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An Analysis Of Renewable Energy Improvement Using Hybrid Capacitor Solar Cell Method

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ABSTRACT

This study aims to analyze the increase in the use of renewable energy through the application of the Hybrid Capacitor Solar Cell method. Solar cells are one of the most potential renewable energy sources, but their storage efficiency is still a challenge, especially in terms of unstable energy availability because it depends on the intensity of sunlight. This study uses a simulation approach to test the performance of the hybrid capacitor-solar cell method. The system is designed to optimize energy storage in capacitors when energy production from solar cells is excessive and provide energy reserves when sunlight intensity is low. The results of the study show that this hybrid method is able to increase energy storage efficiency by up to 30% compared to the use of conventional solar cells that only rely on batteries. In addition, this hybrid system is also able to extend the life of energy storage devices and reduce dependence on chemical batteries, which generally have limited lifespan and environmental impacts. Conclusion of this study is that the Hybrid Capacitor Solar Cell method has great potential in increasing the efficiency of renewable energy and can be a sustainable solution to increase the utilization of solar energy. The implementation of this technology is expected to help accelerate the transition to clean energy and reduce dependence on fossil energy sources.

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INTRODUCTION

In the era of the Industrial Revolution 4.0, the community's need for electrical energy is increasing, which is due to population growth, economic growth, and energy consumption patterns themselves. This is due to the high demand for fuel oil which is not accompanied by an increase in production capacity. The ability to provide non-renewable energy in the form of fossil energy which is decreasing is one of the causes of the world energy crisis, this phenomenon also has an impact on the world's electrical energy sector which is approaching a critical threshold because the Full-fillment of electrical energy is mostly still supplied from power plants that use fossil energy.

Where to overcome and anticipate the energy crisis is by using alternative energy. Where alternative energy is energy that can be renewed and cannot run out. The use of

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solar energy is known as the Solar Power Plant (PLTS), where the Solar Power Plant is a power generating machine that utilizes energy from sunlight into electrical energy so that it can be used. This Solar Panel works by converting solar energy from sunlight into electrical energy, the current generated from the PLTS is flowed in two directions, namely to the load and flowed to the battery. The battery is used to store electric current and help supply current to the load when there is no sunlight.

However, there are times when the battery must be recharged to support the electricity that is flowed to the load. Another electrical component that has a capacitor function that is hybridized with PLTS where the capacitor is an electrode device that has the ability to store energy charges within a certain time limit. In household electronic loads that drain quite a lot of energy from the battery such as refrigerators and Air Conditioners (AC) so that it reduces the resistance of the battery itself. batteries have a high energy storage ratio but their power is limited. On the other hand, supercapacitors can provide high power levels while they have a much lower energy storage ratio. In addition, SCs can act as a buffer against large magnitudes and rapid power fluctuations.

The installation of this capacitor is expected to improve battery performance in the PLTS. On this basis, the researcher took the title "Analysis of Supercapacitor Installation in Solar Power Plants". Based on the formulation of the problem that has been explained previously, the objectives to be achieved are: To design and install supercapacitors on PLTS, and to analysed the impact of installing supercapacitors on PLTS. Both types of hybrid generators are operated simultaneously on one rail/busbar to carry the load. This study will discuss the combination or synchronization of hybrid power from wind and solar energy based on DC-AC inverters as one of the solutions offered in solving electricity problems that are considered capable of increasing the electrification ratio in remote areas while reducing fossil energy consumption in Indonesia.

Literature Review

Solar Panels

Solar cells are defined as a technology that produces dc electricity from a semiconductor material when exposed to light. As long as the semiconductor material is exposed to light, the solar cell will always produce electrical energy, and when not exposed to light, the solar cell stops producing electrical energy. (Ranny Dwidayanti, 2017)

Figure 1. Solar Panel

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Solar cells work using the principle of the pn layer, which is a layer between p-type and n-type semiconductors. This semiconductor consists of atomic bonds, where there are electrons as the basic components. N-type semiconductors have excess electrons (negative charge) while p-type semiconductors have excess holes (positive charge) in their atomic structure. The condition of excess electrons and holes can occur by doping the material with dopant atoms. For example, to obtain p-type silicon material, silicon is doped by boron atoms, while to obtain n-type silicon material, silicon is doped by phosphorus atoms.

