Smart Crop Health Diagnosis and Treatment Unit Powered by Green Fuel

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Abstract

Majority of India's economy depends on agriculture. Rice being the staple food for people of eastern and southern parts of India, its yield directly depends on the lives of the farmers. Among various diseases that affect the Paddy crop, Blasts in leaves are predominant. Without sufficient knowledge about the health of the crop, cultivators may use excessive pesticides which affects the environment in various phases. Energy being one of the major crisis, agriculture sector does not get proper supply of electricity to maintain the yield. The proposed project establishes an effective solution for the above mentioned problems by integrating Solar Power and a system to monitor the crop health and provide treatment, if necessary. Rural street lighting can be an added advantage of the project.

Keywords: K-means clustering, segmentation, image acquisition, image processing, classification, PV system, smart irrigation, Arduino.

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List of Abbreviations and Notations:

PV Panels	Photo Voltaic Panels
GPRS	General Packet Radio Services
BP	Affected area of leaf
BP1	Unaffected area of leaf
u	Percentage of affected area of leaf
DC	Direct Current
TDH	Total Dynamic Head
g	Acceleration due to gravity (9.8 m/s^2)
AC	Alternating Current
USB	Universal Serial Bus
GSM	Global System for Mobile
pH	Power of Hydrogen

1 Introduction

Over the past few years, the living conditions for any living beings has become difficult as an effect of various problems. Targeting huge yield and aiming at a greater profit, cultivators have started ignoring the quality of the yield and rather have been focusing on the quantity. In addition to the deteriorating human health, degradation of the environment has been a rising concern among the environmentalists. The excessive use of fertilizers and pesticides contaminate the groundwater and also are responsible for soil erosion and other serious effects. Another severe issue concerning the world is the energy crisis. With the rising energy demand, there is a steep inclination towards renewable sources of energy.

Judicial use of the available resources is extremely necessary for the survival of the crop as well as ensuring its quality. To accomplish this, a new self-sustainable system has been introduced [1–5]. As an improvement on the existing systems, remote control of the irrigation system with the help of GPRS, where the control can be turned ON and OFF by sending a simple text message to the system via a mobile phone, has been implemented [6]. Incorporating multiple sensors to track numerous data continuously and analyse and detect any form of abnormalities with the help of a microcontroller has been reported [7]. Moisture sensors can read the moisture content of the soil and inform the farmer in case the moisture level goes below the optimum levels. This is done by incorporating microcontrollers with the GPRS technology [8]. Making such a self-reliant system demands that the efficiency of the power source is maximum. In order to extract maximum efficiency of the solar panels, a maximum power point tracking method is executed [9–15]. Electrifying the rural areas of India has been on the rise recently and it is a tedious task. One way of aiding this process would be to rely less on the grid for power and store the excess power produced during the day by the system, to power up the street lights after nightfall, which can prove to be supportive to the people and make the battery system more efficient by having a persistent charging and discharging cycle [16–19].

2 Overview of the System

Figure 1 shows the block diagram of the proposed system. The primary elements of the system are detailed in the forthcoming sections.

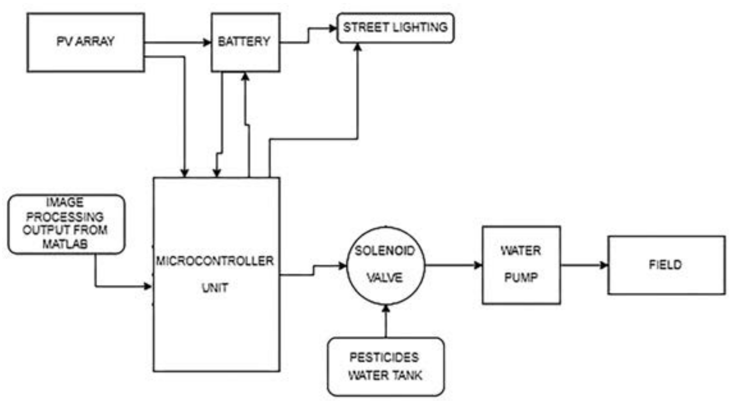


Figure 1 Block diagram of the proposed system.

