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Prediction of Alternative Solar Energy Utilization in Internet of Things Based Systems Using Random Forest Algorithm

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ABSTRACT

The continuous use of fossil energy is depleting available energy sources, necessitating the adoption of alternative or renewable energy sources, such as solar energy. Particularly in Internet of Things (IoT) applications such as ThingSpeak, new monitoring solutions are becoming available. ThingSpeak can be used to monitor and control device outputs efficiently. Controlling the work of the tool is one of the efforts to save energy. In this study utilizing the ThinkSpeak application with the support of the ESP 8266 component to send information obtained through the sensor to be displayed on the monitor screen and set the output on or off. This work aims to present results for battery charge predicting using optimization with the Random Forest (RF) algorithm. The results of this study show that the output of sensor readings that appear from the serial monitor via the Arduino application is almost the same as the display on Think Speak. So that this tool can support energy saving both in terms of solar energy utilization, the tool work control system for utilization according to needs and can also monitor the condition of the battery whether it is still in good or bad condition.

1. INTRODUCTION

Indonesia, as a tropical country traversed by the equator, has significant potential for solar energy harvesting. This condition shows the advantage of using solar heat as an alternative energy. Alternative and renewable energy has a very important role in meeting energy needs. This is due to the use of fuel for conventional power plants in the long term will deplete sources of oil, gas and coal which are depleting and can also cause environmental pollution [1].

Currently what is being developed is a tool based on the Internet of Things. One example is utilizing the ThinkSpeak application in controlling and monitoring the work of the tool [2]. In running the tool required a source of electrical energy. Utilization of energy sources that are being developed is solar energy. Solar energy as an alternative energy to power motors, lights and others [3].

Electrical energy is energy that is very important for human life on earth [4]. Electrical energy acts as a power source for technology and various electrical equipment made by humans. Therefore, humans are very dependent on electrical energy to help human life on earth. However, the availability of energy sources is very limited because humans always use excess energy for their own needs. Especially petroleum energy resources which are dwindling and will not last long. Actions that must be taken to prevent the depletion of energy resources is by saving the use of alternative and renewable energy sources such as solar cells [5].

The utilization of solar energy as an alternative electricity source in Indonesia is highly efficient and environmentally friendly. While solar power plants are widely adopted globally, and solar panels are considered environmentally beneficial, current solar panel installations have limitations. The main drawback is that, namely in general Solar panels only stand upright and cannot be rotated in the direction where the light source is located, so that the light source and the resulting electrical energy are not maximally added [6]. This is due to the absence of monitoring carried out on solar panels. Even though it is relatively minimal in the use of electric power on gadgets, if you multiply it by the number of users, the electrical energy needed is not small. Utilization of fossil energy sources to be used as electrical energy also cannot last continuously because the number of people is increasing, automatically it also has an impact on the increasing consumption of electrical energy [7].

The latest literature describes prediction of the amount of solar energy will be stored in the battery. The data stored in cloud can also be analyzed using the MatLab. The CSV file from the cloud is taken for analysis in R. The web application can be developed for interaction with the end user [8]. The current solar cell monitoring method is still conventional, only collecting solar cell output parameter data in the form of a text file with a certain format. This data also cannot be stored for a long time. The flow of voltage and current to the load, i.e. lamps or motors, can be controlled, but with tools that consist of components that are quite expensive and less efficient. Therefore, this research aims to develop tools and applications to monitor the power usage of solar panel batteries to run Direct Current (DC) motor or Internet of Things-based lighting using ESP 8266 to send data to be displayed to monitors via the ThinkSpeak application [9]. The data sent in the form of current and voltage comes from the INA219 sensor. The data will appear on the LCD monitor with the help of the ThinkSpeak application. Seeing the results displayed through the serial monitor on the Arduino is in accordance with the ThinkSpeak application display, so that the information that appears in the application ThinkSpeak in the form of current, voltage, power and relay work according to the work of the tool, especially the INA 219 sensor readings [10]. This paper aims to improve the random forest algorithm by using a simple prediction algorithm to find the best battery condition, using random forest analysis on battery charge and other factors (e.g. load, relay conditions, room conditions, and step up connections). Another advantage is the high prediction rate without adjusting or modifying the acquired data.

