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Automated Fertigation System with Internet of Things Capabilities

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ABSTRACT

Although severe food insecurity remains in many regions of the globe, raising agricultural output in a sustainable way is now a feasible goal. Farming is critical to global food supply and economic prosperity. High yields from agricultural food are dependent on the fertility of land, moisture in the soil, and other climate factors. This article is intended to develop an Internet of Things (IoT) system that is based for monitoring soil conditions and automating fertilization processes in agriculture. The system includes sensors that measure soil moisture, temperature, and nutrient levels, which are then transmitted to a central control unit using wireless communication. The control unit processes the data and makes decisions about when and how much fertilizer to apply based on predefined rules and algorithms. An auto-fertilizer feeder device is also integrated into the system to dispense the needed quantity of fertiliser at the proper moment. This technique has the capacity to greatly increase agricultural yields and reduce labor costs for farmers, while also promoting sustainable agriculture practices by minimizing fertilizer waste and protecting the environment.
Keywords: Farming, Agriculture, IoT, Irrigation and Fertilized system.

I. INTRODUCTION

The agriculture industry plays an important role in the economy for any country's economy, and it is also an essential factor for human survival. Soil quality is the primary factor for crop growth and productivity. The determination of this project is to progress a system based on the internet of things that measures the soil's moisture, pH level, and temperature and automatically feeds the crops with the required nutrients, i.e., NPK fertilizers.

The use of machinery has made it possible to do even the most laborious tasks in the simplest manner possible in the modern day. There is no question that the use of automation results in a rise in productivity as well as significant time and labor savings. Irrigation is one of the key factors that will determine your success to return from the money you spend in farming or gardening. In spite of this, there are a number of devices available for use in the agricultural sector that may make the job of farmers and gardeners much simpler. This irrigation system's primary function is to analyze the level of moisture present in the ground and then to control the motor pump accordingly. In addition to working in agriculture, we also need an automatic plant watering system at our house so that our plants may continue to thrive even when we are not there to tend to them. The inefficiency of conventional irrigation systems, which may lead to overwatering, is responsible for almost half of the water that is lost. The motor pump will turn off whenever the circuit determines that there is an enough amount of moisture in the soil.

The use of fertilizers and water to the surface at the same time, in conjunction with irrigation, with the goal of enhancing crop yields and plant development is referred to as "fertilizer and irrigation." The term "rain-fed" refers to agricultural land that receives its primary sustenance from precipitation. Irrigation and drainage, an artificial evacuation of visible and surface waters from a particular region, are often discussed together. Drainage may be natural or artificial. It should come as no surprise that the management of water runoff over agricultural areas plays a significant part in the production of crops and the nourishment of plants. This includes shielding the plants from the effects of cold, preventing the growth of weeds in grain fields, and contributing to the avoidance of problems linked with the soil.

II. RELATED WORKS

The purpose of this study [1] is to design an automatic irrigation system that can detect the amount of moisture present in the ground and then either switch on or turn off the pumping motor accordingly. Just the value of the soil's moisture is taken into account in this study; however, the suggested project offered an addition to the already existing work by adding the values for temperatures and humidity.

This suggested paper [2] is an Arduino-based automated irrigated system built for the agriculture farmstead. The device is situated in a distant area, and it supplies the needed amount of water for the plantation if the moisture of the soil drops under the set-point value.

In this work [3], an older version of microcontroller containing less memory is utilized to manage the system. Nevertheless, the suggested method makes usage of an Arduino Yun board, which is both consumer pleasant and supports dump programs quickly.

In this particular work of research [4], hydration is carried out using the soil moisture values; however, the suggested system also shows temperature and humidity readings.

The automated irrigation systems are carried out in this work [5] by using the soil moisture measurements and DHT11 sensor readings for the PLC to carry out the automated of the irrigation system.

The authors of this study [6] presented an irrigation system based on a microcontroller system with real-time information for the purpose of observing and controlling the events associated with drip irrigation. The user is the only one who can regulate the functioning of the system at any given moment via the utilization of the ZigBee controller module [7]. This is done without any previous resolve of the temp or wetness of the atmosphere around the plant.

[8] describes the development of a similar prototype of an intelligent irrigation system that is based on microcontrollers. The technique of irrigation consisted of dividing the area into zones, each of which had its own moisture sensor, pesticide sprinkler, and soil humidity sensor [9]. It would seem that the system [10] is fully automated. Nevertheless, the temperature of the surrounding air was not taken into account, despite the fact that it is one of the most essential factors that determines how well plants develop.

2.1 Materials and Methods

The application of irrigation and fertilizer to the soil at the same time in order to enhance crop output and plant development is referred to as "fertigation". The following is a list of the various essential components that are required for the configuration of an irrigation system in order to assist in the cultivation of farming crops, the maintenance of landscapes, and the re-vegetation of soil that has been disturbed in arid regions and during times of insufficient rainfall.

Soil Moisture Sensor

The term soil moisture sensor refers to a device that measures the amount of moisture in the ground. These sensors may be used to determine the quantity of water that is stored in the soil horizon. Sensors that monitor soil humidity do not measure the water contents of the soil directly. Instead, they monitor the variations in some other aspect of the soil that is connected to the water content of the soil in a determinable manner.