2.1 Image Processing

As mentioned earlier about the image processing techniques used in this prototype, a brief elucidation of these techniques will be presented in this segment.

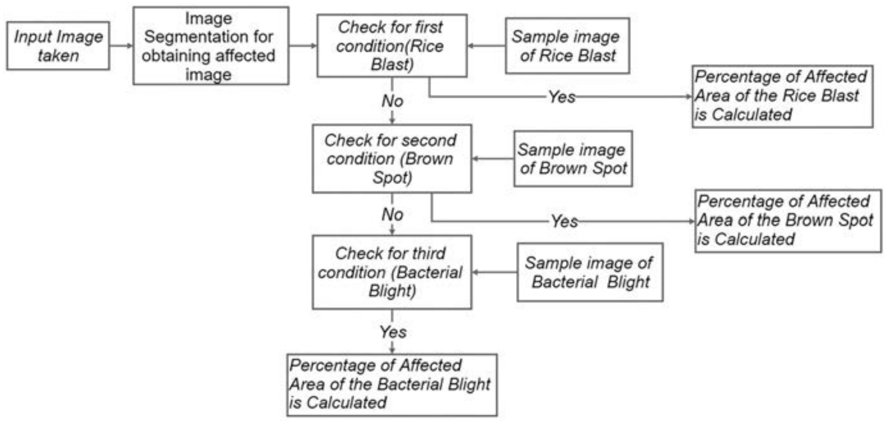


Figure 2 Flow chart of the disease discrimination.

i. K-means Clustering

It's a technique of vector quantization, formerly from signal processing, that is popular for cluster analysis in data mining. *K-means* clustering targets to partition *n* observations into *k* clusters in which each observation belongs to the cluster with the closest mean, aiding as a model of the cluster. This results in a partitioning of the data space into Voronoi cells. As mentioned, the image of the sample leaf is segmented, and classified into affected area, unaffected area and leaf area. The end result of this will be the percentage of the affected area of the leaf.

Images for rice blast, brown spot and bacterial blight and their clustered image obtained from the k-means clustering block are displayed in Figures 3a, 3c, 3e and Figures 3b, 3d, 3f respectively.

ii. Image Segmentation

Image Segmentation is the process of segregating an alphanumeric image into numerous fragments. The objective of segmentation is to abridge the illustration of the image into something that is more expressive and easier to examine.

An image of a leaf with bacterial blight disease is considered for analysis and the analogous cluster image is as seen in Figures 4a and 4b respectively.

The image from the case study is mapped with rice blast, brown spot and bacterial blight sample images (Figures 5a, 5b, 5c). Matching points

