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Eco-Friendly Solar Powered Insecticide Spray System for Sustainable Agriculture

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Abstract

In this paper, agriculture industry is being developed by various information and advanced communication technologies, such as the Internet of Things (IoT). The rapid implementation of such technologies has remapped almost all other industries and advanced agriculture transforming the industry from statistical to quantitative. Developing solar powered insecticide spray system with internet of things for smart agriculture. It provides green power to the system as it uses solar panels to provide energy to the entire system to maximize results. IoT sensors and devices are installed in the smart farm to capture real-time data on pests and diseases, crop status, as well as environmental data to facilitate efficient and effective insecticide applications. This smart system helps in cutting down the amount of chemicals used and improving the methods of protecting crops through the identification of the affected parts that merit chemical treatment. Solar powered insecticide spray system modifies the use of renewable energy and IoT to improve smart agricultural productivity.

1. Introduction

Agriculture is the practice of growing plants and raising animals to meet human needs like food and other essentials. This was changed from a nomadic way of living since individuals started growing crops and grains to encourage early urbanization. Today farming is important in defining the interactions of people in societies. Looking at a country's use of agricultural practices, the effect it has on a country's Biodiversity [1]. However, it is necessary to overestimate it and replace the whole system of farming adapted to the urban conditions. This is true that more high-tech tools are necessary to assist in the farming activity in the city because they have a different environment than normal farming areas [2].

A smart spraying system in agriculture may be described as a spraying technique that affords the right chemical in the correct place at the right time without necessarily causing much harm to the environment. Furthermore, smart Agriculture does not directly improve watering but incorporates the use of technologies like the Internet of Things (IoT) applications and Machine Learning algorithms [3]. However, inspecting the sprinkles of a farming field may sometimes be a time and cost-consuming process, especially if they are spread over a large area, placed far apart, or if they may be isolated and inaccessible. The spraying technology has been found to have a positive impact on agricultural businesses in that it reduces the airborne spray drift by 87%, reduces the spray loss on the ground by 93%, decreases the use of pesticides by more than half, and provides the same level of pest control as a conventional sprayer [4].

Thus, the latest innovations and instruments enhance agriculture operations during the crop's development stages, such as crop harvesting, cropping materials transportation, and storage conditions. The insecticide spray system with IoT for smart agriculture is very important and can be used for the farmers in Malaysia as it offers them a cheap solution and makes the processes easier [5]. However, solar energy is good energy and has quickly risen to popularity as one of the best sources of power for most of the farming communities in rural areas. Farmers are advised to invest in the installation of solar panels with a view to attaining longer-term returns resulting from the reduction of the cost of running electricity. The totally solar-powered system that will be developed will be used to examine the most efficient way the process and the management of resources will be enhanced by the perfect application of input such us, water, fertilizer, poison, and an IoT system to produce enhanced agricultural yields [5].

2. Methodology

The system is produced with a solar panel that converts sunlight to electricity for recharging a 12V 12Ah sealed lead battery by a solar charger controller for times of low sunlight. A voltage regulator module is used to reduce input voltage for components which need less power. The system also has voltage sensors for the solar panel, battery, and the ESP32, which would allow real-time measurement, control and evaluation of the system efficiency and the identification of defects on the battery. A 2-channel relay turns 12V DC submersible water pumps for water and poison supply on/off by activating signals by ESP32 based on sensor and control parameters. An LCD monitor is used for displaying the status of the system and the readings of various sensors attached to the system, Blynk IoT platform makes it possible to remotely monitor, change settings and control the system through a smartphone application. This block diagram explains a full fusion of renewable energy, precise control, and IoT-based smart automation, making it a right-fit solution for contemporary smart agricultural applications [6]. Fig. 1 below shows the block diagram of the project.

