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Automatic Control for Greenhouse Farming

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***Abstract* — Greenhouse Precision farming is the break-through farming system where the state-of-the-art technology is implemented for a sustainable production, by maximizing the efficiency of the resources through information based management, using appropriate technologies suitable to the production variables such as soil, water, seed, varietal characters of the crop, agrochemical inputs , climate , etc. The efficiency of the production resources are maximized by providing precise quantities of the inputs to the crops in right composition. The decisions are made based on the information compiled on variables like soil fertility status, intake of nutrients by the plants and crop growth parameter. The inputs are provided to plants in an integrated manner where all the required nutrients are provided to the root zone instead of blanket application of major nutrients in the top soil in two or three phases of the crop growth. The information technology tools like wi-fi systems are also utilized to draw inferences in the decision making process. Further to the improved efficiency of inputs, precision techniques have its advantages in environmental and ecological aspects. The efficient utilization of inputs will lead to the less wastage and pilferage of agro chemicals to the environment like streams, ground water sources, water bodies and non-target vegetative area. Water has become the scarcest resource in farming activity with diminishing ground water levels and erratic rainfall pattern. Precision techniques enable the system to maximize the productivity from the unit quantity of water, thereby conserving the water resources to the communities. Microcontroller PIC 18 is used for data processing and controlling various operations like the amount of water, temperature control through bulb and fan. The data obtained is sent through Wi-Fi that can be seen in the website with a given domain.**

Keywords— Microcontoller; Precision farming; Sensors.

1. INTRODUCTION

The highlight of the precision farming techniques and its management systems is that it effectively imbibes the criteria of all major globally accepted quality assurance programs like ***Good Agriculture Practice (GAP) protocols***, sustainability standards and fair-trade principles. This enables an effective quality assurance mechanism that influences a producer-consumer community where quality of the food is assured for a healthy society. This is done using cost effective technology consisting of Microcontroller, sensors and Wi-Fi. Figure.1 represents a typical greenhouse.

Many of the systems consist of various sensors, namely soil moisture, temperature and light. These sensors sense various parameters temperature, soil moisture and light intensity and are then sent to the PIC microcontroller.

Figure 1.Greenhouse Farming[7]

The microcontroller constantly monitors digitized parameters of various sensors and verifies them with predefined threshold values and checks if any corrective action is to be taken for the condition at that instant of time, it activates the actuators to perform a controlled operation. An array of actuators can be used in the system such as ***relays,*** *contactors, and change over switches* etc. They are used to turn on AC devices such as motors, coolers, pumps, fogging machines, sprayers. For the purpose of demonstration relays have been used to drive AC bulbs to simulate actuators and AC devices. A complete working system can be realized by simply replacing these simulation devices by the actual devices. This paper discuss about the implemented prototype in which actual devices are used to control specific actions [1]. An automated greenhouse was built with a purpose of investigating watering system's reliability and if a desired range of temperatures can be maintained. The microcontroller used to create the automated greenhouse was an Arduino UNO. This project utilizes two different sensors, a soil moisture sensor and a temperature sensor. The sensors control two actuators which are a heating fan and a pump. The heating fan is used to change the temperature and the pump is used to water the plant. Both watering and temperature control system is tested separately. Result showed that temperature could be maintained in the desired range and soil moisture sensor parameters were unstable and difficult and needs attention to control. The main motto of this project is to precisely acquire the data and monitor them to utmost accuracy and reliability [2]

2. ARCHITECTURE OF THE PROPOSED METHODOLOGY

The present greenhouse system architecture is based on Internet of Things (IoT). Figure.2 depicts the proposed architecture.