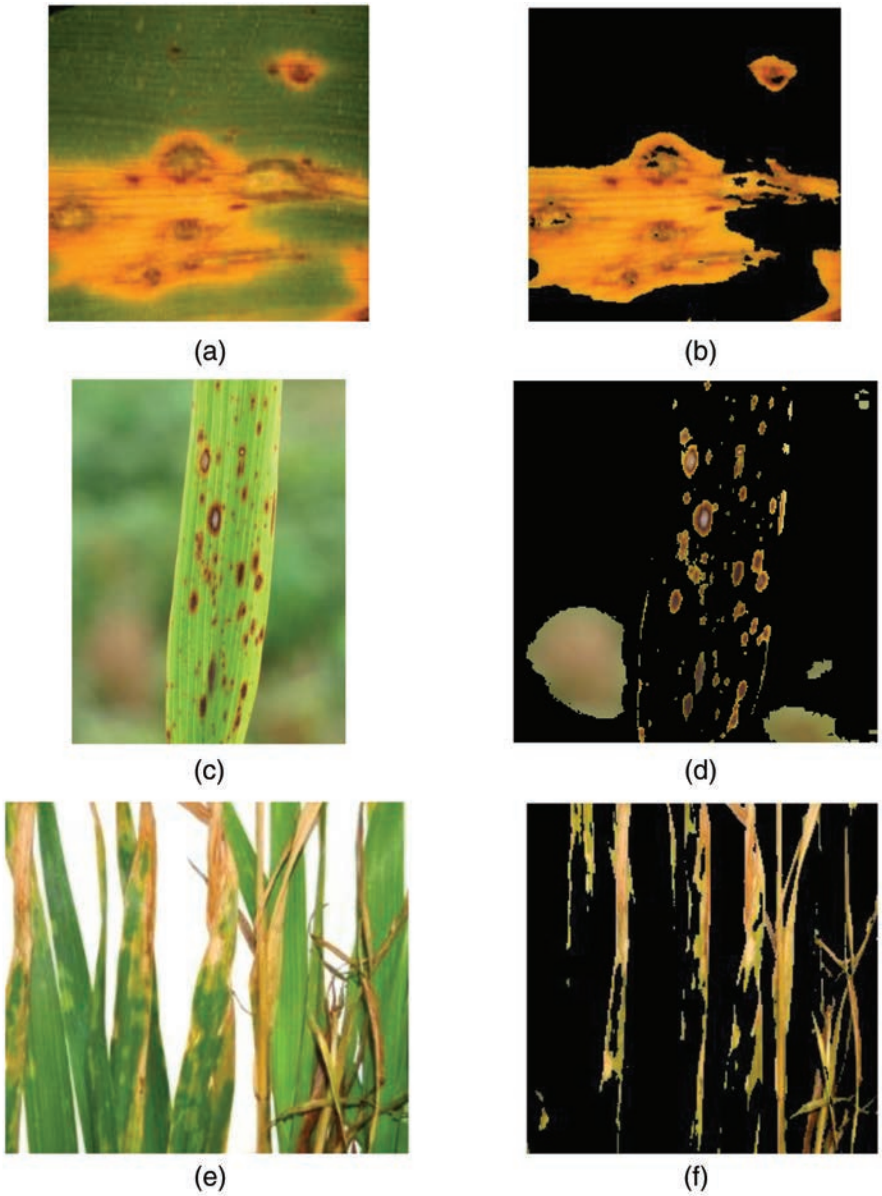


Figure 3 (a) Sample Image of Rice Blast (b) Clustered Image of Sample Rice Blast (c) Sample Image of Brown Spot (d) Clustered Image of Sample Brown Spot (e) Sample Image of Bacterial Blight (f) Clustered Image of Sample Bacterial Blight.

(a) (b)

Figure 4 (a) Test Image for analysis (b) Clustered Image of the Test Image.

are obtained from the mapped image and it is observed that the test image mapped with rice blast had only one matching point and that with brown spot had nine matching points whereas the matching points with bacterial blight had 31 points as shown in Figures 5a, 5b and 5c.

The matching points for the case study was the highest for bacterial blight and hence the output for the same in MATLAB command window is as follows:

The disease identified is ***"Bacterial Blight Disease"***
Affected area, BP = 15367
Unaffected area, BP1 = 18616
Affected area Percentage, u = 45.2197%

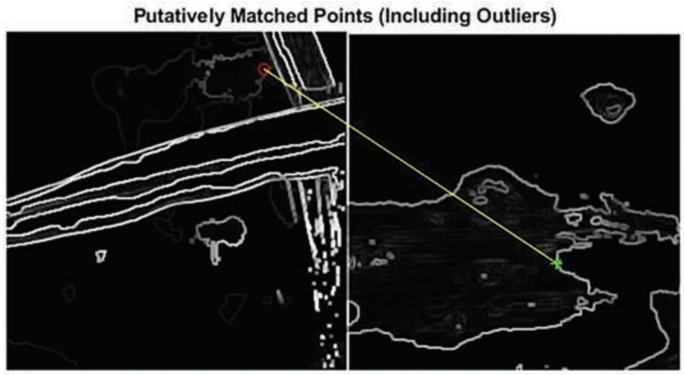
This percentage of affected area is fed as input to the microcontroller (Arduino) to select a particular relay to dispense the corresponding pesticides as discussed in Section 3.

2.2 Microcontroller

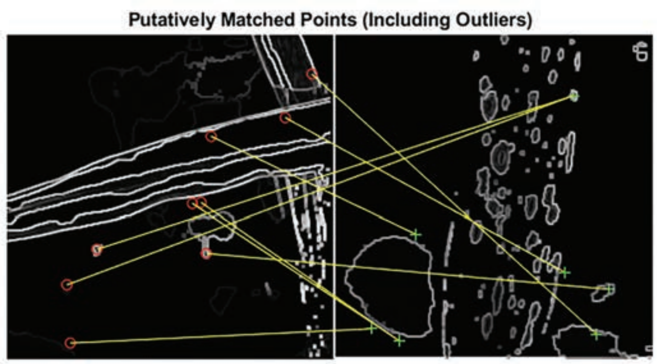
Arduino Uno is a type of microcontroller used for object interaction and controlled. For interfacing the Arduino with MATLAB, USB is connected to the Arduino.

