

WIRELESS SOLAR POWERED AUTOMATIC DRIP IRRIGATION SYSTEM

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Abstract: In India, the water table is experiencing a continuing decline due to long-term pumping for irrigation with limited recharge, water pumps at farmland is being kept still due to non-availability of grid power in the remote areas, where the potential of sunlight availability is tremendous throughout the year and Farmer controlling each and every process staying at the field is too mainstream. The increase in agriculture production depends to a large extent on the availability of water and power. If solar power is harnessed, an agriculture pump can run during a day hours without depending on the power grid and by using IoT user can control all the equipment off-field. The main objective is to save water and reduce farmers work by establishing a Wireless Solar Powered Automatic Drip Irrigation System (WSPADIS) with the assistance of Soil and Water Assessment Tool (SWAT), system uses IoT for interconnection of devices and GSM for transmission of data from field to other components, Water Draining System to remove excess stagnated water and the whole system powered by Hybrid energy based on solar cells. The user can control the whole device off field and a large quantity of water could be saved. SWAT and WSNT employed in this work contribute not only to save energy, water, fertilizers but also ensures the pH value, Humidity value and temperature for watering the crops uniformly at the right time. Drip irrigation is used, less amount of water over a large amount of time yields the Best. The Drainage Removal system ensures that if the water stagnated over the land exceeds a stipulated amount, that portion of water is removed from the field without manual intervention. By uploading the timely status of all equipment and machine on to the Server, which can be viewed by the farmer using an android app or PC, leading to enhance the quality and quantity of agricultural yields.

Keywords: WSPADIS, SWAT, GSM, WSNT, Arduino, pH, motor driver, Soil moisture, temprature sensor, drainage system, solar cells, drip irrigation, Evapotranspiration.

1. Introduction

Agriculture is the backbone of Indian economy. It is one of the major occupations for many people in India. Out of 2/3rd water found on the Earth, only 3.5% is fresh water that can be put into use in any day-to-day activities. About 55% of this available freshwater is used in agriculture and 10-30% of this percentage gets wasted on a regular basis due to many reasons. Over the years different means of irrigation has evolved to minimize this wastage of water in agricultural lands. However, one of the major problems that still remains, leading to wastage of water, is the lack of proper knowledge of the farmers about the soil moisture content, and hence the requirement of the amount of water in the agricultural soil. As per worldometers, the world population clock shows the current world population as 7517.80 million (i.e., as on 12th July 2017 at 03:00 p.m.), India with 1342 million, holds second place after China which has 1388 million. Every one minute the world population is increasing by 160175. Due to this tremendous increase in population, India is expected to overtake China by 2025. After 25-30 years there will be a serious problem for food. In order to meet this food problem, there is a need for producing more agriculture yields using the available limited resources and by adopting the best techniques. The available traditional irrigation techniques are ditch irrigation; terraced irrigation; drip irrigation and sprinkler system [2]. The global irrigation scenario is categorized based on increased demand for higher agricultural productivity and decreased the availability of water and power.

With the advent of open source Arduino boards along with cheap moisture sensors, floating sensor, pH sensor and the water drainage system, it is viable to create devices that can monitor the soil moisture content and accordingly irrigating and removes the excess water from the fields or the landscape as an when needed. The proposed system makes use of microcontroller ATMEGA2560 on Arduino Uno platform and IOT which enable farmers to remotely monitor the status of sprinklers installed on the farm by knowing the sensor values thereby, making the farmers'

work much easier as they can concentrate on other farm activities.

SWAT is known as soil and water assessment tool which is used to acquire information about the humidity temperature water's height over the fertile land and pass the values to the microcontroller. SWAT comprises pH sensor, soil moisture sensor, floating sensor, temperature sensor and vertical float switches or point level sensors. The main process by which water can be saved is by sprinkling the water only to the places required and for a stipulated time drip irrigation is used in this project to control the time and amount of water used in the field. An efficient connection between the sensors and the base station (microcontroller or main system) is made by Wireless Sensor Network Technology, where each sensor acts as a node in a graph.

2. Literature Review

WSNs have been widely used in many irrigation systems to obtain accurate results. Each application has its own characteristics and objectives. [10] Proposed an Automatic Irrigation System using ZigBee – GSM, the objective is to make use of wireless sensor network and communication technology such as ZigBee and GSM in industrial field to make low-cost automated irrigation system to monitor the condition of the soil and to lower the energy consumption. At any abnormal condition, the farmer is informed and will be able to take actions remotely by using GSM. The system requires user intrusion which can be done automatically.

