Smart Water Distribution for Irrigation System (SWDIS)

Qamar Uddin Khand, Ali Raza Barket

Abstract - Agriculture plays a vital role in the economy of any country. Therefore it needs more enhancements by improving its manual methods with the help of technology. In irrigation system, water plays a vital role in crop production. This study proposes smart water distribution system for irrigation system. Microcontroller is used to control the water distribution according to the requirements of crops. Real time watering requirements are measured through embedded sensors placed in each field. A user-friendly GUI based application is developed that enables the user to monitor and control the water distribution. By using this application, user can schedule the water distribution plan for automatic distribution in advance. User can also easily analyze the history of water distribution in the form of graphs and also estimate the consumption of power with respect to crops.

Keywords: Smart Water Distribution, Intelligent irrigation, Automatic Irrigation System, Smart Irrigation System, Renewable Energy.

I. INTRODUCTION

Agriculture is the practice of farming, including cultivation of the soil for the growing of crops and the rearing of animals. In order to cultivate the soil for growing the crops, different irrigation methods are proposed and followed according to the environment and available resources. Therefore, efficient irrigation system plays an important role in crop productions and has direct effect on country's economy.

In irrigation system, the crops mainly rely on water that is supplied through canal systems but tube wells are also used as an alternative resource of water. Unfortunately, underground water is falling down due to reduction in rainfall because forest cutting is increasing day-by-day. Sometimes other factors also contribute; like climate changes (i.e. water stored in the ground, underground seepage) that deals to reduce crops production [1]. Therefore, there is a huge need of efficient usage of available water resources according to the needs of crops for better produce. Furthermore, in irrigation management, irrigation scheduling is an important element to improve irrigation efficiency. Irrigation scheduling research focus on evapotranspiration (ET) estimation methods and improved sensors technology for irrigation scheduling. Several new plans and soil water sensor technologies have huge impact to improve irrigation management [2].

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In manual irrigation system, farmer has no precise measurement control over the distribution of water in each field that leads to the improper water distribution. The farmer needs to have an adequate knowledge and ability to determine the water needs for proper cultivation according to crops type. What amount of water is exactly useful and necessary for proper cultivation of their crops? In order to do this, farmers need to have an awareness about latest technology that can help them save consumption of water by determining exact needs of water required to a particular crop filed at particular time. The farmers can also measure the soil's moisture level, maintain the history, automatically control the whole management system and provide them energy efficient solution for tube wells at an affordable cost.

In this research, tube wells are considered as a main resource of water distribution. For this purpose, gates are fixed at each field, and the operation of gates for water distribution is basically based upon the water demand(s) of the particular crop(s) in the field. In order to know which field needs water can be sensed via sensors embedded in each field. This information collected from embedded sensors in each field also helps in monitoring and scheduling different events over land and collected information can further be used for different analysis and research purpose. The proposed method suggests an innovative research based solution that will give bust-up to agri-business in terms of the crop production and impact over water utilization through the use of modern technology. The system Smart Water Distribution for Irrigation System (SWDIS) is designed for the better production of crops by using alternate energy resources. The system will operate tube well using energy generated from the solar energy for the continuous operation as a primary source. This will help minimize the overall cost (i.e. operational, human resource) that will result in enhancement of the crop production. The aim of this research is to bring a new dimension to conventional irrigation system by smart water distribution and supplying affordable and eco-friendly energy through renewable resources (i.e. solar). This research can reduce cost, optimize resources utilization and can make the irrigation methods fast, flexible, readily available and reliable.

II. LITERATURE REVIEW

Most of the farmers use manual methods for irrigation which leads to insufficient utilization of resources and waste of water. Therefore, there is a huge need to improve the manual irrigation methods by using technology for better production. In this context, various studies have been undertaken for improvement in the irrigation methods where researchers have introduced.