2.3 Driver Circuit

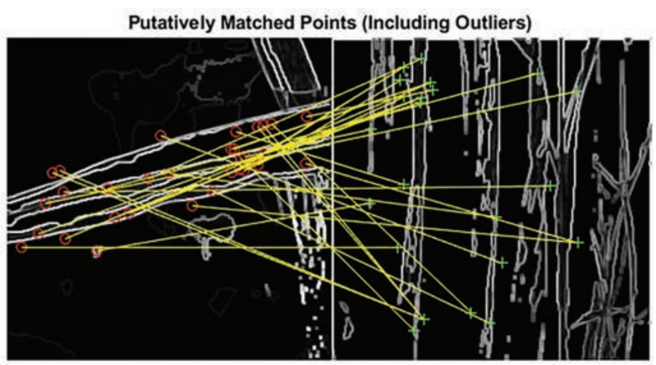
A driver circuit is an electrical circuit that is used to control a component. This driver circuit enables the selectivity of the particular pesticides that needs



(a)



(b)



(c)

Figure 5 Mapping of test image with (a) Rice Blast (b) Brown Spot (c) Bacterial Blight.

to be used and also control the time period for which the pesticides need to be delivered. The terminals of the relay are connected to the terminals of the power source and the solenoid valves as well as the water pump. The components used in our circuit are described below:

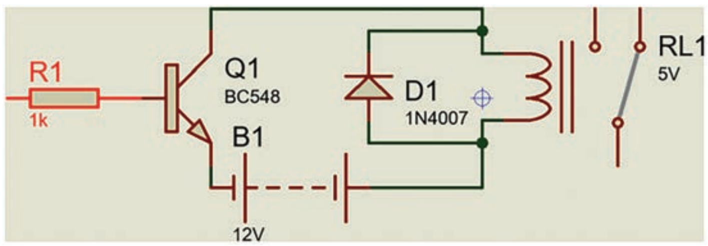


Figure 6 Driver Circuit.

i. BC548

BC548 is an NPN bipolar junction transistor that are generally used in electronic switching and amplification. The primary advantage is its low cost and availability of the device.

ii. 1N4007

It is an electronic component used to conduct the current in a unique direction with the resistance to be minimum at one end and high resistance at the other end. 1N4007 is been used for blocking reverse voltage.

iii. Relay

Relay is used as a switching device. Most of the relays are electromagnet to mechanically operated switch. A low power signal is used by the relay to control the circuit. The relay is turned on when electric current passes through the coil so magnetic field is generated which activates the armature of the relay. So based on electric current, breaking or making occurs.

2.4 DC Water Pump

It is a device which facilitates the flow of fluids by the mechanical action governed by electrical energy. There are two types of water pumps used AC and DC water pump. Compatibility with PV panels demands DC water pump.

One terminal of the pump is connected to the battery terminal and the other end of the battery terminal is connected to one terminal of the relay from Figure 6 and the other end of the relay is connected to the other end of the pump. Hence, DC50K-24160S model DC Water Pump was preferred for the proposed system.

2.5 Solenoid Valve

It is a device controlled by solenoid. There is an electromechanically operated valve which facilitates opening and closing the flow of the fluid. These are preferred for their fast switching and high reliability. The terminals of the solenoid valves are connected to the terminals of the batteries and the terminals of the relay from the driver circuit in Figure 6.

