Monitoring of Water Flow on Solar-Powered Pump for IoT-Based Agriculture

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ABSTRACT

Irrigation is one of the efforts to maximize crop yields, but not all agricultural areas have sufficient water. Using diesel as a tool for irrigation to agricultural land is also less effective. The utilization of solar energy is an environmentally friendly solution by developing a solar-powered water pump system. The solar-powered water pump system utilizes solar panels to convert solar energy into electrical energy. The electrical energy produced is then stored in the battery to generate a water pump with the help of a solar charge controller. This study also monitors water flow on the internet of things (IoT) using a water flow sensor controlled by the NodeMCU esp8266, and the data is displayed on the Blynk application. Testing on the system for 20 minutes resulted in a water flow with an average of 1.3215 liters/minute and a total volume of 26.43 liters. In the monitoring system displayed on the Blynk application, the total volume for ±2.5 hours is 243.64 liters. The maximum voltage of the solar panel is 20V and the average load of the water pump is 12.12V. The water pump voltage affects the water flow produced, the hose at the inlet is also one of the factors that influence the water flow.

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1. INTRODUCTION

Indonesia is a country with a large agricultural area [1]. More than half of the world's human population, including Indonesia, lives in the agricultural sector. Agriculture is also a place for human activities to utilize natural resources to produce or process food, industrial raw materials, or other energy sources [2]. Generally, the staging process in the agricultural sector consists of seeding, maintenance, and harvesting [3]. Besides seeding, maintenance is a series of processes that require special attention to maximize yields in the agricultural business domain.

One of the factors that affect yields is the irrigation system [4][5]. If the irrigation for this plant is well-supplied, then the results will be good with a comparable maintenance accompaniment [6]. However, not all agricultural areas in Indonesia have sufficient water to irrigate their paddy fields. Paddy fields can be irrigated by draining water from rivers, community-made water reservoirs, rain, and or flowing using a water pump or diesel fuel/water pump with oil fuel. The use of diesel is less-effective because it must use oil fuel which will increase air pollution [7][8]. In addition, oil fuel is one of the non-renewable energies [9].

Renewable energy that is very easy to find is solar energy [10]. Solar energy can be used to replace oil fuel to generate water pumps with electrical energy [11]. The existence of a water pump with electrical energy derived from renewable energy is expected to facilitate the process of irrigating agricultural land and be more efficient [12][13]. This effort to utilize solar energy uses solar panels to convert sunlight into electrical energy [14]. Therefore, a system is needed to monitor the amount of water flow flowing into each paddy field. Then, in order to facilitate the process of water flow monitoring, an IoT-based system was created [15].

Internet of Things (IoT) is a system where equipment used by humans can be connected to the internet [16]. With this result, equipment users can monitor or control the equipment remotely. IoT has been implemented in many area such as pipe line water [17], smart home system [18], weaver ant cage [19], laboratory [20], water pump voltage [21], agriculture [22][23]. This monitoring is carried out via a smartphone using the Blynk application that supports IoT features. Then, a microcontroller equipped with Wi-Fi such as NodeMCU ESP8266, is programmed so that it can be done with IoT. In addition, the sensor used is a water flow sensor with type YF-S201.

2. METHODS

This study presents the design of equipment that utilizes renewable energy in the form of solar energy. The equipment used for research is a solar-powered water pump. The use of solar energy is expected to reduce the use of oil fuel as an energy source for the generation of diesel-powered water pump. The subject of this research is a water pump generated by a solar panel that produces a flow rate value from the water pump. The water flow generated by the water pump is observed using a water flow sensor, and voltage observations are carried out using a solar charge controller. This study also monitors water flow remotely using an IoT system.