A system proposed by Sonu Kumar, C. Sethuraman and Kota Srinivas [7] employed solar powered automatic irrigation system, which uses drip irrigation methodology for watering crops and wireless network to keep the whole system encapsulated. This system can save water up to 40%. This same system is of high cost and low efficacy.

A. Anusha and D. gouthami [13] proposed a system stating that Wireless sensor networks and their application for precision agriculture are an automated irrigation system used to enhance the use of water for agricultural crops. The system consists of a wireless network that is the soil moisture sensor and the temperature sensor placed under the soil where plants roots are reached which is a distributed network. The system has a water level sensor which will indicate the presence of water level in the tank. A gateway unit manages the information related to sensors which trigger the actuators, and data is transmitted using GSM module. But the proposal didn't focus on how to remove the excess of water present in the agriculture area.

Joaquin Gutierrez, Juna Francisco Villa-Median [22] proposed a system in which web application is used to store the history of data. In this system, the nodes are connected wirelessly and all the sensors are

combined using a single sensor called Wireless Integration unit (WIU), the whole system is based on the star topology. The land is sprinkled on the basis of calculated time, once the sprinkling is started I wouldn't stop until the time is over in case of rain the land is over watered and may lead to leaching and any problem caused in WIU the whole system is collapsed, the algorithm used is highly complex which make the decision making really difficult during rainy times. Since the system is always active and depends on external power, the power consumption is highly expensive.

Rajeshwari Madli, Santhosh Hebbar, Vishwanath Heddoori, G. V. Prasad [15], proposed a system that aims at increasing the yield of crops by using an intelligent irrigation controller that makes use of wireless sensors. Sensors are used to monitor primary parameters such as soil moisture, soil pH, temperature, and humidity. Irrigation decisions are taken based on the sensed data and the type of crop being grown. The system provides a mobile application in which farmers can remotely monitor and control the irrigation system. Also, the water pump is protected against damages due to voltage variations and dry running.

S. Siva Sankari, Dr. G. Mary Jansi Rani [19], proposed a system that aims at automatic irrigation system for controlling a motor. Soil moisture sensor is used to measure the amount of moisture content present in the soil and the water sensor is used sense water availability resource in a tank. Sensor output data can be fed into the microcontroller; it acts according to the control algorithm. The two GSM module is used in the network can act as transmitter and receiver are used for communication purpose. Here when a particular moisture level reaches the threshold value, the motor will be turned ON. When a moisture level reaches the threshold value, the motor will be turned OFF. The soil moisture content and the motor functionality status can be monitored in Lab view. The same webpage can be created on other PC via LAN connection.

3. System Study

This project has totally 6 segments which are source segment, Field section, master segment, drainage removal segment, user interface segment and server segment, where field section is the SWAT (composition of pH sensor, Soil moisture sensor, Floating sensor, temperature sensor, motor driver, and relays). Source unit consist solar charge controller, inverter, batteries and solar panel. The master segment consists Arduino microcontroller and GSM unit. Drainage removal segment comprises solenoid valve and vertical float switch or point level sensor. User interface segment comprises the UI layer for PC, laptops, smartphones which are executed using ".exe" or ".APK" files. The server segment comprises the tables related to the timing and the amount of water released during a

stipulated time and the error history which comprises on/off statuses of the overall system. All these are connected using Wireless Network.