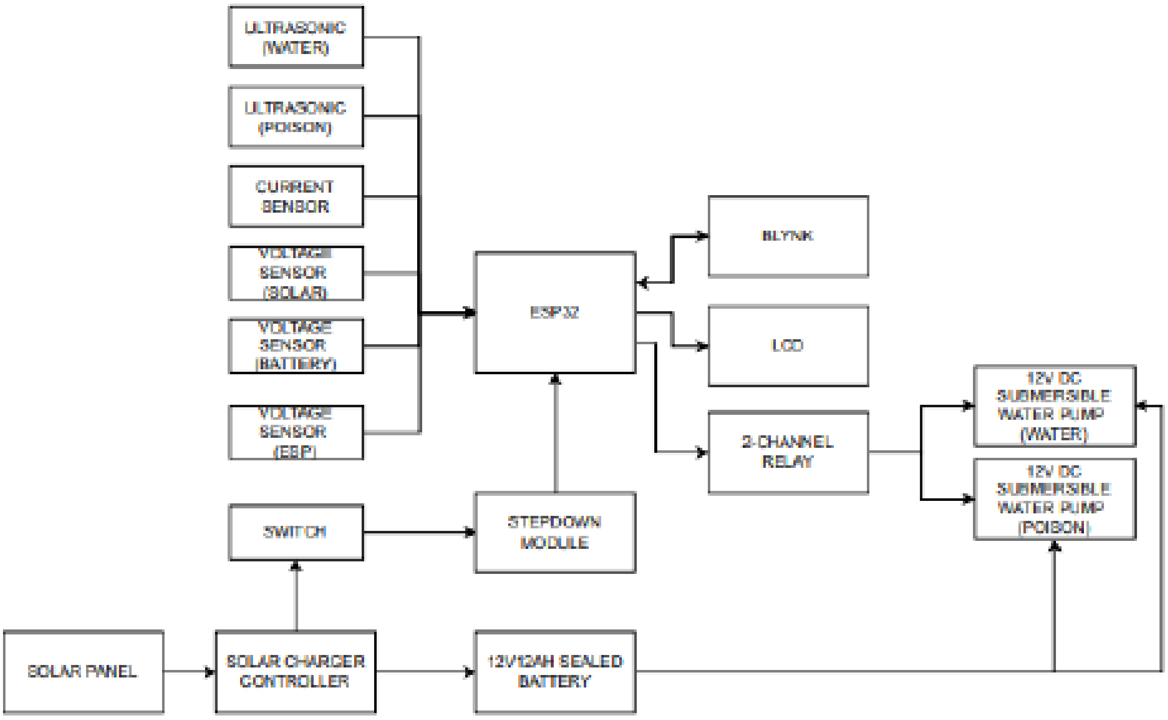


Fig. 1 *Block diagram of the project*

2.1 Circuit Design

This section explains the circuit design for this research. This circuit design shows a solar system consisting of a solar charge controller alongside a solar panel as well as a battery storage system. In addition, it has components like sensors, microcontroller, display for monitoring and control of the system. The fundamentals of the system are a solar panel, a solar charge controller that regulates the amount of charge placed into a battery pack. Battery is connected to the charge controller which provides the system DC voltage in appropriate amount. It also provides an armory of parameters, which uses an ESP32 microcontroller as the main control unit. The microcontroller samples input from ultrasonic sensors for distance and environmental condition monitoring sensors. All these sensors are connected to the microcontroller through both analog and digital pins. The data collected by the sensors can be converted and displayed on an LCD displaying information concerning the state of the system to the users. The benefit of the IoT is that it allows the users to control and supervise the operations of the spraying system using a Smartphone. Thus, this circuit applies renewable energy, automation, and IoT, which are environmental-friendly and suitable for the contemporary agricultural world. Fig. 2 shows the circuit design for this research.