Greenhouse System consists of:

1. Wireless Sensor Network (WSN), Wi-Fi
2. Geographical Information System[GIS]
3. PIC Microcontroller
4. Sensors & Actuators

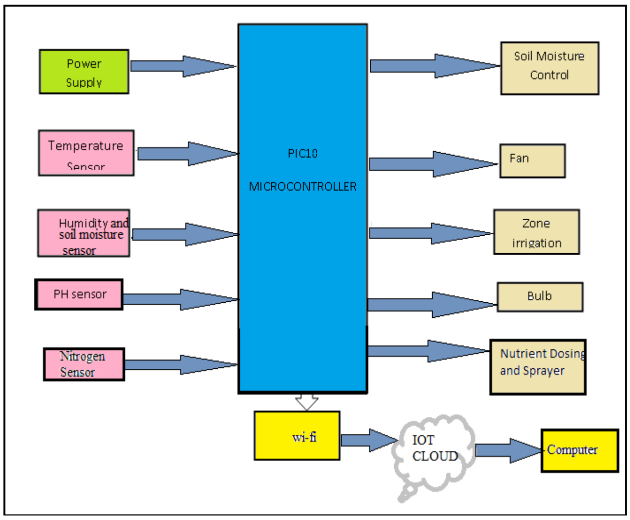

Figure 2: Proposed Greenhouse System Overview

a. Wireless Sensor Network (WSN)

A wireless sensor network is a spatially distributed to monitor physical or environmental conditions. The WSN is built of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one or multiple sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna or connection to an external antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery or an embedded form of energy harvesting. A sensor node might vary in size from that of a shoebox down to the size of a grain of dust, although functioning "motes" of genuine microscopic dimensions have yet to be created. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Size and cost constraints on sensor nodes result in corresponding constraints on resources such as energy, memory, computational speed and communications bandwidth.

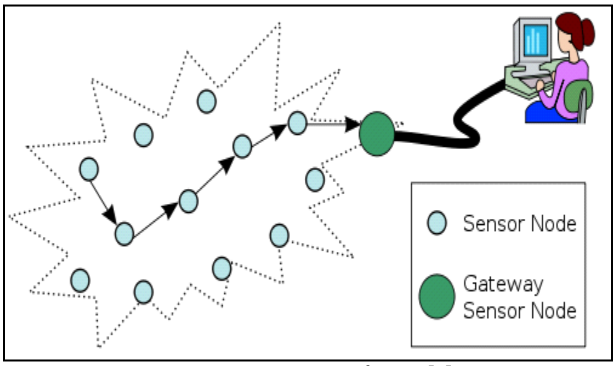

Figure 3: Description of WSN [6]

The topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. The propagation technique between the hops of the network can be routing or flooding. Key sensors include Soil Moisture, temperature, Humidity, nitrogen, PH etc., to cooperatively pass their data through the network to a main Board. The network is bi-directional, also enabling control of sensor activity. Sensors nodes are designed to be battery operated. Here only one node is implemented and the data is taken and this is shown in Figure.3.

b. Wi-Fi

Here the Wi-Fi model used is ESP8266EX. Espressif's ESP8266EX delivers highly integrated Wi-Fi SoC solution to meet users' continuous demands for efficient power usage, compact design and reliable performance in the Internet of Things industry. With the complete and self-contained Wi-Fi networking capabilities, ESP8266EX can perform either as a standalone application or as the slave to a host MCU. When ESP8266EX hosts the application, it promptly boots up from the flash. The integrated highspeed cache helps to increase the system performance and optimize the system memory. Also, ESP8266EX can be applied to any micro-controller design as a Wi-Fi adaptor through SPI / SDIO or I2C / UART interfaces. ESP8266EX integrates antenna switches, RF balun, power amplifier, low noise receive amplifier, filters and power management modules. The compact design minimizes the PCB size and requires minimal external circuitries. Besides the Wi-Fi functionalities, ESP8266EX also integrates an enhanced version of Tensilica's L106 Diamond series 32-bit processor and on-chip SRAM. It can be interfaced with external sensors and other devices through the GPIOs. Software Development Kit (SDK) provides sample codes for various applications. Espressif Systems' Smart Connectivity Platform (ESCP) enables sophisticated features including fast switch between sleep and wakeup mode for energy-efficient purpose, adaptive radio biasing for low-power operation, advance signal processing, spur cancellation and radio co-existence mechanisms for common cellular, Bluetooth, DDR, LVDS, LCD interference mitigation.