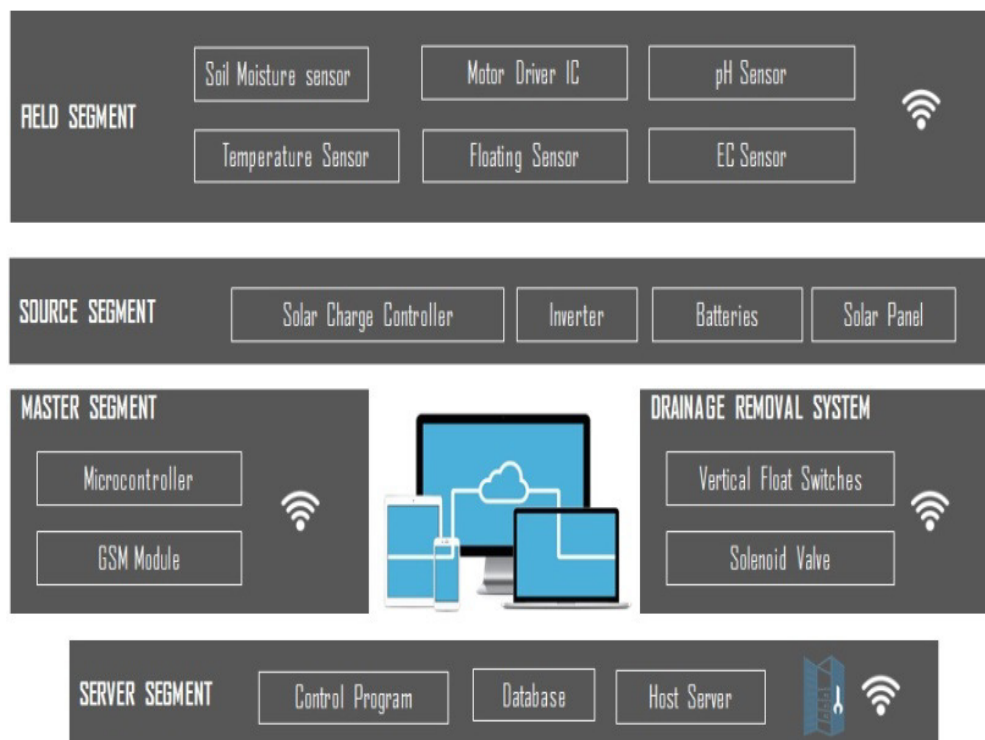


Figure 1. Proposed Wireless Solar Powered Automatic Drip Irrigation System

A. Field Segment

Field segment is the portion of land which is embedded with all SWAT components, namely,

- Soil Moisture Sensor
- Temperature Sensor
- pH Sensor
- EC Sensor
- Motor Driver IC
- Floating Sensor

1. Soil Moisture Sensor

Soil moisture sensors measure the volumetric water content in soil. Since the direct gravimetric measurement of free soil moisture requires removing, drying, and weighting of a sample, soil moisture sensors measure the volumetric water content indirectly by using some other property of the soil, such as electrical resistance, dielectric constant, or interaction with neutrons, as a proxy for the moisture content. The relation between the measured property and soil moisture must be calibrated and may vary depending on

environmental factors such as soil type, temperature, or electric conductivity. Reflected microwave radiation is affected by the soil moisture and is used for remote sensing in hydrology and agriculture. Portable probe instruments can be used by farmers or gardeners.

2. Temperature Sensor

A temperature sensor is a device, typically, a thermocouple or RTD, which provides for temperature measurement through an electrical signal. Temperature is a primary factor affecting the rate of plant development. Warmer temperatures expected with climate change and the potential for more extreme temperature events will impact plant productivity. The use of temperature sensor in this project is to find the surrounding temperature and limit the water according to the temperature.

3. pH Sensor

Soil pH or soil reaction is an indication of the acidity or alkalinity of soil and is measured in pH units. The pH scale goes from 0 to 14 with pH 7 as the neutral point.

As the amount of hydrogen ions in the soil increases, the soil pH decreases, thus becoming more acidic. From pH 7 to 0, the soil is increasingly more acidic, and from pH 7 to 14, the soil is increasingly more alkaline or basic. Using a strict chemical definition, pH is the negative log of hydrogen (H^+) activity in an aqueous solution. The point to remember from the chemical definition is that pH values are reported on a negative log scale. So, a 1 unit change in the pH value signifies a 10-fold change in the actual activity of H^+ , and the activity increases as the pH value decreases. To put this into perspective, a soil pH of 6 has 10 times more hydrogen ions than a soil with a pH of 7, and a soil with a pH of 5 has 100 times more hydrogen ions than a soil with a pH of 7. Activity increases as the pH value decreases. soil pH does play a role in nutrient availability, pH sensor helps the master segment to maintain the value.

4. EC Sensor

Electrical Conductivity and Soluble salts are dissolved inorganic solutes. Soluble salts above the normal range for a prolonged period may cause root injury, leaf chlorosis, marginal burn and sometimes wilting. When soluble salt levels are above the normal range, growers are advised to identify the source for the high levels. Electrical conductivity is the ability of a solution to conduct an electrical current. As soluble salts increase the media, the solution becomes a better conductor of electricity and the EC increases. It is necessary to measure EC to maintain fertility.

5. Motor Driver IC

A motor driver IC is an integrated circuit chip which is usually used to control motors in autonomous robots. Motor driver ICs act as an interface between microprocessors and the motors which is used to turn the direction of the water source (tube/ sprinklers). The motor driver switches its output signal according to the input received from the microprocessor.