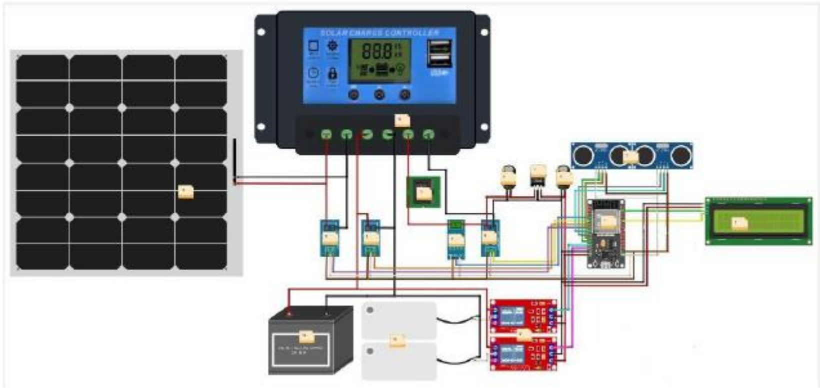


Fig. 2 *Circuit design for this research*

2.2 Evaluation of Solar Panel Orientation

Malaysia, being a developing country with high energy intensity, has also taken strides to incorporate RE. Renewable energy is generated from natural resources including wind, solar Photovoltaic (PV), biomass, flywheel, batteries, fuel cell and distributed generation (DG). Ecosystem factors are primary drivers in this sort of change. Among them, solar PV technology, the technology that can convert sunlight to electricity directly, is most appropriately suited for Malaysia's climate since it is hot all year round. Furthermore, the actual power and Voc (V), Isc (A) attributes for two-axis have been studied based on the open circuit voltage (Voc) and short circuit current (Isc).

Outdoor testing has been done to know the functionality of the horizontal, vertical, and 45º degrees axis solar towards sunlight. The outdoor testing is done on 19th December 2024, and the weather is in good condition. Comparison of Voc(V), Isc(A), power, and efficiency between the horizontal, vertical axis and 45º solar panels with fixed angles. Testing and data analysis are taken start from 0900 hours until 1700 hours. Next, this testing was conducted in three axis which is horizontal, vertical and 45º degrees because the axis solar detects the sunlight in two directions that is east to west. Fig. 3 shows the evaluation of solar axis.

(a) (b) (c)

Fig. 3 *Evaluation of solar (a) horizontal axis (b) vertical axis (c) 45º degrees*

2.3 Location of Observation

This project is focused on the project solar powered insecticide spray system with internet of thing for smart agriculture at Stadium Pusat Sukan UTHM coordinated at (latitude: 1.51087N, longitude: 103.05025E) Parit Raja, Batu Pahat, Johor. Moreover, outdoor testing the functionality of the horizontal, vertical and 45º degrees axis solar towards sunlight. Besides that, testing and data analysis are taken from 0900 hours until 1700 hours and get a comparison of Voc(V), Isc(A), power, and efficiency between horizontal, vertical axis and 45º solar panels with fixed angles. Fig. 4 shows the location of observation.

(a)

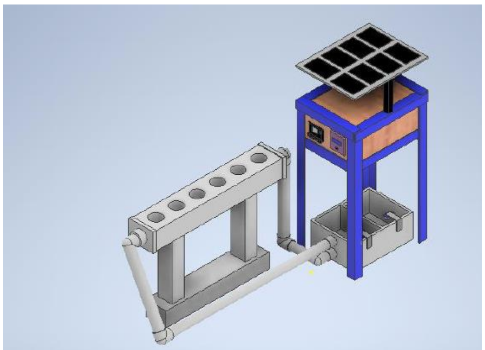
(b)

Fig. 4 *Location of site project*

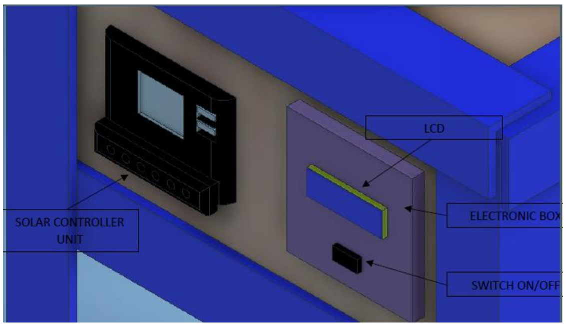
3. Result and Discussion

3.1 Prototype Design

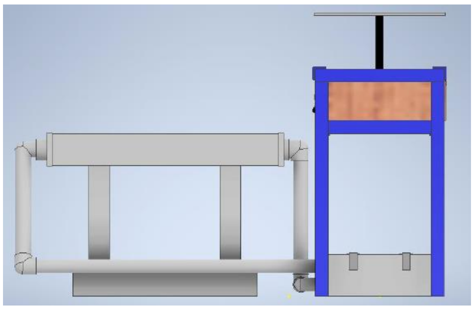
This section explains and shows the 3D design of the project. The drawings of this prototype hardware were created by using the Autodesk inventor software as shown in Fig. 5.