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various techniques for enhancement in irrigation systems. Some of the related research works are discussed below:
In "Microcontroller Based Closed Loop Automatic Irrigation System", an automatic irrigation system is introduced which uses temperature and water usage monitoring through sensors, and ZigBee technology for data transmission. Where commands are transmitted through ZigBee technology from field to control system that controls the state of motor and irrigation valves according to the needs [3]. Although ZigBee technology proposed in this system has low power consumption, it has some disadvantages such as short range, low data speed which causes delay for sending commands. There is no any auto scheduling mode for water distribution.
In another study entitled "Autonomous Solar Powered Irrigation System" has proposed an OFF grid application system that uses renewable energy mainly sunlight to generate electricity and solar powered water pump is used to water the fields. The system is automated to manage power usage and farmer can irrigate the fields by sending commands through GSM technique. An acknowledgement message is also sent to user about situation of crops [4]. This system only uses manual switching for running the tube well and there is no any automatic control mechanism provided.
Another research work is also reported named as "Solar Powered Smart Irrigation System". In this research paper, a smart system is proposed that consists of solar powered water pump that can automatically control water flow using a moisture sensor and reduce water wastage in the field. The valves are used to control the flow of water on the basis of data received from sensors [5]. This system is only used for watering for single field. There is no any water distribution method introduced for more than one fields and also no any auto schedule is suggested for different fields. In this system, there is no any remote controlling mechanism used.
A research paper on "Automated Solar Based Agriculture Pumping" is also published where an automated system is proposed to turn on the pump at fixed timings on daily basis. There is also an option for changing the on/off time of pump manually [6]. This study is suitable for storing the water in tanks which is further used for irrigation purposes. There is no any automatic water distribution system suggested and also no any scheduling mode is provided for irrigating different crops at different timings according to their needs.
A system is developed for water saving in agriculture entitled "Wireless Solution for Water Saving in Agriculture Using Embedded System". In this system, cellphone approach (miscall and SMS) is used for communication between system and user. This study is focused on the voltage protection and dry-running of the pump. A microcontroller is used to monitor the temperature and voltage variation of the pump and notify the users by miscalls on their cell phones [7]. Hence in this system, delay will occur due to miscall approach, and also there is no any feedback control system for automatic water distribution. Every time user has to control the system on runtime. This study is only focused on pump rather than fields for controlling.
In our proposed research, a solar based automatic system is provided for smart water distribution. In this system, automatic water distribution is made through microcontroller, and decision of water distribution is based on data received from sensors embedded in the fields. Farmers can also schedule the watering with respect to date and time for different fields. They can monitor the status of fields at any time using wireless technology through their mobile devices. In this system, a user-friendly GUI based interface is provided. This interface enables farmers to set the water scheduling plan for their fields and also check the real time statue of each field. This system also maintains the backup history of watering plans for future planning and analysis.

III. DESIGN AND ARCHITECTURE OF SYSTEM

SWDIS architecture is mainly composed of control system, server and the user; connected through cellular network. Along with the energy generation from renewable resource (solar power), system especially focuses on the efficient utilization of water distribution in each field. The complete architecture is illustrated in **Fig. 1**. It demonstrates overall project design that includes user interface, server and control system.

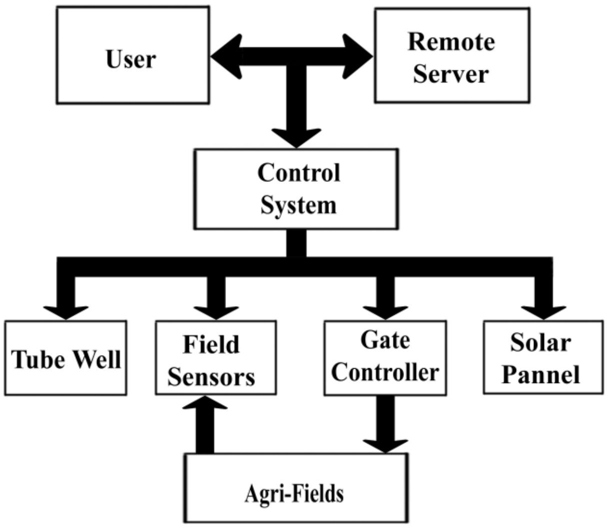

Fig. 1: System Block Diagram

A. *Project Design*

The proposed system (SWDIS) consists of application that uses client-server based approach for controlling the operations, embedded sensors, and microcontroller.
This microcontroller based system gives control to the farmer for water distribution through controlled gates that are fixed at the head of every field. The user-friendly GUI based application is developed which enables them to communicate with gate system via wireless technology and commands are transmitted directly to microcontrollers. The sensors embedded in the fields, sense water and humidity levels and transmit data from each field to the system. This data will help system in making decision and future predications for water distribution among the fields.
The un-interrupted power supply for operating the system is also considered for continuous operation.

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This study suggests the usage of solar energy for its operations, which is the cost effective method for electricity generation. The solar generated energy utilization is a milestone to achieve a sustainable and healthy environment around us plus greatly conserve scarce resources like water and energy. However, this system can also be compatible with all other types of power resources. These resources can be used as a stand-by backup for continuous operations.

