INTL JOURNAL OF ELECTRONICS AND TELECOMMUNICATIONS, 2019, VOL. 65, NO.3, PP. 353-358
Manuscript received March 19, 2019; revised August, 2019. DOI: 10.24425/ijet.2019.126321

Design and Development of Cost effective Automatic Fertilization System for Small Scale Indian Farm

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***Abstract*—Most of the developing countries economy largely depends on the agriculture. More than half of the population rely on agriculture related activities for their survival. In spite of dependency on agriculture, the technological development of agricultural work in developing country is not comparable to the countries like Australia or Israel. The main reason behind the lack of development is the small size of farms. Such farmers cannot afford expensive technology available in the market due to limited profit margins. The report describes an autonomous fertilization system that takes care of the fertilization requirements of the small scale farms at affordable rates. The system is divided in two parts namely User Interface and Control System. The user interface is designed using the state of the art Raspberry Pi board and a touch screen LCD. The control system is developed using the Arduino platform and can control five fertilizers at a time. The output of the system is the mix of the fertilizer, which is forced into the drip irrigation system of the farm. The system has built in data for the fertilization requirement for important crops and vegetation. The system also facilitates the customize fertilization requirements to be added in the system as per the user requirements.**

***Keywords*—Fertilization, Automation, Electronics in Agriculture, GUI, Embedded System**

I. Introduction

THE agriculture dependencies of developing countries demands latest technological developments for the betterment. The small-scale farms or the local farmer can’t afford the advanced automatic tools for farming. The lack of advancement affects the growth of the farming and the people directly or indirectly involved with the same **[1]**. The latest technological advancement in the electronics and automation equipment makes it possible to develop state of the art automatic farming tools at a lower cost. The expense incurred in the deployment of tools is not the only requirement, but it is also necessary that the tools is easy to use so that the farmer effectively utilize the capabilities of the tool **[2, 1]**.

The amount of water available for the irrigation is a scarcity in modern farming. The drip irrigation is a remedy for the said issue **[3]**. Most of the countries, farming with the drip irrigation is very popular. The work aims to develop an ad-on system for the existing drip irrigation to make it more appropriate for small scale farming.

The main reason behind the lack of development is the small size of farms in developing countries. Such farmers cannot afford expensive technology available in the market due to limited profit margins. Occasionally, the farmers afraid of using the new technology due to lack of confidence in the use of the same. The idea is to develop a sophisticated automatic fertilization unit, which is a low cost solution of available costly equipment for the same task. This will bring ease of operation in the process of fertilization and low cost will motivate the farmers to use it. The developed system should be compatible with the existing drip irrigation systems of the farm. Moreover, the systems must be easy to use, so that an unlearned farmer can effectively use the same.

The specific goals for the Automatic fertilizer system are as follows:

- To design an automatic fertilization system for agricultural purpose.
- To develop accurate flow control to maintain the exact proportion of fertilizers to be added in the existing drip irrigation system.
- To develop a prototype system, which is generated hereby, can further be utilized for designing a larger size, practically implementable system.

II. Automation of Drip Irrigation Systems with Fertilizers

Automation of micro/drip irrigation system mentions to operation of the system with no or minimum manual interventions. Irrigation automation is well acceptable where a large area to be irrigated is separated into small sections called irrigation blocks and sections are irrigated in sequence to match the flow or water available from the water source.

Today in developing countries preferences towards atomization of drip irrigation with proper fertilization is gaining thrust due to following reasons.

- Automation eliminates manual operation of closing or opening the valves, especially in exhaustive irrigation process.
- Possibility to optimize the irrigation and fertilization process.
- Adoption of advanced crop systems and new technologies, particularly new crops system that are difficult and complex to operate manually.
- Use of water from different sources and increased water and fertilizer use efficiency.
- System can be functioned at night, thus the daytime can be employed for other agricultural activities.
- Pump starts and stops exactly when required, thus improving energy requirements

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Automated irrigation has various advantages including efficient use of water, greater precision and reduction in human error. It is very useful, particularly in moist areas where unpredictable and unevenly distributed summer rainfall disturbs fixed irrigation schedules. Automated irrigation system also facilitates high frequency and low volume irrigation.

The scientific scheduling of irrigation water and required minerals/nutrition to cropping system needs regular sensing of soil, microclimatic and soil moisture parameters **[4]**. The system having such sensors for water and nutrition will have its own real-time scheduling of the same. This saves lot of time, water resource, labor and nutrients, eventually reducing periodic costs of crop production.