2. RELATED WORK

Current sensors and voltage dividers are used as sensors to assess current and voltage, then this data is sent to the raspberry Pi to be sent so that it can be displayed via a computer. In this study using DC lights as output because the current generated from solar panels is DC. The results of the study are the value of current, voltage and power displayed through the computer screen in real time with the help of the internet [11]. In this study, this power monitoring system is to determine the maximum power output from solar panels. The power enters the microcontroller circuit to read the power, current and voltage which is assisted by using sensors to be displayed on the LCD. In addition to using the LCD display can be viewed via cell phone. In addition, it can be easy to analyze daily or monthly from the data obtained [12].

This research discusses the application of a system to determine the performance of batteries on electric scooters. The data read by the ACS 712 Sensor as a current sensor, voltage sensor and LM 35 sensor as a temperature sensor is sent to the microcontroller to continue with the help of the internet so that the data can appear on a smart phone with the help of the blynk application. After testing, the accuracy rate of the ACS 712 sensor is 96.46%, the voltage sensor is 99.31%, the LM 35 sensor is 97.57%. In addition, the high performance of the battery depends and the high speed of the vehicle is directly proportional [13].

3. METHODOLOGY

This research methodology consists of several sequential stages, some of which can be seen in Figure 1.

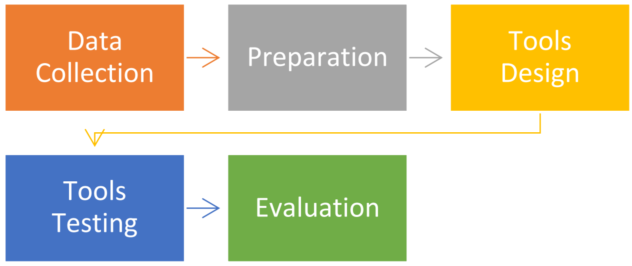

FIGURE 1. RESEARCH METHODOLOGY

A. Data collection

In the initial step of the implementation method is to collect data related to the battery monitoring system [14], both the concept and the components used in making the tool.

B. Preparation

The initial step in this method is to look for supporting components to design the tool. These components consist of the input component, namely the INA 219 sensor as monitoring voltage, current and power, then the control component, namely using the ESP 8266. After that, the circuit is designed to proceed to the next method stage, namely tool design [15].

C. Tools Design

In this method, monitoring tool design is carried out, namely assembling tools directly sourced from the previous method, namely tool design. This stage is carried out to be able to find out real monitoring of voltage and current. Furthermore, you can see whether you can adjust the output on and off remotely.

D. Tools Testing

After the tool has been designed, the next stage is testing the tool. This condition looks at the utilization of solar energy whether it can be used as alternative energy and monitoring whether it is running well or not with the ThinkSpeak application. Additionally, see if the flame of the device can be run through the ThinkSpeak application.

E. Evaluation

After the tool has been tested, if something is not suitable, then a redesign of the monitoring tool is carried out so that it is in accordance with the research objectives.

The components used in this study are:

A. Solar/photovoltaic Panels

Solar panels are devices or tools that are useful to assist humans in utilizing sunlight as a source of electrical energy [16]. The energy produced by solar cells depends on the heat of sunlight shining on the surface of the solar cell. the ability to generate energy is also in accordance with the size of the voltage that the solar panel has. Solar cells have different voltage sizes according to the energy power requirements needed to use electrical energy. The current generated by each solar cell is usually proportional to the amount of light and the area of the solar cell. Solar cells can be connected in series and parallel configurations. The overall voltage is proportional to the number of solar cells connected in parallel, according to basic electrical theory. The overall current is increased by using multiple series connections. A photovoltaic solar system is a module that is an assembled unit of several photovoltaic solar cells. The photovoltaic module is composed of several photovoltaic cells connected in series and parallel. This technology is quite sophisticated, and the advantages are that it is cheap, clean, easy to install and operate and easy to maintain. More details on solar panel images can be seen in Figure 2.