The role of this pn junction is to form an electric field so that electrons (and holes) can be extracted by the contact material to produce electricity. When p-type and n-type semiconductors are in contact, excess electrons will move from the n-type semiconductor to the p-type, forming a positive pole on the n-type semiconductor, and vice versa a negative pole on the p-type semiconductor. As a result of the flow of electrons and holes, an electric field is formed, which when sunlight hits the pn junction arrangement, will push electrons to move from the semiconductor to the negative contact, which is then used as electricity, and vice versa, holes move to the positive contact waiting for electrons to come, as illustrated in the image below.

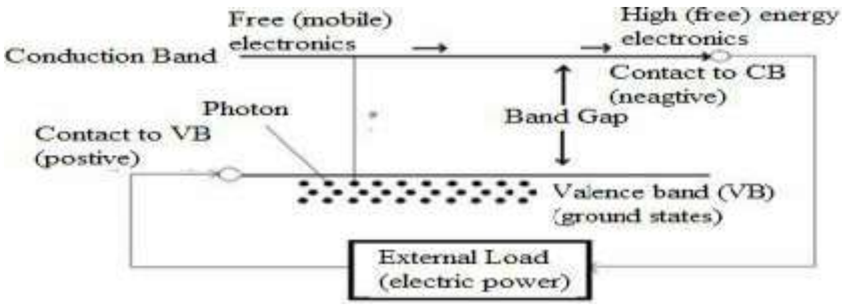

Figure 2. Illustration of a solar cell with a pn layer

In accordance with the development of science and technology, the types of solar cell technology have also developed with various innovations. There are so-called first, second, third and fourth generation solar cells, with different structures or cell components. In this article, the structures in solar cells will be discussed with the following figure 3.

Figure 3. Solar cell structure

Figure 3 shows an illustration of a solar cell and its parts. In general, it consists of: :

1. Substrate/Metal backing, The substrate is a material that supports all components of the solar cell. The substrate material must also have good electrical conductivity

because it also functions as a positive terminal contact for the solar cell, so that metal materials such as aluminum or molybdenum are generally used. For dye-sensitized solar cells (DSSC) and organic solar cells, the substrate also functions as a place for light to enter so that the materials used are conductive but also transparent materials such as indium tin oxide (ITO) and fluorine doped tin oxide (FTO). (Aditiyan, 2015)

2. Semiconductor materials, Semiconductor materials are the core part of solar cells which usually have a thickness of up to several hundred micrometers for first generation solar cells (silicon) and 1-3 micrometers for thin film solar cells. This semiconductor material functions to absorb light from sunlight. The semiconductor used in solar cells is silicon material, which is commonly applied in the electronics industry. While for thin film solar cells, semiconductor materials that are commonly used and have entered the market are for example Cu(In,Ga)(S,Se)2(CIGS), CdTe (cadmium telluride) and amorphous silicon, in addition to other potential semiconductor materials that are under intensive research such as Cu2ZnSn(S,Se)4 (CZTS) and Cu2O. The semiconductor part consists of a junction or combination of two semiconductor materials, namely p-type semiconductor (the materials mentioned above) and n-type (n-type silicon, CdS, etc.) which form a pn junction. This pn junction is the key to the working principle of solar cells. (Aditiyan, 2015)
3. Metal contact/contact grid, In addition to the substrate as a positive contact, transparent conductive material is usually coated on top of some of the semiconductor material as a negative contact. (Aditiyan, 2015)
4. Antireflective coating, Light reflection must be minimized to optimize the light absorbed by the semiconductor. Therefore, solar cells are usually coated with an anti-reflective layer. This anti-reflective material is a thin layer of material with a large optical refractive index between the semiconductor and the air that causes light to be deflected towards the semiconductor, thus minimizing the light reflected back. (Aditiyan, 2015)
5. Encapsulation/cover glass, This part functions as encapsulation to protect the solar module from rain or dirt. (Aditiyan, 2015).

