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An Automated Soil PH and EC Indicator cum Controller System for Nutrigation Adjustment

Anshika Sharma[1] and Dr Avnesh Verma[2]

[1] M. Tech Student, Department of Instrumentation, Kurukshetra University, Kurukshetra-136119 (Haryana) INDIA.

[2] Assistant Professor, Department of Instrumentation, Kurukshetra University, Kurukshetra-136119 (Haryana) INDIA.

anshika3438@gmail.com, verma.avnesh@rediffmail.com

Abstract: Improper ratio of nutrients input in soil severely affects the human health and enviournment. Appropriate irrigation and nutrilization is essential to produce good quality growth in plants. The plants growth can be successfully regulated by managing the pH and EC of the Nutrigation solution according to soil requirement. An automated soil pH and EC indicator cum controller system for Nutrigation has been developed to provide balanced nutrition level in plants. Developed system comprises of two sensors (pH sensor, EC sensor) to measure pH and EC of the Nutrigation solution, AT89C51 microcontroller is used as the manager and controller of sub-modules such as valve control module, EC/PH measurement module, and power module etc. The output signals from the sensors are interfaced to microcontroller through ADC. Computed results are displayed on LCD. The results show that the system is controlling nutrient application is more accurately and uniformly. This system has shown ample benefits such as immediately available to plants, the system is very simple to operate, install, requires less maintenance and can be easily used for on-field testing. It also minimizes the risk of environmental harm. The simulation results shows that the controller developed can realize the intended function accurately i.e. pH and EC of Nutrigation solution in maintained on the basis of output readings from pH and EC sensors.

Keywords; *Nutrients, Enviournment, pH & EC, AT89C51 microcontroller, sensors.*

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1. INTRODUCTION:

India is an agriculture based country. More than half of our economy depends upon agriculture. It occupies a weight age of about 50% in GDP. For many years; Farmers have been using Traditional methods of farming. With continuous cultivation and inefficient management of fertilizers inputs has resulted in the consumer malnutrition, environmental concerns and decrease in crop yield. With the evolution of technology, the farmers have adopted many new techniques to increase their production. The main factors which restricts the development of agriculture, is the inefficient management of nutrients. In such a case, it is advisable to exploit advanced Nutrigation equipment which nutrigates the soil according to the crop requirement [1,2].

A high quality vegetable products and its need in large amount to meet the growing demand of world population. It justifies the development of automated Nutrigation system which nutrigates crops according to the demand of nutrients in the growing procedure by managing the pH and EC level of soil. It not only increases the crop yield and quality of farm produces, but also saves nutrient resources.

This is why modern Nutrigation techniques will be the main direction for our agriculture. Nutrigation System provides balanced nutrition level to the plant by modifying the pH and EC level of nutrients w.r.t soil parameters. The delivery of nutrients in the field with irrigation water is known as Nutrigation. Its efficiency in nutrient management has greater control over crop performance [3-6].

The authors have proposed a multi-ion measuring system (MIMS) for proximal sensing of soil nitrate, potassium and sodium using Ion Selective Electrodes (ISEs). This system automates the measurement process including ISE calibration, temperature compensation, and soil analysis with nutrient estimation in less than 30 seconds [7]. A Wireless Sensor Networks (WSN) is used in agriculture applications through Sensors to measure soil pH [8]. This paper has proposed a solenoid valved sensors to maintain balanced nutrition level for plants by managing pH and Electrical conductivity level in fertilizer solution [9]. This paper aimed to present the effect of the concentration of the nutrient solution, controlled as electrical conductivity (EC), on water uptake of tomato (cv. Counter) in closed hydroponic systems [10]. The authors have proposed pyrosequencing technique to characterize bacterial communities in 88 soils from across North and South America, and have found that overall bacterial community composition, in the relative abundances of Acidobacteria, Actinobacteria, and Bacteroidetes across the range of soil pHs [11]. Some authors emphasized that appropriate irrigation and fertilization is critical to produce good quality plants in a sustainable way. Irrigation can be controlled with capacitance sensor, and this study had the objective of developing a system to control fertilization and irrigation [12].The authors developed an automatic control system for real time preparation and application of nutrient solution for tomato production [13].

