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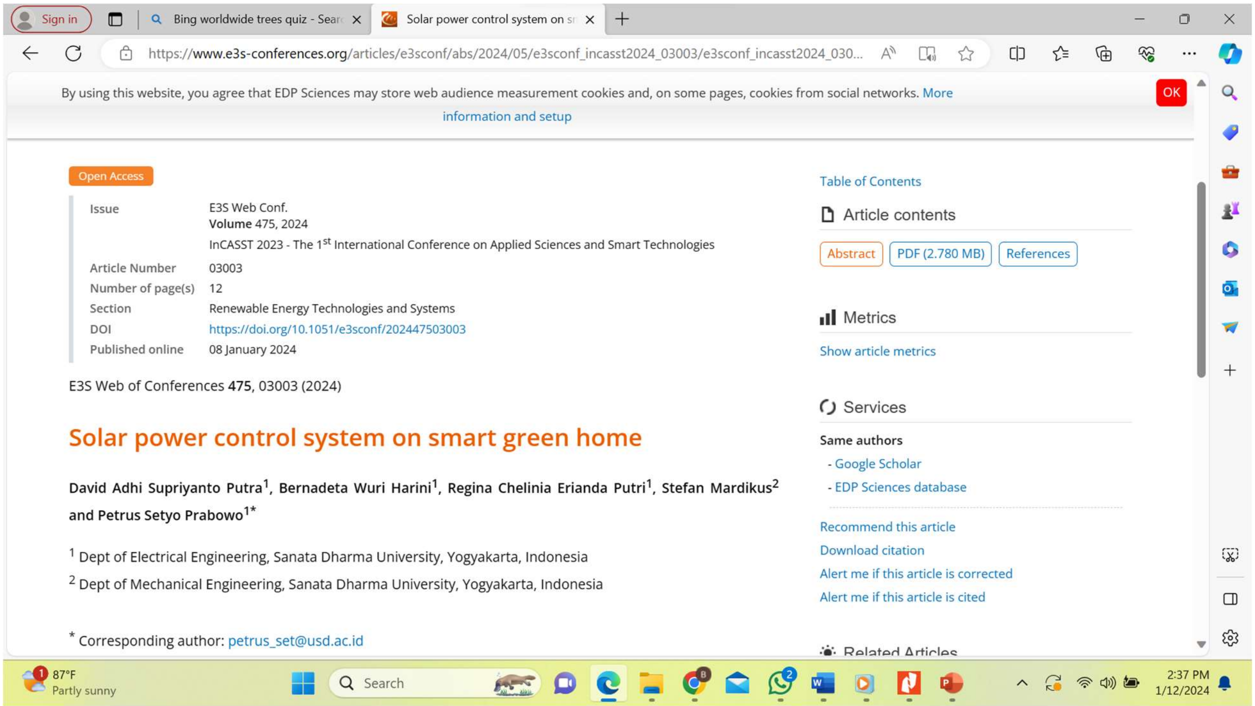

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Solar power control system on smart green home

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PREFACE

The 1st International Conference on Applied Sciences and Smart Technologies (InCASST 2023) has been organized by the Faculty of Science and Technology, Sanata Dharma University, Yogyakarta, Indonesia. This event was held on October 18–19, 2023, in Yogyakarta, Indonesia. As an effort to contribute in distributing research outcomes, especially in the search for renewable and clean energy, waste management, environmental management, and sustainable agriculture. InCASST 2023 presented four honorable international keynote speakers from representative countries: 1) Prof. Tokuro Matsuo, Advanced Institute of Industrial Technology - Japan; 2) Prof. Ir. Sudi Mungkasi, Ph.D., Sanata Dharma University-Indonesia; 3) Assoc. Prof. Dr. Peerapong Uthansakul, Suranaree University of Technology – Thailand, and 4) Assist. Prof. Dr. Eng. Rando Tungga Dewa, The Republic of Indonesia Defense University-Indonesia. This event selected local researchers and overseas fellows to share their best research works at this conference to reach a broader network of researchers. After a rigorous selection process, the Scientific & Editorial Board decided to publish 46 papers in E3S Web of Conferences, open-access proceedings in environment, energy, and earth sciences, managed by EDP Sciences, and indexed on Scopus, Scimago.