Wi-Fi Protocols Description:

- 802.11 b/g/n/e/i support. • Wi-Fi Direct (P2P) support.
- P2P Discovery, P2P GO (Group Owner) mode, GC(Group Client) mode and P2P Power Management.
- Infrastructure BSS Station mode / P2P mode / SoftAP mode support. • Hardware accelerators for CCMP (CBC-MAC, counter mode), TKIP (MIC, RC4), WAPI (SMS4), WEP (RC4), CRC.
- WPA/WPA2 PSK, and WPS driver.
- Additional 802.11i security features such as pre-authentication, and TSN.
- Open Interface for various upper layer authentication schemes over EAP such as TLS, PEAP, LEAP, SIM, AKA, or customer specific.
- 802.11n support (2.4 GHz).
- Supports MIMO 1×1 and 2×1, STBC, A-MPDU and A-MSDU frame aggregation and 0.4µs guard interval. Espressif 1/25 2016.12 1. Overview
- WMM power low U-APSD.
  Multiple queue management to fully utilize traffic prioritization defined by 802.11e standard.
- UMA compliant and certified.
- 802.1h/RFC1042 frame encapsulation.
  - Scattered DMA for optimal CPU off load on Zero Copy data transfer operations.
  - Antenna diversity and selection (software managed hardware).
  - Clock/power gating combined with 802.11-compliant power management dynamically adapted to current connection condition providing minimal power consumption.

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- Adaptive rate fallback algorithm sets the optimum transmission rate and Tx power based on actual SNR and packet loss information.
- Automatic retransmission and response on MAC to avoid packet discarding on slow host environment.
- Seamless roaming support. • Configurable packet traffic arbitration (PTA) with dedicated slave processor based design provides flexible and exact timing Bluetooth co-existence support for a wide range of Bluetooth Chip vendors.
- Dual and single antenna Bluetooth co-existence support with optional simultaneous receive (Wi-Fi/Bluetooth) capability.
- For the working of Wi-fi, AT commands are used. Figure.4 shows the Wi-fi module.

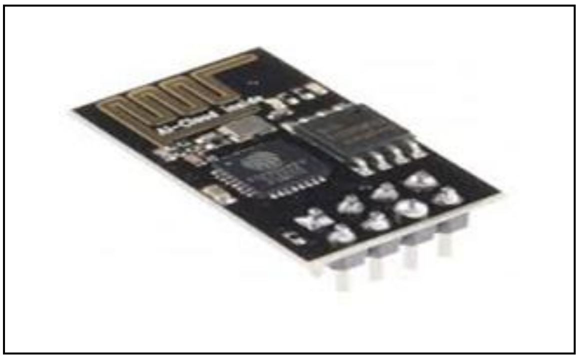

Figure 4: Wi-Fi Module ESP8266EX

c. Geographic Information System(GIS)

A Geographic Information System (GIS) is a computer system designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data. With the rich data collected from the Wireless Sensor Network and images obtained from 'Remote Sensing', GIS data can be improved and used for recommending crops to grow and yield predictions.

Remote sensing is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on-site observation. Remote sensing is used in numerous fields, including geography and most Earth Science disciplines (for example, hydrology, ecology, oceanography, glaciology, geology); it also has military, intelligence, commercial, economic, planning, and humanitarian applications.

