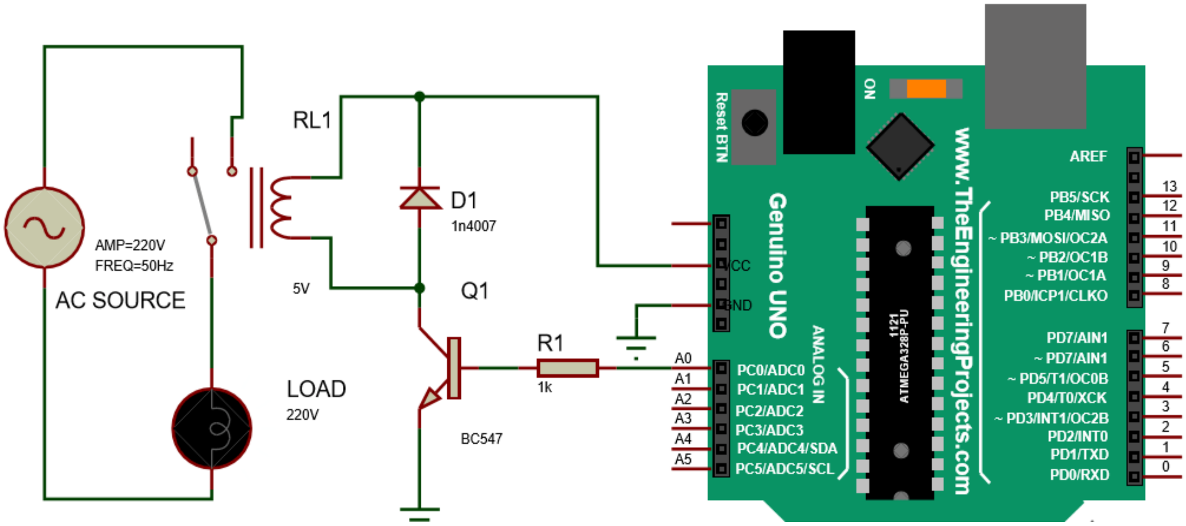


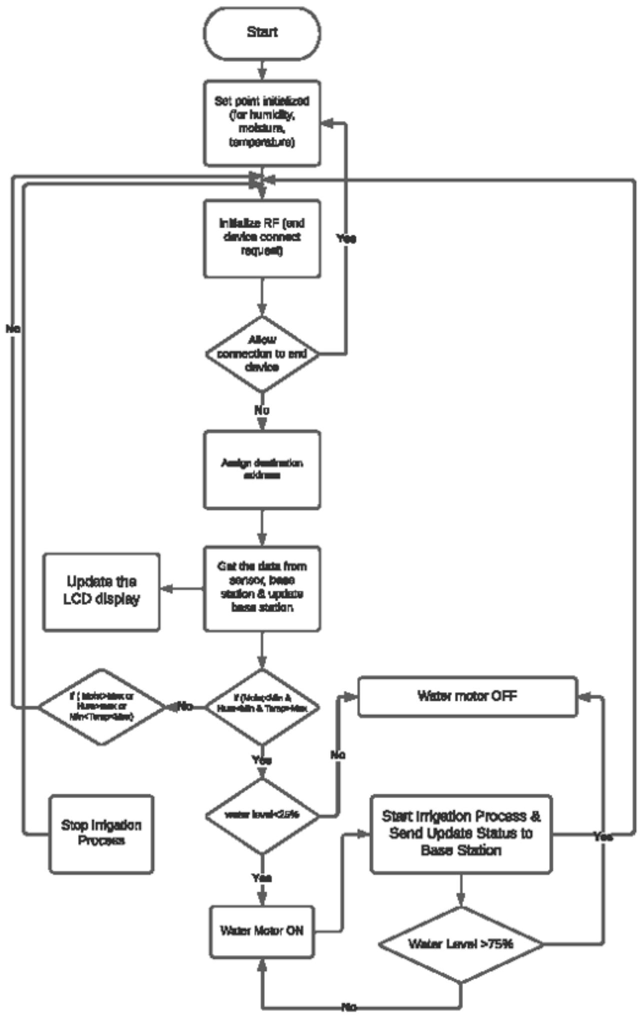
Figure 8: Relay Connection with ATMEGA328P