2.6 PV and Battery System

PV and battery system consists of PV panels, batteries and switching circuits. During the day, when the solar radiations are at its peak (or in this case, when the output voltage is around 36 V) the PV panels can directly be used to power the system as well as to charge the batteries. But during the night or during days with very low solar radiations (when the output voltage is less than 36 V), the power source has to be switched to the battery module to provide uninterrupted supply. The driver circuit has to be used so as to achieve this. The driver circuit allows the PV panels to directly power the system when the output voltage is 36 V or more and automatically switch to the battery module when the output voltage dips. In this case, all three relay terminals of the driver circuit are connected, one to the PV panel arrays and the other to the battery module.

i) PV System

The energy from the sun is converted to electrical energy by the PV panels. Each panel is rated by its standard DC output. The assumptions and design calculation for number of solar panels are listed below:

Assumptions:

Operating factor (O_f) = 0.75%

Efficiency of the pump (η_p) = 0.3

Mismatch factor (Mf) = 0.85

No. of peak sunshine hours = 6

PV panel Requirement calculation for Pump:

a) Pump Hydraulic energy requirement = density * volume * g* TDH.
b) Total Wattage of the PV Panels = Pump Hydraulic energy/Number of sunshine hours = 6.302 Watts.
c) PV panel Requirement for Pump = Total PV Panel Wattage/ (η_p * Mf * O_f) = 32.94 Watts.

PV panel Requirement calculation for Total Load Connected:

a) Total Energy produced by single 40 W panel/day = Peak power rating * Operating Factor * Combined Efficiency * Number of sunshine hours = 145.8 Watt-hour.

  a. Number of solar panels required to satisfy given estimated daily load = Total Watt-hour rating (daily load)/Daily energy produced by a panel = 5.

ii) Batteries

Batteries are storage units that store electric power which can be used for future requirements. Various types of batteries with different ratings and capacities are available in the market for different uses. The batteries used in this prototype are lead acid batteries.

Battery requirement

Total Amp Hour required

= Total Watt-hours ratings/(Depth of Discharge * Battery Voltage)

= 61.334

Number of Batteries Required

= Total Ampere Hour rating/(Battery Rating Under use)

= 4

The summary of components used are listed in Table 1.

Table 1 Component and Specifications

Component	Specification	Values
PV Panel	Voc	21 V
	Vmp	16.4 V
	Isc	2.6 A
	Imp	2.26 A
	Pmax	37 W
	Model	MS-F12
Battery	Model	AT12-1.3
	Voc	12 V
	Isc	1.3 A
BC548	Vbr	30 V
	Ic	100 mA
Relay	Frequency	50/60 Hz
	Vop	5 V
	Model	RW-SH-106D
Water pump	Flow rate	1000 L/hr
	Vop	24 V
	Isc	1.3 A
	Head	7 m
	Model	DC50K-24160S
Solenoid valve	Vop	24 V
	Isc	500 mA
	Model	G1/180

3 Functioning of the Structure

The output from the image processing unit, which is the percentage of the affected area of the leaf is directed to the Arduino, is used to determine the type of disease that the crop has been affected by and also helps to determine which pesticide has to be used for that particular disease and in what quantity. Based on the results the Arduino enables the DC pump and the particular solenoid valve to the corresponding pesticide tank for the calculated time. Since paddy is a flooded irrigation type crop, water level sensors maintain the water level in the field by continuously monitoring the water level and compensating by turning on the pump. During nightfall, the real time sensed by the Arduino activates the lighting unit which is powered by the battery system that is in turn charged by the PV panel during the day.

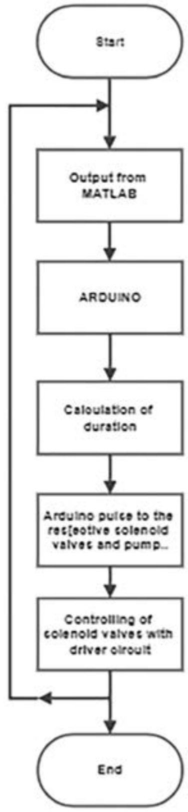


Figure 7 Flowchart of the Proposed System.

4 Simulation of the Setup

Figure 8 shows the simulated circuit diagram from Proteus software. The Arduino controls the whole circuit by triggering the corresponding relays (R2, R3, R4, R5) to power the respective motors. Figure 8a and 8b illustrates the output voltage when the PV System voltage is 36 V and less than 30 V in that order. From Figures 9a and 9b it is evident that Battery (at 27 V) gets charged from PV Panel (at 36 V) and the solenoid valve follows the Arduino pulse.