The published papers have passed all necessary improvement requirements following the Web of Conferences standard, reviewer's comments, and similarity tests by the Turnitin program. We want to thank the official committee, scientific & editorial boards, and organizing partners. Thanks to our co-host partners, Universitas Katolik Widya Mandala Surabaya, Universitas Prasetya Mulya, and Institut Teknologi Nasional Yogyakarta, for trusting and supporting this conference. Finally, we would like to briefly thank all presenters and attendees for their participation in sharing wonderful ideas and making creative decisions to inspire further research and exchange scientific reasons. We hope this time, all papers can be compiled into scientific works as the first publication of the 2023 InCASST. Lastly, we hope this conference encourages further research collaboration and see you at the next conference.

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Solar power control system on smart green home

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Abstract. The need for fossil fuel electricity usage is increasing every year. If used for a long period of time, it will eventually run out. To reduce the use of fossil fuel energy, other alternatives are needed to maintain the availability of natural resources, one of which is by utilizing renewable energy. Utilization of solar power as an electrical energy source using photovoltaic panels. In its application, a solar power plant requires a controller that can regulate the energy produced. This controller is responsible for regulating the process of selecting the battery to be used. The working principle of this device is that when the battery reaches the minimum voltage threshold, the battery usage will be diverted to another battery with a voltage above the minimum threshold. The results of the research show that the system is capable of performing switching processes well using the smart switching method with a 100% success rate. The system uses an INA219 sensor for reading voltage and current from the battery. This research uses a 10-watt DC lamp, 20-watt DC lamp, and 30-watt DC lamp as loads. The battery can last for 4,8 hours by using a 10-watt DC lamp as a load, 2,4 hours by using 20-watt DC lamps as a load, and 1,6 hours by using 30-watt DC lamp as a load.

1 Introduction

1.1 Background

The need for electric power is increasing but the demand for electric power is not proportional [1,2]. The fossil fuels used in electricity production also increase because availability of electricity is increased [3]. To reduce the use of fossil fuel energy, other alternatives are needed to maintain the availability of natural resources, one of which is the use of renewable energy. Renewable energy is energy that comes from natural resources and is not limited or can be renewed. An example is solar energy, which can be continuously used. The main benefit of using renewable energy is that it produces no emissions [4,5]. For example, using solar panels, which do not produce pollution, because renewable energy does not release dangerous gases when producing energy.

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Utilization of solar power as a source of electrical energy using photovoltaic panels Photovoltaic is a technology that uses solar energy by converting sunlight energy into electrical energy [6].

Solar energy can only be utilized from morning to evening when the weather is sunny. There are two types of solar panels: monocrystalline solar panels and polycrystalline solar panels. The most significant difference between the two types of panels is their efficiency. The performance of monocrystalline solar panels is superior to that of polycrystalline solar panels. Monocrystalline solar panels are able to produce more energy even in varying weather conditions and air temperatures [7].

The energy generated by PLTS can be used directly. However, because sunlight is only available in the morning and evening, a battery is needed to store energy so that it can be used at night. In order for this to be done, more than one battery or a battery with a large capacity is needed so that the electricity supply is not interrupted. Therefore, a battery management system is needed. If the capacity of one of the batteries runs out, then the use of the battery will be automatically transferred to another battery that has a higher voltage [8–11].

The changeover switch (COS) method is a solution to switching electric power automatically. Research on battery management systems that has been carried out by C.A. Osaretin, E. Ibhadode, and S.O. Igbinovia with the title "Design and Implementation of Automatic Changeover Switch (With Step Loading) For Renewable Energy Systems". In this study, the system uses two sources, namely sunlight and a generator. However, the system in this study only uses a step-down transformer [12]. This system development has also been carried out by L.S. Ezema, B.U. Peter, O.O. Harris (2012) with the title "Design of Automatic Change Over Switch with Generator Control Mechanism". However, in this study, the source used was only a generator. Therefore, this research will be used to develop existing research. In the tool, there will be a number of batteries to overcome the problem of battery capacity and a number of solar panels [13]. Apart from that, Novi Kurniawan, through the research "Electrical Energy Monitoring System and Automatic Transfer Switch (ATS) Controller with the Internet of Things for Solar Power Plants," discusses automatic transfer switch technology that works at a certain battery capacity according to the user's settings [14].