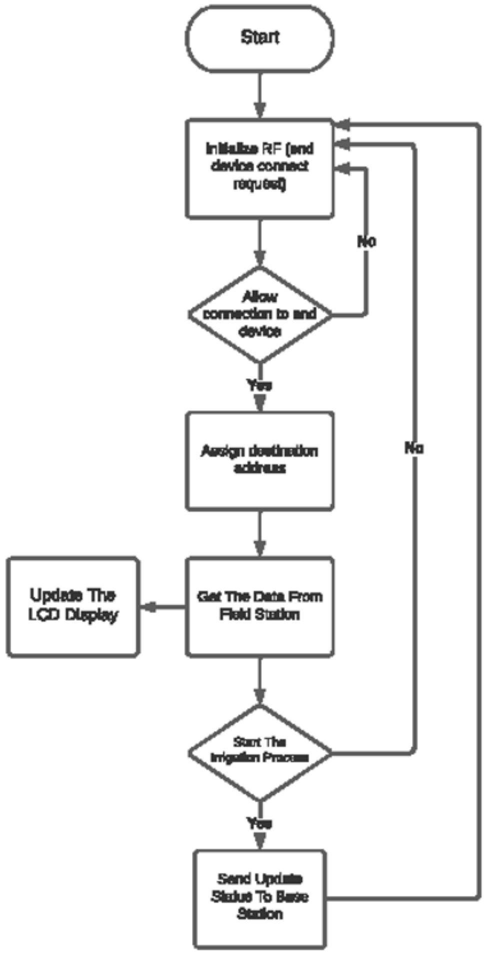
3.7 Microcontroller Programming:

The Arduino microcontrollers were programmed using the Arduino compiler. Arduino allows the programmer to write microcontroller code in higher level language like C and C++ closer to English rather than in assembly language and upload to an Arduino board allowing the board to control the actions of electronics connected to it. The hardware itself is inexpensive, open source and extensible. The language Arduino C can be expanded with libraries on the C++ platform. The Arduino compiler converts a C language to an assembly algorithm which is then uploaded to the microcontroller. Uploading is achieved via a simple 5V USB cord specially designed to transfer data as well as supply power to the microcontroller's 5V port. The Arduino hardware is enabled with a flash memory storage facility to hold data such as Sketches, the Static Random-Access memory – SRAM is where variables defined in the sketch are manipulated while the program is running. Finally, the Electronic Erasable Read Only Memory – EEPROM is a memory space where programmers store information for the long-term. It persists when power is turned off or it is cycled. Software design includes:

- Transmission and reception of wireless signal using RF Module.
- Read the sensors values through analog to digital convertor.
- Update the status of relay switches to on off solenoid valves and water motor.
- Display the status on LCD display accordingly.

The main program for this system is written by using the embedded C++ programming language. The schematic diagram for this system which consists of all the components was designed by using the Arduinos 1.8.5.




Start
Initialize RF (and device connect request)
No
Allow connection to and device
Yes
Assign destination address
No
Update The LCD Display
Get The Data From Field Station
Start The Irrigation Process
Yes
Send Update Status To Base Station

CHAPTER 04: RESULTS

4.1 PARAMETRIC INTERPRETATION OF IOT-BASED SMART IRRIGATION SYSTEM

The results of the study are shown as models, graphs, tables, and their relative analysis. The recorded parametric information from the field and lab is interpreted quantitatively by Graphical User Interface (GUI) and also with the help of different tools of MS Excel, like pivot tables, graphs, and tables. These different productive results created a pattern that shows the real-time variation of ambient temperature, humidity, and soil moisture content (SMC) along with time to time and day by day as shown in tables and graphs.

Forward displaying all the data getting from smart irrigation system is analyzed in different forms e.g. in 10 minutes, then on day wise average and at the end all the data shown through a single graph that how the daily variation in the pattern of temperature, humidity, and soil moisture content.