The pH and EC are two important indices of Nutrigation. They represent the whole quality and characteristics of nutrients and soil. It varies for different plants and soils. The pH is a measure of the acidity of the water or soil based on its hydrogen ion concentration and is mathematically defined as the negative logarithm of the hydrogen ion concentration, or pH=-log [H^+], where the brackets around the H^+ symbolize "concentration"

The pH of a material ranges on a logarithmic scale from 1-14, where pH 1-6 are acidic, pH 7 is neutral, and pH 8-14 are basic. Lower pH corresponds with higher [H^+], while higher pH is associated with lower [H^+]. The Electrical conductivity (EC) is a measurement of the dissolved material in an aqueous solution, which relates to the ability of the material to conduct electrical current through it. Higher the dissolved material in a water or soil sample, the higher the EC will be in that material [14-21].

After this brief description, the paper is outlined as follows: **Section 2:** Hardware description; **Section 3**: Fertilizer selection; **Section 4:** Software design; **Section 5:** Results and **Section 6:** Conclusion

2. HARDWARE DESCRIPTION OF AUTOMATED SOIL pH AND EC INDICATOR CUM CONTROLLER SYSTEM FOR NUTRIGATION ADJUSTMENT

2.1 pH and EC Indicator cum Controller Design:

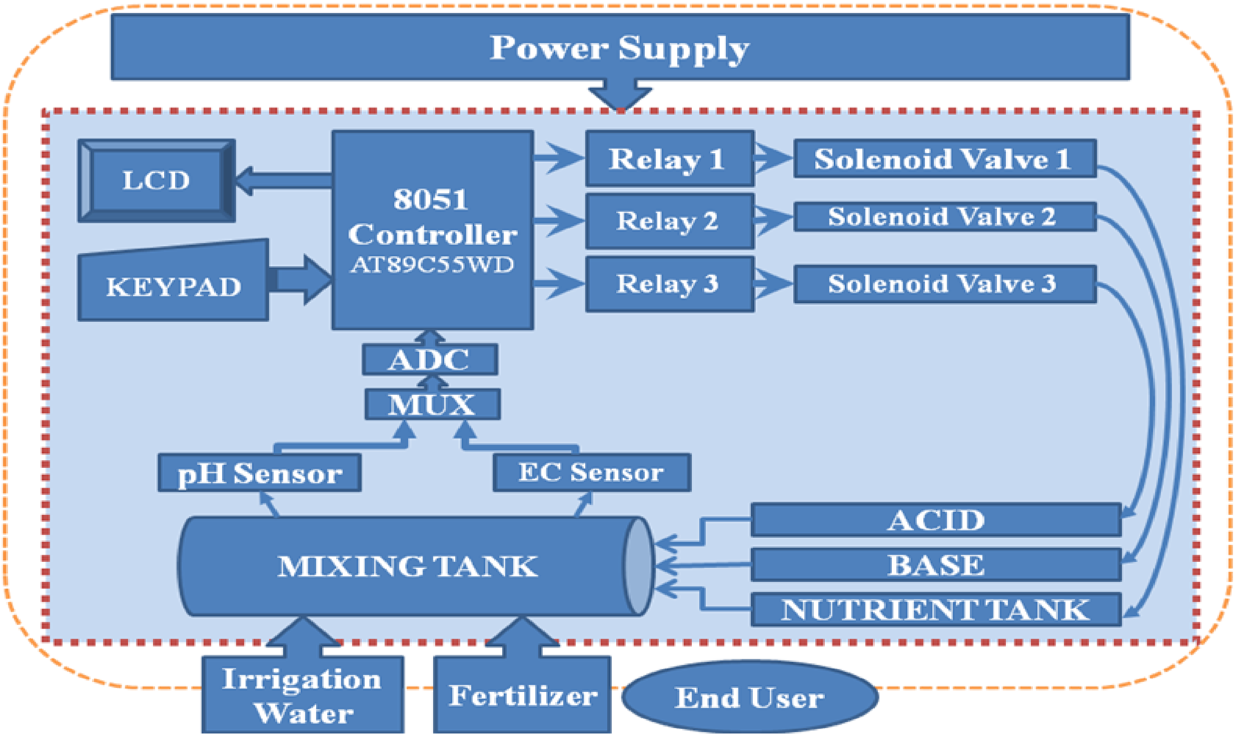

Fig.1 Block diagram of Proposed Controller.