DHT 11 Sensor

Among the most widely used temperature and moisture sensors is the DHT11, which comes with a specialized NTC for detecting temperature and an eight-bit microcontroller for exporting temperature and saturation values. A equipment that can detect and analyze differences in temperature, that data into an electrical signal, is known as a temperature sensor. The ability of humidity sensors to detect changes in the air's temperature and electrical currents is what allows them to do their jobs. There are three primary varieties of humidity sensors, including capacitive, resistive, and thermal sensors.

Arduino Microcontroller

The Arduino platform is composed of two components: a physical board and a piece of software called an IDE. IDEs enable you to write computer programs and upload it to physical boards.

PH Sensor Module

The PH sensor module is a compact and easy-to-use module for measuring the pH value of liquids. It is based on the industry-standard PH electrode, which determines the concentration of hydrogen ions in a solution.

Soil Moisture Sensor Module Datasheet

Sensor module for soil moisture is a simple and easy-to-use tool for measuring the moisture content of soil. There are many applications for this product, including agriculture, gardening, and environmental monitoring.

NPK sensor

NPK sensors indicate nitrogen, phosphorus, and potassium, the three macronutrients essential for plant growth. These nutrients are often found in fertilizers and are essential for healthy soil and plant growth.

Soil quality sensors are devices that can measure various parameters in the soil, such as moisture content, temperature, pH, and nutrient levels (including NPK). In addition to monitoring soil health, these sensors help gardeners and farmers make informed decisions about fertilizer application.

12V air pump mini module

This 12V air pump mini module is a compact and lightweight pump that can be used for a variety of applications, such as inflating air mattresses, air cushions, and inflatable toys. It has a low power consumption and is easy to install. The pump is capable of producing a pressure of 0.02-0.05MPa and a flow rate of 1-2L/min.

Fertilizer Sensor

The sensor analyzes the amounts of ammonium in the ground, which is the molecule that soil bacteria use as a precursor to producing nitrites and nitrates. It combines this information with meteorological data, the amount of time that has passed since the last time fertilizer was applied, measures of pH and soil conductivity, and uses a kind of AI known as machine learning. This information is used to make predictions about, the total nitrogen the soils has right now and how much nitrogen it will possess up to 12 days from now in order to determine when the best time is to apply fertilizer.

Moisture Sensor

It consists of two tests, one of which examines the blockage of the soil and the other of which determines the amount of moisture in the soil. Both of these tests include the passage of current into the soil. The device is organized according to this attribute of strength. When the resistance is converted into voltage and this may be achieved via the utilization of a circuit that is shown inside the sensor and which transforms the resistance into voltage.

Relay

An electrically operated switch is referred to as a relay. Each input terminal accepts a single control signal or a large number of them, while the contact terminals are used to operate the device. Electric switches known as relays make advantage of electromagnetism to multiply the effects of very little electrical impulses by connecting them to bigger currents. It is simple to switch contacts. Discretely separates the activation component from the actuating component. It performs well even when heated to extremes. While it requires a very little amount of electricity to activate, it is capable of setting in motion very powerful and huge machinery.

III. PROPOSED METHODOLOGY

The fundamental goal of this article is to provide a basis for monitoring remote soil moisture from afar and dealing with ground moisture so that it does not affect the goods. The IOT fundamentally based organized structure shown in this evaluation is useful for completing such a task. This study's prototype framework assessment permits monitoring of any agricultural arrival and maintains soil moisture. This concept would undoubtedly motivate any nation to transition to sustainable agriculture. The outline is designed to calculate and produce records over time. The suggested method was demonstrated using the Thingspeak cloud service.

The systems execution is split into two key components: hardware and software. In proposed module, we use PLC instead of Arduino, for larger power system and integration of multiple output system as required in this figure 1 below.

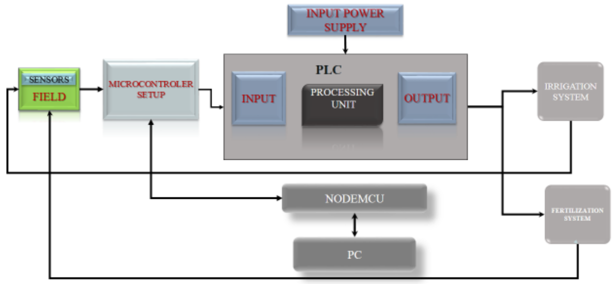

Figure 1: Block Diagram of Proposed Diagram

3.1 Programmable Logic Controller

A PLC, or Programmable Logic Controller, is a ruggedized system that is used for industry automation. These controllers are capable of automating a single operation, a machinery function, or perhaps an entire manufacturing line.

3.1.1 Automation in PLC

A programmable logic is a digital computer that is used to automate generally industrial electromechanical activities such as controlling equipment on industrial manufacturing lines, entertainment rides, or lighting fixtures. PLCs are found in a wide range of equipment and industries. PLCs are built for different configurations of digitized and analogue inputs and outputs, expanded temp ranges, acoustic noise immunity, and vibrations and shock resistance.