2.1. System Design

The stage of designing a Monitoring System of Solar-Powered Water flow for IoT-based Agriculture first studies the model of the solar water pump system that is already on the market. Manufacturing the optimal model compared to equipment on the market based on literature studies and previous data collection. Whether it is about the solar panel module, the type and specifications of the water pump used, the program used for the microcontroller, the wiring system used for IoT, etc. If the process of studying literature and collecting data is ready, then the design is carried out by designing the system and then installing the system. The system design is in the form of a block diagram shown in Fig. 1. Input is in the form of solar energy which is absorbed by solar panels and converted into electrical energy. In the process section, the electrical energy generated by solar panels is entered into the solar charge controller to regulate the battery charging process.

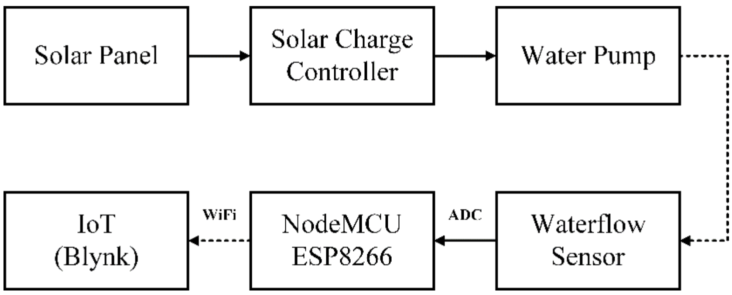


Fig. 1. System block diagram

Furthermore, the first output of this generating system, the electrical energy that has been stored by the battery connected into the water pump, so that the water pump can be used properly. The return input is for the water flow reading system. The water flow generated by the pump becomes data input for the water flow sensor so that the sensor detects the input. Then the data is processed by the NodeMCU ESP8266 microcontroller [24]. The processing outcomes from the NodeMCU ESP8266 microcontroller are sent to the smartphone via the internet or Wi-Fi network displayed on the Blynk application [25]. Based on the system block diagram, there is a water flow sensor and NodeMCU ESP8266 microcontroller as a system that is used to read the flow flow generated by the water pump [26]. The series of the system can be seen as shown in Fig. 2.

Based on Fig. 2, the microcontroller used is NodeMCU ESP8266 which is equipped with a Wi-Fi module. There is a YF-S201 water flow sensor, power supplied from the NodeMCU with a voltage of 3.3V marked with a red cable. Then, for the pins between GND are connected with black cable marks. The water flow sensor reads the pulse wave data which the NodeMCU processes. The sensor signal pin is connected to pin D5 on the

NodeMCU, which is marked with a yellow cable. Input and output tables between the NodeMCU and the water flow sensor can be seen in Table 1.

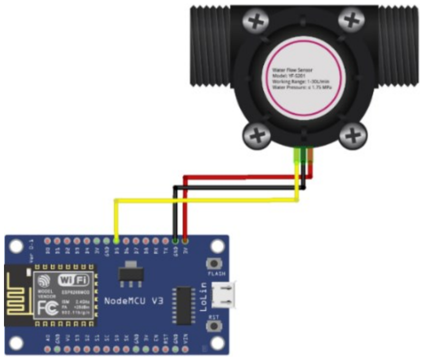


Fig. 2. Wiring diagram

Table 1. Input and output pin

No	NodeMCU	YF-S201
1	GND	GND
2	3.3 V	VCC
3	D5	Signal

2.2. Algorithm

This study presents a system flow diagram that is easy to understand from the beginning of the process to the end of the equipment built to obtain research data. The flow diagram is shown in Fig. 3. A system starts when the solar panel captures solar energy input, then converted into electrical energy and processed by the solar charge controller. The solar charge controller processes the electrical energy stored in the battery as a backup of electrical energy when there is no sunlight [27]. The next process is channeling electrical energy into the water pump to generate it. Then, the water pump will turn on and distribute water. The water flow originating from the pump output will be connected to the water flow sensor for water flow data collection [28]. The data will be processed by the NodeMCU ESP8266 microcontroller, sent to the smartphone via the IoT system, and displayed on the Blynk software.