The microcontroller AT89C51 has been programmed in such a way that it will take feedback from two sensors i.e. pH & EC and will give command to Solenoid Valves for opening & closing with the help of

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relays so as to mix nutrients in the mixing tank if requires. Solenoid valve schedule perform according to predetermined program that controls the valve according to the pH and EC of the solution. The pH and EC Indicator cum Controller comprises two sensors (pH sensor, EC sensor) to measure pH and EC values in Nutrigation solution. The microcontroller AT89C51 is used as taskmaster of sub-modules. pH values are used to control availability of nutrients in the nutrient solution. The EC values are used to give information about the quantity of fertilizer being injected into that nutrient solution. If EC values are higher than the required amount, so higher amounts of nutrients are required to be injected in the fertilizer solution. Nutrient tanks supplies nutrients and mixing tank are used to mix nutrients in the soil solution as shown in fig.1 [22-25].

2.2 HARDWARE DESIGN:

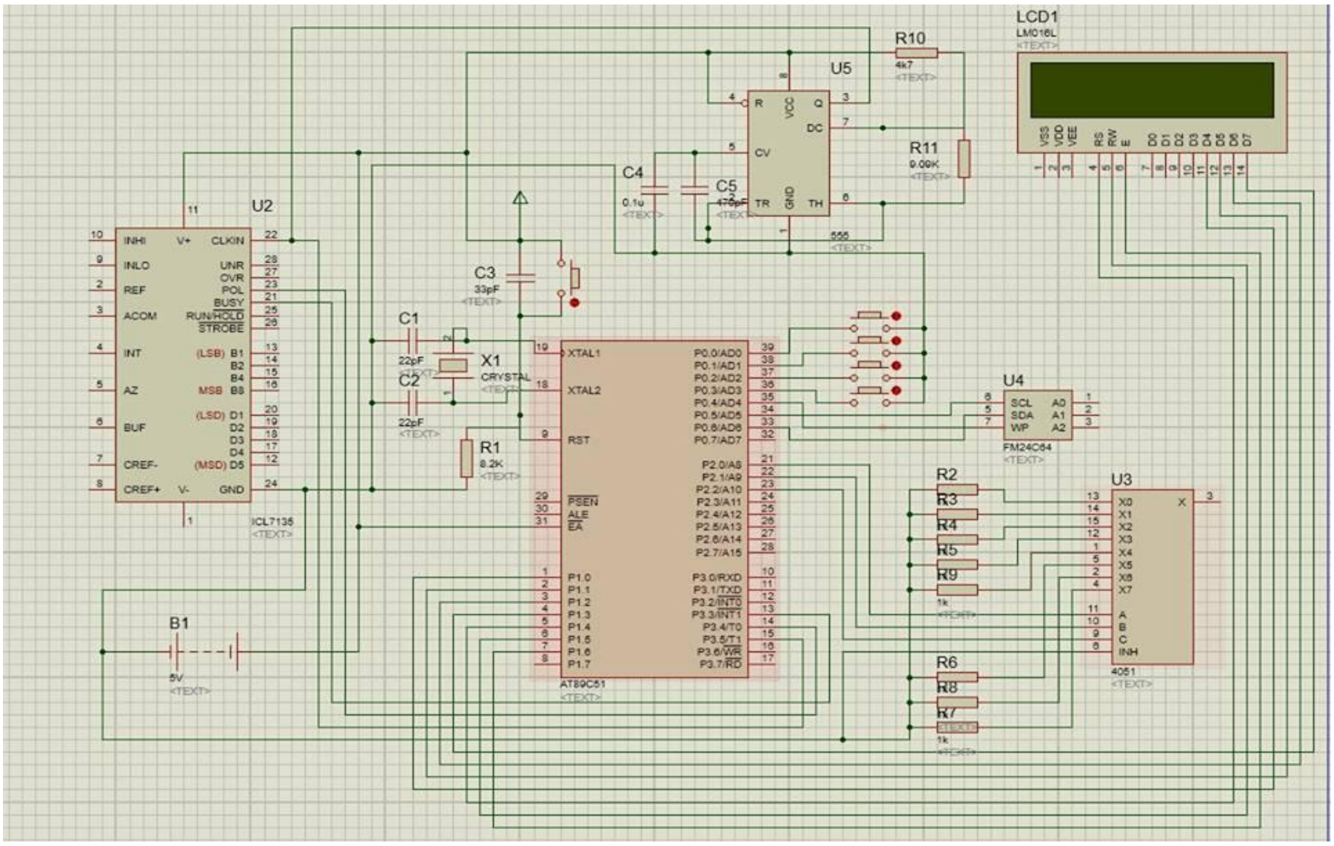

Fig. 2 Circuit Diagram of the System

Fig 2 shows 8-bit AT89C51 Microcontroller which has been programmed for the dedicated application with 4K Bytes. AT89C51 Microcontroller has been selected due to its features such as erasable read only memory (PEROM) and 128 bytes of RAM, it also has an inbuilt UART for serial communication. The other device in the circuit is 64Kbit CMOS non-volatile serial EEPROM FM24C64 with 8K x 8 bit memory. Another device 4051 is connected due to its inherent features of MOS (metal oxide semiconductor) technology with Single 8-channel analog multiplexer/demultiplexer. The ICL7135 is 4 1/2 Digits, BCD Output, A/D Converter [22-23].

The pH and EC sensors convert the soil parameters into electrical signals. Signals are then amplified and processed so that these can be fed to the multiplexer (MUX 4051). 4051 is an analog multiplexer/demultiplexer is a digitally controlled analog switch having low ON impedance and very low OFF leakage current. This device is a single 8-channel multiplexer having three binary control inputs, A, B, and C, and an inhibit input. The three binary signals select 1 of 8 channels to be turned on, and connect one of the 8 inputs to the output. When a logic "1" is present at the inhibit input terminal all channels are off Pin 13 & 14 are connected to the pH and EC module and the output of Multiplexer (pin num 3) is given to ADC 7135 (pin num 10), it converts the analog signal into digital signal [23-24].