3.1.2 Working of PLC

Input data is collected and analyzed by the PLC, after which outputs are activated based on pre-programmed settings. An industrial PLC is capable of analyzing and storing run-time data, such as machinery production or operating temperatures, automating start and stop operations, creating alarms if a machine fails, and more, depending on the inputs and outputs. PLCs are versatile, robust, and can be used for a wide range of applications, as illustrated in Figure 2.

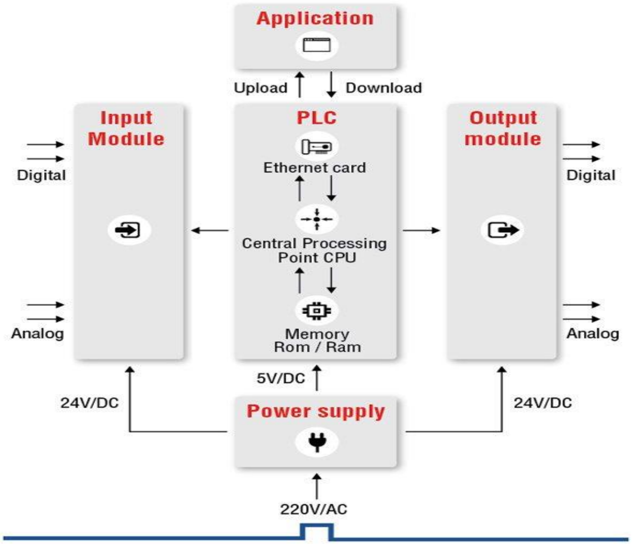

Figure 2: Working of PLC

To regulate the irrigation, a PLC is employed. Based on the ladder logic programming language, PLCs have the benefit of being simple to program. They are also reprogrammable, which aids in the setup's scalability. The field sensor inputs are received, the ladder logic is run, and the results are updated depending on the input readings. A soil moisture sensors is a piezoelectric moisture sensor that uses Time Domain Transmission (TDT) technology to monitor volumetric water content. A soil fertility metre measures the electrical conductivity of soil and water to determine the quantity of soil nutrients. It calculates the sum of NPK values.

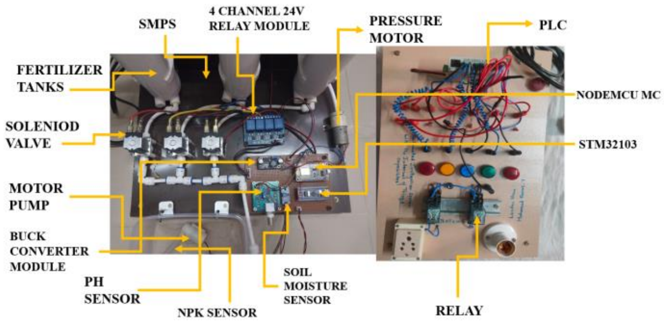

Figure 3: Hardware Model

In the proposed system giving 230vac power supply to PLC and it step down and convert power supply into 24vdc. The connections are given from PLC power supply to moisture sensor, NODEMCU microcontroller, and relay. Here we are giving output connection from soil moisture sensor is used as an input to PLC and output connections are given from PLC to relay and relay is connected to buzzer and pump. If the level of water in the soil is less, then it indicates soil is dry and buzzer starts ringing and PLC sends signal to turn ON the pump and dripping of water starts. If the level of water in the soil is more, then it indicates soil is soggy and PLC sends control signal to turn OFF the pump and dripping of water is stopped. The soil moisture sensor detects whether, soil is dry (or) soggy and provides to PLC. Here the water content is high, so it displays soggy on app, PLC sends control signal turn OFF the pump. Similarly, if the water content is low, it displays dry on IOT system and PLC sends control signal to turn ON pump. This entire system operation and periodic levelling of sensors can be shown in MobileApp. This is integration of PLC with IOT capabilities in the agriculture Domain. Each sensors are linked to a Microcontroller arrangement in order for the measured data to be sent. The values are delivered and received by an RF transmitter and receiver that are linked to the PLC via control relays. The PLC decides whether to deliver water and fertilizer to plants based on the humidity sensor and soil fertility meter results by operating the pump of the relevant tank. The fluid level in the storage tank is controlled by PLC through the tank's float switch. The weather information supplied by weather stations on their networks is used to schedule irrigation.

Soil Monitoring:

The moisture of soil sensor, the pH sensor, and the temperature sensors are all linked to the stm 32 board. The sensor readings are recorded by the stm 32 board, and the data is transmitted to the Blynk Application through the internet. The farmer can monitor the soil moisture, pH level, and temperature from anywhere using the Blynk Application.

Automatic NPK Fertilizer Feeder:

Based on the soil moisture, pH level, and temperature data, the NPK fertilizer feeder is automatically controlled by the stm 32 board. The required amount of NPK fertilizer is fed to the crops when the soil moisture level is low, pH level is out of range, or temperature is below the threshold value.

Data Logging:

The sensor readings are also sent to the Adafruit IO platform, where the farmer can see the Temperature, pH, and moisture levels of the soil over time.

Alerts:

If the soil moisture level is too low, pH level is out of range, or temperature is too high or low, the farmer receives an alert on their phone through the Blynk Application.

Machine Learning Model:

A machine learning model is developed to predict the crop yield based on the historical data of soil moisture, pH level, and temperature.