In current usage, the term "remote sensing" generally refers to the use of satellite- or aircraft-based sensor technologies to detect and classify objects on Earth, including on surface and in atmosphere and oceans, based on propagated signals (e.g. electromagnetic radiation). It may be split into "active" remote sensing (i.e., when a signal is emitted by a satellite or aircraft and its reflection by the object is detected by the sensor) and "passive" remote sensing (i.e., when the reflection of sunlight is detected by the sensor).Here the remote sensing is done through Wi-fi and the data is sent to a web domain(thingspeak.com) so that the data can be used for monitoring.

d. PIC Microcontroller

PIC Microcontroller is a high-performance 8-bit RISC Microcontroller. This is used to capture data form WSN, process the data and send it to cloud using Wi-fi communication. This family offers the advantages of all PIC18 microcontrollers – namely, high computational performance at an economical price – with the addition of high-endurance, Flash program memory. On top of these features, the PIC18(L)F2X/4XK22 family introduces design enhancements that make these microcontrollers a logical choice for many highperformance, power sensitive applications.[1] Figure.5 represents the PIC18 microcontroller.

New Core Features:- XLP TECHNOLOGY

All of the devices in the PIC18(L)F2X/4XK22 family incorporate a range of features that can significantly reduce power consumption during operation. Key items include:

- Alternate Run Modes: By clocking the controller from the Timer1 source or the internal oscillator block, power consumption during code execution can be reduced by as much as 90%.
- Multiple Idle Modes: The controller can also run with its CPU core disabled but the peripherals still active. In these states, power consumption can be reduced even further, to as little as 4% of normal operation requirements.
- On-the-fly Mode Switching: The powermanaged modes are invoked by user code during operation, allowing the user to incorporate powersaving ideas into their application's software design.
- Low Consumption in Key Modules: The power requirements for both Timer1 and the Watchdog Timer are minimized. See Section 27.0 "Electrical Characteristics" for values.

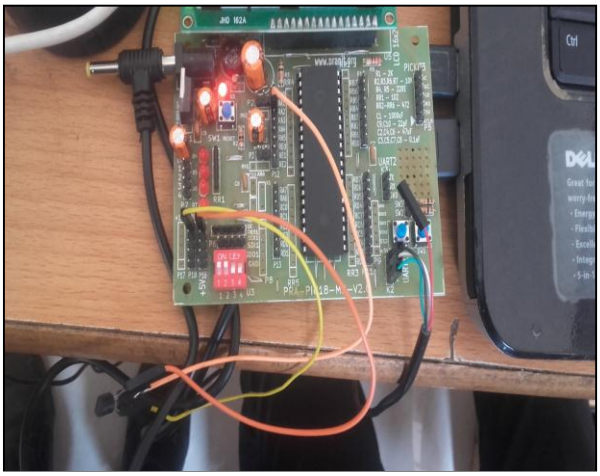

Figure 5: PIC Microcontroller

e. Sensors

In the broadest definition, a sensor is an electronic component, module, or subsystem whose purpose is to detect events or changes in its environment and send the information to other electronics, frequently a computer processor. A sensor is always used with other electronics, whether as simple as a light or as complex as a computer. Various sensors like temperature sensor, humidity sensor, soil moisture sensor, PH sensor, Nitogen sensor are used to collect the data and sent for processing to microcontroller.

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f. Actuators

An actuator is a component of a machine that is responsible for moving or controlling a mechanism or system, for example by actuating (opening or closing) a valve; in simple terms, it is a "mover". An actuator requires a control signal and a source of energy. The control signal is relatively low energy and may be electric voltage or current, pneumatic or hydraulic pressure, or even human power. The supplied main energy source may be electric current, hydraulic fluid pressure, or pneumatic pressure. When the control signal is received, the actuator responds by converting the energy into mechanical motion. Here the actuators used are fans(internal and external), bulb, water pump. For the working of actuators relays, driver IC and level shifters are used.[1]

Figure.2 shows the various sensors interfaced with microcontroller such as Temperature sensor, Pressure sensor, PH sensor and the controlling actuators such as fan and bulbs to control the temperature and humidity and it shows the overall architecture of Real Time Precision farming in Green House. With the internet connection, Authorized person can access the all the details from the cloud. The sensor values are updated in to the cloud through the wi-fi.