1) Server Controlling

Server site is responsible for performing the functionality of keeping record of the data received from the embedded sensor network on the control site. It enables user to command microcontroller for operation of tube well based on stored data and use this data for future examination of the system and further enhancement. Server manages database of each event and also manages automatic scheduling of watering set by user on particular date and time. In **Fig. 2,** the whole structure of the server with user and control system is shown.

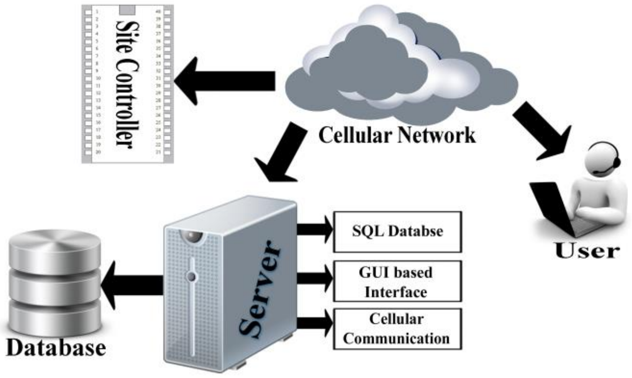

Fig. 2: Server Diagram

2) User Interface

The user controls and monitors the system at remote location with the help of GUI based Application. The GUI application provides two modes of operation; manual and auto. In manual mode, user can control the water distribution by pressing buttons for starting and ending the irrigation. In auto mode, user can set the schedule of watering for particular fields. Therefore, watering will be done automatically according to user's defined schedule. GUI Application also gives the details about all occurred event at particular timings. User can analyze the energy consumption and also watering time of particular field in the form of graphs and tables. Which help user maintain his/her budget and future planning.

3) Control System

Main functioning of the automated system is performed by the site controlling part, which uses energy generated from the alternative resource (i.e. Solar) and supply of energy to operate the tube well. The automatic operation of the tube well's motor and controlling of gates via microcontroller to properly distribute water to each field. The proper controlling of Gates along with efficient water distribution is based on the data taken from the embedded sensors in each field. The system will optimize the manual irrigation system and automate the system to distribute water in various fields according to their water requirements.

B. Rsearch Methodolgy

The research methodology is depicted in **Fig. 3**, where the first stage is to start-up the water distribution system and initialize the water level sensors and wait for the instruction from the user for distribution modes that can be either manual or auto. The user-friendly GUI based application is provided to facilitate the user for controlling the water distribution. In this application, both modes are available for the user for water scheduling.

The water level sensors are placed in each field for measuring the water levels. Sensors will continuously monitor the water level and send data to the microcontroller for decision making. The microcontroller will compare the water level with the overflow level set by the user. If water level is equal to the overflow level, the system will automatically close the gate and turn off the tube well irrespective of the operational modes. In next stage, user will be given two modes for scheduling the water distribution: manual mode and auto mode.

In auto mode, user has facility to set the schedule of water distribution for each field according to a particular day and time, where the user will have to set the start and end time for the water distribution to each field for a particular day. The decision for water distribution schedule is based upon the need of the crops and experience of the farmer. In next step, system will continuously compare the scheduling time with system time. When system time will equal to the scheduling time set by the user, the water distribution is started according to the instructions. Microcontroller will send the signal to open the particular gate and turn on the tube well for watering the field according to schedule. The water distribution will stop when system time will be equal to the ending time or when the water level reaches to overflow level measured through sensors. When either condition is true, system will send the closing command to the microcontroller for ending the water distribution. The levels of water will be set according to the field's surface and measurement of water level requires in normal irrigation.

As an alternative, the user is also provided manual control over water distribution. This mode gives facility to distribute the water to the fields on emergency/random basis according to the urgent need of water. In Manual mode, user will press the button for particular field to open the gate and turn on the tube well manually. For this purpose, buttons are provided in GUI application to control the operations of tube well and gates. When user will press the buttons to turn on the tube well and open the gate of particular field, system will send signal to the microcontroller for execution of operations accordingly. The water distribution will stop when user presses the close button to end the operation, or when the water level reaches to overflow level measured through sensors. When either condition is true, system will send the closing command to the microcontroller for stopping the water distribution.