Solar Charger Controller

*Solar Charger Controller*is one of the components in the solar power generation system, functions as a regulator of electric current both for the incoming current from the Solar Panel and the outgoing load current / used. Works to keep the battery from overcharging. Solar Charger Controller regulates the voltage and current from the Solar Panel to the battery. Most 12 Volt Solar Panels produce an output voltage of around 16 to 20 volts DC, so if there is no regulation, the battery will be damaged from overcharging. In general, 12 Volt batteries require a charging voltage of around 13-14.8 volts (depending on the type of battery) to be fully charged. (Purwoto, Jatmiko, F., & Huda, 2017). The function of the Solar Charger Controller is:

1. When the charging voltage in the battery has reached full, the controller will stop the electric current entering the battery to prevent overcharging. Thus the battery life will be much more durable. In this condition, the electricity supplied from the Solar Panel

will be directly distributed to the load / electrical equipment in a certain amount according to the power consumption of the electrical equipment.

2. When the voltage in the battery is almost empty, the controller functions to stop the electric current from being taken from the battery by the load/electrical equipment. In certain voltage conditions (generally around 10% of the remaining voltage in the battery), the controller cuts off the load current. This protects the battery and prevents damage to the battery cells. In most controller models, the indicator light will light up with a certain color (usually red or yellow) indicating that the battery is in the charging process. In this condition, if the remaining current in the battery is empty (below 10%), the electric current from the battery will be cut off by the controller, so that the electrical equipment/load cannot operate. Certain types of controllers are equipped with digital meters with more complete indicators, to monitor various conditions that occur in the solar power generation system. (Purwoto et al., 2017).

*Charger*The battery on the Traffic Light or traffic light is used as a battery charger for the Traffic Light or when there is no sunlight, here the function of the battery charger is for the charging process of the dry lithium Ion type battery. To calculate the battery charging time can be determined through the following equation (1):

$$H = \frac{Ah\text{–Battery}}{I}$$

with :

H : Battery charging time

Ah : Battery Capacity

I : Output current on the charger

Advantages and Disadvantages of Arduino

*Arduino*has the following advantages:

1. Cheap
   Arduino boards (hardware) are usually sold relatively cheaply (between 125 thousand and 400 thousand rupiah only) compared to other pro microcontroller platforms.
2. Simple and easy programming
   It is worth noting that the programming environment in Arduino is easy to use for beginners, and flexible enough for those who are more advanced.
3. The software is open source
   The Arduino IDE software is published as Open Source, available to experienced programmers for further development. The language can be further developed through C++ libraries which are based on the C language for AVR.
4. The hardware is open source
   Arduino hardware is based on ATMEGA8, ATMEGA168, ATMEGA328 and ATMEGA1280 microcontrollers (latest ATMEGA2560). So anyone can make (and then sell) this Arduino hardware, especially since the bootloader is available directly from the Arduino IDE software.

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You can also use a breadboard to create an Arduino device and other required peripherals. *Arduino*has the following disadvantages:

1. The hex code is relatively large
2. Fuse bit errors often occur when creating a bootleader.
3. Flash storage is reduced, because it is used for the bootleader.