3. PROPOSED PROTOTYPE IMPLEMENTATION

Numerous applications of a control system have significantly increased through the development of new materials for highly efficient actuation and sensing, thereby reducing energy losses and environmental impacts. An automatic control system includes sensors, microcontroller and actuators. The algorithm for automatic control of the greenhouse microclimate includes several steps:

1. The sensor detects the level of climate parameter and sends a signal to the microcontroller.
2. The microcontroller checks whether it is in the range or not (above or below).
3. When the measured value is above the maximal or below the minimal preset value the microcontroller performs action. It runs the actuators until the climatic parameter is brought back to its optimum.

Heating system could be based upon the perimetric pipelines, under benches, or by overhead fan radiators . A bulb heating system is the best way to provide uniform temperature distribution in the greenhouse. The bulb heating system includes: an incandescent bulb and a temperature sensor. A temperature sensor placed in the greenhouse detects ambient temperature. It also sends a signal to the microcontroller.

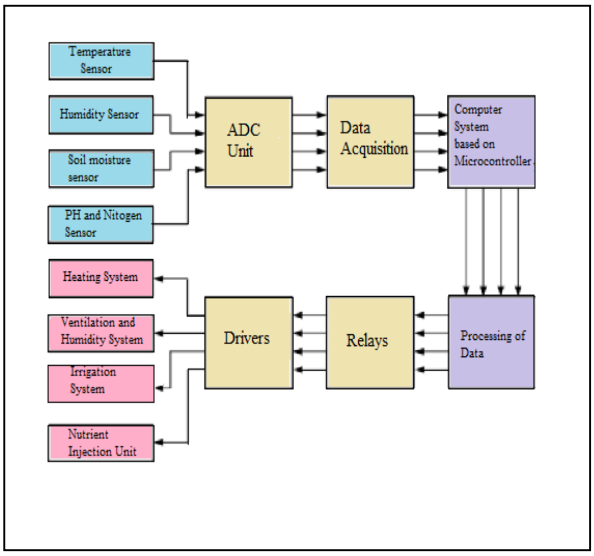

Figure 6. Block Diagram

The microcontroller then calculates the necessary temperature in the greenhouse based on difference between the detected and desired (set) optimal temperature. If it is below the threshold set, the temperature in the system is controlled to maintain the desired greenhouse temperature, by using the temperature from the incandescent bulb at a constant flow rate.Figure.6 depicts block diagram.

Ventilation and humidity system is most important for controlling the temperature, relative humidity and nitogen level. A good ventilation in the greenhouse can be achieved with a combination of a roof vent, front doors and fans . Plants grow under the influence of the PAR radiation (diurnal conditions), performing the photosynthesis process. Furthermore, temperature influences the speed of sugar production by photosynthesis, and thus radiation and temperature have to be in balance in the way that a higher radiation level corresponds to a higher temperature . In the case of high temperature and relative humidity (thermohygrometer) or nitrogen concentration (carbon dioxide sensor) in the greenhouse, the microcontroller activates the electric motors and external fans thus reducing temperature and humidity. Microcontroller performs check up and if the control parameter hasn't been brought back to its optimal level, the fans keep activating. This process continues until the parameter does not drop below the maximum allowable value.. The role of the fans is to maintain the uniform temperature and humidity field. The fresh air enters at one side and replaces hot stale air that moves out at the opposite side of the greenhouse. The fans induce the air flow and raise the hot air up. The operating principle is the same, the microcontroller calculates the time needed for fans to run and activates its electric motor. Internal fan system consists of a set of fans that release water under the high pressure and create a fine spray, which increases ambient humidity and lowers the temperature. Mist flow is varied by fans which are controlled by the microcontroller. To achieve a rational use of water and fertilizer it's best to use a fertigation system (drip irrigation), which involves the pumps, filters, control panel, nitogen and pH sensor .This system provides the required mixture based on current needs of the crops. The nitogen sensor measures nitrogen levels and checks the concentration of respective mixture components. The microcontroller receives a signal from the sensor which detects

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three soil parameters: water content (soil moisture), nitrogen levels and PH. Based on the quoted information and considering solar radiation and growing crops season, the microcontroller calculates the required amount of water and fertilizer. Fertilizer is injected and dosed directly into the water by a pump. That mixture flows through pipelines propelled by the circulation pumps. The mixture flow can be modified by solenoid valves governed by the microcontroller.