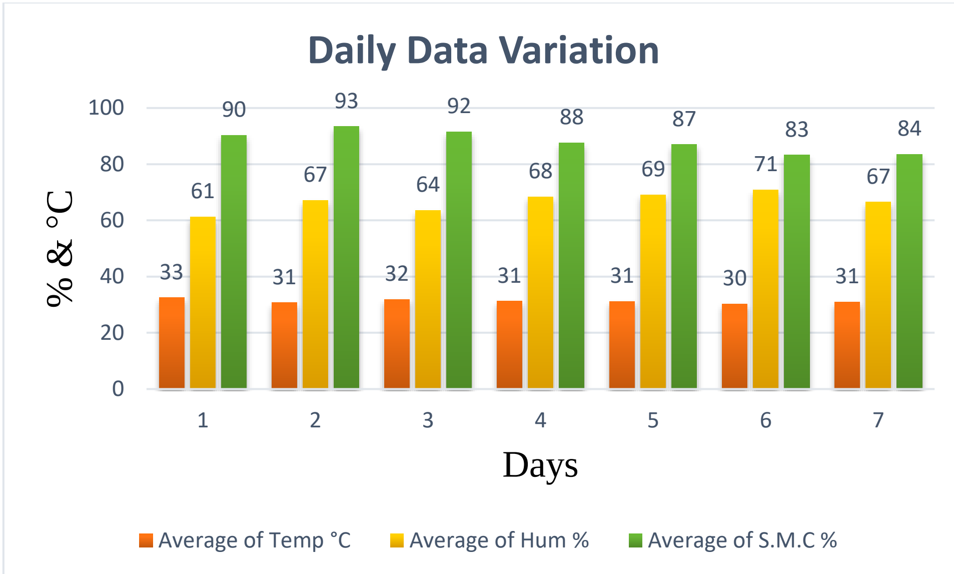


Figure 4.1: Graphically representation of daily data

PARAMETRIC Data Collection

1.1.1 Day 1 of Data Collection

The system is made up of both hardware and software. The hardware prototype, which comprises a wireless field unit and base unit, is seen in the earlier drawings. The RF module transmits the field unit's detected data to the base station. A table and graph displaying the real-time sensed data acquired by a field unit are saved in the database for later decision-making.

For the lab experiment, a soil sample of 10 kg is prepared in a pot and 2000 milliliters of water is added to the soil for proper water penetrations soil after that the field unit of the smart irrigation system is installed with a pot and soil moisture sensor installed in the soil in such way that both props of the sensor firmly and fully dipped in the soil sample, and then start the irrigation system for the attainment of data on the serial monitor of the base unit

SITE-SPECIFIC GUIDELINES

- IoT has a lot of potentials to positively affect society, the environment, and the economy through adaptability. Agriculture, Smart Homes and Greenhouses, Environment monitoring Public Safety, Medical and Healthcare, Industrial Processing, and Breeding, and Independent Living are just a few of the fields where IoT principles have been used.

- The crop is undoubtedly influenced by the temperature of the area if there is water accessible to ensure maximum fulfillment. The germination phases, which include hydration and enzyme activation, its breakdown, and embryo development, are temperature sensitive due to biochemical processes. Valid explanations for why temperature monitoring is essential.
- Analysis showed that moisture measured by resistive soil moisture sensor is not much effective as it is neither stable nor reliable over other moisture sensors e.g. capacitive.
- Resistive Soil Moisture can be used more accurately when we have to deal with moisture less than 10% because in this range it showed some accuracy.
- The performance of the DHT-22 sensor was quite satisfactory and it can be used at any site because it can be proved fully operational in the range of -40 to 125 degrees Celsius it also showed some impressive responses in the experiment according to weather conditions and gave the stable results of humidity and temperature.

4.4 CONCLUSION

It was feasible to determine that despite several advancements over the last few years in the field investigations of wireless sensor networks, machine-to-machine communication, and the internet of things that were conducted in conjunction with one another. The primary work created within the framework of the frameworks described above was not effectively integrated with the opportunities that a cloud computing platform may provide since cloud computing is a relatively new resource giving technique. The system is used to remotely measure the temperature, relative humidity, and soil moisture. In order to measure the temperature and humidity using a DHT22 over a period of time, analysis is performed. Resistive sensors are used to monitor the moisture content of the soil. The research demonstrates that while the resistive sensors are more sensitive than the capacitive sensors, these are also more unstable. Because they do degrade over time, resistive sensors are more dependable.

SUMMARY

In the fields of agricultural engineering, irrigation engineering, and geological and hydrological studies, accurate monitoring of soil moisture content and other environmental factors like temperature and humidity is crucial. In this study, a lab-based experiment is carried out and successfully realized via a smart irrigation system built on the basis Internet of Things. For real-time data, a resistive moisture sensor and DHT-22 sensor are employed with this system. Additionally, the performance of both sensors is evaluated using the experimentally collected data. The DHT-22 performs pretty effectively, according to the analysis of the quality of fit of the smart irrigation system, however, the resistive soil moisture sensor is not as steady as it should be since the results indicated numerous undulations. All the parameters were visualized through the serial monitor and CoolTerm software to make it in the form of the text file and store it automatically. And then based on results obtained over almost 7 days statistical analysis has been implied for the monitoring of parametric variations throughout the day because all the data was obtained every 10 minutes of duration to check the smooth variation of moisture in the soil and environmental parameters.

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