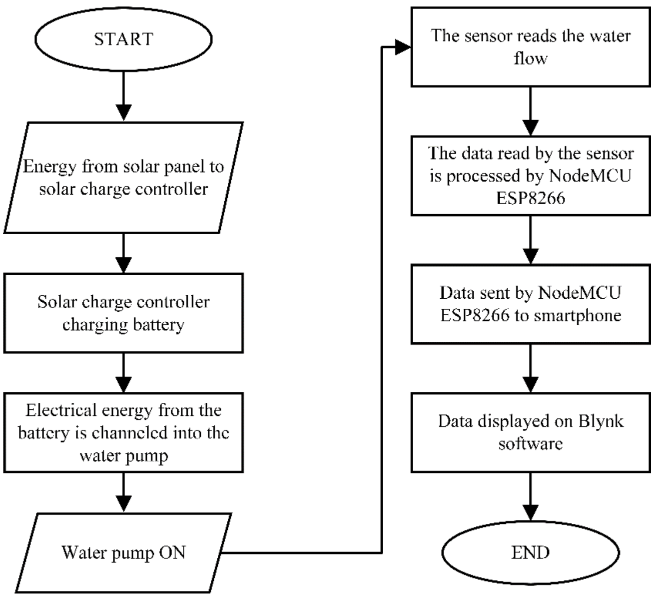


Fig. 3. System flow diagram

3. RESULT AND DISCUSSION

3.1. Sensor Test

This study installed the water flow sensor testing on the water pump output channel. The pinwheels will activate the water flow entered into the sensor, so there is a hall-effect phenomenon [29]. This phenomenon occurs due to a change in the magnetic fields [30][31]. Then, the data generated by the sensor is processed by the microcontroller so that digital data is obtained. The measurement data performed by the water flow sensor is displayed on the Blynk, and the data logger is performed using Google Spreadsheet [32].

Based on this measurement, water flow data is saved in excel, and data can be processed. The test was carried out with a height of the water head of 14 cm. The data obtained in this measurement will be compared with the measurements using a measuring glass so that an error value can be obtained between the sensor and the value of the comparison tools. The data sample used is 20 data. The measurement results can be seen in Table 2.

Table 2. Data of water flow measures

Data Order	Time	Sensor Data (L/m)	Measuring Cup (L/m)	Diff
1	11.04.48 – 11.05.48	1.52	1.58	0.06
2	11.06.30 – 11.07.31	1.71	1.84	0.13
3	11.07.39 – 11.08.41	1.51	1.96	0.45
4	11.08.52 – 11.09.50	1.45	1.38	-0.07
5	11.09.58 – 11.11.06	1.44	1.92	0.48
6	11.11.14 – 11.12.01	1.26	1.30	0.04
7	11.12.11 – 11.13.16	1.59	1.72	0.13
8	11.13.24 – 11.14.23	1.37	1.42	0.05
9	11.14.29 – 11.15.34	1.39	1.72	0.33
10	11.15.39 – 11.16.39	1.22	1.50	0.28
11	11.16.45 – 11.17.40	1.03	1.42	0.39
12	11.17.45 – 11.18.54	1.12	1.68	0.56
13	11.18.59 – 11.19.56	1.04	1.54	0.5
14	11.20.03 – 11.21.05	1.08	1.68	0.6
15	11.21.10 – 11.22.11	1.11	1.52	0.41
16	11.22.17 – 11.23.07	1.03	1.36	0.33
17	11.23.13 – 11.24.26	1.49	2.46	0.97
18	11.24.31 – 11.25.37	1.42	1.94	0.52
19	11.25.44 – 11.26.42	1.26	1.58	0.32
20	11.26.49 – 11.27.51	1.39	1.64	0.25
Average		**1.3215**	**1.658**	**0.3365**

Based on Table 2, data analysis was carried out to calculate the standard deviation value. The standard deviation value is an indicator of finding out the deviated data. The difference value will be used to determine the standard deviation value. This was conducted in order to facilitate the circulation of standard deviation values. Then, the difference value is likened to the value of "x". From the value of "x," calculated the average and obtained a value of 0.3365. In conducting data analysis, Table 3 was made.