The sensors used here are

1. Soil Moisture Sensor(KTC CONS Labs)
2. PH sensor(E201-C-9)
3. Humidity Sensor(HSM 20G)
4. Temperature Sensor(LM35)
5. Nitrogen Sensor(MQ135)

The microcontroller used here is PIC18F44K22 and the wi-fi model with which data is sent to a web domain is ESP8266EX.

4. RESULTS AND DISCUSSIONS

The sensors are interfaced with the microcontroller using MPLab software and C18 compiler. Some of the sensors interfaced and their results obtained are shown below.

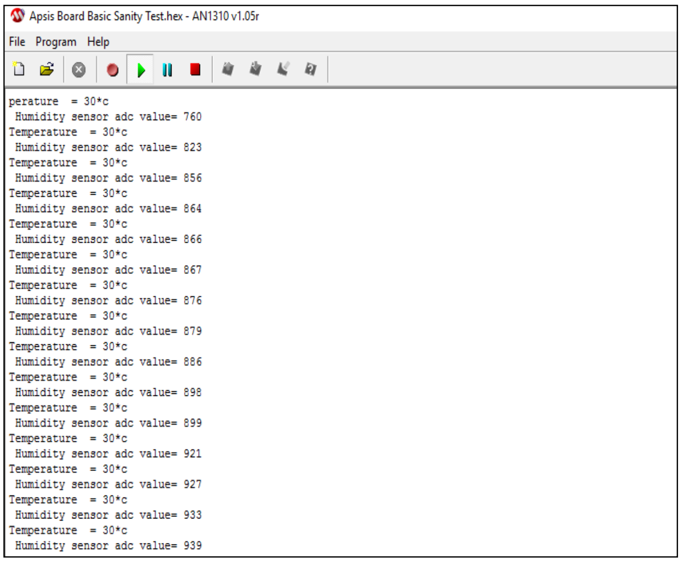

Figure 7. Sensor Output in MPlab window

The setup is fixed as shown below and the power supply is given for the proper working of all circuitry. The sensor data is displayed in LCD screen of microcontroller.