Hardware Parts

In this research or thesis I use Arduino Uno to control Traffic Lights. The following is a picture of the Arduino Uno:

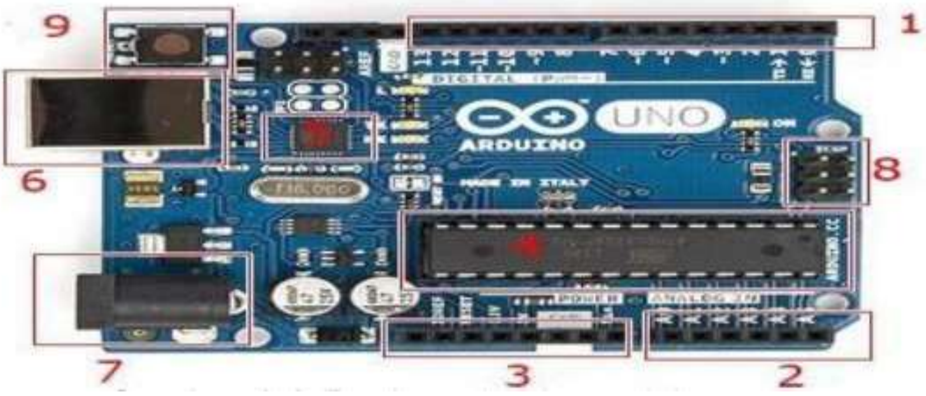

Figure 4. Arduino Uno Parts

1. Digital input/output pins (labeled '0 to 13') In general, these I/O pins are digital pins, namely pins that work at digital voltage levels (0V to 5V) for both input and output. However, on some analog output pins, which can output analog voltages of 0V to 5V, these pins are pins 3,5,6,9,10 and 11, in addition to that, pins 0 and 1 also have special functions as serial communication pins.
2. Analog input pins (labeled „A0 to A5‟). These pins can receive analog voltage input between 0V to 5V, this voltage will be represented as the number 0 – 1023 in the program.
3. Pins for voltage sources This pin group is a collection of pins that are related to the power source, for example 5V output, 3.3V output, GND (2 pins) and Vref (reference voltage for internal ADC reading)
4. IC ATMega328 As explained, this IC acts as a data processing control center.
5. IC ATMega16U This IC is programmed to handle data communication with a PC via a USB port.
6. USB Jack is a USB type B socket that connects serial data to a PC.
7. Jack Power is a socket for external power supply between 9V to 12V DC.ICSP (In-Circuit Serial Programming) Port This port is used to program Arduino without a bootloader.
8. Reset button is used to reset the Arduino microcontroller board to start the program from the beginning. (Rochman, Sagita and Prijo Sembono, 2014)

Structure Programming

The programming language is one of the most senior computer programming languages that is still used today. First released in 1972 by Dennis Ritchie, C is the basis of various more modern programming languages such as C++, C#, Java, PHP to JavaScript.. A C language program is a program consisting of one or more functions. The main function and must be present in the C program that we create is the main() function. This main() function is the first function that will be processed when the program is compiled and run, so it can be called a function that controls other functions. Because the structure of the C program consists of other functions as part programs (subroutines), the C language is usually called a structured programming language. The way to write a function in a C language program is to name the function and then open it with an open curly bracket ({) and close it.

Other functions besides the main function can be written after or before the main function with a description of the function prototype at the beginning of the program. It can also be written in another file that if we want to use or call a function in another file, we must write the file header, with the preprocessor directive #include. This file is called a library file. C programs include program documentation, preprocessing directives, global declarations, main () functions, programming-made functions, delimiters, end statements, and program styles.

Providing documentation on a program is very useful to help clarify the logic flow of the program. Because its purpose is only as documentation, comments written on the program are not processed by the compiler. Comments can begin with a two-character symbol consisting of a slash and an asterisk (/*) and end with an asterisk and a slash. The comment character /* can be placed anywhere in the program and can include more than one comment, provided that each /* must be closed with */. At the beginning of the program, the comments given are usually intended to explain what the program does, while in other parts of the program the purpose is to clarify the program logic.