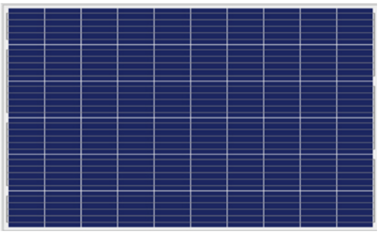

FIGURE 2. SOLAR PANELS

B. TP 4056 module

TP4056 is a module specially made to charge Li-ion batteries. This charger output ranges from 4.2 Volts. This module is equipped with a voltage protection feature to maintain optimal battery life and is also able to recharge automatically. Mini USB 1A Lithium Battery Charger Module is a module that can be used for charging 1 cell Lithium Ion or Li-Ion batteries with a charging current of 1A utilizing a USB connection from a computer or other device. The TP 4056 charger module has two LED indicators, namely a red LED indicating charging mode and a green LED indicating full charging mode. The TP 4056 charger module is equipped with protection, so when the battery is fully charged, the power supply for the circuit will be directly supplied from the 5V voltage coming from the charger module [17]. More details on the TP 4056 module image can be seen in Figure 3 below.

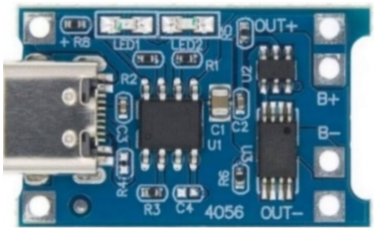

FIGURE 3. TP 4056 MODULE

C. MT 3608 Module

The MT3608 module is a module that can be used to increase the DC voltage up to 28 V. The MT3608 is a low power DC to DC Step-up booster module that has an input operating voltage of 2 Volts to 24 Volts and an output of 5 Volts to 28 Volts, with a maximum current that can flow 1 A. This MT3608 module has a value efficiency of 93%. This MT 3608 module is used for power supply. The MT 3608 module acts as a DC voltage step up with a DC to DC step up module (V DC power to V DC electricity). The specifications for the MT 3608 module are 2 VDC – 24 VDC Max (Vin input) for output 5V – 28 V max. More details on the MT 3608 module image can be seen in Figure 4 below.

FIGURE 4. MT 3608 MODULE

D. Battery DOD System

Battery is a process that can store and release electrical energy. Batteries get energy sources from the process of changing sunlight into electrical energy that occurs in solar panels (photovoltaic). Solar Power Plants (PLTS) will work when solar panels receive sunlight, this becomes an obstacle when sunlight as an energy source at night is not available. This can be overcome when during the day the electricity generated by the solar panels will be stored in the battery using a charge controller, and at night the energy stored in the battery can be used. More details about the DOD process can be seen in Figure 5 below.

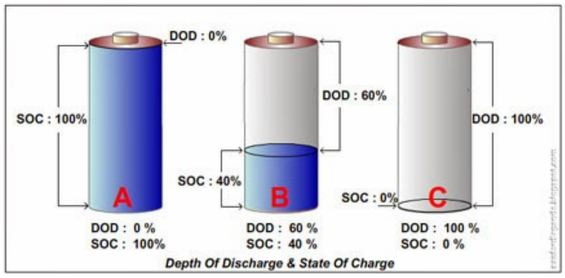

FIGURE 5. BATTERY DOD SYSTEM

E. ESP8266

NodeMCU ESP8266 is a development derivative module from the ESP8266 type ESP-12 IoT platform module. Functionally this module is similar to the Arduino platform, but the difference is that it is connected to Internet 12. This module is one part of the fully equipped ESP8266 family. In contrast to the previous ESP-01 module which was only a chip without being equipped with a USB Uart. This module is equipped with a minimum system and USB port which makes it easy to use and enter programs on the module. With these various advantages, this module is very suitable to be selected as an IoT microcontroller system. NodeMCU is an open source IoT platform. It consists of hardware in the form of an on-chip ESP8266 system made by an expressive system. More details about the relay image can be seen in Figure 6 below:

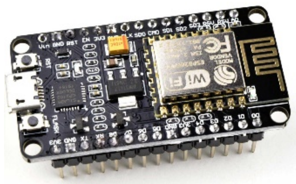

FIGURE 6. ESP 8266 MODULE

F. INA 219 module

INA 219 is a sensor module that can monitor voltage and current in an electric circuit. INA 219 is supported by an I2C or SMBUS-COMPATIBLE interface where this equipment is capable of monitoring shunt voltage and supply bus voltage, with program times conversion and filtering. The INA 219 has a maximum input amplifier of ±320mV, which means it can measure currents up to

±3.2A. With an internal data 12-bit ADC, resolution in the 3.2A range is 0.8 mA. With internal gain set at minimum div8, max current is ±400mA and 0.1 mA resolution. INA 219 identifies the shunt voltage on the 0 – 26 V bus. The INA219 sensor is a sensor module capable of measuring voltage, current and power simultaneously. More details on the INA 219 module image can be seen in figure 7 below:

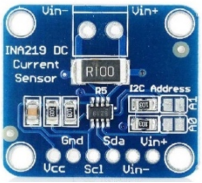

FIGURE 7. INA 219 MODULE

G. Relays

Relay is an electromechanical device or component used to operate a set of switch contacts, by utilizing electricity as a source of energy[18]. By utilizing an iron-core coil that is energized, of course it will produce a magnetic field at the end of the iron core when the coil is electrified. Relay is one part of the electronic components that can implement logical switching. An electro-mechanical relay that can give an action when it gets electrical energy. Defined a device that uses electromagnetic force to close or open a switch contact. Relays use electromagnetic principles to move the switch contacts so that with a small electric current (low power) they can conduct electricity with a higher voltage. More details about the relay image can be seen in figure 8 below:

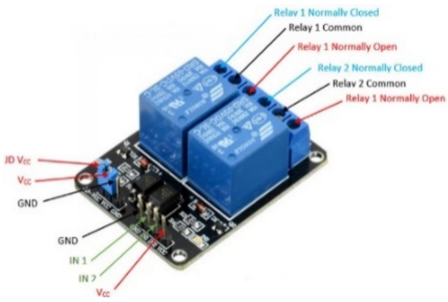

FIGURE 8. RELAYS

This research utilizes currently developing technology, namely the Internet of Things (IoT)[19]. The work of a system that uses IoT technology is to utilize the INA 219 sensor to determine current, voltage or power, which is then sent by ESP 8266 to a computer using the internet. So that the data can be accessed anytime and anywhere if it has an internet network. Figure block diagram can be seen in Figure 9 below:

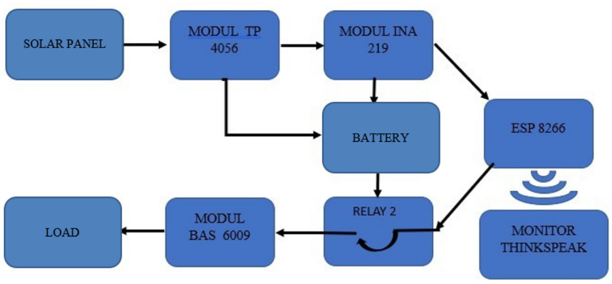

FIGURE 9. SYSTEM BLOCK DIAGRAM

The voltage source used comes from solar panels. Sunlight received by solar panels is converted into DC electrical energy [20]. The DC electricity is channeled through the TP 4056 Module which is normally closed, namely direct electricity so that the battery is charged. The function of the TP 4056 module is to regulate battery charging. If the voltage is less than the maximum limit of 4.2 Volts, the battery will carry out the battery charging process to produce an output voltage according to the battery voltage, in addition to the INA 219 module. The function of the INA 219 sensor is to read current, voltage and power through the shunt voltage. Information from this sensor is forwarded to the ESP8266 via the SDA and SCL pins. Next, the data is sent to ThinkSpeak for display. Apart from that, the ESP 8266 also manages output work through the ThinkSpeak application so that the relay is on. Then the voltage from the relay is increased using the MT 3608 module to 12 V DC. Below you can see the flowchart of the battery management circuit. More details about the relay image can be seen in Figure 10.