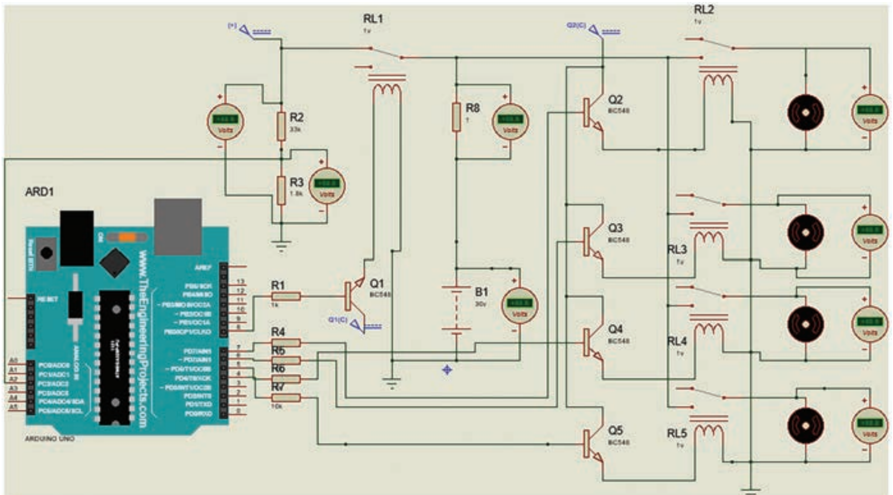
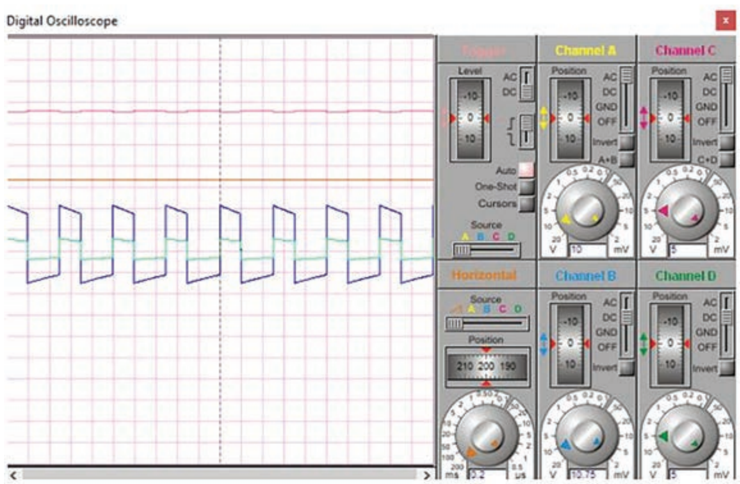
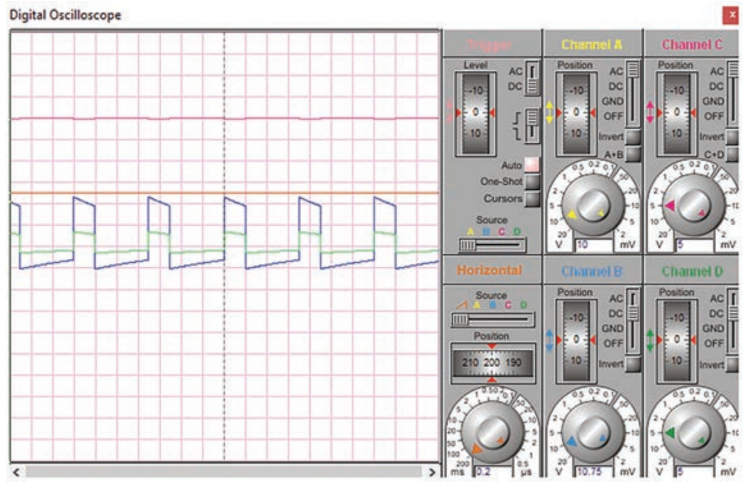


Figure 8 Simulation of the System.



(a)

Figure 9 Output Waveforms when Solar Voltage is (a) 36 V (b) <30 V.