In processing program codes, the C compiler carries out several stages, namely carrying out pre-processing to make the necessary preparations. a compiled program file. In the preprocessing directive program, it is preceded by the # character which is written in the first lines of the program. Preprocessors treat program files as a sequence of lines of text: reading, processing, and writing the results back into the original file. Preprocessors remove all preprocessing command lines from the source file and make changes to the source file according to the instructions given. Broadly speaking, these services can be divided into three groups:

1. File Insertion (#include)
2. Macro definition (#define)
3. Compiler Control Directories (#ifdef, #ifndef).

METHOD

This study uses an experimental and simulation approach to analyze the increase in renewable energy efficiency using the Hybrid Capacitor Solar Cell method. A literature review was conducted to understand the basic concepts and relevant theories regarding solar cells, capacitors, and hybrid technology in energy storage systems. The literature used includes scientific journals, textbooks, and other references related to renewable energy,

energy storage, and solar cell technology. The hybrid system design is carried out by combining solar cells with capacitors as energy storage components. This system is designed to store excess energy produced by solar cells into capacitors, which can then be released quickly when needed, especially when sunlight intensity is low or when the load increases. Simulations are carried out using special software that is able to model the behavior of solar cells and capacitors in real-time. Simulation parameters include sunlight intensity, capacitor storage capacity, energy conversion efficiency, and system output power.

This simulation aims to analyze system performance under various weather and load conditions. Experimental testing was carried out using a prototype hybrid capacitor-solar cell system in the laboratory. Measurements were taken to obtain data on voltage, current, storage capacity, and system efficiency under various lighting conditions. This data is used to validate the simulation results. The data obtained from the simulation and experiments were analyzed to evaluate the performance of the hybrid system. The efficiency of energy storage, the response of the capacitor in releasing energy, and the comparison between the hybrid system and conventional solar cells were analyzed in depth.

Based on the results of the analysis, a conclusion was made regarding the effectiveness of the Hybrid Capacitor Solar Cell method in increasing the efficiency of renewable energy. In addition, recommendations were given for further development and application of this technology on a wider scale. With this method, the study is expected to provide a clear picture of the benefits and limitations of the hybrid capacitor-solar cell system and its potential application in maximizing the utilization of renewable energy. After the basic performance evaluation, testing was conducted to examine the stability and durability of the hybrid system over a certain period of time. This testing involved long-term usage simulations where the system was forced to work under various loads and different lighting conditions. The goal was to measure performance degradation, capacitor resistance, and overall system wear. In this step, the results of the hybrid capacitor-solar cell system were compared with the results of a conventional solar cell system that only uses batteries.

Response time in providing energy when the load increases Implementation and maintenance costs Energy storage lifetime (capacitor vs battery) After the system has been tested and analyzed, an economic study is conducted to assess the potential long-term cost savings from using this hybrid system compared to a conventional solar cell system. This analysis considers the initial installation costs, maintenance, component replacement, and the impact on overall energy consumption. In addition, a sustainability study is also conducted to assess how much this technology contributes to reducing carbon emissions and supporting the transition to clean energy.

All research results, both from simulations and field tests, are systematically documented to be compiled into a research report. This report includes the methodology, test results, data analysis, and conclusions drawn from the research. If the research results show great potential, a full-scale prototype development step can be carried out as part of further research. This prototype is designed to be used on a larger scale, for example for household or small industrial purposes, to test its effectiveness in a real environment.

The system works based on the program that has been created and uploaded to the controller IC in this case on Arduino Uno. The controller will read input through one of the analog inputs. A relay will work automatically, namely switching to the battery source if the PLN current is cut off and will be switched back if the source is available again. The following will explain the function and working of each component used in the system.

RESULT

Research result

The result of this research is a power supply system based on solar energy. The power supply is used to supply a traffic light. To simulate a solar power plant, the power supply system is built in a miniature size with a scale of 1:30. A 20 Watt /12V panel is used to convert light into electricity. The electricity generated is then charged to a lithium battery with the help of a solar charger controller. The system is also equipped with a charger from PLN electricity to optimize and avoid the unavailability of sunlight for a long period of time.