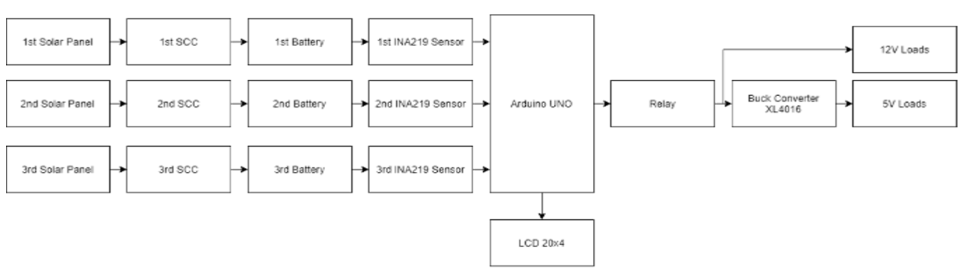

Fig. 1. Block diagrams.

2 Research methods

The methods used in this study include: (1) Literature study aims to study literature related to solar electric control systems in smart green home, namely the application of Arduino UNO, and to design several components such as converters, INA219 sensors, and LCDs used in the tool design process. (2). System design is the stage of designing the electricity supply method for a solar electric control system for a smart green home system by considering the problems and needs that have been determined. (3). Program design: designing a program for a solar power control supply system in a smart green home system by automatically switching battery use if the capacity of one of the batteries experiences a voltage drop using a

Changeover switch (COS) system. If the voltage on one of the batteries drops, then it will be read by the Arduino UNO, and battery use will automatically switch to a battery that has more voltage. It is assumed that not all batteries are empty. (4). The process of collecting data, conducting tests, and taking measurement results on sensors and battery management systems the test is carried out by testing the voltage and current values detected on the INA219 sensor according to the voltage and current values measured via a multimeter. Data collection is carried out by testing the output voltage and current on each battery, which are measured by the INA219 sensor, which will be displayed via a 20x4 LCD and compared with a multimeter to determine the accuracy of the tool. (5). Analysis and conclusion of the experimental results: analysis and conclusion are carried out by comparing the percentage of error and the accuracy of the INA219 sensor in measuring the current and voltage on the battery. The LED serves as an indicator of which battery is being used. Then data analysis is carried out by comparing measuring instruments with sensors, and conclusions will be drawn based on the tool.

2.1. Block diagrams

In this stage, a method for supplying electricity to a solar electric control system for a smart green home system is designed by considering the problems and needs that have been determined. The system design can be seen in Figure 1.

2.2. Flow chart

The switch process will be carried out automatically using the changeover switch (COS) method. The initial stage of the switch process is to set the minimum voltage drop on the battery. It is assumed that not all batteries are full. Then the system will read all the voltage and current in each battery with INA219 sensor. If all batteries voltage is low, then all relays will off. When there is a full battery, the battery will provide a high input to the relay, and the relay will turn on then be used to supply the load. When the voltage from the battery drops, it will give a low input to the relay, and the relay will be off. Then, if the relay is off, the use of the battery will be automatically transferred to another battery that has a higher voltage. The switching process flow diagram can be seen in Figure 2.

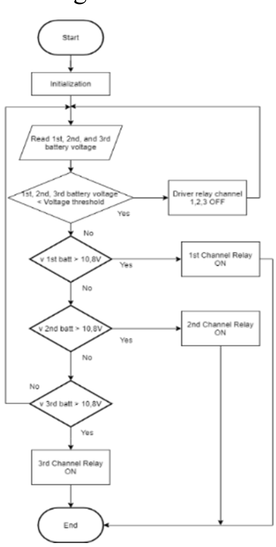

Fig. 2. Flow chart.

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3 Test result

This chapter will discuss the results of observations from each sensor used in the research of the Electrical Control System in the Smart Green Home System. Observations are in the form of data from testing each sensor. The test to be carried out is a comparison between the measurement results of the tool and those of other measuring instruments. In addition, testing will be carried out to determine the suitability of the tool with respect to its benefits and objectives.

3.1 Electronics circuit

The following is the overall circuit shown in Figure 3.