Table 3. Calculation data of deviation standard value

n	x	$\bar{x}$	$x - \bar{x}$	$(x - \bar{x})^2$
1	0.06	0.3365	-0.3075	0.09456
2	0.13		-0.2375	0.05641
3	0.45		0.0825	0.00681
4	-0.07		-0.4375	0.19141
5	0.48		0.1125	0.01266
6	0.04		-0.2965	0.08791
7	0.13		-0.2375	0.05641
8	0.05		-0.3175	0.10081
9	0.33		-0.0445	0.00198
10	0.28		-0.0875	0.00766
11	0.39		0.0225	0.00051
12	0.56		0.1925	0.03706
13	0.5		0.1325	0.01756
14	0.6		0.2325	0.05406
15	0.41		0.0425	0.00181
16	0.33		-0.0375	0.00141
17	0.97		0.6025	0.36301
18	0.52		0.1525	0.02326
19	0.32		-0.0475	0.00226
20	0.25		-0.1175	0.01381
Σ	**7.35**			**1.13086**

Based on Table 3, the standard deviation is calculated [33]. The standard deviation can be formulated as (1) [34].

$$S^2 = \frac{\sum_{i=1}^{n}(x - \bar{x})^2}{n-1} \tag{1}$$

where S^2 is variant, S is standard deviation, x is difference value, $\bar{x}$ is average of difference value, n is number of samples. Determination of standard deviation from 20 samples of water flow data can be formulated as (2).

$$S^2 = \frac{\sum_{i=1}^{n}(x - \bar{x})^2}{n-1} \tag{2}$$

$$S^2 = \frac{1{,}13086}{20-1}$$

$$S^2 = \frac{1{,}13086}{19}$$

$$S^2 = 0{,}0595$$

$$S = \sqrt{0{,}0595}$$

$$S = 0{,}244$$

The calculation shows that the standard deviation value obtained is 0.244. The average value of 20 samples of water flow data is 0.3365. It is compared that the standard deviation value is lower than the mean value. Hence, the distribution of each data/individual data is close to the average of the sample values used. A graphic comparison of the data read by the sensor and the data measured on the measuring cup can be seen in Fig. 4.

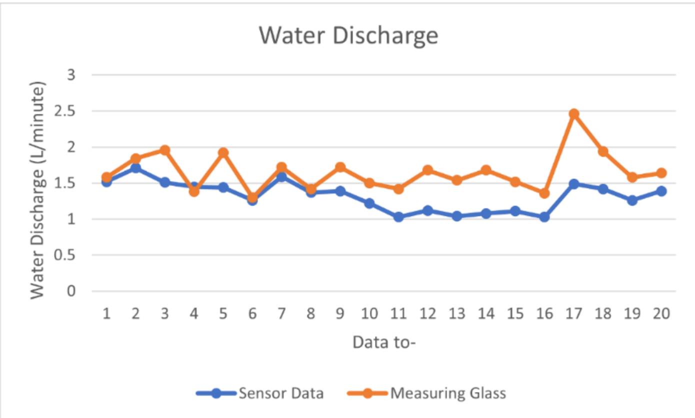


Fig. 4. Graph of water flow between sensor and measuring cup

Based on Table 3, the average value generated by the water flow sensor is 1.3215. From this data, it can be seen that the total volume produced for 20 minutes. The calculation of generated volume is as (3).

$$Discharge = \frac{Volume}{Time} = \frac{l}{minute} \tag{3}$$

$$Volume = Discharge \times Time = \text{L}$$

The data:
Average of water flow : 1.3215 liters
Time : 20 minutes
Calculation:
Volume = 1.3215 × 20
= 26.43 liters
Thus, the total volume read by the sensor within 20 minutes is 26.43 liters.

3.2. Water Pump Test

This test can determine the effect between the voltage used to supply the water pump and the generated water flow [35]. Is there a difference change in the voltage supplied to the water pump? This test is carried out by observing voltage change on the solar charge controller when the load section is connected.