The PLN charger itself is controlled by an Arduino device to control the charger process and keep the battery in prime condition. The calculation of the generating capacity is adjusted to the load used in this case is a traffic light device with railroad crossing gate integration. In miniature size, the solar panel capacity is 20 watts and the battery capacity is 6000 mAh. The load usage power is less than 0.7 amps so that if calculated, the battery can supply current for up to 8.5 hours. The recharging time by solar panels depends greatly on the intensity light at that time. While charging using PLN electricity with a current of 0.6 ampere is for 10 hours.

Analysis

Real calculation analysis of a solar power generation system to supply traffic light devices. A traffic light system requires energy to power the lights. For 2 intersections, there must be at least 4 lights on at the same time. The average power of LED type lights is 25 watts/unit. So it takes 100 watts just for the lights. The traffic light system requires a control circuit to control it. In this case, the predicted power for the circuit is 20 watts. Integrated system with railroad crossing gates and buzzers. Where the crossing gates do not move continuously but periodically. So it is necessary to calculate how many times the train passes through the area. According to information on the average frequency of crossingtrainfire at the location is 28 times per day. While the motor power needed to close the gate is at least 3.8 kilowatts. Power consumption to open and close is only a few seconds, namely 11 seconds to close and 1 second to reopen. The need to supply electrical energy to traffic lights is 24 hours/day. Based on the information above, the power required to supply the system can be calculated so that the generating tool can be realized. Closing takes only a few seconds, namely 11 seconds to close and 11 seconds to reopen. For the door latch drive motor: door latch power drops by 1320 watt / 220V the power of the gate increases 1584 watts / 220V. So the average power is the power up + the power down divided by 2 = 1452 watts, while the use of the rail gate in 1 day is 11 seconds x 2 x 28 times / day. = 616 seconds or = 0.17 hours. Thus the energy to drive the motor per day is: E = 1452W x 0.17 H = 246.84 WH = 247 WH

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The need to supply electrical energy to traffic lights is 24 hours/day. Based on the information above, the power required to supply the system can be calculated so that the generator can operate. realized. The system is made in miniature size for simulation and proof of concept purposes. The scale comparison of miniature with real is about 1:30. The panel used in the miniature is 20 Watt. And the battery is 3000 mAh. The results obtained from the test are the characteristic data of a 20 wp solar panel in sunny weather conditions. The data was obtained from measurements taken from 9 am to 5 pm. Every hour the data is measured with a volt and ampere meter.

Measurements were made under no-load and loaded conditions. The measurement results are shown in table 4.1 below. No-load measurements are measurements of the panel output under open-loop conditions, that is, no load is attached to the output. The purpose is to determine the characteristics of the open-loop panel voltage. Furthermore, loaded measurements were made by attaching a load to the panel output. The load was selected as a 12V 20W and 10W incandescent lamp. With the load, there is a current flowing, thus measurements were also made on the current. The current was measured with an ammeter in series with the load. The following are the results of the measurements.

Figure 5. Results of Solar Panel Measurement Without Load

Table 1. Measurement Results with Lamp Load

NO	O'CLOCK	VOLTAGE WITHOUT LOAD (V)	WithLoad 10Watt		With a load 20Watt	
			V	I	V	I
1	09:00	18.9	11.45	0.74	10.99	1.51
2	09:30	19	12.05	0.80	11.90	1.65
3	10:00	19.58	13	0.88	12.69	1.76
4	10:30	19.15	12.1	0.84	12.54	1.73
5	11:00	19.08	12.85	0.86	13.02	1.80
6	11:30	19.31	12.55	0.84	12.67	1.74
7	12:00	20.1	13.2	0.89	12.9	1.79
8	12:30	18.9	11.45	0.78	11.96	1.65