6. Floating Sensor

With a float switch, you have a device that is designed to detect the level of liquid in a tank. Used to share information about the height of water inside the source tank in which water is stored.

B. Master Segment

In this present study, Arduino mega 2560 micro controller has been used. The different pins (digital, analog and power supply) of Arduino are illustrated in the following Figure 7.

Plants to grow it require specific amount moisture in the soil in which it has been planted. The amount of moisture varies from crop to crop. Out of supplied water, plants will absorb fraction of water and remaining will be hold in the soil itself and excess water if any applied it will get evaporated. For better irrigation management one has to do the water balance and it can be done by Evapotranspiration (ET) method. In this method Class A pan, by integrating climatic factors, is commonly used to measure the quantity of water getting evaporated.

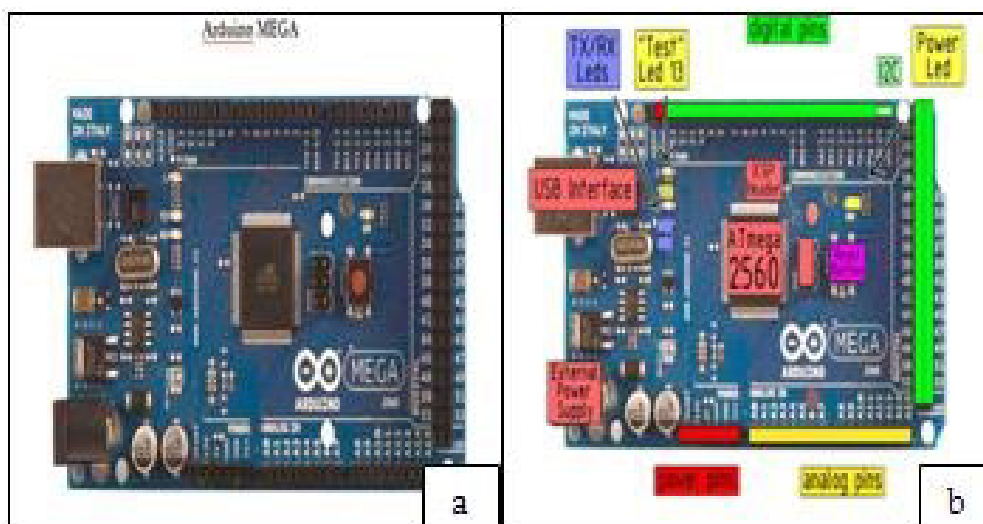


Figure 2. Arduino mega 2560 (a: pin diagram, b: pin description)

Specifications of Arduino ATmega 2560 are given below:

Operating voltage	: 5V
Input voltage	: 7-12V
Input voltage limit	: 6-20V
Digital I/O pins	: 54
Analog input pins	: 16
DC current per I/O pin	: 40mA
DC current for 3.3V pin	: 50mA
Flash memory	: 256kB
SRAM	: 8kB
EEPROM	: 4kB
Clock speed	: 6Mhz

The main objective of irrigation is to provide strength to the plant to prevent stress which is the main factor for reduction in yields. New irrigation system, design and selection techniques are continually being developed and tested to obtain the highest practically attainable efficiency in water irrigation. The irrigation scheduling frequency and quantity of water to be supplied depends upon the local climatic conditions; type of crops; its growth stage and soil characteristics. Irrigation time can be estimated without the knowledge of ET rates. A laymen way is to observe crop indicators such as change of color in the color of leaf or leaf twisting angle, but this information may appear to be late and it is not going to indicate the exact moisture content in the soil and due to which watering will not be done at right time which causes reduction in crop yields. Though the basic information on weather data is available, ET estimate based on weather data has not been made in India. Presently, in India, irrigation is done based on plant water stress, soil moisture status or soil water potential measurement. Because of its simplicity soil moisture measurement can be the most preferred option. Hence, in our investigation it has been decided to go for automatic solar power drip irrigation based on soil moisture measurement. Water content by gravimetric and volumetric in the soil can be calculated using the following formula:

$$\text{Gravimetric water content (\%)} = \frac{\text{Mass of wet soil} - \text{Mass of dry soil}}{\text{Mass of dry soil}} \times 100$$

Volumetric water content is commonly used to express the soil water content, is obtained by multiplying the bulk density of the soil by the gravimetric water content.

$$\text{Volumetric water content (\%)} = \frac{\text{Bulk density of soil} \times \text{Gravimetric water content (\%)}}{\text{Density of water}}$$