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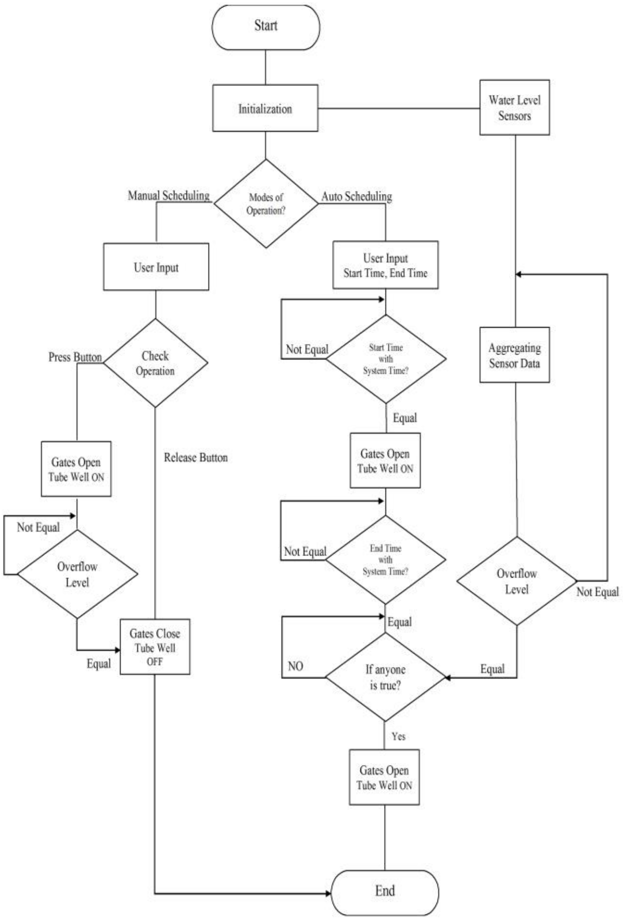

Fig. 3: Flow Diagram

IV. DEVELOPMENT TOOLS

The system of Smart Water Distribution for Irrigation is composed of different types of hardware components and software modules. The details about specification and usage of hardware modules are described in **Error! Reference source not found.**, and software components are described in **Table 1**.

Table 1: Software Components

Software Components	Specification	Usage
LabVIEW	2010 Version 12.0 (64 bit)	Develop GUI based User-friendly Application for monitoring and controlling the System and display monitory graphs.
Microsoft Access	2013	Manage Database of all events in form of tables with respect to time.

Table 2: Hardware Modules

Hardware Modules	Specification	Usage
Water pump		For delivering water from boring to fields
Microcontroller	AT89C51	Controlling Tube Well and gates of fields, Aggregating Data from Field Sensor.
DC Motor	12V, Metal Gear Motors	Use to Close/Open the Distribution Gates in Fields.
Water Level Sensors	2N2222 NPN Silicon Transis tors, Rod	Water level sensor continuously notifies user about the status of fields through Microcontroller.
Liquid Crystal Display (LCD)	16x2 LM016L	Display status of each event and status of field along with tube well.
RS-232 (Recommended Standard)	MAX232	Standard protocol used to connect Microcontroller with its peripheral devices like Cellular networks and enable serial data exchange between them.

V. RESULT AND DISCUSSION

The results of this paper comprise of two different aspects including irrigation scheduling and monitoring energy consumption.

For Irrigation Scheduling, we had developed user friendly system through which farmer can easily set watering schedules and monitor/control all operations related to water distribution and management. This application enables farmers to set schedule that can be either day-wise, week-wise even month-wise according to the nature of the crops and their need. The GUI based interface of application is depicted in **Fig. 4.**

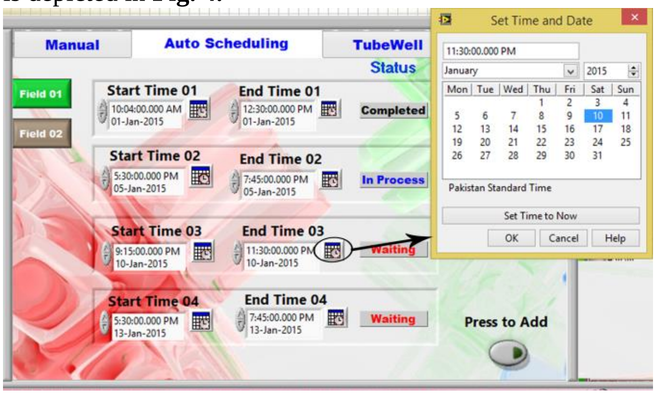

Fig. 4: GUI based Interface

In this paper, the term irrigation is referred to watering the fields for their growth. For simplicity, four different fields are considered for irrigation scheduling. In these four fields, four different types of crops are planted that are wheat, Cotton, Rice and Sugarcane. These four crops are mostly cultivated in Pakistan. The irrigation simulation were carried out by considering the average irrigation requirements of each crop in the region of upper Sindh, Pakistan 8.