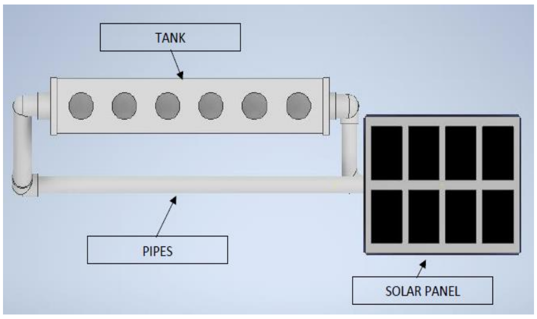
(a)



(b)



(c)



(d)

Fig. 5 *Prototype design (a) actual view (b) close up (c) front view (d) top view*

3.2 Electrical Parameters of PV System with and Without Load

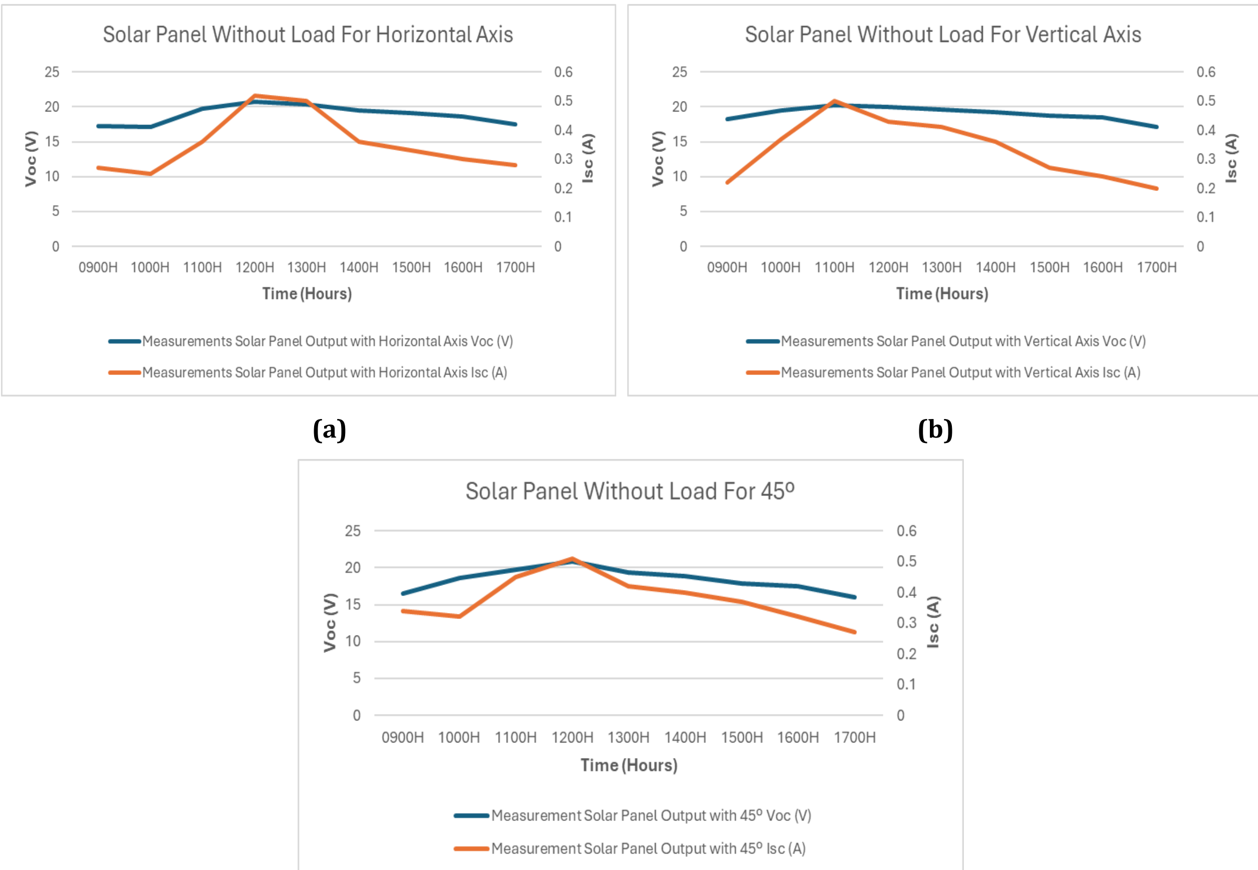
3.2.1 Electrical Parameters Without Load Solar Panel