Bulk density is the expression of mass of dry soil per unit volume of soil.

$$\text{Bulk density} = \frac{\text{Mass of dry soil}}{\text{Volume of soil}}$$

Global System for Mobile (GSM) technology can be used for communication purpose to inform farmers about the exact field condition. In addition to an automated drip irrigation system, implementing of mobile communication can also help the farmers to have full remote access on their field cultivation activities which includes watering the crops at right time by operating the pump remotely. GSM based motor control board is shown in Figure 11. GSM contains a Subscriber Identity Module (SIM), farmers can communicate with this SIM-Number. Simple commands such as STN9444728563 for storing the mobile number 9444728563; STS for getting the status; OWN for accept command from registered number only; ANY for accept command message from any number; ON for Pump ON or 1st missed call Pump ON; OFF for Pump OFF or 2nd missed call for Pump OFF.

By adding some more features into the developed WSPADIS, it can also be used for monitoring other field parameters like soil temperature, air temperature, pH, nutrients etc. The data related to micrometeorological information in and around the field, i.e., air temperature, relative humidity, precipitation, wind speed, wind direction, and solar radiation can also be obtained from nearby weather station for knowing environmental parameters and plan farming activities accordingly. This type of system can also be used at Cricket stadiums or Golf stadiums and in public garden area for proper irrigation purpose.

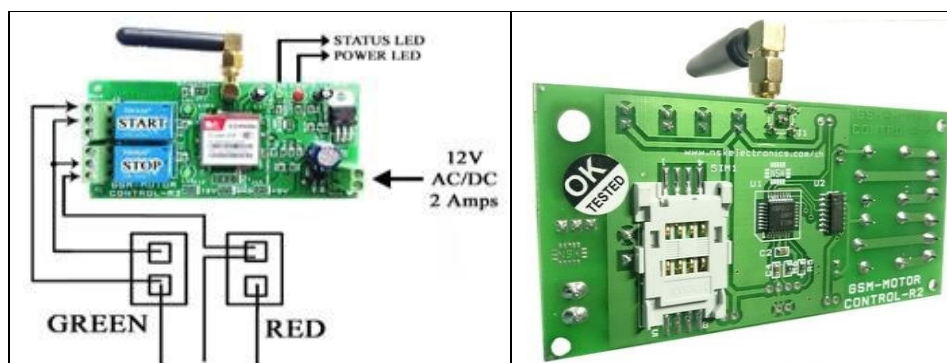


Figure 3. GSM based SWAT Motor Controller

C. Source Segment

Photovoltaic cell use sun light to generate electricity, the generated power is the product of voltage times the current (i.e., $P = V \times I$). The amount of electrical power generated by an individual photovoltaic cell at its output terminals depends upon the amount of solar radiation that hits its PN junction as well as the percentage of solar radiation it actually converts into electricity, in other words its efficiency. It is known that the optimum operating voltage of a PV cell under load is about 0.46 volts, generating a 3A current in full sunlight. Hence, the power output of typical solar photovoltaic cell is 1.38W. The power generated by a single cell is not enough to do any useful work. In our case, the battery theoretical capacity is 67.2W, hence we need more power. Considering the solar radiation in Chennai, 1kW solar panel can produce about 6kWh per day. As it has been worked out that the per day energy consumption of submersible pump selected for SPADIS was 450Wh and to generate this required capacity of the solar panel would be 75W. For trouble free operation, 2nos of 75W solar panel were connected in parallel. Figure 9 shows the photo image of solar panel used in this present study. The details of solar charge controller and its specification is shown in Figure 10. The following Figure 11 shows the photo image of 250VA Inverter used to convert the DC power obtained from the battery to AC power need to be given for submersible pump. The complete schematic diagram SPV system is shown in Figure 12. Solar panel is connected to battery through charge controller. Charge controller is connected with battery, inverter and AC main supply.

The solar panel will be disconnected from the circuit if its voltage goes below battery voltage and the battery will be only source to run the pump. If grid power is available then the SPV will be disconnected from the circuit and only AC power from main will be drawn to run the pump.