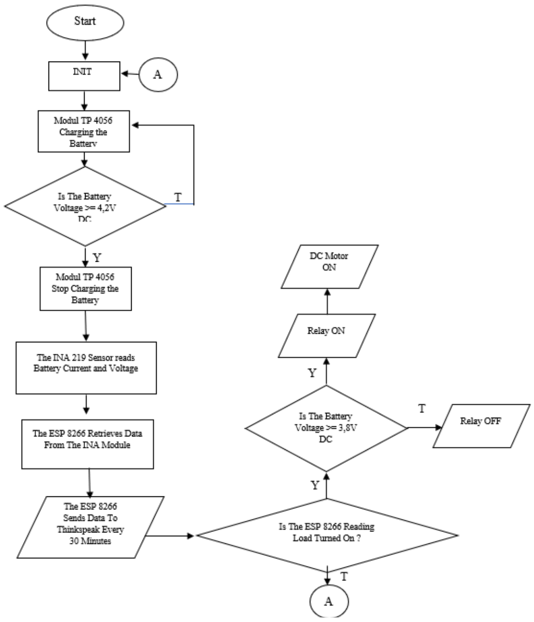

FIGURE 10. FLOWCHART

The voltage generated by the solar panel is regulated through the TP4056 battery charging module. The battery charging process continues until the voltage reaches or exceeds 4.2 V DC, then the battery charging process is stopped. Then proceed to the INA 219 sensor module to measure voltage and current. Information from the INA 219 sensor in the form of voltage and current readings is continued to ESP 8266 to be displayed on the monitor via the Thinspeak application for 30 minutes. Apart from sending information to the ThinkSpeak application, the ESP 8266 also functions to control the output flame. If the ESP 8266 receives an on-relay command via the ThinkSpeak application, the Relay will on if the battery voltage exceeds or equals 3.8 Volts DC. If the voltage on the battery is less than 3.8 Volts DC, the relay does not run the output, which is a DC motor.

4. RESULT AND DISCUSSION

Implementation is done by looking at how it looks on the Arduino serial monitor with the ThinkSpeak application. This process can be seen by using the ESP 8266 as a component for sending information received by the INA 219 sensor which is then displayed through the ThinkSpeak application. More details on the tool image can be seen in Figure 11.

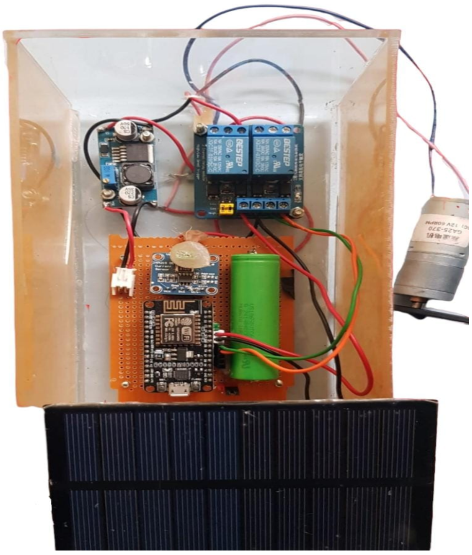

FIGURE 11. MONITORING AND CONTROLLING TOOLS

In the figure above is a figure of the tool. The system architecture comprises a solar panel, a TP 4056 battery charging module, a current and voltage reading module, namely the INA 219 module, ESP 8266 as a support for sending data read by the INA 219 sensor in the form of current and voltage. In addition, to pass on to the relay as a switch on whether a load such as a DC motor or lamp is on. The output voltage of the relay is increased using the MT 3608 module to become 12 Volt DC. This voltage is used to run the output, which can be a DC motor or lamp.

The experimental testing was conducted using an INA 219 sensor for data acquisition, namely in the form of current, voltage, On/Off relay and power displayed through the ThinkSpeak application. The display on ThinkSpeak is compared to the display on the serial monitor in the Arduino application.

The system testing yielded comparative results between Arduino and ThingSpeak Serial Monitor displays, demonstrating the following measurements: Figure 12 shows the display on the Arduino serial monitor without load at 8.00 state relay 0, current is 23.6 mA and power is 92 mW. While the display on ThinkSpeak for relay 0, the current is 0.023 A, and the power is 0.092 mW. This condition is no-load, and the step-up module is connected in the chamber.