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NO	O'CLOCK	VOLTAGE WITHOUT LOAD (V)	WithLoad 10Watt		With a load 20Watt	
			V	I	V	I
9	13:00	19.1	12.7	0.85	12.26	1.70
10	13:30	19.07	12.07	0.84	12.7	1.77
11	14:00	18.9	11.5	0.78	11.45	1.60
12	14:30	19.18	11.12	0.76	11.3	1.59
13	15:00	19.12	12.5	0.84	11.19	1.57
14	15:30	18.9	11.47	0.78	11.49	1.59
15	16:00	17.91	10.98	0.71	10.46	1.45
16	16:30	17.48	10.18	0.70	10.09	1.40
17	17:00	17.23	9.95	0.67	10.08	1.40

From the table and graph above, it can be seen that the voltage produced is very dependent on the sunlight absorbed by the panel. The brighter the sunlight, the higher the voltage produced. The highest voltage measured was 20.1 without load, namely at 12 noon. This is because the sun is in a perpendicular position to the panel and is not covered by clouds so that the energy absorbed is very maximum. The power provided by the panel can be calculated using the power equation, namely P V x I, The next table is a table of power measurement results for 10 W and 20 W loads.

Figure 6. Solar Panel Measurement with 10 Watt Load

Table 2. Measurement Results with 10 Watt Incandescent Lamp Load

NO	O'CLOCK	VOLTAGE WITHOUT LOAD (V)	With Load 10Watt		Solar Cell Power (watt)
			V	I	
1	09:00	18.9	11.45	0.74	8.47
2	09:30	19	12.05	0.80	8.91
3	10:00	19.58	13	0.88	11.44
4	10:30	19.15	12.1	0.84	10.16
5	11:00	19.08	12.85	0.86	11.05
6	11:30	19.31	12.55	0.84	10.54
7	12:00	20.1	13.2	0.89	11.74

NO	O'CLOCK	VOLTAGE WITHOUT LOAD (V)	With Load 10Watt V	I	Solar Cell Power (watt)
8	12:30	18.9	11.45	0.78	8.93
9	13:00	19.1	12.7	0.85	10.79
10	13:30	19.07	12.07	0.84	10.13
11	14:00	18.9	11.5	0.78	8.97
12	14:30	19.18	11.12	0.76	8.45
13	15:00	19.12	12.5	0.84	10.5
14	15:30	18.9	11.47	0.78	8.94
15	16:00	17.91	10.98	0.71	7.79
16	16:30	17.48	10.18	0.70	7.12
17	17:00	17.23	9.95	0.67	6.67

Peak power is generated at peak voltage, which is 13.2V for a 10 watt load and 12.9 for a 20 watt load, which is 11.74 watts and 23.09 watts. While the power at 4 pm decreased sharply, this is because it started to get cloudy at that time so that the intensity of sunlight decreased. Thus there was a decrease in panel voltage. From the measurement results above, the internal resistance of the load can also be found, namely by using the equation R = V / I, find the resistance of each measurement and find the average value of the calculated resistance. The following is the calculated resistance value R1 = 11.45V / 0.74A = 15.4 Ohm.

Figure 7. Solar Panel Measurement with 20 Watt Load

Table 3. Measurement Results with 20 Watt Incandescent Lamp Load

NO	O'CLOCK	VOLTAGE WITHOUT LOAD (V)	With Load 20Watt V	I	Solar Cell Power (watt)
1	09:00	18.9	10.99	1.51	16.59
2	09:30	19	11.90	1.65	19.63
3	10:00	19.58	12.69	1.76	22.33
4	10:30	19.15	12.54	1.73	21.69

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NO	O'CLOCK	VOLTAGE WITHOUT LOAD (V)	With Load 20Watt V	I	Solar Cell Power (watt)
5	11:00	19.08	13.02	1.80	23.43
6	11:30	19.31	12.67	1.74	22.04
7	12:00	20.1	12.9	1.79	23.09
8	12:30	18.9	11.96	1.65	19.73
9	13:00	19.1	12.26	1.70	20.84
10	13:30	19.07	12.7	1.77	22.47
11	14:00	18.9	11.45	1.60	18.32
12	14:30	19.18	11.3	1.59	17.96
13	15:00	19.12	11.19	1.57	17.56
14	15:30	18.9	11.49	1.59	18.26
15	16:00	17.91	10.46	1.45	15.16
16	16:30	17.48	10.09	1.40	14.12