In 40 pin AT89C51, there are four ports designated as P_1, P_2, P_3 and P_0. All these ports are 8-bit bi-directional ports, *i.e.*, they can be used as both input and output ports. Except P_0 which needs external pull-ups, rest of the ports have internal pull-ups. When 1's are written to these port pins, they are pulled high by the internal pull-ups and can be used as inputs. These ports are also bit addressable and so their bits can also be accessed individually. Port P_0 and P_2 are also used to provide low byte and high byte addresses, respectively, when connected to an external memory. Pin num 21, 22 and 23 of ADC are connected to pin num 13, 15 and 14 of microcontroller (AT89C51) respectively. It has internal watch dog timer that keeps check on the working of the controller and gives pulses to it. This controller sends signals to the display and indicates the pH and EC readings of the solution. Keys are interfaced to enter or select the values of pH and EC. And these values of pH and EC selected or entered are compared with the solution's pH & EC readings. On the basis of this calculation, relays perform their functions by opening the particular solenoid valves to meet the desired level of pH and EC. Port 3 has multiplexed pins for special functions like serial communication, hardware interrupts, timer inputs and read/write operation from external memory [22-25]. In each case the microprocessor can instruct the A/D when to begin a measurement and when to hold this measurement.

2. FERTILIZER SELECTION

The irrigation water quality, growing place, soil characteristics and plant characteristics are the major components which affect the fertilizer composition. The main factors affecting fertilizer composition are the plant characteristics, soil characteristics, irrigation water quality and growing place. The dominant nutrients are supplied to the plants through nitrogen (N), phosphorus (P) and potassium (K). On the other hand nutrigation processes are occasionally applied in the field through calcium (Ca) and magnesium (Mg). The micronutrients such as Boron (B), iron (Fe), manganese (Mn), zinc (Zn), copper (Cu) and molybdenum (Mo) are generally feed through foliar sprays because they are required in small amounts. With the application of such fertilizer solutions the overall soil pH is altered. Ammonium composed fertilizers make solution Acidic while nitrate composed fertilizers make solution alkaline. Urea fertilizer solution is used to decrease pH level. Elements such as Sulphur, ammonium sulphate and compounds such as iron or aluminum sulphates can reduce the soil pH. Many a times lime solution has to be added to the soil to neutralize Acidic soils, the composition of the lime depends upon the buffering capacity of the soil. Gypsum is commonly used to remove extra sodium (Na+) ions from soil profile and improve saline soil.