This process is carried out simultaneously with the measurement of water flow data, so that can be seen the impact of voltage changes [36]. In this process, the battery is also in a state of charging. So that the generated voltage is also affected by the presence of sunlight [37]. The voltage value of the water pump and the generating water flow are shown in Table 4.

Based on Table 4, the water flow is directly proportional to the voltage. Water flow that is used as a reference is measured using a measuring cup because the legible data is more accurate than sensor data.

Table 4. Voltage value therewith water flow

Data Order	Time	Data Sensor (L/m)	Measuring Glass (L/m)	Voltage (V)
1	1m	1.52	1.58	12.4
2	1m 1d	1.71	1.84	12.4
3	1m 2d	1.51	1.96	12.4
4	58d	1.45	1.38	12.1
5	1m 8d	1.44	1.92	11.9
6	45d	1.26	1.30	11.8
7	1m 5d	1.59	1.72	11.8
8	59d	1.37	1.42	11.9
9	1m 5d	1.39	1.72	11.9
10	1m	1.22	1.50	11.9
11	55d	1.03	1.42	12.1
12	1m 9d	1.12	1.68	12.0
13	57d	1.04	1.54	12.2
14	1m 2d	1.08	1.68	12.1
15	1m 1d	1.11	1.52	12.1
16	50d	1.03	1.36	12.3
17	1m 13d	1.49	2.46	12.4
18	1m 6d	1.42	1.94	12.3
19	58d	1.26	1.58	12.2
20	1m 2d	1.39	1.64	12.2
Average		**1.3215**	**1.658**	**12.12**

The data in Table 4 shows that the voltage affects the pump's suction power. The greater voltage, the stronger the suction power of water pump [38]. So that generated of water flow also greater. Data in Table 4 represents when the data is at the same interval time with different voltages, the comparison of generated water flow can be seen. The comparison is presented in a graph that can be seen in Fig. 5.

The graph lacks details when comparing water flow alteration caused by voltage alteration in the same interval time. This is because of alteration in voltage value is not large enough, so the water flow only altered slightly.

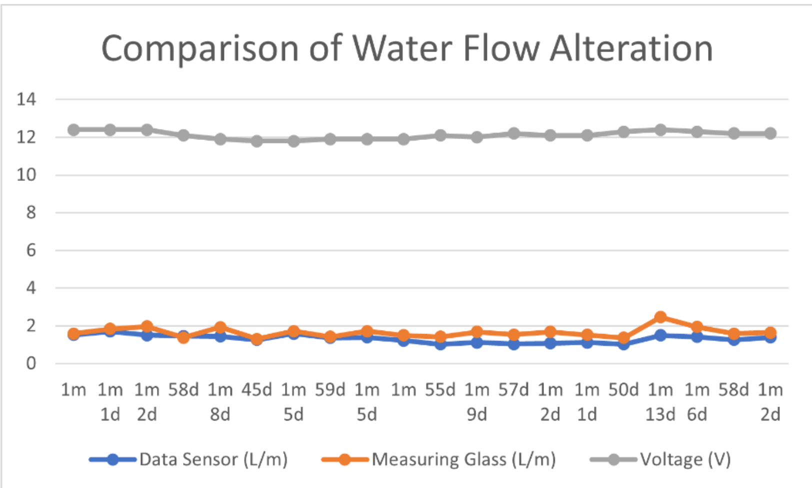


Fig. 5. Comparison of water flow alteration

3.3. Monitoring System Testing

Blynk is a software/platform that can be accessed using a smartphone or the Blynk website [39]. Blynk functions as a controller and monitoring microcontroller equipped with a Wi-Fi module. So that the control and monitoring process can be carried out remotely as long as the microcontroller is connected to the internet network, this study used a NodeMCU ESP8266 microcontroller to assist in the water flow monitoring process [40]. The display of Blynk that has been configured is shown in Fig. 6.