The automation of the irrigation process is vital for three main reasons:

- Shortage of water
- Well-timed irrigation
- Supreme crop profit.

Automatic irrigation systems presently available are costly and are not adopted by most of the developing countries farmers. Therefore, appropriate low cost technology has to be established to facilitate high water and fertilizer use efficiency.

III. FERTILIZER AUTOMATION SYSTEM BLOCK DIAGRAM

Figure 1 shows the block diagram of the developed system. The idea is to develop a hardware unit that adjusts the amount of fertilizers to be added in the water supply of drip irrigation system. The farmer needs to fit the values of fertilizer requirement for a specific in to the system.

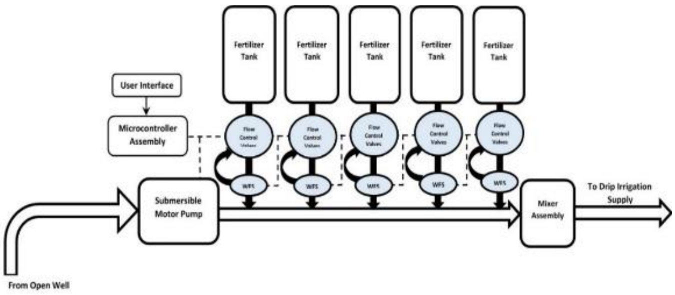

FIG. 1. PROPOSED BLOCK DIAGRAM

The system then automatically adjusts the amount of fertilizer in the outgoing water supply. To fulfill the requirements various electronic components are used. The requirement of the various components is stated step-by-step. The first component of the fertilization system is the Motor/ Submersible Pump. The job of the motor/pump is to pull the water from the open well or tank and push the same in the drip irrigation system. The aim of the project is to adjust the amount of fertilizer in the outgoing water supply depending on the preset fertilization values. To store the fertilizers the storage tanks are required. There are five storage tanks used in the present work. Which will support five various fertilizers to be added in the outgoing water. To control the amount of the outgoing fertilizer, every fertilizer tank is provided with a solenoid valve. The solenoid valve will work as an electronic tap and will allow the flow of water through it as and when required. To control the accurate amount of fertilizer is a challenging task. The solenoid valve is not an intelligent device. It will either allow the flow of water when on or not allow the flow when close. The flow of water from the solenoid valve depends on the pressure from the fertilizer available in the tank. If the tank is totally full then the amount of pressure is different from the case when the tank is partially filled. The variations in the pressure is decided by the amount of liquid present in the tank, which will vary depending on the usage of the fertilizer. To control the amount of fertilizer accurately, the solenoid valves are accompanied by water flow sensor. The water flow sensor will sense the amount of fertilizer flowing through the solenoid valve and the valve will be opened or closed accordingly. All the fertilizer tanks are equipped with the assembly of a solenoid valve and a water flow sensor.

The different amount of fertilizers is added to the outgoing water supply. It is not necessary that all the solenoid valve are open or closed at the same time. The mis-synchronization of the operation of the solenoid valve makes it difficult to make a proper mixture of all the fertilizer.

It may happen that in a specific portion of outgoing water a particular fertilize is absent, because the requirement of amount of that fertilizer is very less and the solenoid valve opens only once in a particular time to supply that fertilizer. This makes the distribution of fertilizer uneven. To avoid such situation, a mixer tank is provided in the system. All the fertilizer tanks are connected to the mixer tank. The amount of fertilizers required to add for a specific vegetation are mixed in the mixer unit first and then the mixer of all the fertilizer is provided to the outgoing water supply. The entire system is electronically controlled. A human interface will facilitate the user to add the amount of fertilizer required for a specific vegetation or to make the necessary changes for the new vegetation he needs irrigate.

IV. IMPLEMENTATION OF AUTOMATIC FERTILIZER SYSTEM

This section discusses various algorithmic steps followed for the designed Automatic Fertilization System. The development of the automatic fertilizer system is mainly divided in two parts.

A. Automation Control of the system
B. GUI Development of the system

The automation control unit mainly deals with the development related to Arduino board. The programming of Raspberry Pi and interfacing with the touch screen LCD are part of the GUI Development.

A. Automation Control

The automation control is designed using the Arduino board. The Arduino board controls the operation of the solenoid valve through the relay board till it receives the feedback from the flow sensor. The data for the control of the solenoid valve is received from the Human Interface. The entire process repeats when the mixer tank gets empty. The algorithm of the entire process is listed below step wise.