The mixing container with 50-75% of the required water should be used in the mixture if using dry soluble fertilizers. Always put acid into water rather than water into acid.

4. SOFTWARE DESIGN

4.1 ALGORITHM

Figure 3 depicts the flow chart of fertigation control system algorithm. The main steps of flow chart are given as following:

1. Start the device and initialize it
2. Select the crop from table if existing and check if change of parameters (pH& EC) required or not
3. In step 2, if change of parameters is required then enter the required parameters of crop
4. Now find the sample solution actual pH & EC using sensor
5. Comparison of the required parameters of Crop with actual parameters of sample solution is done using microcontroller
6. Select the parameter which is to be modified i.e. pH or EC
7. As per the selected parameter microcontroller will get the signal from sensor

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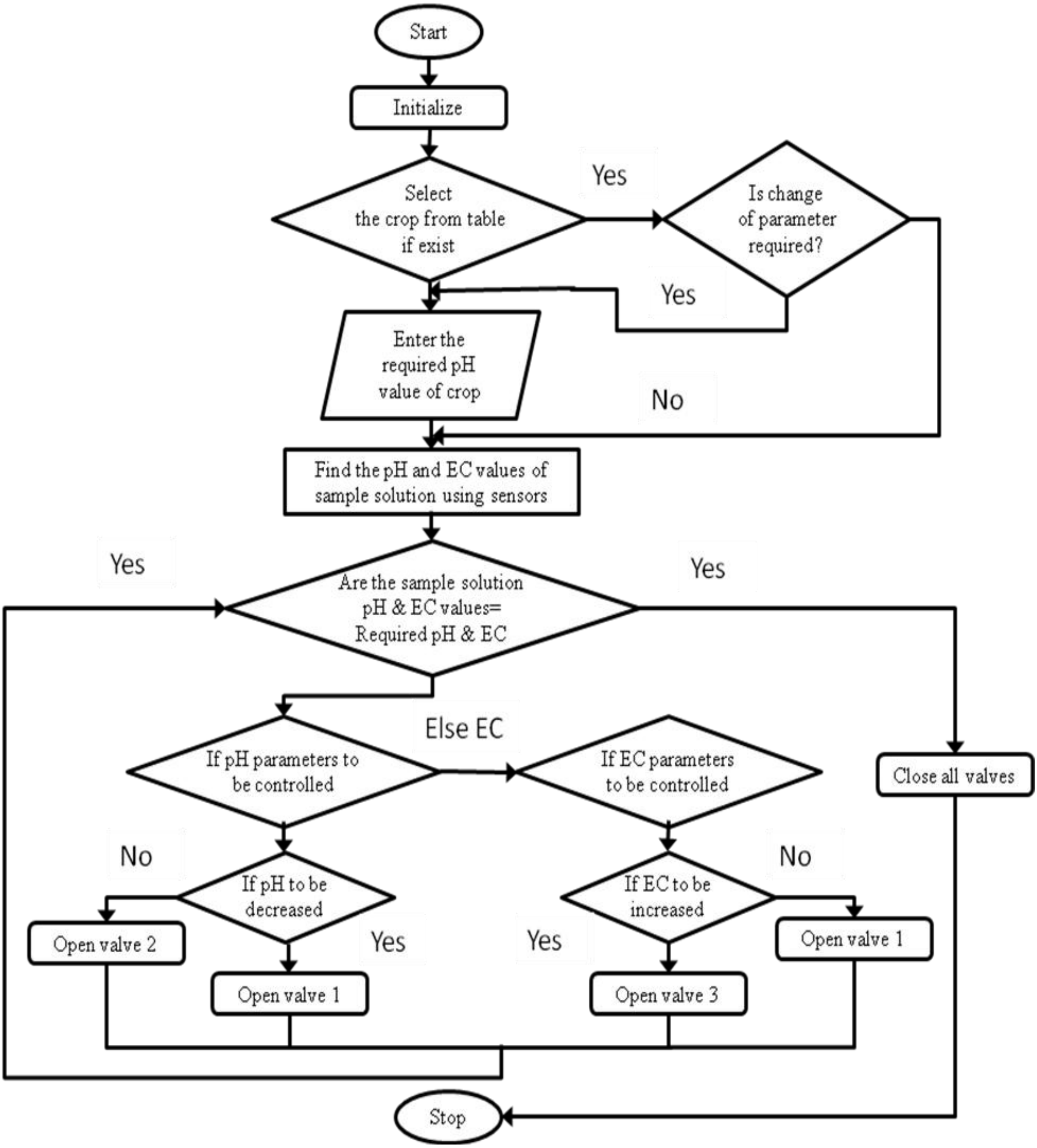
8. Comparison of actual value of selected parameter with required value of crop is done using microcontroller and on this basis, microcontroller will turn on and off the particular solenoid valve and corresponding nutrients from the tanks will be poured in the mixing tank till requirement is achieved
9. When required parameters are achieved, the system will stop and will go back to the start.