Fig. 6. Display of Blynk application user interface

In Fig. 6, an LCD display arrangement with descriptions of "Water Flowing" and "Water Not Flowing" will be displayed during the process. There is a Gauge to display generated water flow. Then, an LED indicator will light up green when the water flow is legible. Finally, there is a number value that will display the total volume of water flow that has been read by the sensor.

The test for the monitoring system is carried out by observing the water flow and the total volume displayed on the Blynk application for ±2.5 hours. The Blynk interface displays water flow data and total volume, as shown in Fig. 7.

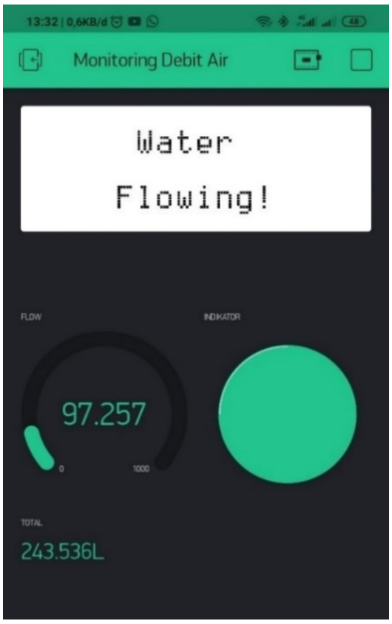
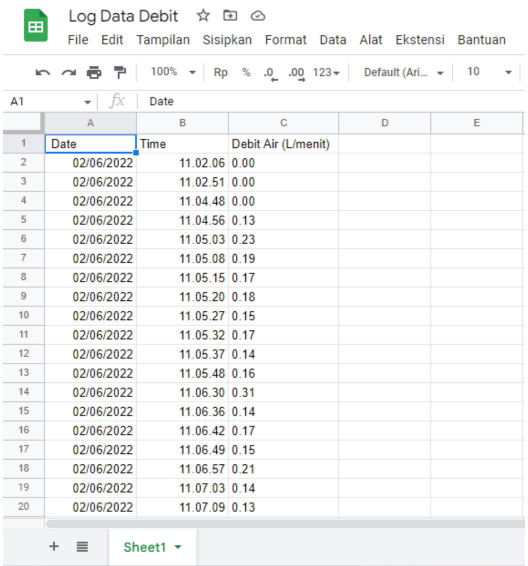


Fig. 7. Display monitoring process on the Blynk application

This monitoring process is sent to Google Spreadsheet for data acquisition [41]. The monitoring display on the spreadsheet is shown in Fig. 8. During the test process with a time of approximately 2.5 hours and produces a total volume that is legible by the sensor every 30 minutes. The results of the total volume obtained are shown in Table 5.



Log Data Debit

Date	Time	Debit Air (L/menit)
02/06/2022	11.02.06	0.00
02/06/2022	11.02.51	0.00
02/06/2022	11.04.48	0.00
02/06/2022	11.04.56	0.13
02/06/2022	11.05.03	0.23
02/06/2022	11.05.08	0.19
02/06/2022	11.05.15	0.17
02/06/2022	11.05.20	0.18
02/06/2022	11.05.27	0.15
02/06/2022	11.05.32	0.17
02/06/2022	11.05.37	0.14
02/06/2022	11.05.48	0.16
02/06/2022	11.06.30	0.31
02/06/2022	11.06.36	0.14
02/06/2022	11.06.42	0.17
02/06/2022	11.06.49	0.15
02/06/2022	11.06.57	0.21
02/06/2022	11.07.03	0.14
02/06/2022	11.07.09	0.13

Fig. 8. Display monitoring process on the google

In Table 5, a graph plot is carried out to assist in the data analysis process. The graph of the volume every 30 minutes is shown in Fig. 9.