This section presents the outdoor result. Open circuit voltage (Voc) and short circuit current (Isc) values for PV systems with and without load have been considered in this analysis to compare output values for fixed solar. In this study, Voc and Isc are considered for the experiment test.

Table 1 shows the measurement solar panel output value without load between horizontal, vertical and 45 degrees on 19th December 2024. Voc and Isc values are measured, and the result is shown graphically in Fig. 6. The performance of solar panels varies across different orientations. In the horizontal axis orientation, Voc and Isc gradually increase from 9:00 AM to midday and decrease gradually until 5:00 PM, while Voc values are also increasing and decreasing continuously but with little fluctuations compared to Isc. The vertical axis orientation is similar but yields smaller Voc and Isc because of less irradiance. The Voc and Isc ratio in the 45° tilt orientation has the best performance whereby Voc and Isc levels increase in the morning and reach their peak at midnoon and then decrease in the afternoon. This tilt angle enhances the capture of sunlight energy hence higher energy outputs than the vertical orientation but a little lower than the horizontal under the best situations.

Table 1 *Measurement of solar panel output value between horizontal, vertical and 45 degrees axis solar panel*

	Measurement output at horizontal axis			Measurement output at vertical axis			Measurement output at 45 degrees axis		
Time	Voc(v)	Isc(A)	Power(W)	Voc(v)	Isc(A)	Power(W)	Voc(v)	Isc(A)	Power(W)
0900H	17.3	0.27	4.67	18.26	0.22	4.02	16.52	0.34	5.62
1000H	17.17	0.25	4.29	19.5	0.37	7.22	18.64	0.32	5.96
1100H	19.79	0.36	7.12	20.27	0.5	10.14	19.77	0.45	8.90
1200H	20.7	0.52	10.76	19.98	0.43	8.59	20.84	0.51	10.63
1300H	20.4	0.5	10.20	19.6	0.41	8.04	19.36	0.42	8.13
1400H	19.51	0.36	7.02	19.24	0.36	6.93	18.84	0.4	7.54
1500H	19.14	0.33	6.32	18.77	0.27	5.07	17.91	0.37	6.63
1600H	18.61	0.3	5.58	18.5	0.24	4.44	17.55	0.32	5.62
1700H	17.48	0.28	4.89	17.11	0.2	3.42	15.98	0.27	4.31



(a) **(b)**

(c)

Fig. 6 *Comparison Voc and Isc withoud load(a) Horizontal axis (b) vertical axis (c) 45 degrees*

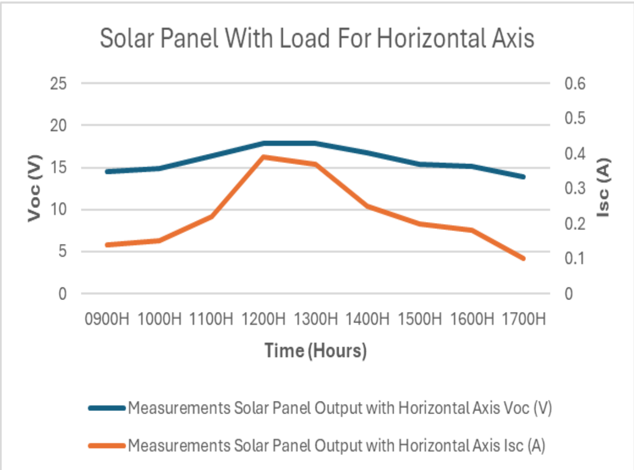
3.2.2 Electrical Parameters with Load Solar Panel

The testing has been conducted on fixed solar panel. Table 2 shows the measurement solar panel output value with load between horizontal, vertical and 45 degrees on 19th December 2024. Voc and Isc values are measured and the result is shown graphically in Fig. 7. The performance of solar panels varies across different orientations.