FIGURE 12. SERIAL MONITOR DISPLAY CONNECTED IN THE ROOM

Figure 13 shows the display on the Arduino serial monitor without load at 8.10 state relay 0, voltage 4.08 V, current 2.5 mA and power 10 mW. The display on ThinkSpeak is for a voltage of 4.076 V, a current of 0.0025 A and a power of 0.01 mW. This condition is no-load, and the step-up module is not connected in the chamber.

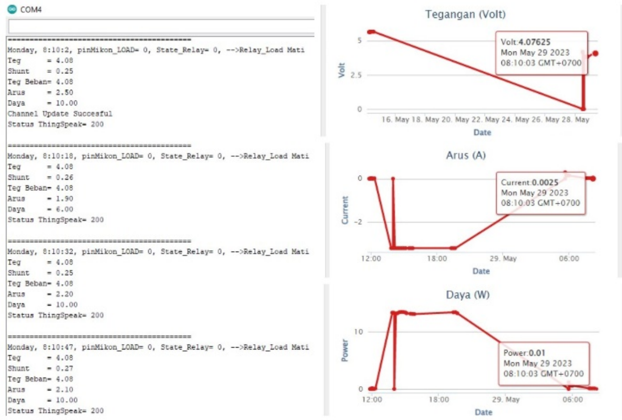

FIGURE 13. SERIAL MONITOR DISPLAY NOT CONNECTED IN THE ROOM

Figure 14 shows the display on the Arduino serial monitor without load at 9.00 o'clock state relay 0, voltage 4.08 V, current 3.5 mA and power 14 mW. The display on ThinkSpeak is for a voltage of 4.076 V, a current of 0.0035 A and a power of 0.014 mW. This state is no-load, and the step-up module is connected outdoors.

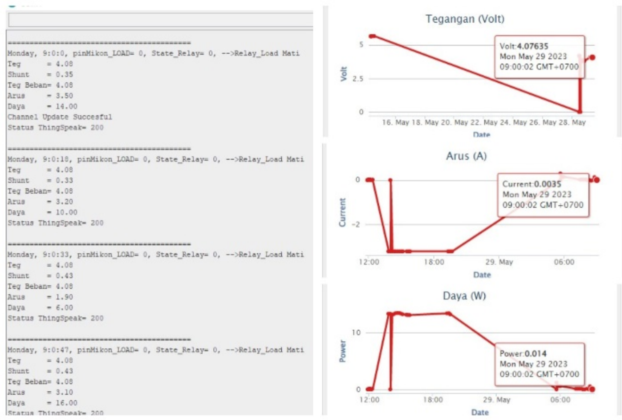

FIGURE 14. SERIAL MONITOR DISPLAY CONNECTED OUTDOORS

Figure 15 shows the display on the Arduino serial monitor without load at 8.30 state relay 0, voltage 4.08 V, current -25.3 mA and power 102 mW. The display on ThinkSpeak is for a voltage of 4.077 V, a current of 0.0253 A and a power of 0.102 mW. This state is no-load, and the step-up module is not connected outdoors.

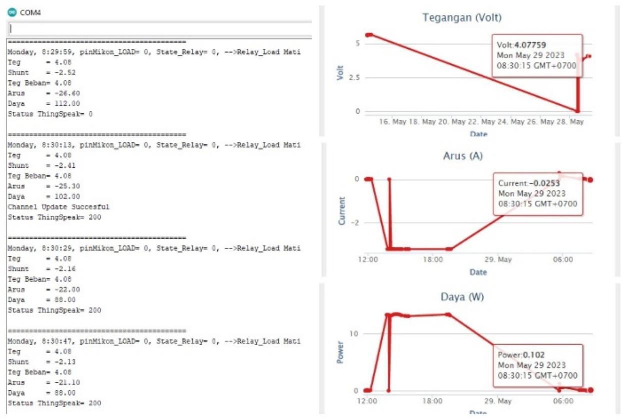

FIGURE 15. SERIAL MONITOR DISPLAY NOT CONNECTED OUTDOORS

Figure 16 shows the display on the Arduino serial monitor with a load at 10.00 o'clock state relay 1, voltage 4.01 V, current 186.8 mA and power 754 mW. The display on ThinkSpeak is for a voltage of 4.05 V, a current of 0.1868 A and a power of 0.754 mW. This condition is no load and in space.