Step 1: Check the amount of fertilizer present in the mixer tank. This task is performed using the ultrasonic sensor connected on the top of the mixer tank. The ultrasonic sensor measures the upper surface of the fertilizer solution present in mixer tank. Two thresholds are decided for the mixer tank. One threshold is to start the filling process and the second is to stop the filling process. The ultrasonic sensor transmits the sound waves and the same are reflected back from the surface of the liquid present in the tank. The relation of the voltage received and the measured distance using ultrasonic sensor is presented in Table I.

TABLE I

MEASUREMENTS OF ULTRASONIC SENSOR

Digital Value Received on Board	Actual Distance
1722	30 cm
1148	20 cm
845	15 cm
536	10 cm
251	05 cm

Step 2: Check for the new values received from the Human Interface

If the mixer tank is found empty then the next task is to fill the mixer tank with the fertilizers. The process is carried out depending on the data received from the Human Interface, which is connected to the UART of the Arduino board. The Arduino board checks receive pin of the UART terminal. If any new data is to be transmitted from the Human Interface then it will trigger the Arduino board for the same and it receives the data serially.

Step 3: Control the Solenoid Valve

The solenoid valve is connected to the digital output of the Arduino board. Each digital pin is allocated to each solenoid valve. To make the valve on, the pin is forced to high or vice versa. The solenoid valve has three connections.

Step 4: Measurement of the flow

The flow sensor is a Hall Effect sensor. It generates specific number of square pulses for a specific amount of flow passing through it. The Arduino uses the external interrupt on any digital pin. This is used to read the output pulses coming from the water flow sensor. When Arduino detects the pulse, it immediately triggers the counter and increments it. Thus the total number of pulses are detected for a specific amount of time. In this case the pulses are counted for 1s. The flow rate is determined by change in velocity of fertilizer flowing through the sensor. Velocity depends on the pressure that forces the through pipelines. As the pipe's cross-sectional area is known and remains constant, the average velocity is an indication of the flow rate. The basic relationship for determining the liquid's flow rate in such cases is $= V \times A$, where Q is flow rate/total flow of water through the pipe, V is average velocity of the flow and A is the cross-sectional area of the pipe. In this case the pulse frequency is calibrated experimentally as:

$$\text{Pulse frequency (Hz)} = 7.5Q \qquad (1)$$

The pulse frequency is measured using the counter that counts the number of pulses in a second. Once the number of pulses is found, the Q can be found out using (1). Once the flow is achieved as per the requirements, the Arduino forces the solenoid valves to go off.

In the steps discussed above, the DC motor of the mixer tank that mixes the fertilizers from various tanks is continuously on and keeps on mixing the liquid coming from all the tanks. The steps discussed above are presented by a flow chart in Figure 2.

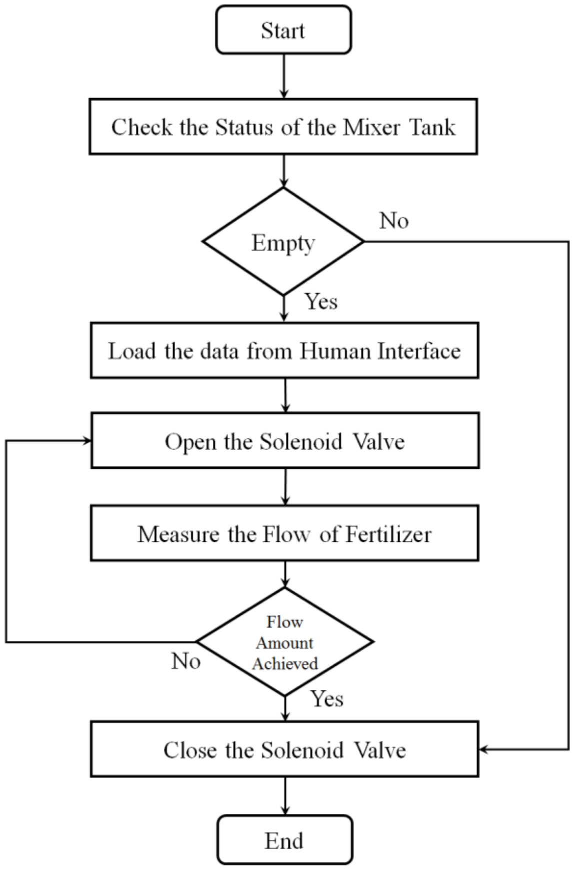

FIG. 2. FLOW CHART OF AUTOMATION CONTROL UNIT

B. GUI Development

The GUI is a Graphical User Interface developed to provide ease of use. The GUI is developed on the Raspberry Pi board. To develop the GUI, Guizero tool is used. Followings are the snap shots those indicate the developed GUI using Guizero.