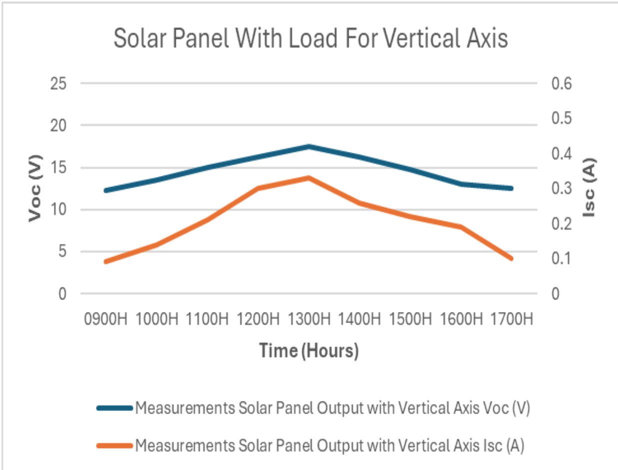
Each orientation demonstrates distinct patterns influenced by sunlight exposure throughout the day. For the horizontal axis orientation Voc and Isc reach their maximum values during the day when the sunlight exposure is maximum thus, the maximum energy is produced. The vertical axis orientation also depicts the same trend, but they yield less output because of the little intensity of sunlight. The 45° tilt has an excellent orientation as it provides a equal output throughout the day and the output is higher than that of the vertical position but slightly lower than the horizontal one during peak hours. The horizontal orientation performs best, the 45° tilt is satisfactory and provides sufficient stability, the vertical orientation ranks worst.

Table 2 *Measurement of solar panel output value between horizontal, vertical and 45 degrees axis solar panel*

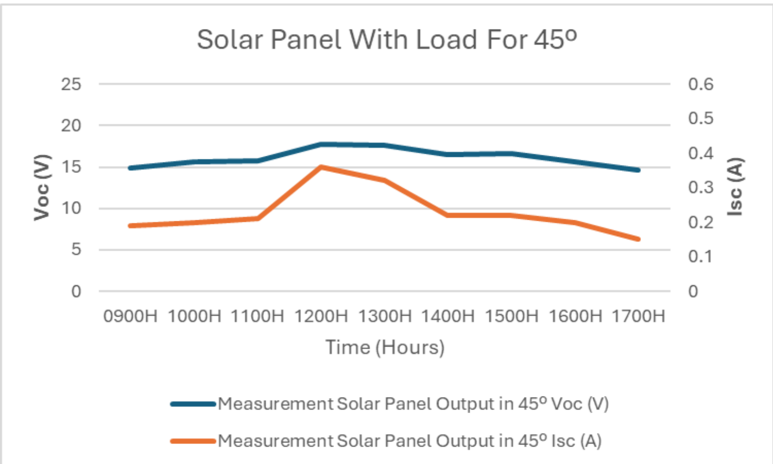
	Measurement output at horizontal axis			Measurement output at vertical axis			Measurement output at 45 degrees axis		
Time	Voc(v)	Isc(A)	Power(W)	Voc(v)	Isc(A)	Power(W)	Voc(v)	Isc(A)	Power(W)
0900H	14.57	0.14	2.04	12.21	0.09	1.10	14.89	0.19	2.83
1000H	14.89	0.15	2.23	13.49	0.14	1.89	15.58	0.2	3.12
1100H	16.36	0.22	3.60	15.01	0.21	3.15	15.78	0.21	3.31
1200H	17.93	0.39	6.99	16.2	0.3	4.86	17.8	0.36	6.41
1300H	17.86	0.37	6.61	17.51	0.33	5.78	17.63	0.32	5.64
1400H	16.75	0.25	4.19	16.29	0.26	4.24	16.46	0.22	3.62
1500H	15.42	0.2	3.08	14.7	0.22	3.23	16.62	0.22	3.66
1600H	15.16	0.18	2.73	13.06	0.19	2.48	15.59	0.2	3.12
1700H	13.88	0.1	1.39	12.57	0.1	1.26	14.68	0.15	2.20