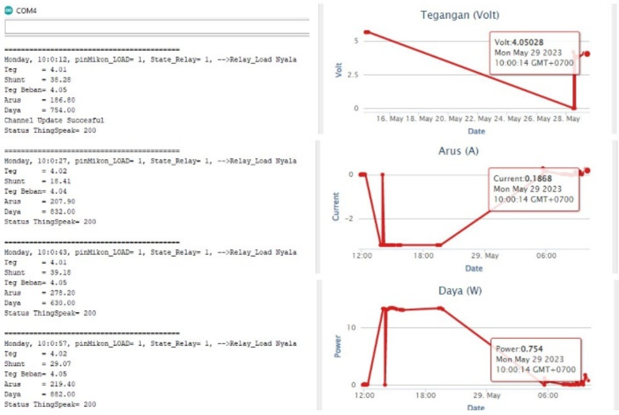

FIGURE 16. SERIAL MONITORS USING INDOOR LOADS

Figure 17 shows the display on the Arduino serial monitor with a load at 09.50 state relay 1, a voltage of 4.03 V, a current of 256.6 mA and a power of 1036 mW. While the display on ThinkSpeak is for a voltage of 4.03 V, a current of 0.1868 A and a power of 1.036 W. This condition is that there is a load in the room.

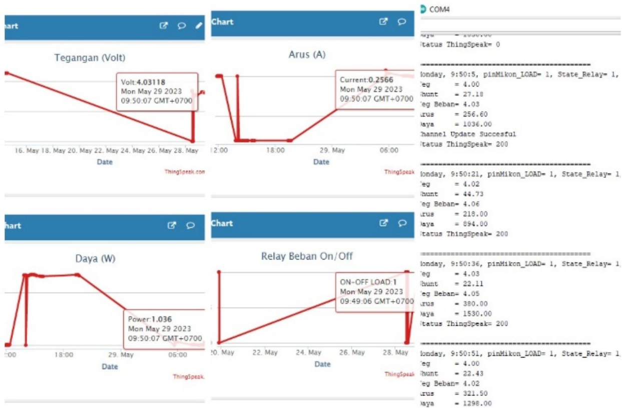

FIGURE 17. SERIAL MONITORS USING OUTDOOR LOADS

In addition, when outside the room you can see the output in the form of a 12 V DC motor that can be run by utilizing solar energy. In addition to monitoring, the updates contained in this circuit can control the motor work through relays. One example of relay control can be seen in the picture below. The following is the Off-load command switch off the relay and the on-load command switch on the relay.

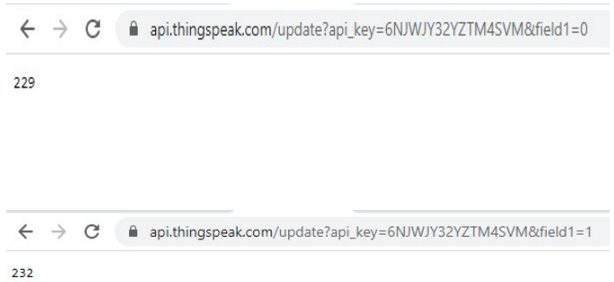

FIGURE 18. RELAYS FOR ON/OFF LOAD COMMAND

The following is an example of a dataset generated from Arduino in the form of observations with 8 variables (Timestamp, Voltage, Current, Power, Load, Relay Condition, Condition, Step Up):