In this simulation model, Wheat crop is cultivated in field 01, which is normally planted in the month of November and December. Under optimum growing conditions, 4 to 5 irrigations turns are sufficient for normal wheat crop, where first irrigation should be given 3 to 4 weeks after sowing the crop. In normal conditions, irrigation is applied to wheat crop with 18 to 22 days interval 9. By taking these requirements of wheat, irrigation schedule is planned and illustrated in **Fig. 5**

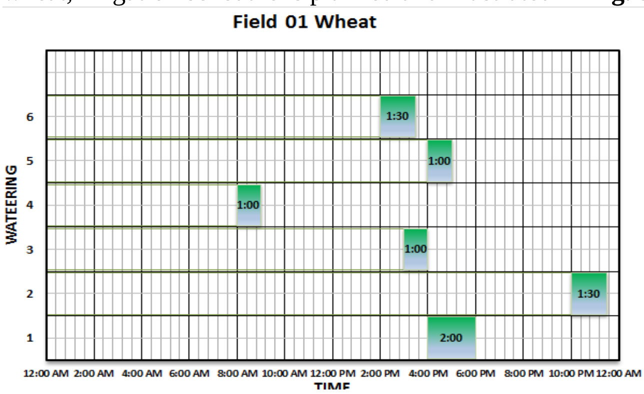

Fig. 5: Wheat Irrigation Scheduling

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Similarly, cotton crop is planted in field 02. Cotton is normally planted in the month of June and cultivated in September or October. It requires 7 to 8 irrigation turns after 35 to 40 days of its sowing. According to the water requirements of the cotton crop, irrigation scheduling is planned with 15 days interval as shown in **Fig. 6.**

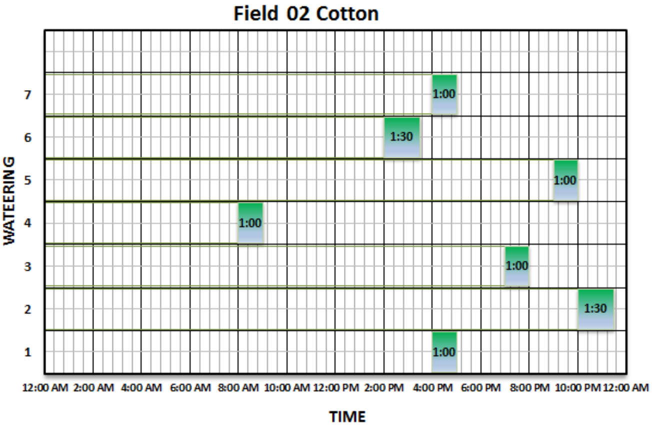

Fig. 6: Cotton Irrigation Scheduling

Rice is one of the crops which requires more water than other crops. Water should be available all the time in the fields of rice crops. Therefore, it is planted in field 03 for water scheduling.

The rice crop is planted in the month of June and July and cultivated in September to November. The irrigation interval for rice crop is 7 to 8 days. According to these requirements of rice, irrigation scheduling is shown in **Fig. 7.**

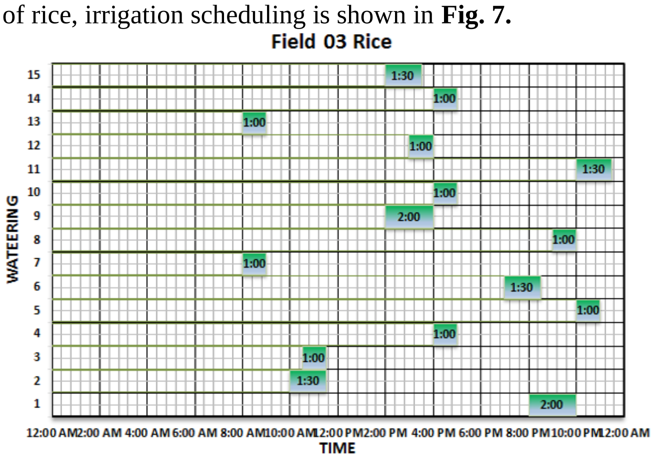

Fig. 7: Rice Irrigation Scheduling

Likewise, Sugarcane is planted in field 04 for irrigation scheduling. Sugarcane is cultivated in the spring season in the month of February or March and harvested in November or December. Its maturity period is 10 to 12 month in Pakistan. Sugarcane requires 20 to 25 irrigations turns during the whole year 10. According to these requirements, irrigation is scheduled with 15 to 20 days interval as shown in Error! Reference source not found..