4.2 FLOWCHART



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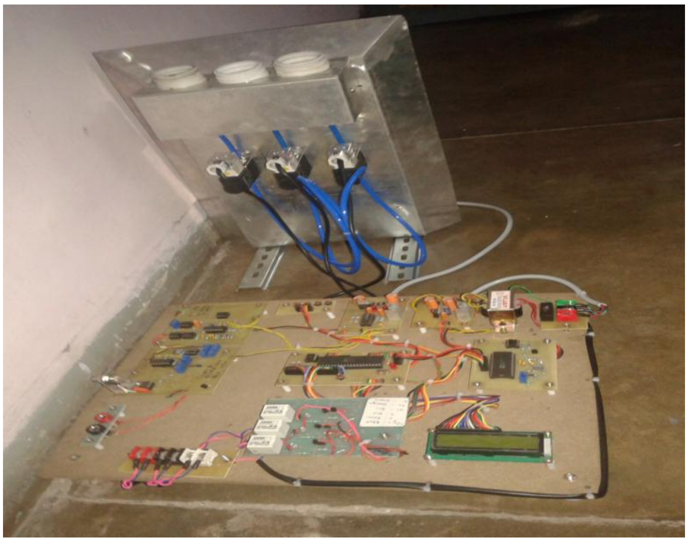
4.3 Complete Enclosure of the Product



5.RESULTS AND DISCUSSION

The developed system was tested using hydrochloric acid and sodium hydroxide. The control unit presents satisfactory operation of all the valves as per the programming. Bicarbonates, carbonates and hydroxides increase the alkalinity of water. Phosphoric, nitric and sulfuric acids decrease the pH and make the solution acidic. Fertilizers are forms of salts and therefore electrical conductivity rise with addition of fertilizers.

4.1 pH CHARACTERISTICS

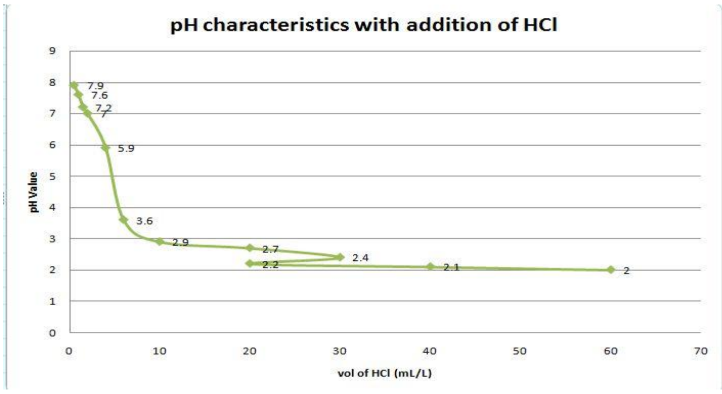


Figure 3. pH characteristics according to the addition of acid fertilizer

Figure 3 clearly indicates that with the addition of acid (HCl) to water lower the pH level of solution from 8.0 to 2.4 even upto 2.0 i.e. addition of acid or acid containing fertilizers lowers down the pH of soil/water sample according to the crop requirement.