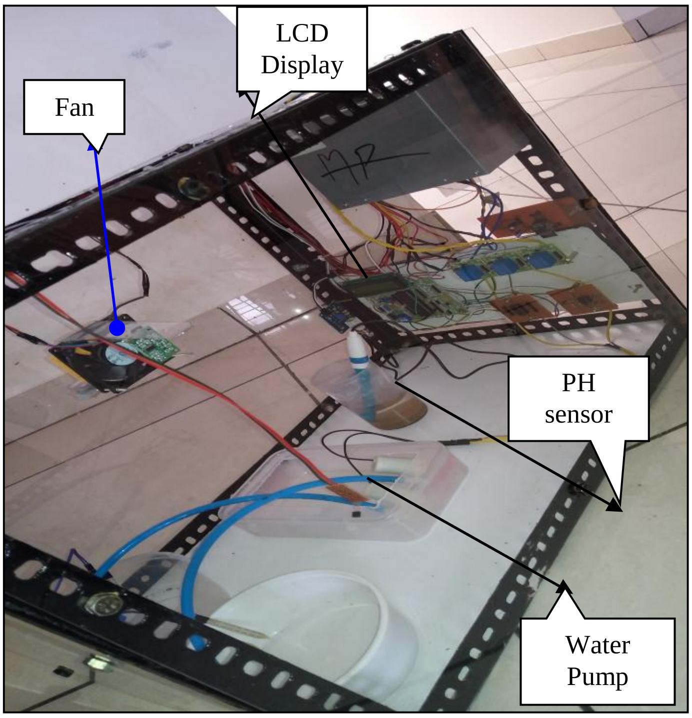

Figure 8. System Setup

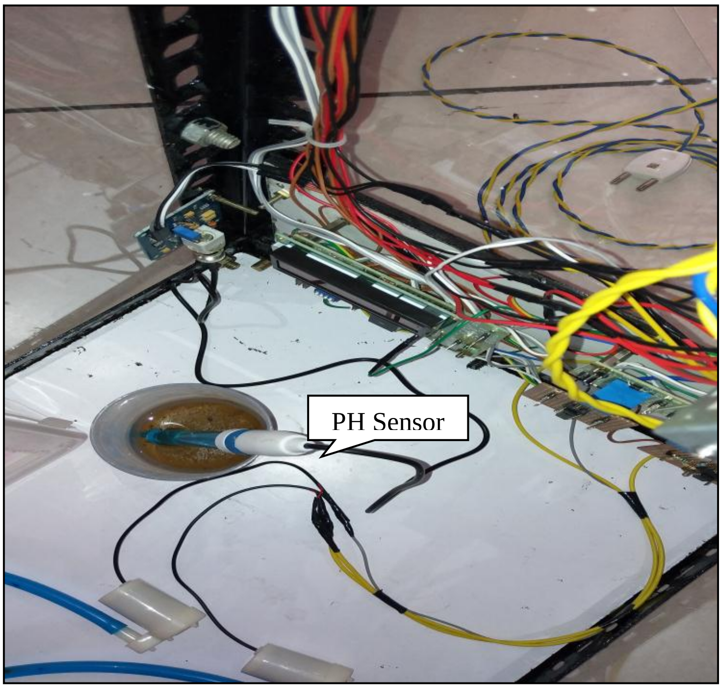

Figure.9 Sensors and LCD setup

Finally the data obtained is transmitted through the Wi-Fi module and obtained in a web domain as follows

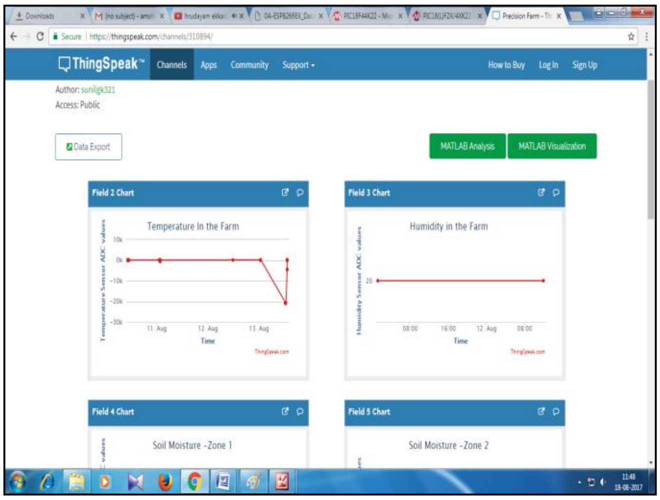

Figure 10. Data obtained in web domain

Here the data obtained is collected in the form of graphs with X-axis representing the time in terms of 5 minutes and Y-axis representing the sensor values.

5. CONCLUSION

A step-by-step approach in designing the microcontroller based system for measurement and control of the four essential parameters for plant growth, i.e. temperature, humidity, soil moisture, and nutrients i.e., nitrogen and PH has been followed. The results obtained from the measurement have shown that the system performance is quite reliable and accurate. The system has successfully overcome quite a few shortcomings of the existing systems by reducing the power consumption, maintenance and complexity, at the same time providing a flexible and a low cost precise form of maintaining the environment. The performance of the system can be further improved in terms of the operating speed, memory capacity, and instruction cycle period of the microcontroller by using other controllers such as AVRs and PICs. The number of channels can be increased to interface more number of sensors which is possible by using advanced versions Microcontrollers. Further the nutrient dosing can be made more accurate by developing NPK sensors and using those accurate sensor values.

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