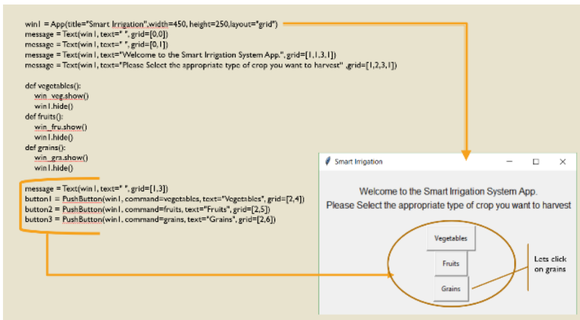

FIG.

FIG. 3. WELCOME MASSAGE OF THE GUI

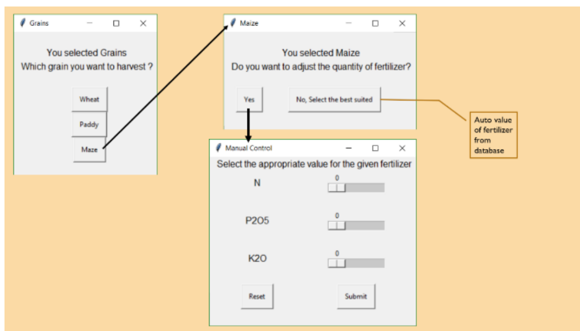

FIG. 4. GUI FLOW

The flow is loaded on the Raspberry Pi board. The database for storing the fertilization values for different vegetation needs to be stored in the Pi board. For the storing of the data, the My SQL software is used.

Once the installation and configuration of the required OS and tools are completed, the required database is to be create. After the configurations, the table as per the choice of the user is created. The said table is linked with the code written in Python and associated with the GUI developed. The user may follow the command on the GUI and select the pre-stored database or may also add any new data for the new vegetation. Once the table and the system for entering the data is ready, the next step is to store the data for specific vegetation in the system. The developed systems has the fertilizer tanks for 20 liters capacity. The mixer tank is also of the capacity of 20 liters. The algorithm is set such that the amount of fertilizer from a specific tank is decided keeping the mixer tank as a reference. Suppose a venture valve gives X percent of amount compared to 1 liter of outgoing water. The mixer tank is of 20 liters that makes the outgoing water of $2000/X$ liters for 20 liters of the mixer solution. In this solution the amount of fertilizer is $(2\times Y)/X$ liters, where Y is the milliliters amount of fertilizer required in 1 liter of water. Table II shows the database considering the above calculations. This database is prepared using the literature review carried out and **[3, 4, 5, 5, 2, 6, 1, 7, 7, 8]**. The amount shown in the table for any fertilizer is in ml if the outgoing water supply is 20 liters.

TABLE II

DATABASE STORED IN THE SYSTEM

Crop	Ammonium nitrate	Ammonium Sulphate	Potash Chloride	Potassium Sulphate	Mono Ammonium Phosphate
Cotton	0.09	0.09	0.028	0	0.19
Groundnut	0	0.12	0.125	0.125	0.52
Jute	0.813	0	0.204	0.204	1.2
Maize	0.08715	0.08715	0	0.03328	0.278
Paddy	0.01867	0	0.009396	0	0.0239
Pearl Millet	0	0.00528	0.0221	0.0221	0.177
Pigeon pea	0.4059	0.4059	0.132	0	1.505
Rapeseed	0	0.0946	0	0.01176	0.131
Sorghum	0.32175	0	0.08025	0.08025	0.545
Sugarcane	0.0659	0.0659	0	0.1	0.17
Wheat	0.01988	0	0.00384	0	0.024

V. RESULTS

The developed system is a hardware system and the results are mainly in form of the demonstration of the working hardware. This section presents various snap shots for the developed project. The interfacing of various components with the Arduino board is displayed. The developed GUI is also presented in this section.

A. Automation Control Unit and Components

The system software starts with the status of the mixer tank. Figure 5 shows the mixer tank connected with a DC motor for the mixing of the solution added to it. It also contains the ultrasonic sensor for the measurement of the status of the liquid inside the tank.