Python Script:

A python script is developed to fetch the historical data from Adafruit IO, process the data, and predict the crop yield using the machine learning model. Conclusion: This project provides a solution to the problems faced by farmers in monitoring the soil quality and feeding the crops with the required nutrients. The IoT-based system automatically feeds the crops with the required NPK fertilizers, which saves time and resources. The historical data of soil moisture, pH level, and temperature can be used to predict the crop yield using machine learning, which helps the farmer to make informed decisions.

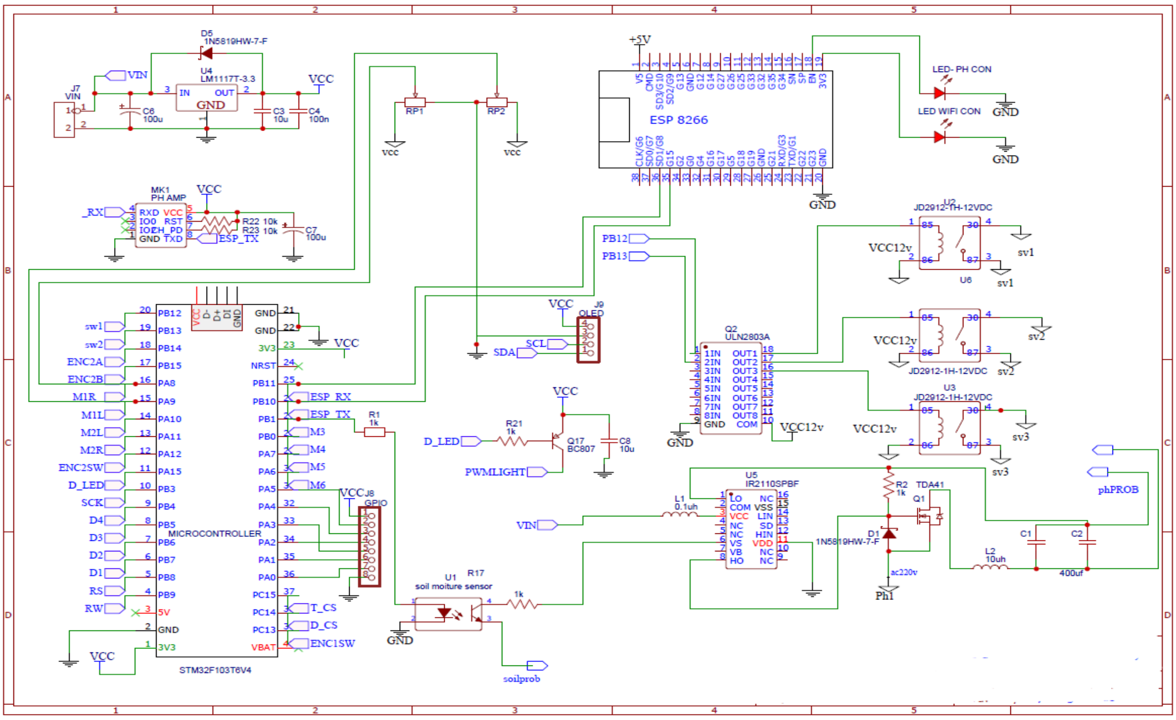

Figure 4: Circuit diagram of the proposed system

The analog output of the moisture of soil sensor is linked to analog channel 0. The sensor's digital output is attached to the nodemcu's GPIO-16 or D0 pin. The nodemcu 3.3 volt output powers the soil moisture sensor. The data output of the DHT-11 tempe and the sensor of humidity is linked to GPIO-0 or D3 of the nodemcu esp-8266-12e WiFi module. There is just one vacant pin on the dht-11. DHT-11 is available with two alternative pin outs. In figure 4, I utilized the GPIO-13 or D7 pin of the nodemcu esp8266-12e WiFi module to control the relay.

Note: The transistors ground should be connected to the nodemcu ground as well as the main power supply Vs. Vs is the external power source for the transistor, which drives the relay. If you're using a 12 volt relay, Vs is determined by the relay.

- A DC pump should have its ground connected to the ground of its power supply.
- The anode and power lead should be connected to the NO pin of the relay. Anode or com-point of the relay should be connected to the anode of the motor.
- If the pump runs on alternating 110 or 220 volts, connect the pump's lead to the power rail. The relay's NC contact should be connected to another rail, and the relay's COM to the pump's second lead.

Switching unit

The unit consists of a 12 volt relay that is powered by the power supply. Water is turned on by this device when the soil moisture content drops below 30% (2V), and the LCD unit and GUI show the data in real time. In order to flip the relay, the A1015 transistor acts as a current amplifier. the base current was modeled using the mathematical model in (1).

$$Vcc = IcRc + Vce \qquad (1)$$

Where I_b represent base current, I_c represent collector current, V_{cc} represent collector-to-collector (DC supply voltage) and h f e represent transistor Gain.