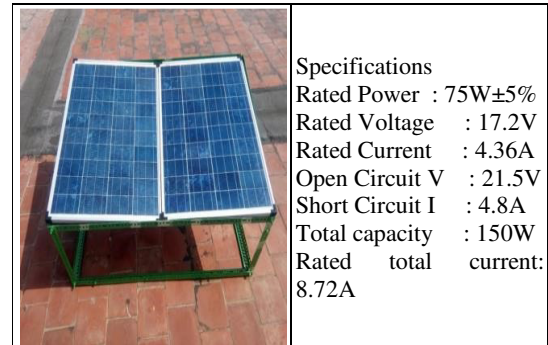


Figure 4. Solar Panel (75W, 2Nos)

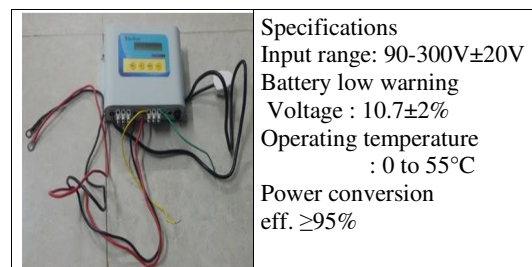


Figure 5. Solar Charge Controller

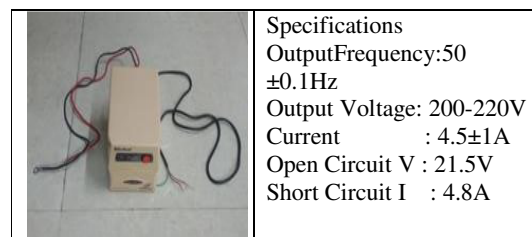


Figure 6. Inverter (250VA/12V)

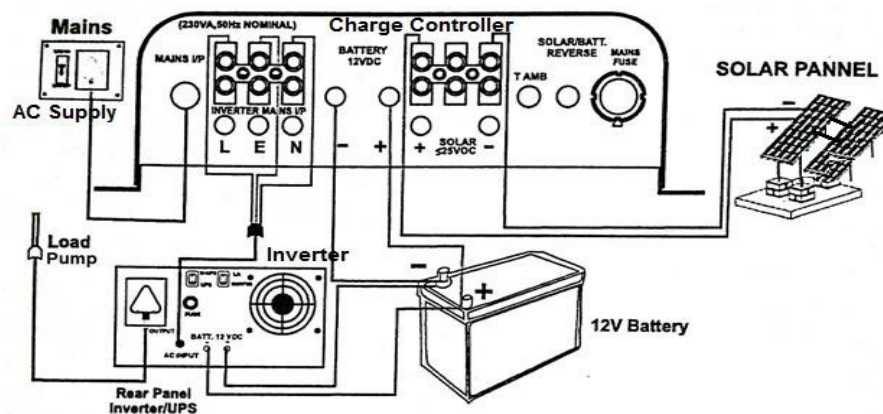


Figure 7. Schematic layout of Solar Photovoltaic System

D. Drainage Removal Segment

The main purpose of this system is to remove the extra water or the stagnated water over the fields. This process is done by calculating the amount of water which stands over the field, once a particular height is reached the water is moved out just by opening a valve or by pumping.

The vertical float switches or the point level sensor calculate the height of the water stagnated over the field and the information is sent to Arduino microcontroller, the respective response is sent back to the solenoid valve whether the valve should be opened or remain closed.

A solenoid valve is an electromechanically operated valve. The valve is controlled by an electric current through a solenoid: in the case of a two-port valve the flow is switched on or off.

Solenoid valves are the most frequently used control elements in fluidics. Their tasks are to shut off, release, dose, distribute or mix fluids. They are found in many application areas. Solenoids offer fast and safe switching, high reliability, long service life, good medium compatibility of the materials used, low control power and compact design.

E. Server Segment

The main purpose of this segment is to store and retrieve information about the irrigation i.e. about the activity status of the overall machine, the total time the crops have been watered, no of times the water has been removed from the field, information about the no. of components present the field i.e. like sensors no of cell in the source segment etc. and information about the motor statuses. This segment embeds GPRS to locate the sensors in the field, the server which acts as

base for communication and the database table which stores information.

F. User Interface

This layer acts as interface between the user and the whole system the user can even switch on and off the whole machine using IoT. This is a GUI which user can see and access the information stored in the database tables like the activity status of the overall machine, the total time the crops have been watered, no of times the water has been removed from the field, information about the no. of components present the field i.e. like sensors no of cell in the source segment etc. This layer is coded with the basic concept of MVC architecture by using JAVA language for PC.