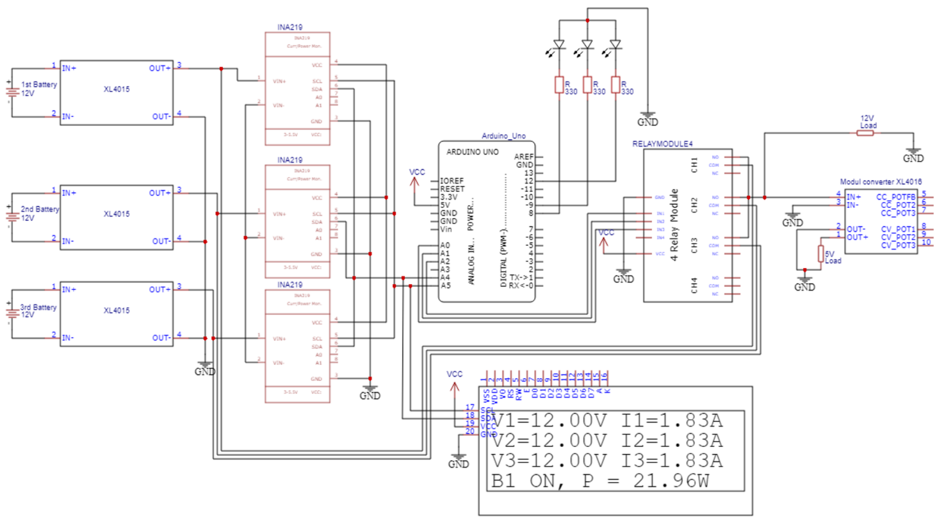

Fig. 3. Electronics circuit.

3.2 Hard ware Implementation

This section describes the hardware implementation and measurement results for each sensor used.

3.2.1 Physical form of the tool

The physical form of the device contains the smart switching system. The tool is made with a box that has a length of 18cm, a width of 11 cm, and a height of 6 cm and is made of plastic. These boxes can be purchased at offline and online stores.

The battery selection process is governed by a smart switching system. The smart switching box has an indicator and an LCD. The LCD displays voltage, current, and battery power, as well as the battery being used. The indicator shows the selection of the battery being used. There are three outputs on the smart switching device. The first output is 5 volts, and the other two outputs are 12 volts each for DC voltage. The physical form of the tool can be seen in Figure 4.

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Fig. 4. Physical from of the tool.

3.2.2 Battery input ports

The battery input port is used to supply power to the system. Power from the three solar power plants is then channelled to the battery, and from the battery, it will be channelled to the system. Then it will enter the system through the XL4015 converter. The display of the battery input port is shown in Figure 5.

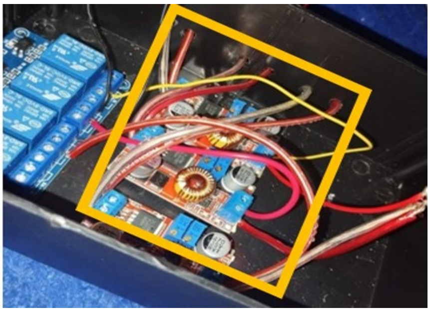

Fig. 5. Battery input ports.

3.2.3 Smart switching

This circuit consists of an Arduino UNO as a microcontroller, an INA219 as a sensor to measure current and voltage, and a 4-channel 5V relay. Arduino UNO functions to regulate the entire work process of the system, starting from the ADC reading process to setting the minimum battery voltage limit. In this smart switching, power from the battery will be received by the INA219 sensor. This sensor functions to read the current and voltage from the battery, which will then be sent to the Arduino UNO to control the switching process on the relay.

The relay functions as a switch between the battery and the load. The relay will supply power to the load after receiving a command from the Arduino UNO. The COM (Command) port on relay 1 will be connected to battery 1, and the NO (Normally Open) port will be connected to the load. Likewise, relays 2 and 3 The difference in this relay port will create logic when the battery voltage is equal to the minimum voltage limit or when the voltage of one battery is greater than the voltage of the other two batteries. Then the battery that has the same voltage as the minimum voltage limit or that has a lower voltage than the battery used will not be used to supply the load, and the charging process will be carried out.