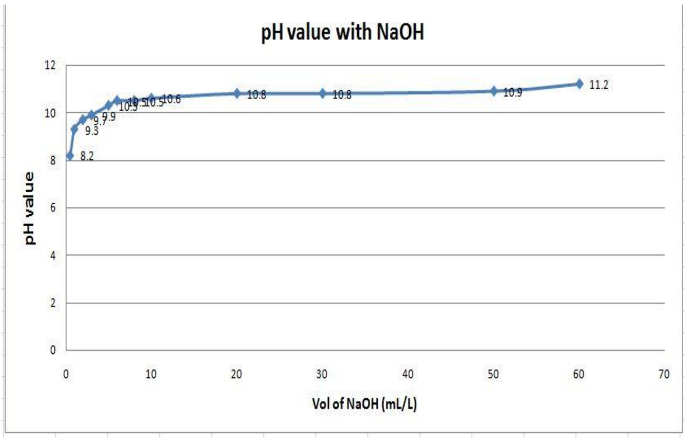


Figure 4. pH characteristics according to the addition of base fertilizer

Figure 3 clearly indicates that with the addition of base (ammonium hydroxide) to water, the pH in solution raises from 8.2 to 11.2 i.e. addition of bases will raise the pH of soil/water sample according to the crop requirement.

Ammonium forming fertilizers make solution acidic while nitrate forming fertilizers contains basic ions and are less acidic forming make solution alkaline. Elemental sulphur, ammonium sulphate and nitric acid and compounds such as iron sulphates can reduce the soil pH. And if chemical containing fertilizer is not the priority then acidic soils can be neutralized over time with the application of lime.

4.2 ELECTRICAL CONDUCTIVITY CHARACTERISTICS

Addition of acids and bases one by one to the water sample increases the conductivity level as the water sample is neither acidic nor alkaline described in the graph drawn below. The EC value with the addition of acid has been sharply increased from 240 to 1180. Whereas EC value with the addition of base has remain somewhat steady its value changes from 240 to 425.

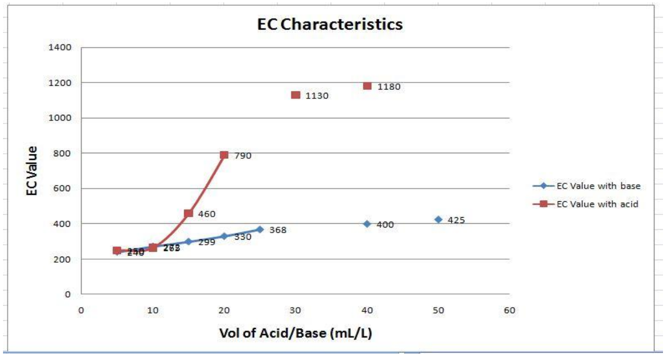


Figure 5. EC characteristics according to the addition of acid and base

Addition of Urea also raises the conductivity level of solution. Saline soils are also termed as alkaline soil. Gypsum is the most common amendment used to remove excessive amounts of sodium ions from soil profile and improves saline soil.

If the sample is acidic, then adding alkaline fertilizer will raise the EC level of solution and if the sample is alkaline then adding of acidic fertilizer will lower down the EC level of solution.

So, it is necessary to check the pH value of sample solution first which will tell us that if we need to lower or raise the EC level of solution according to crop requirement.

5. CONCLUSION

The Investigator has developed a system using microcontroller to automatically control the pH and EC of the Fertigation solution with respect to the crop parameters. The hardware design of the module microcontroller has been realized. This will reduce the effect of high concentration of salt and minimize the pH problems in the soil by spreading fertilizers in the controlled manner and also will improve the productivity. The result of solution's pH measurement gives the information about availability of nutrients in solution and EC readings are indicative of amounts of fertilizers being injected into the Nutrigation system. After implementation of the developed automatic soil pH & EC indicator cum controller system for Nutrigation, parameters pH and EC have been controlled. It was observed that it will lead to a remarkable saving in use of fertilizers. This will not only saves money of a farmer but also protect the fertility of soil and crop yield. This system may help in the efficient use of fertilizer and also helps to improve soil structure and environment. So this indigenously developed low cost auto fertilizer control system ensures better returns to human's health and environment.

6. FUTURE SCOPE

The developed system can be upgraded to control the pH and EC of Nutrigation solution for more crops and also controlling the fertilizers quantity with respect to irrigation water. Also the developed system can be powered totally by solar power system (solar energy). In this manner, the system can be installed at rural and remote locations to achieve reductions in costs and produce better yield for crops cultivated using Nutrigation systems.

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