At Saturation,

VCE = 0 where,

$$Vcc = IcRc \qquad (2)$$

But, R_c = Resistance of relay = 100 ohms

$$Ic = \frac{Vcc}{Rc} \qquad (3)$$

$$Ic = \frac{5}{100} = 0.05A \qquad (4)$$

$$hfe = \frac{Ic}{Ib} \qquad (5)$$

Assuming h f e = 12V,

Then,

$$lb = \frac{0.05}{12} = 4.167mA \qquad (6)$$

When microcontroller is high, it produces 4.0V. Therefore, Base resistance can be modelled as;

$$Rb = \frac{Vb}{Ib} \qquad (7)$$

$$Rb = \frac{4.0}{4.167} = 959.92\ ohms \qquad (8)$$

Rb = 1kilo ohms is suitable for the A1015 transistor to limit the base current flow through the transistor.

Evapotranpiration model

Evapotranspiration (Eto) net may be estimated utilizing the Penman-Monteith combination eq, that has been widely acknowledged as a systematic method for agronomists, soil scientists, and others to estimate and monitor fresh water consumption and sustained crop production. Evapotranspiration is the total of evaporation, soil surface, and plants perfusion that regulates water and balances energy in the environment for agricultural productivity.

$$Eto = \frac{0.408\Delta\,(R_n - G) + y\dfrac{900}{\gamma + 273}U_2(e_s - e_a)}{\Delta + y(1 + 0.34u2)} \quad (9)$$

$$\Delta = \frac{409eo(T)}{(T + 273.3)^2} \quad (10)$$

$$e^o(T) = 0.6108 \exp\left(\frac{17.27T}{T+273.3}\right) \quad (11)$$

$$\gamma = \frac{CpP}{\varepsilon\lambda} \times 10^{-3} = 0.001628\,XP\,/\,\lambda \quad (12)$$

Where:

Eto = Evapo-transpiration reference [mm day^{-1}]

G = Soil heat flux density [mm m^2 day^{-1}]

Rn = Net radiation at the crop surface [mm m^2 day-1]

E_a = Actual Vapour pressure[kpa]

E_s = Saturation Vapour pressure [kpa]

λ = Latent heat of vaporization = 2.45 [MJ kg-1]

^{c} = ratio molecular weight of water vapour / dry air = 0.62

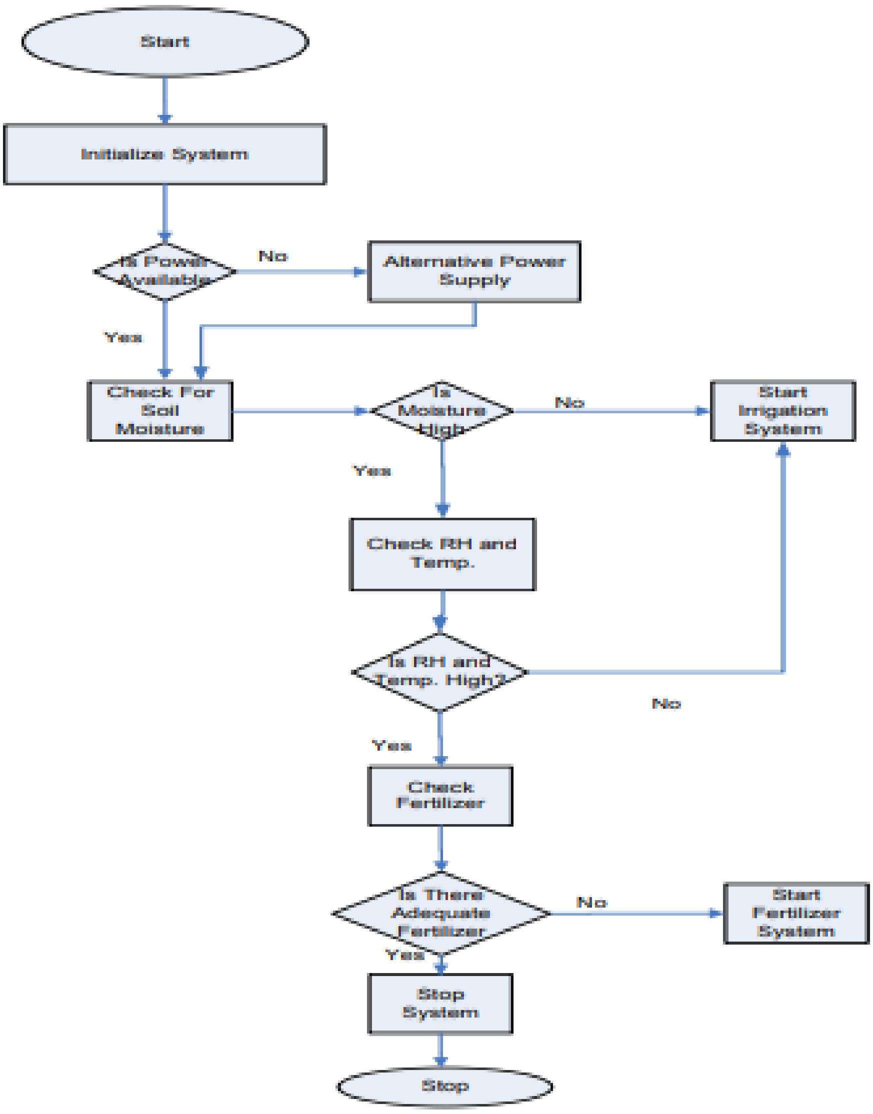

Figure 5: Flow chart of System Operational Model

IV. EXPERIMENTAL RESULTS

Sensors used in autonomous fertigation include ultrasonic sensors, valve sensors, and electrical conductivity sensors combined with temperature sensors. This allows the level of water or solution in the tank to be accurately measured. In order to determine the height of the pipe when seen from above, the ultrasonic sensors have been placed at the highest point of the pipe, as illustrated in Figure 3.