For monitoring the energy consumption, irrigation data is recorded for future analysis and planning. This will also help to calculate the energy consumption for each field. The total consumption of power and irrigation is given in the Error! Reference source not found.. This information will help farmer to set the budget accordingly and also for future planning.

In this table, total time of irrigation is shown for one year with respect to field and month. For example, field 01 shows the total irrigation time of Cotton crop with respect to each month. The power consumption is calculated in watt hour (Wh). This table shows that total time of irrigation of cotton crop is 8 hours and power consumption is 733.33 Wh. Similarly, total time duration of irrigation and power consumption for all other fields is also given in this table. Therefore, with the help of this table; farmer can easily estimate the total power consumption during irrigation of the crops and expected cost of energy cost if commercial power is used.

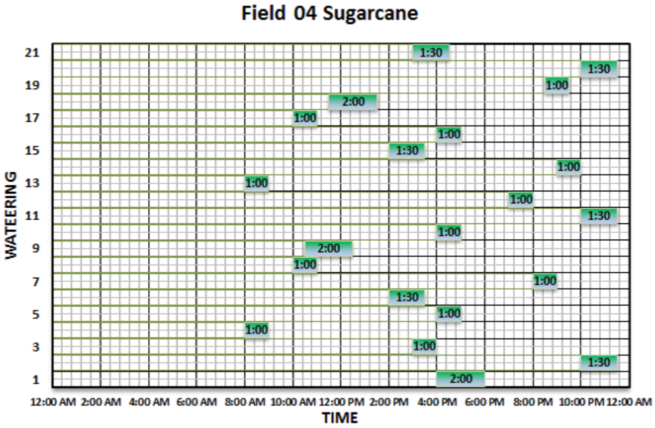

Fig. 8: Sugarcane Irrigation Scheduling

Automating the system and providing field access via wireless communication through GUI based application gives user friendly environment to farmers for controlling the fields remotely. This system helps reduce the effect of energy crisis by using alternate energy like solar, labor cost and time. This presented system can also provide accurate and efficient way to operate the tube well and controlling of gates even in case of any emergency. Farmer can also access to monitor the whole irrigation of each field and power consumption of irrigation with the help of history backup. This approach will also help for future planning and also estimating the budget of each crop accordingly.

Table 3: Power Consumption of Tube well

Months	Field 01 (Wheat)	Field 02 (Cotton)	Field 03 (Rice)	Field 04 (Sugarcane)	Duration H:M:S	Power Consumption (Wh)
January	1:30:00				1:30:00	137.50
February	1:00:00				1:00:00	91.67
March	1:00:00			2:30:00	3:30:00	320.83
April	1:00:00			2:00:00	3:00:00	275.00
May	1:30:00			3:30:00	5:00:00	458.33
June				4:30:00	4:30:00	412.50
July		1:00:00	5:30:00	2:00:00	8:30:00	779.17
August		2:30:00	4:30:00	3:30:00	10:30:00	962.50
September		2:00:00	4:30:00	3:00:00	9:30:00	870.83
October		2:30:00	4:30:00	1:00:00	8:00:00	733.33
November				1:30:00	1:30:00	137.50
December				1:30:00	1:30:00	137.50
Total Time (H:M:S)	6:00:00	8:00:00	19:00:00	25:00:00	58:00:00	
Power Consumption (Wh)	550.00	733.33	1741.67	2291.67		5316.67

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VI. CONCLUSION

This study presented Smart Water Distribution for Irrigation System (SWDIS) that helps to solve some of the major problems of irrigation system faced by agricultural sector particularly efficient water distribution to the crops. By using proposed automatic gate control system, wastage of water resources considerably reduced, and this will lead to better utilization of water resources for other purposes. This study suggested that operational cost can be significantly reduced due to the usage of renewable energy resources. Although initial cost of system deployment will be high, gradually it will cut down the expenses in term of human resources and energy. This system enables farmers to take overall control of the system through GUI based interface and also helps farmer to schedule the water distribution of crops. The proposed system economizes water consumption through efficient distribution of water resources according to the requirements of the planted crops.

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