Table 5. Voltage value therewith water flow

No	Time	Total Volume (L)
1	11.35	38.45
2	12.05	50.61
3	12.35	37.41
4	13.05	42.96
5	13.35	74.21
	Total	**243.64**

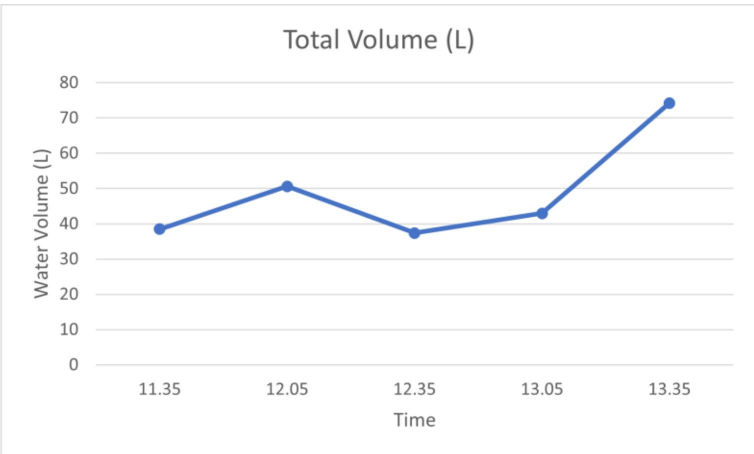


Fig. 9. The graph of water volume every 30 minutes

There is an unstable volume, at 13.35, the largest total volume was obtained, which is 74.21 liters, due to the effect of the fixes hose by the author when doing the test. When testing the water inlet section, the hose used a poor-quality hose. In this study, using a hose dramatically affects the flow of water produced. The hose used can be seen in Fig. 10.

Fig. 10. Hose used for testing

3.4. Whole System Testing

This test was carried out on land planted with chili aged approximately five months. Irrigation conducted by using water from reservoirs made by farmers on some of their agricultural land. The test was carried out for 6 hours with the water head between the water pump and water surface at approximately 37 cm, as shown in Fig. 11.

Fig. 11. The height of the water head

The test was carried out from 09.00 to 15.00 on agricultural land planted with chilies of around 180m2. The test results are 30 data samples with 5 minutes each at different hours. The results obtained for water flow are shown in Table 6.

Table 6. Data sample of water flow

Data Order	Time	Water Head (cm)	Data Sensor (L/minute)
1	09.01.13 – 09.02.14	37	1.09
2	09.02.21 – 09.03.20		1.02
3	09.03.29 – 09.04.31		1.10
4	09.04.40 – 09.05.42		1.07
5	09.05.52 – 09.06.50		1.12
6	10.31.08 – 10.32.09		1.12
7	10.32.18 – 10.33.20		1.38
8	10.33.32 – 11.34.35		1.26
9	10.34.48 – 11.35.51		1.24
10	10.36.02 – 11.37.03		1.13
11	12.14.45 – 12.15.40		1.17
12	12.15.48 – 12.16.52		1.42
13	12.16.59 – 12.17.56		1.33
14	12.18.07 – 12.19.05		1.22
15	12.19.13 – 12.20.11		1.34
16	14.05.17 – 14.06.15		1.23
17	14.06.23 – 14.07.26		1.36
18	14.07.34 – 14.08.37		1.22
19	14.08.44 – 14.09.42		1.17
20	14.09.53 – 14.10.52		1.24
Average			**1.2115**

Based on Table 6, the water flow at each time of 5 minutes with 30 data and a water head height of 37 cm, obtained an average value of 1.2115. Compared to Table 5, that is obtained 1.3215 with 14 cm a water head height. It can be said that the higher the water head, the generated water flow will be affected by testing on agricultural land with different water head heights.