(a)



(b)



(c)

Fig. 7 *Comparison Voc and Isc with load(a) Horizontal axis (b) vertical axis (c) 45 degrees*

3.2.3 The Average Power Value Obtained with the Orientation Axis

The orientation and load significantly influence the panels' efficiency. These results focus on the differences in power generation in different angles and under different environmental conditions. The average power delivered without load was 7.04 W and 6.76 W for the 45^0 and the horizontal orientation respectively 6.43 W for the vertical orientation. When load was applied, the power output was reduced and the 45^0 axes remained the highest at 3.77 W, the horizontal axis at 3.65 W and the vertical at 3.11 W. These results suggest that 45^o degrees was the one that generated the most power because the angle put the array in the best position in terms of sun exposure and other environmental factors. Fig. 8 shows the average power with different orientation.

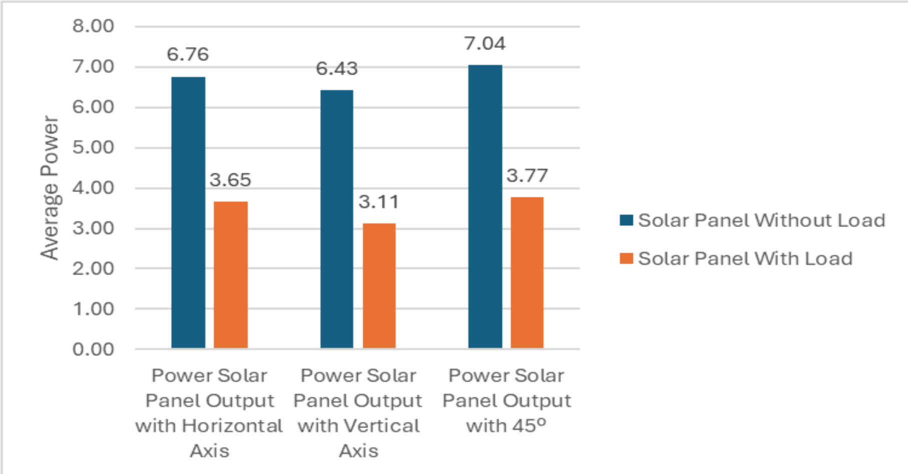


Fig. 8 *The average power with different orientation*

4. Conclusion

The research project is an innovative approach to agriculture by employing green energy and technological solutions. A solar operated insecticide spray system is one of the progressive forms of innovations for smart agriculture in the future. The thinking behind this concept is to focus on using renewable energy resources that can lessen reliance on traditional power, making farming more environmentally sustainable. An important part of this system is a means of maintaining the amount of insecticide and its connection to an application based on IoT for the control and management of the spray system and the solar power. Through applying IoT considerations, the system allows for accurate control and actual-time consumption of insecticide, thereby increasing effectiveness and decreasing utilization. By aiding farmers with spray decisions and predicting disease outbreaks, this technology helps farmers to achieve better crop yields with efficiency and less resource use.

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Conflict of Interest

Authors declare that there is no conflict of interest regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Muhammad Shafiq Bin Abdul Rahman, Khairul Anuar Bin Mohamad;* ***data collection: Muhammad Shafiq Bin Abdul Rahman; analysis and interpretation of results:*** *Muhammad Shafiq Bin Abdul Rahman, Khairul Anuar Bin Mohamad;* ***draft manuscript preparation:*** *Muhammad Shafiq Bin Abdul Rahman, Khairul Anuar Bin Mohamad. All authors reviewed the results and approved the final version of the manuscript.*

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