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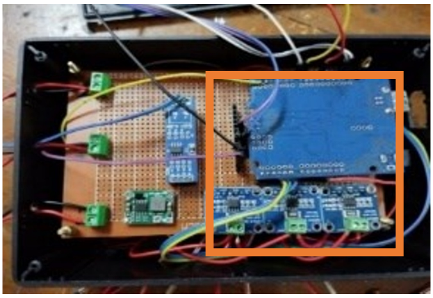

Fig. 6. Sub-system smart switching.

3.2.4 LCD display

The LCD display functions to inform the user of the battery state of the system so that the user can find out the condition of the battery. Users can monitor which batteries are active, each battery's voltage and current, and each battery's power. The LCD display can be seen in Figure 7.

Fig.7. LCD display when the battery is used.

Figure 7 shows the display if the battery chooses one battery. If one battery is selected, the fourth line will display which battery is used and the power used. If all the batteries are weak, then the last line of the LCD will not display the batteries used and the power used but "ALL BATT IS LOW," as shown in Figure 8 below.

Fig. 8. LCD display when all batteries are off.

3.3 Testing and analysis

In this section are the results of testing the entire tool system. This tool uses a microcontroller to carry out the process of reading the voltage and current of each battery. The value of the battery voltage and current will be displayed via the 20x4 LCD as a user interface with a display of 80 characters. It has four lines, and each line has 20 characters. Then the data displayed on the LCD will be compared with a digital multimeter as a measuring tool to determine the accuracy of the sensor.

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3.3.1 Battery life testing

This tool uses three batteries, with each battery using a solar panel to charge the battery. Battery life testing is carried out using various loads. The first test was carried out using a 10W lamp load, as shown in Figure 9.

Fig. 9. Testing with 10W lamp load.

The following are the results of testing battery life with a light load of 10W can be seen in Table 1.

Table 1. Battery life test data with 10W lamp load.

Time (Minute)	Voltage (V)	Current (I)	Power (Watt)	Loads
0	12,30	0	0	Without loads
0	12,08	0,39	4,71	10 Watt
30	12,01	0,38	4,56	10 Watt
60	11,94	0,37	4,42	10 Watt
90	11,86	0,36	4,27	10 Watt
120	11,80	0,35	4,13	10 Watt
150	11,74	0,35	4,11	10 Watt
180	11,66	0,34	3,97	10 Watt
0	11,76	0	0	Without loads

In Table 1, it can be seen that the initial voltage of the no-load battery is 12.3 volts. When given a 10W lamp load, the voltage drops from 0.22V to 12.08V. After experimenting with a 10W lamp load for three hours, the battery voltage decreased by 0.47V. To calculate battery life, assume the full battery voltage is 13 volts and the minimum voltage limit is 10.8 volts. So, the battery can last for 14.04 hours with a light load of 10 W using the equation:

$$\text{Endurance}=\frac{\text{maximum voltage-minimum voltage}}{\left(\frac{\text{Voltage drop (V)}}{\text{Usage time (Hours)}}\right)} \quad (1)$$

After testing with a 10W lamp load, a test was also carried out with a 20W lamp load. The following is a table for testing battery life with a load of 20 W can be seen in Table 2.

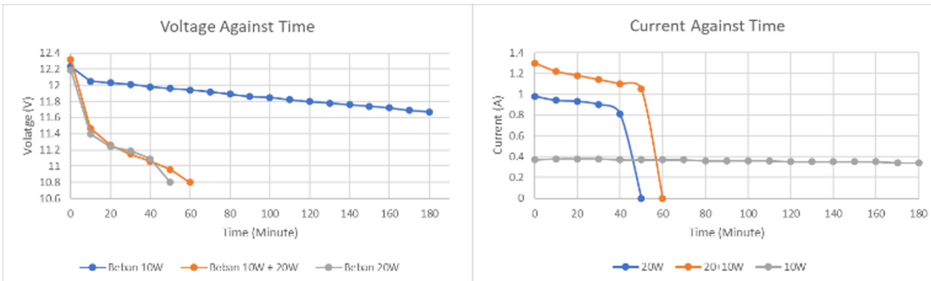

Fig. 10. Chart of each voltage and current against time.

Table 2. Battery life test data with 20W lamp load.