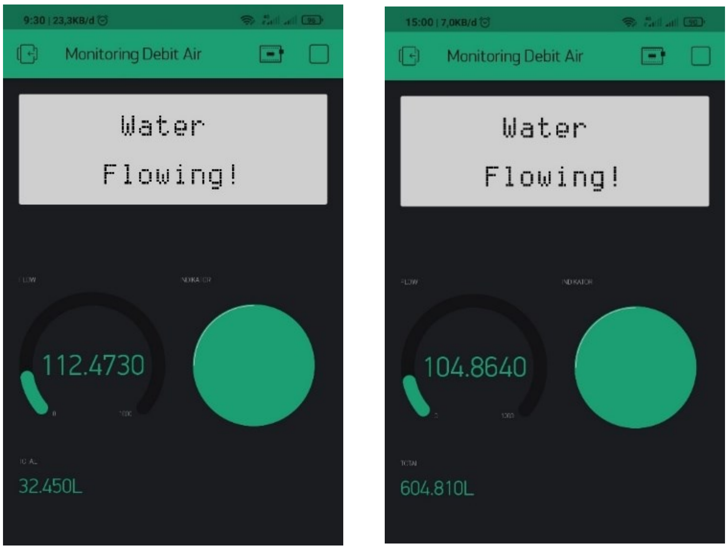
Furthermore, the voltage test consists of solar panel voltage, battery voltage, and water pump voltage. This test was conducted for 6 hours every 20 minutes by measuring the voltage contained in the SCC socket using a multi-meter, and the results are shown in Table 7.

Table 7. Measurement of the solar panel voltage, batteries, and water pumps

No.	Time	Solar Panel Voltage (V)	Battery Voltage (V)	Water Pump Voltage (V)
1	09.00	17.8	11.8	11.6
2	09.20	18.0	12.0	11.8
3	09.40	18.0	12.5	12.2
4	10.00	18.5	12.8	12.4
5	10.20	19.0	13.0	12.5
6	10.40	19.0	13.2	12.5
7	11.00	19.0	13.5	12.6
8	11.20	19.0	13.8	12.6
9	11.40	19.5	14.0	12.8
10	12.00	19.5	14.2	12.9
11	12.20	20.0	14.2	13.0
12	12.40	19.8	14.5	13.2
13	13.00	20.0	14.0	12.9
14	13.20	20.0	13.5	12.7
15	13.40	19.0	13.0	12.4
16	14.00	19.0	12.8	12.4
17	14.20	18.5	12.5	12.2
18	14.40	18.5	12.2	12.0

Based on Table 7, the battery and water pump voltage is smaller than the solar panel voltages because the SCC already regulates the voltages. Starting from 10.20 to 14.00, the voltage obtained is quite optimal. However, the water flow obtained in Table 6 is smaller than in Table 2. It is affected by the different heights of the water head; in this test, the water head is higher.

Furthermore, the monitoring test of the total volume of water was carried out every 30 minutes. This test was conducted by monitoring the total volume that has flowed in the agricultural land area through the Blynk application. The monitoring process can be seen in Fig. 12. More details of the total volume every 30 minutes is shown in Table 8.



(a) (b)

Fig. 12. Monitoring process conducted by Blynk application

Table 8. Water volume monitoring

No.	Time	Water Volume (L)	Total Volume (L)
1	09.30	32.45	32.45
2	10.00	38.42	70.87
3	10.30	43.78	114.65
4	11.00	49.37	164.02
5	11.30	54.91	218.93
6	12.00	56.36	275.29
7	12.30	66.42	341.71
8	13.00	62.87	404.58
9	13.30	57.63	462.21
10	14.00	52.34	514.55
11	14.30	47.87	562.42
12	15.00	42.39	604.81

4. CONCLUSION

In conclusion, the testing of the water flow sensor obtained a standard deviation value of 0.244 using 20 samples of data, with the average measured sensor value and calibration equipment being 0.3365, so the distribution of 20 data samples in terms of standard deviation value is close to the average value.

The average value of water flow is legible by the sensor for about 20 minutes in the amount of 1.3215. The calculation of the water flow formula is 26.43 liters. The average water flow using 20 data samples in the testing of a whole system is 1.2115 liters/minute, with the total volume for 6 hours being 604.81 liters.

Based on this study, some factors affect the amount of water flow produced, specifically the water head. The higher the water head, the smaller the water flow will be produced. In the testing of water pump voltage, voltage alteration affects the water flow produced by the pump. The worse hose quality is used; when the pump's suction power is high, the worst quality of the hose will quickly flatten and affect the water flow produced.

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