TABLE 1. DATASET

Volt.	Current	Power	L	R	Condi.	Step Up
4,07	22,1	102	0	0	Indoor	Connected
4,07	22,5	92	0	0	Indoor	Connected
4,07	22,9	96	0	0	Indoor	Connected
4,07	24,6	102	0	0	Indoor	Connected
4,08	2,50	10	0	0	Indoor	No Connected
4,08	1,90	6	0	0	Indoor	No Connected
4,08	2,20	10	0	0	Indoor	No Connected
4,08	2,10	10	0	0	Indoor	No Connected
4,08	4,00	16	0	0	Outdoor	Connected
4,07	4,70	20	0	0	Outdoor	Connected
4,08	4,10	14	0	0	Outdoor	Connected
4,08	4,60	4	0	0	Outdoor	Connected
4,08	-26,6	112	0	0	Outdoor	No Connected
4,08	-25,3	102	0	0	Outdoor	No Connected
4,08	-22,0	88	0	0	Outdoor	No Connected
4,08	-21,1	88	0	0	Outdoor	No Connected
4,01	186,8	754	1	1	Outdoor	Connected
4,02	207,9	832	1	1	Outdoor	Connected
4,01	278,2	630	1	1	Outdoor	Connected
4,02	219,2	882	1	1	Outdoor	Connected
4,00	256,0	1036	1	1	Outdoor	Connected
4,03	218,0	894	1	1	Outdoor	Connected
4,02	380,0	1530	1	1	Outdoor	Connected
4,00	321,5	1298	1	1	Outdoor	Connected

A total of 100 sample data points from the IoT system were processed in this study. Categorical data such as "Indoor" or "Outdoor" were converted into numerical form for easier processing, with "Indoor" assigned a value of 0 and "Outdoor" assigned a value of 1. The same approach was applied to the "Step Up" variable, where the status "Connected" was assigned a value of 1 and "Not Connected" was assigned a value of 0. Time-related information such as hour, day, and month was also included as additional factors that could influence the prediction results. The data was divided into two parts: 70 data points for training the model and 30 data points for testing it. A Random Forest model was created with 100 decision trees, where each tree used a randomly selected subset of the data to improve prediction accuracy. Each decision tree operated by asking binary questions, such as "Is the voltage greater than 4.5 volts?" or "Is the panel located outdoors?" The answers to these questions were used to determine the predicted power output of the solar panel.

Feature importance analysis revealed that electric current and voltage were the dominant factors influencing prediction results, followed by the placement of the panel, measurement time, Step Up status, as well as the day and month of measurement, which had a smaller influence. The analysis results also showed that time remained the most influential variable, with power production patterns showing a significant increase between 09:00 and 14:00. Placing the panel outdoors was found to increase power production by up to 85% during peak radiation periods (11:00-14:00) and by 60-70% during other periods. The effectiveness of the step-up converter also varied based on input voltage, with optimal efficiency improvement occurring at voltages below 4.2V (up to 55%).

To test the model, solar panel data with a voltage of 4.8 volts, a current of 32 milliamperes, and various other factors were used. Each decision tree provided slightly different predictions, with the result calculated as the average of all trees. The Random Forest model successfully identified the optimal combination of factors that produced up to 290 mW (outdoor panel, 12:00-14:00, with a step-up converter). More importantly, the model identified "sweet spots" during transition periods (08:30-09:30 and 15:00-16:00), which still generated relatively high power (210-230 mW). Partial dependence plots revealed key thresholds in system operation: the significant benefits of outdoor panel placement became evident at light intensities around 60% of the maximum, while the step-up converter provided optimal benefits within the voltage range of 3.8-5.2V.

5. CONCLUSIONS

The use of solar panels to support energy savings can be applied as alternative energy to carry out daily needs, for example the use of DC motors or lamps with solar panels that are supported by batteries. The use of IoT on this device can be realized, as can be seen from the information obtained by the INA 219 sensor in the form of voltage and current information seen on the monitor via the ThinkSpeak application which is almost the same as the results displayed on the serial monitor via the Arduino application. In addition, the ThinkSpeak application can control the output flame by turning the relay On. Another condition for the relay to be on is if the battery voltage exceeds 3.8 Volts DC, conversely if the battery voltage is less than 3.8 Volts DC then the relay will not turn on even though there is an on command via ThinkSpeak. The output used is a 12 Volt DC motor. DC motors can be controlled either on or off via the ThinkSpeak application. Monitoring and controlling are running in real time. So that this research can support energy saving both in terms of solar energy utilization, tool work control systems for utilization according to needs and can also monitor the condition of the battery whether it is still in good condition or not in good condition.

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