(b)

Figure 9 Continued

5 Hardware Implementation

MATLAB output serves as the sensing unit for the whole system. The image processing provides us with the discrimination between diseases and the severity of the infection in terms of percentage of the affected area. These are considered as the input for the treatment unit. There are three solenoid valves each connected to each of the tanks containing 3 different pesticides given in table 2 for rice blast, brown spot and bacterial blight. According to the disease detected by the MATLAB output, the particular solenoid valve with the corresponding pesticide is activated. Based on the percentage provided by MATLAB, the duration for which that particular solenoid should remain ON will be calculated in the Arduino and the pulse for the selected solenoid valve remain HIGH for the stipulated duration.

For example, if the MATLAB detects the disease as Rice Blast, then Solenoid Valve 1 along with the DC pump will be turned ON. Let's say that the severity percentage is 39%. For this range, the solenoid valve must be turned ON for 2 hours as mentioned in Table 2. If the MATLAB detects the disease to be bacterial blight, then Solenoid valve 3 along with the DC pump will be turned ON. And if the percentage is 78%, then the solenoid valve will remain ON for a period of 3 hours. If the MATLAB detects no disease, then only the

DC pump will be turned ON for a specified amount of time to dispense only water.

The hardware also includes a battery switching circuit that automatically switches from solar power to battery backup when the solar power is not sufficient or absent. During the time which the PV panel works, the battery is in its charging phase. When the PV panel is not in operation, the battery is in its discharging phase. A voltage divider circuit is deployed to sense the real time PV system voltage. The sensed voltage is fed to the controller(Arduino) for controlling the power flow between PV system and battery and the loads connected.

Table 2 Pesticides dispensing duration according to the severity

Disease	Pesticides	Severity	Duration
Rice Blast	Systemic Fungicides. Eg. Triocyclazole	10–25%	1 hr
		25–40%	2 hr
		>40%	3 hr
Brown Spot	Fungicides like Iprodione	10–25%	1 hr
		25–40%	2 hr
		>40%	3 hr
Bacterial Blight	CMC (Carboxymethyl Cellulose)	10–25%	1 hr
		25–40%	2 hr
		>40%	3 hr
No disease	Water		1 hr

6 Results and Observations

The system was able to provide the desired outputs by controlling the desired solenoid valves for the required duration. Figure 10 shows the output of the battery switching circuit. In Figure 10a, when the solar power is 36 V, the battery is charging and is at the same voltage as that of solar. Figure 10b shows that, when the solar voltage is below 30 V, the battery starts powering the system and its voltage is 27 V. The pulse from Arduino as shown in Figure 10a and 10b switches the circuit from PV system to battery.

The hardware prototype of the implemented unit is as shown in Figure 11. The input solar voltage, battery voltage and pulses to the solenoid valve and relay, are as shown in Figure 12.

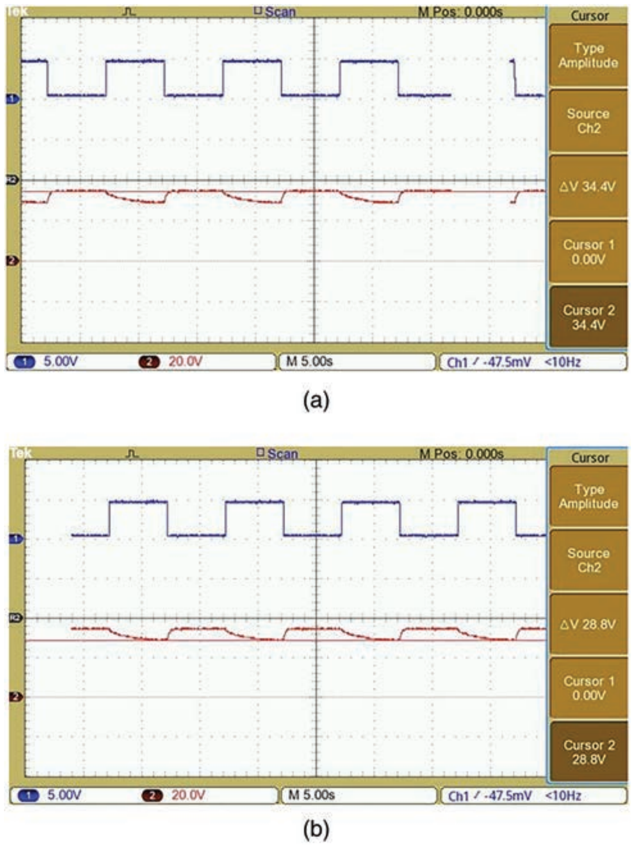


Figure 10 Output waveforms across the battery when the solar voltage is (a) 36 V (b) <30 V.