Time (Minute)	Voltage (V)	Current (I)	Power (W)	Loads
0	12,19	0	0	Without loads
0	11,4	0,98	11,22	20W
10	11,24	0,94	10,61	20W
20	11,19	0,93	10,41	20W
30	11,09	0,90	9,98	20W
40	10,80	0,81	8,79	20W
0	11,93	0	0	Without loads

In Table 2, it can be seen that the initial voltage of the no-load battery is 12,19V. When given a 20-watt lamp load, the voltage drops from 0,79V to 11,4V. After experimenting with a 20W lamp load for approximately 40 minutes, the battery voltage touched the minimum limit, so I switched to another battery. To calculate battery life, assume the full battery voltage is 13 volts and the minimum voltage limit is 10.8 volts. So, the battery can last for 5.64 hours with a light load of 20W using equation 1.

After testing with a 20-watt lamp load, the next test is carried out with a 10W and 20W load simultaneously. The following is a table for testing battery life with a light load of 10W and 20W can be seen in Table 3.

Table 3. Battery life test data with 10W+20W lamp load.

Time (Minute)	Voltage (V)	Current (I)	Power (W)	Loads
0	12,32	0	0	Without loads
0	11,47	1,30	14,86	30W
10	11,26	1,22	13,74	30W
20	11,15	1,18	13,13	30W
30	11,06	1,14	12,64	30W

40	10,96	1,10	12,09	30W
50	10,80	1,04	11,26	30W
0	11,61	0	0	Without loads

In the table 3 above, it can be seen that the initial voltage of the no-load battery is 12.32 volt. When given a load of 10W and 20W lamps, the voltage drops from 0.85V to 11.47V. After experimenting with 10W and 20W lamp loads, which were carried out for approximately 50 minutes, the battery voltage touched the minimum limit, so I switched to another battery. To calculate battery life, assume the full battery voltage is 13 volts and the minimum voltage limit is 10.8 volt. So, the battery can last for 2.58 hours with a light load of 10W and 20W, using equation 1.

In the table 3 above, it can be seen that the initial voltage of the no-load battery is 12,32 volts. When given a load of 30W lamps, the voltage drops from 0.85V to 11.47V. After experimenting with 10W and 20W lamp loads, which were carried out for approximately 50 minutes, the battery voltage touched the minimum limit, so I switched to another battery. To calculate battery life, assume the full battery voltage is 13 volts and the minimum voltage limit is 10.8 volts. So, the battery can last for 2.58 hours with a light load of 30W, using equation 1.

In this study, we used a 12V, 5Ah battery. For the calculation results if using 1 battery, then using equations:

$$\text{Usage time} = \frac{I_{Battery}}{I_{Loads}} - \left(\frac{I_{Battery}}{I_{Loads}} \times \frac{20}{100}\right) \quad (2)$$

The result using equations 2 as follows:

1. With a lamp load of 10W, the usage time is 4,8 hours.
2. With a lamp load of 20 W, the usage time is 2,4 hours.
3. With 10W and 20W lamp loads, the usage time is 1,6 hours.

The above calculation applies if the power supply only uses one battery. If using three batteries, the results of the calculation above are multiplied by 3. From the tests carried out, the results are not in accordance with the existing theory because the load specifications are not in accordance with what is written. The graph of current and voltage against time will be displayed in the form of an image in Figure 10.

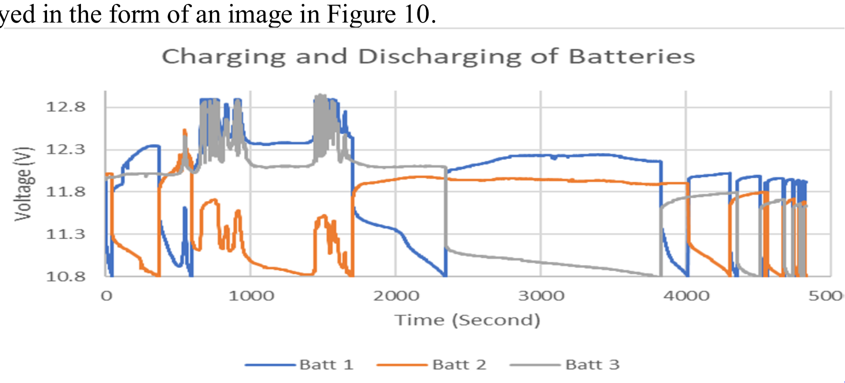

Fig. 13. Chart of battery discharge and charge under 20W load.