From the table above, it can be seen that the difference with the previous table is that the change in current will be directly proportional to the voltage given by the panel. In testing with a battery, the current will decrease even though the panel voltage is high. This is because when the battery is empty, the battery resistance value is smaller so that it will draw a larger current, and when the battery starts to fill up, the resistance becomes large and the current will decrease. Until the battery is full, the current will approach zero amperes. The battery charge voltage limit is 13.8 which is regulated by the charger controller so as not to damage the battery. Testing the battery discharge process.

Battery discharge or discharge testing is carried out to determine whether the battery capacity is in accordance with that stated on the battery body or not. The battery used is a Lithium battery with a capacity of 3000 mAh. The working voltage is 13V. Discharge is carried out by connecting the battery to a load, in this case a 10 watt incandescent lamp. The battery is declared empty if the battery voltage drops below 10 Volts, the test results are as follows.

Analysis of Battery Charging Process with 20 WP Solar Panel

In the analysis to test how long it takes the battery to fully charge using 20 WP solar panels

Table 4. Results of Battery Charging Process with 20 WP Solar Panel

NO	O'CLOCK	VOLTAGE PANEL (V)	Battery 12 volt V	I	Solar Cell Power (watt)
1	09:00	11.90	10.83	0.59	6.38
2	09:30	12.93	11.02	0.68	7.49
3	10:00	13.69	11.08	0.73	8.08
4	10:30	12.54	11.54	0.74	8.53
5	11:00	13.09	12.02	0.81	9.73
6	11:30	12.60	12.68	0.84	10.6
7	12:00	12.91	12.91	0.79	10.1

NO	O'CLOCK	VOLTAGE PANEL (V)	Battery 12 volt V	I	Solar Cell Power (watt)
8	12:30	11.86	12.96	0.70	9.07
9	13:00	12.20	12.99	0.76	9.87
10	13:30	12.71	13.07	0.77	10.06
11	14:00	13.85	13.45	0.60	8.07
12	14:30	13.73	13.81	0.59	8.14
13	15:00	12.69	13.80	0.57	7.86
14	15:30	12.39	13.79	0.59	8.13
15	16:00	11.42	13.56	0.35	4.74

From the table above we can see the peak battery voltage to be full at 14.30, meaning that in simulation the battery will be full in 5 and a half hours, so from the experiment above we can calculate theoretically where the battery capacity we use is 3000 MAH or 3 AH where the average output current of the battery from 09.00 - 16.00 is 0.73 A, so t = AH / I, t = 3 / 0.73 = 4.9 hours = 5 hours

Table 5. Lithium Battery Discharge Test with 10 Watt Incandescent Lamp

Time	Voltage Battery (V)	Load current (A)	Power(Watt)
8:00	13.05	0.90	11.74
9:00	12.76	0.85	11.30
10:00	12.03	0.83	10.40
11:00	11.58	0.80	9.21
12:00	9.79	0.67	6.65
13:00	5.38	0.37	2.01

From the table above, it can be seen that the battery effectively works from 8 to 11 o'clock, at 12 o'clock the battery voltage has dropped drastically and is unable to supply the load up to 80%. So it can be stated that the battery is empty.

CONCLUSION

The load passing through the power supply must be controlled via the SCC. The solar cells needed for a hybrid power supply as an energy source for smart traffic lights in real terms are 100 WP / 8 pcs.m The battery required for the hybrid power supply as an energy source for smart traffic lights in real terms is 260 AH / 6 pcs. The inverter used in real is 208 AH The force of the rail gate when going down is smaller than the force when going up. The real comparison with the simulation is 30 mIn order to increase the hybrid power supply for traffic lights to operate 24 hours without using PLN, the AH of the battery must be increased.

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