By wpl software ,we stimulate the ladder logic shown in the figure 5

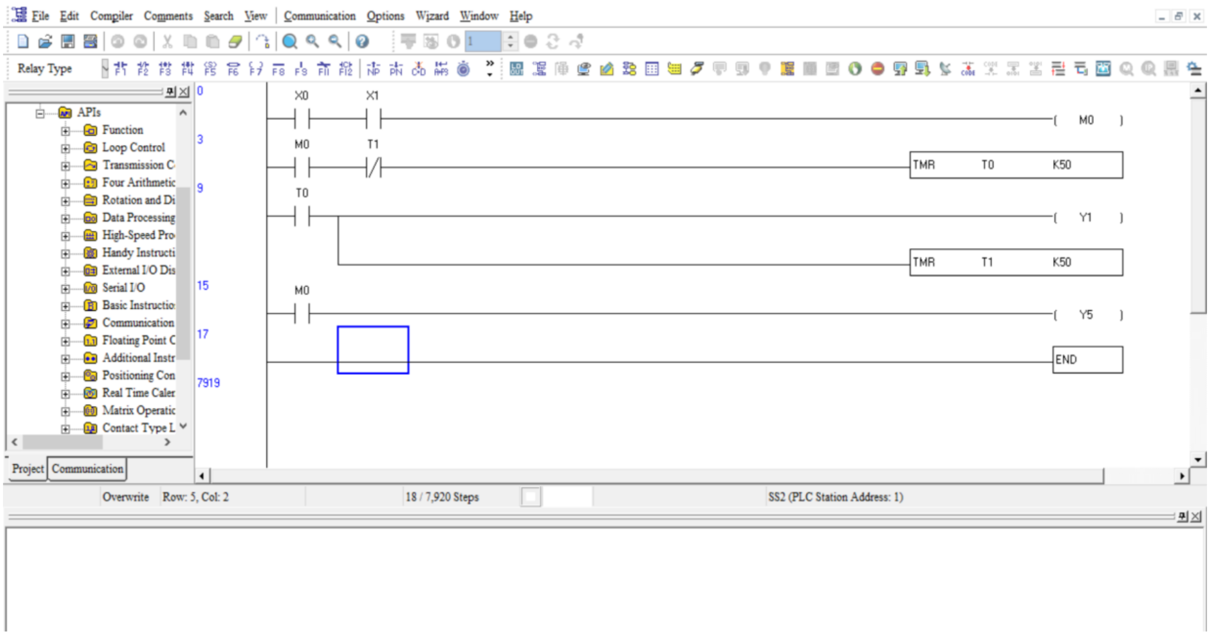

Figure 5: ladder logic diagram

List of inputs and outputs

- X0 = Soil moisture sensor (Input)
- X1 = Micro controller (Input)
- M0 = Memory coil (Output)

- Y1 = Output 0 (Output)
- Y5 = Output 1 (Output)
- T0 = Timmer for output 0 (Timmer)
- T1 = Timmer for output 1 (Timmer)

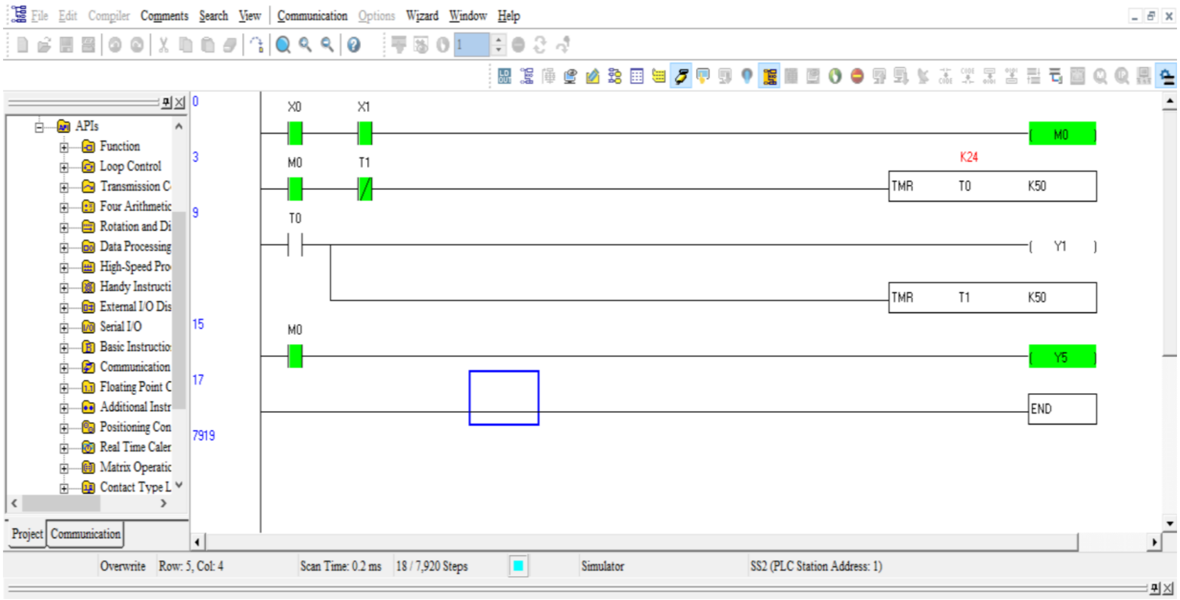

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Figure 6: Execution of ladder logic

Using delta PLC software, automatic mode x0, x1 are soil moisture and micro controller for the irrigation of the system which explain ON and OFF condition of the system. Y1 and y2 are pump motor they are ON condition and it blows green light.