3.3.2 Smart switching testing

The switching carried out in this study locks the input power from one battery to another. The transfer is done automatically using a relay based on the minimum battery voltage. The minimum battery setting is set via a program that is uploaded to the microcontroller. The minimum voltage is set to 10,8 volts and a 10W lamp is loaded to carry out this test. This test is carried out briefly to determine whether the system can perform an automatic switch or not. The following is a picture when the relay is on and off alternately. Movement will be indicated through an indicator in the form of an LED. **The following in Table 4 is the voltage data when the relay is on or off alternately when given a lamp load of 10W.**

Table 4. The voltage when the relay is on/off alternately.

Batteries			**Relay**		
B1	**B2**	**B3**	**CH 1**	**CH 2**	**CH 3**
10.8	11.9	11.74	OFF	ON	OFF
12.03	10.74	11.78	ON	OFF	OFF
10.79	11.73	11.79	OFF	OFF	ON
11.99	11.79	10.80	ON	OFF	OFF
10.79	11.80	11.65	OFF	ON	OFF
10.79	11.66	11.71	OFF	OFF	ON
11.95	11.71	10.80	ON	OFF	OFF
10.78	11.72	11.63	OFF	ON	OFF
10.78	11.64	11.66	OFF	OFF	ON
10.74	10.69	10.71	OFF	OFF	OFF

In the experiment, this system had several advantages and disadvantages. The advantage of this system is that it has a switching system, which makes it easier for users to use the system without having to frequently check and replace the batteries used. Apart from that, another advantage is that this system does not depend on an electricity source because it uses batteries produced from solar energy. The disadvantages of this system is that the amount of power produced is unstable because battery charging depends on solar energy [6,13,14].

3.3.3. Sensor testing

In this section, we will discuss the results of testing the INA219 sensor for voltage and current in the battery using a multimeter as a comparison to determine the level of accuracy of the sensor.

The following is a table for testing current readings from the INA219 sensor with a digital multimeter as a comparison can be seen in Table 6.

Table 6. Comparison of INA219 sensor current readings with measuring devices.

Current in LCD (A)	**Current in multimeter (A)**	**Accuracy (%)**
0,27	0,26	96,30
0,26	0,24	92,31
0,49	0,49	100,00
0,48	0,47	97,92
0,50	0,48	96,00
0,47	0,46	97,87
Average		96,73

It can be seen that the accuracy of reading the INA219 sensor current with a multimeter is 96.73%. Then, for testing the voltage reading from the INA219 sensor with a multimeter as a comparison, it can be seen in the Table 7.

Table 7. Comparison of INA219 sensor voltage readings with measuring devices.

Voltage in LCD (V)	**Voltage in multimeter (V)**	**Accuracy (%)**
11,88	11,81	99,41
11,70	11,65	99,57
11,99	11,85	98,82
11,67	11,50	98,52
11,62	11,51	99,04
11,67	11,55	98,96
Average		99,05

It can be seen from the table 7 above that the accuracy of reading the INA219 sensor voltage with a multimeter is 99.05%.

3.3.3 Battery discharge and charge testing

This test was carried out with a load of 20 W and cloudy skies. When one of the batteries is used, the battery voltage will decrease, and the other battery will be charged. When the sky is cloudy, the battery is slowly charged, and the amount of battery used is significantly reduced until the battery is transferred to another battery. In the graph, it can be seen that there are two batteries whose voltage has increased significantly. The increase occurred because the sky was quite bright. The following is a graph provided in the form of images, which can be seen in Figure 13.

4 Conclusions and recommendations

From the test results and data collection from experiments that the tool is able to switch automatically based on a battery that has a higher voltage, with a success rate of 100%. Based on the results of the experiments that have been carried out, there are several suggestions that can be used for further development. The suggestion that can be implemented is to use a larger-capacity battery so that the battery lasts longer and can be used for a long period of time. then use a sensor other than INA219 if you want to use a large load because the sensor is only able to read current with a maximum current of 3.2A. If the detected current is greater than that, the sensor will be damaged.

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