4. Irrigation System Operation

The basic workflow of the system starts in initializing the Arduino with the initial information like the cut-off values of soil humidity and pH, initialize the temperature factor on calculating the bulk density, the dimensions of the source tank or pond should be set in the Arduino so that that the cut-off value for the floating sensor will be initialized and the type of the sprinkler or tubes must be chosen and initialized, since grasses require sprinklers and rice requires tubes and so dose other crops for irrigation purpose. Each soil moisture sensor, pH sensor, and the motor drivers should be fitted in the exact position so that the area covered is maximum, each of these should be consider in a graph which is accessed by Depth First Search method so that correct motor drivers can be chosen, the graph information can be saved in the inbuilt RAM in Arduino or in the data base present in the system.

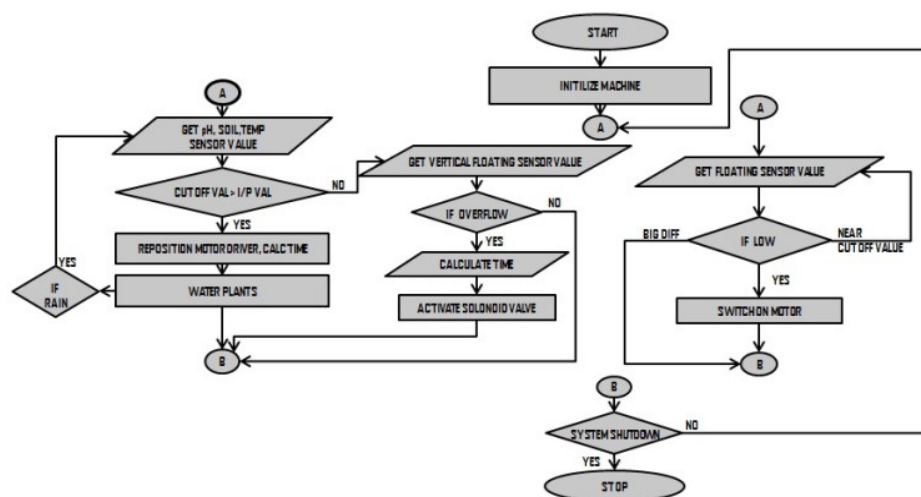


Figure 8. WSPADIS flow Diagram

At first the Arduino makes request to floating sensor requesting information about the amount of water present inside the tank, once Arduino fetches the values from the floating sensor inside the tank, the micro controller checks if the water is sufficient, if the water is sufficient then the process stops till next irrigation process is carried out. If the calculated amount of water is less than the cutoff value then by home sensing technology based on IoT the switch to the motor is switched-on.

The soil moisture senses the humidity or the wetness of the soil in which agriculture is done and the information are sent to the Arduino, each crop requires different humidity values in the soil so depending on that cut-off value is set. Temperature sensor calculates the current temperature, temperature is one of the key factors which plays important role in the water absorption by the soil, and if the temperature is low absorption is less and if temperature is high absorption is high according to this cut-off-value for temperature is set. Similarly, acid content in the agriculture land shouldn't be really high which will lead to the death of the crops so pH values are found, each crop has its own capability of resistance to acid so depending on that the cut-off value is set.

On considering the above factor, the input values from soil moisture sensor, pH sensor and the temperature sensor are compared with their own cut-off values and total time of irrigation is calculated. If only one region lacks of water then using the concept of graph, that particular place is located. Motor driver acts as a stepper motor in this system, once the location and node information are provided to the motor driver, the driver rotates according to the direction provided the relay is activated so that it forms a closed circuit and the

watering is done. During irrigation if suddenly rain comes, then temperature sensor plays a main role, continues signals provided by the temperature sensor reduces the time of irrigation drastically so irrigation is perfectly done. If the cut-off values is in the limit and everything is perfect the system remains calm during day times since its powered by sun light and in night time the machine goes to idle state for some time.

The vertical float switches or the point level sensors present in the field continuously sense the level of the water over the land. For certain crops, water above the soil region is good and for some it is not. Even for the crops which require the water over the surface it has some limit. Once the limit exceeded, it will lead to death to death of crops. So to avoid that the sensed signal by the vertical float switches or the point level sensors is compared with its pre-defined cut-off values if it found to be normal, this step is ignored, if not then the amount of excess water is calculated (in terms of height) and the time taken to evacuate the excess water is calculated, after this information are passed to solenoid valve which opens the way for the water to move out.

All the information received by the Arduino are fetched by GSM and uploaded in a database which is located in a server. The information can be retrieved by the user whenever required using a mobile app designed using java which displayed the current temperature, soil moisture level, acidity of soil, all active motors and water time. Similarly information can be retrieved using Laptop or PC with help of another application with different interface. Using IoT system can be remotely controlled.