- X0 is soil moisture sensor which gives information about soil level in the yeilds through Y1 pump so it can decides that the pump motor should turn ON/OFF.
- X1 is the micro controller gives information to M0 so that M0 can pass the information whether the system operating in automatic mode.
- X1 is the micro controller l it gives information to M0. So Y5 will be turn on and pumped motor will be on condition.

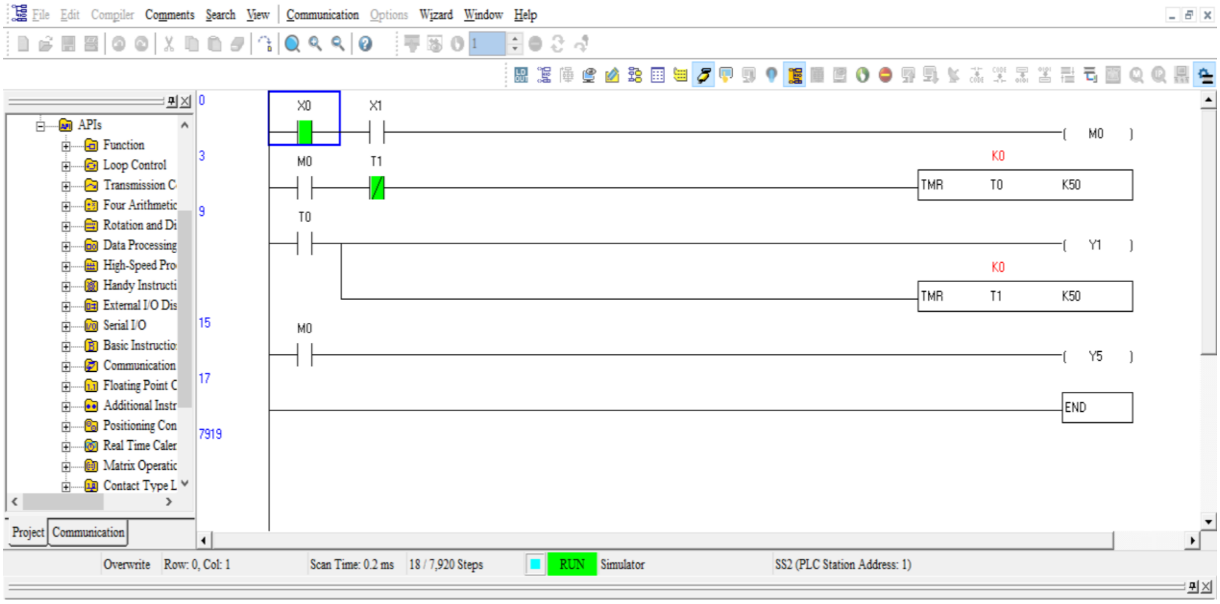

Figure 7. Energizing switches

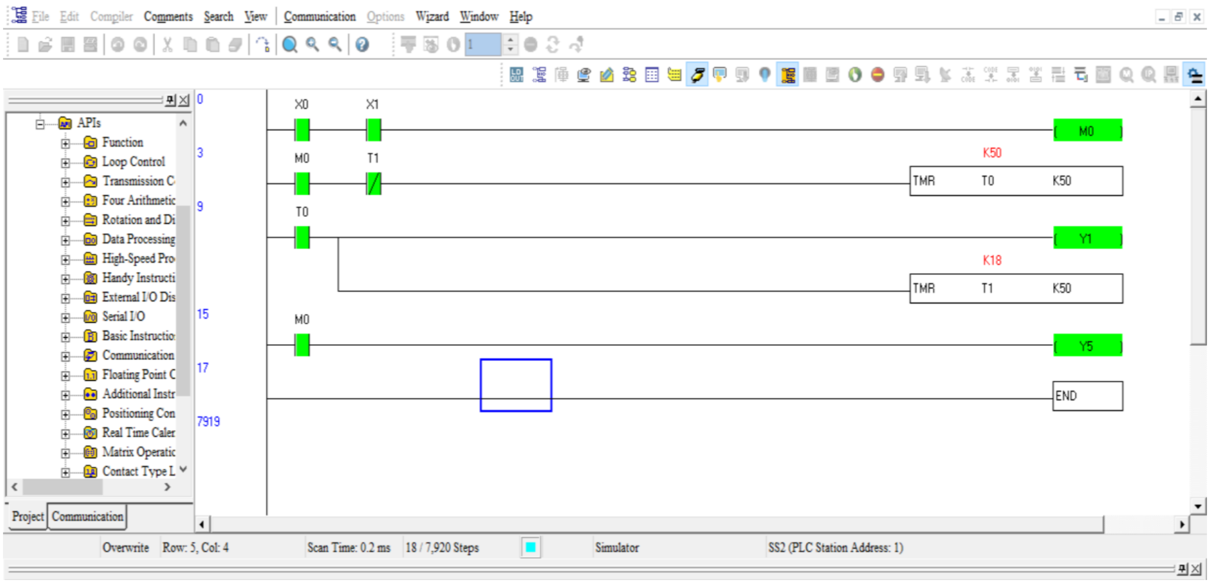

Figure 8. Final running mode diagram

This is all about the ladder logic of the proposed model .This will execute by the switching ON and OFF of the condition of switches.

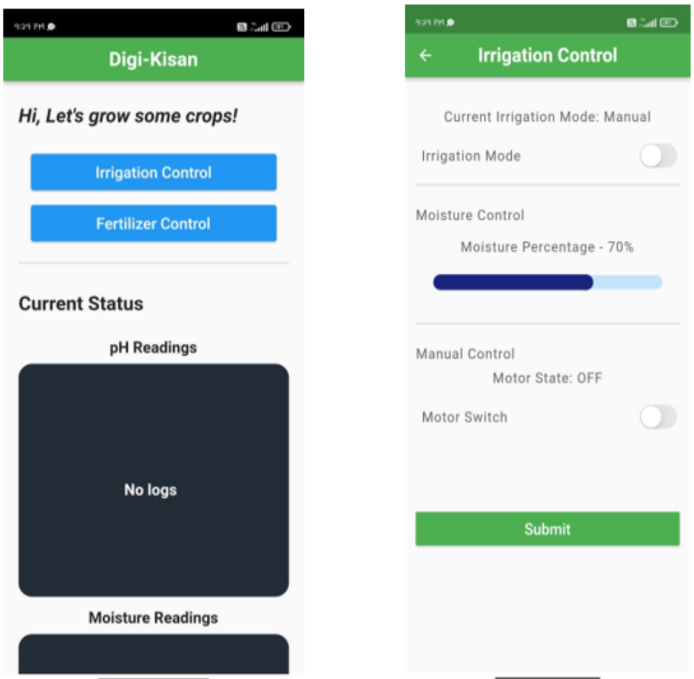

Figure 9. Application Development for Irrigation page

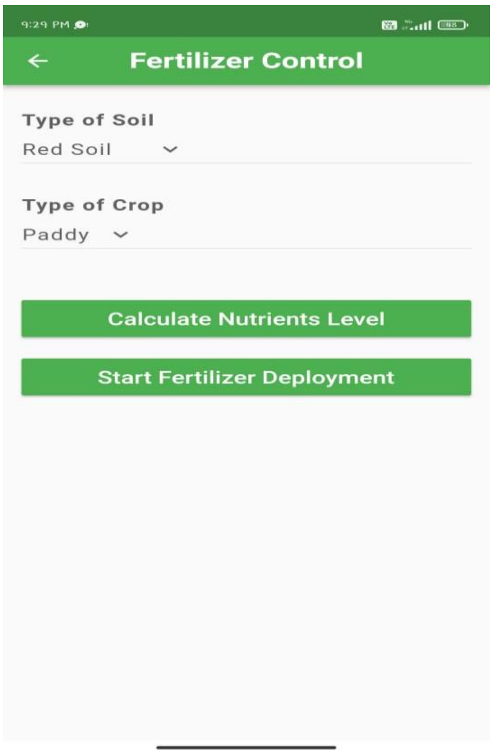

Figure 10. Fertilization control page

Hence, we have successfully monitored Temperature and Humidity data over application using NODEMCU-Esp8266 wifi module in the figure 9 and 10.

Sensor verify testing ensures that the PLC programme will activate the relay to turn on and off the motorized pump, following by the Fertigation system, and that soil moisture conditions are appropriately reflected. If the humidity level is lower than 20%, the ground is dry adequate to enable the motor pumps to operate. If the moisture level is more than 60%, the soil is wet sufficient to enable the motor pump to operate. But, if the sensor reading exceeds 60%, the moisture level is enough for the plants.

V. CONCLUSION

The project's results include the controller's ability to get weather forecasts through the online and regulate the Fertigation. Irrigation is planned with three distinct modes of operations depending on sensitive data, and a mobile application is designed to remote monitoring & operates irrigation. The use of sensors and IoT to create control signals for agricultural irrigation results in significant resource savings. The method also eliminates the need for the farmer to be physically present on the field in order to run the irrigation system. The energy saved may be utilised to manage the remainder of the farm's operations. In addition, the technology allows the farmers to manage a huge farm with little staff. This lowers the produce's manufacturing cost. This, in turn, boosts the farmer's profit. PLCs, being sturdy and time-tested commercial automated controllers, can withstand all of the severe circumstances to that devices are subjected. They are built to be tough. They almost never fail. Thorough testing was performed on the prototypes systems to ensure that the logic was error-free. The system's applications include the ability to irrigate bigger expanses of land with an unified human interface and enhanced drip irrigated with fertilizer management.

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