If the mixer tank is not filled for a required amount of the fertilizer then the feedback is given to the Arduino board and it will trigger the solenoid valve. The solenoid valve is connected with the flow sensor. The combined assembly of flow sensor and solenoid valve is shown in Figure 6.

FIG. 5. MIXER TANK

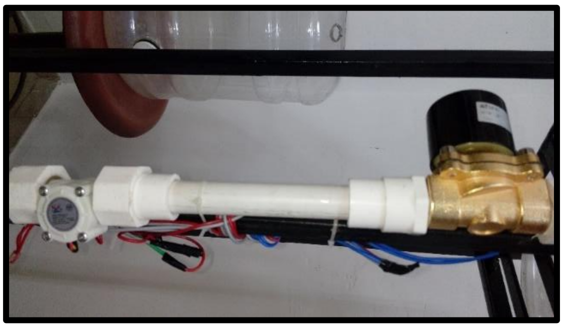

FIG. 6. SOLENOID VALVE AND FLOW SENSOR

The valve and flow system is attached to the fertilizer tank and such five tanks are incorporated in the system as shown in Figure 7.

FIG. 7. FERTILIZER TANKS

The heart of the system is the Arduino board. The interfacing of Arduino board, relay board and SMPS is seen in Figure 8.

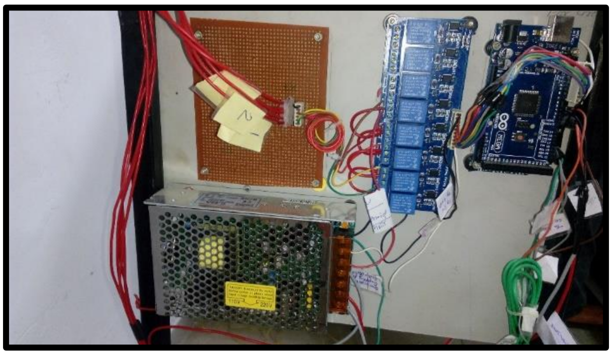

FIG. 8. ARDUINO INTERFACING WITH RELAY BOARD AND SMPS

The touch screen LCD provides the ease of operating the Human Interface. Figure 9 to Figure 11 present the GUI on the touch screen, which is interfaced with the Pi board. Once the power is applied to the system, the first massage that is seen on the screen is a welcome massage. On this menu it also asks the user to choose the option for modifying the existing data or to go with the existing data. Once the existing data option is selected, the menu will ask for the selection of an appropriate vegetation and then the commands are passed onto the automation control unit.

FIG. 9. WELCOME SCREEN

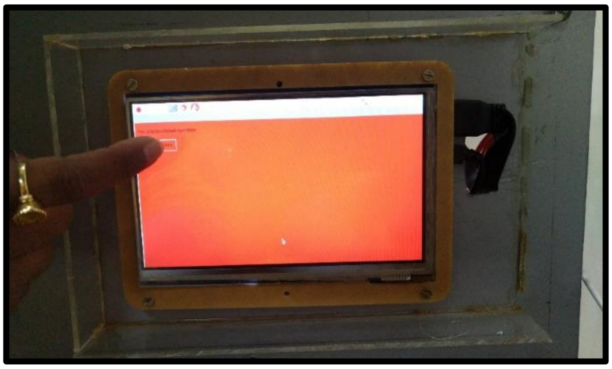

FIG. 10. DATA MODIFICATION OPTION

FIG. 11. SELECTION OF VEGETATION

FIG. 12. AUTOMATIC FERTILIZATION UNIT

The Figure 12 shows the picture of the entire system. The system accepts 230 V AC 50 Hz as supply. It is assembled on a metal rack for support and deployment and can be easily deployed in the small scale farm.

VI. CONCLUSION

The automatic fertilization system is developed, which is low cost and hence suitable for small farming conditions. A system facilitates the use of five different fertilizers to be added in the outgoing water supply. The system can directly be connected with the water supply of drip irrigation system. To control the amount of fertilizers in the outgoing water supply, an accurate control system with use of Arduino board is developed. For modification in the fertilization data and to provide ease of use the system is equipped with a touch screen LCD. The GUI is developed to incorporate the human interface with the system. The low cost system works on 230 V 50 Hz AC supply and appropriate for use in the small-scale farming.

VII. ACKNOWLEDGMENT

Authors are thankful to the Nirma University for providing financial support to carry out project under Minor Research Project funding scheme. Authors are also thankful to Mr. Viral Joshi (Senior Research Associate, Junagadh Agricultural University) for providing their valuable inputs during course of development.

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