5. Results and Discussion

Table 1. Moisture sensor voltage w.r.t water content in the soil

Soil Cup No.	Weight of soil, (Kg)	Added water quantity, (l)	Moisture sensor output voltage, (V)	Soil moisture, (%)
1	20(dry)	0	4.5	0
2	20	12	3.1	38.67
3	20	24	2.6	52.48
4	20	36	2.1	66.29
5	20	48	1.4	85.63
6	20(wet)	60	0.88	100

Based on the created setup, many experiments were conducted to understand the functional behavior of soil moisture sensors, batteries charging voltage, batteries discharging voltage while running the pump by drawing the power from battery alone (i.e., keeping solar panel disconnected from the circuit) and batteries

discharging voltage while running the pump drawing power from batteries and simultaneously it is also kept in charged condition from SPV. The following Table 1 illustrates the voltage developed by the moisture sensor w.r.t addition of water. It was observed that when the soil was completely dry it was developing 4.5V and

when 60l water added, the soil turned into completely wet. For this complete wet, the voltage developed from the soil sensor was 0.88V.

From the Table 1, the moisture sensor which will give voltage output w.r.t the water content in soil can be used as online soil moisture measurement. If the soil is completely dry, the voltage output from the sensor would be 4.5V and if the soil is completely wet then the voltage output would be 0.88V. Hence, this 4.5V relates 0% moisture and 0.88V relates to 100% moisture. The following Figure 17 shows the calibration curve prepared for sensor output voltage versus % of moisture.

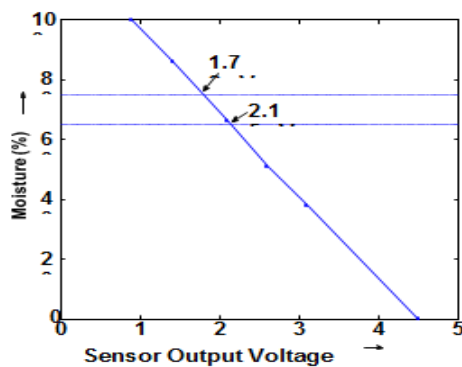


Figure 9. Sensor voltage output vs. Soil moisture

In manual irrigation the pump switch ON was done at soil moisture at 45, 35, 40 and 38. The pump was switched OFF at soil moisture at 98, 92 and 90. In case of SPADIS, the pump was always switched ON at soil moisture at 65% and always switched OFF at soil moisture at 75%. The pump takes about 10 minute to increase the soil moisture from 65% to 75%. With little change in the program, it is possible to maintain the moisture condition in the field at different ranges of values. By running the pump based on moisture measurement and drip irrigation system, about 30 to 70% irrigation water can be saved.

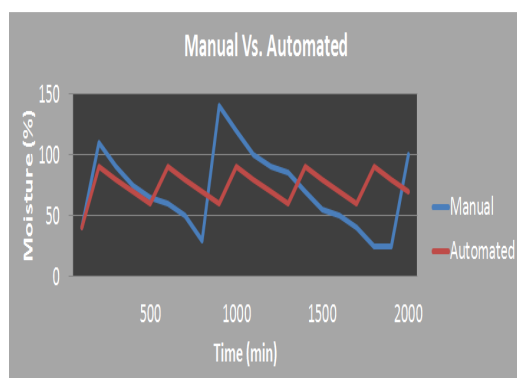


Figure 10. Irrigation Manual vs. Automated

6. Conclusion

The WSPADIS based irrigation system implemented was found to be feasible and cost effective for optimizing water resources for agricultural production. This irrigation system allows cultivation in paces with water scarcity thereby improving sustainability. The irrigation system developed proves that the use of water can be diminished for a given amount of crop production. The use of solar power in this irrigation system is pertinent and significantly important for organic crops and other agricultural products that are geographically isolated, where the investment in electric power supply would be expensive. Use of the IOT and wireless interconnections enables the user to control the whole system remotely. The irrigation system can be adjusted to verity of specific crop needs and requires minimum maintenance. The modular configuration of the automatic irrigation system allows it to be scaled up for larger greenhouse or open fields. The extra stagnated water is removed. The internet controlled duplex communication system provides a powerful decision making device concept for adoption to several cultivation scenarios. Besides the monetary savings in water use, the importance of the preservation of this natural resources justify the use of this kind of irrigation system.

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