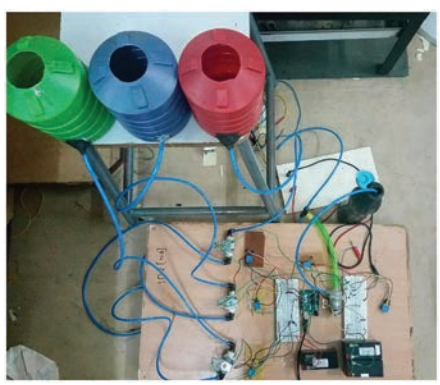
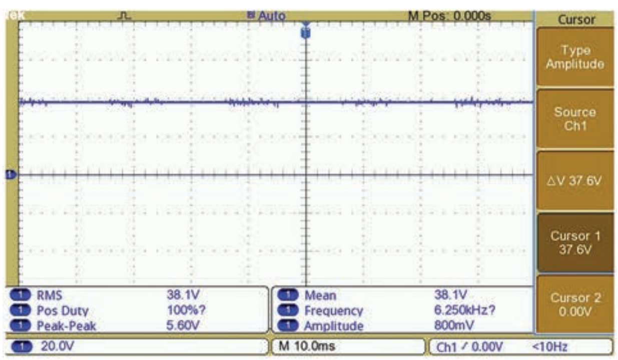
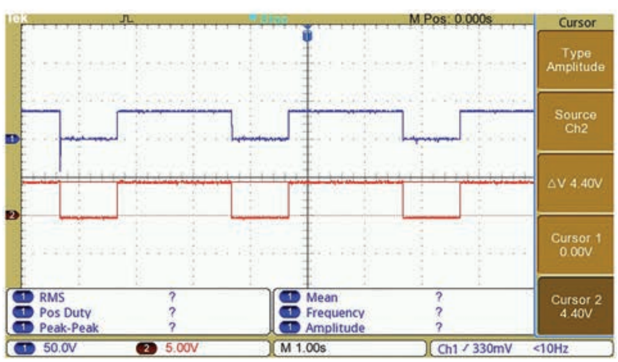


Figure 11 Hardware prototype.

(a)



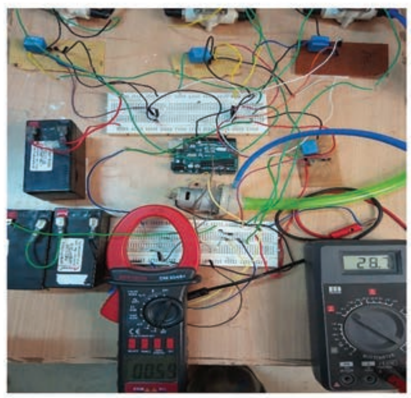
(b)



(c)

Figure 12 (a) Solar input voltage (b) Solar voltage Waveform (c) Relay and solenoid pulses.

(a)



(b)

Figure 13 (a) Battery charging image (b) Battery discharging image.

From the figure it's evident that the solar voltage is 37.1 V, battery voltage is 28.5 V respectively. The current drawn by the battery is positive and measures negative 0.26 A when the solar input is 37 V as shown in Figure 13a. When the solar input is less than 30 V battery reads a current of 0.59 A indicating that the battery discharges to the load as shown in Figure 13b.

7 Conclusion

The proposed system has efficiently discriminated the disease using MATLAB codes. Furthermore, the controller(Arduino) was successful in controlling the solenoids and pump. The hardware prototype built is economical and user friendly unit for farmers. The results further confirm the effective utilization of pesticides which reduces soil pollution and consumer health hazards. With the addition of a few more modules like GSM module, pH sensors, etc., the prototype can be made to sense the nutrient deficiency and treat them by adding the appropriate fertilizers too. The prototype can also be used in detecting disease in other crops. It also can be controlled remotely using the mobile phone.

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