Jurnal Mantik, 6 (4) (2023), ISSN 2685-4236 (Online)

Published by:Institute of Computer Science (IOCS)

Jurnal Mantik

Journal homepage: www.iocscience.org/ejournal/index.php/mantik

The rooftop solar power plant of electrical engineering department of medan state polytechnic with the internet of things

Suprianto[1], Afritha Amelia[2], Cholish[3], Abdullah[4]

[1,3,4] Department of Electrical Engineering/ Electrical, Politeknik Negeri Medan, Indonesia.

[2]Department of Electrical Engineering /Telecommunication, Politeknik Negeri Medan, Indonesia.

A R T I C L E I N F O

Article history:

Received Feb 02, 2023
Revised Feb 16, 2023
Accepted Feb 28, 2023

Keywords:

Analysis;
Performance;
Photovoltaic;
Load;

ABSTRACT

The use of renewable energy for electricity generation in Indonesia and the world continues to increase because it is environmentally friendly and does not depend on fossil fuels. Research on rooftop solar power plants at the Medan State Polytechnic Building, Department of Electrical Engineering with internet of things aims to implement rooftop solar power plants and determine the performance of rooftop solar power plants in serving electrical loads by controlling electrical loads using the Internet of things. The contribution of this research provides an academic reference for the effective design of a rooftop solar power plant electrical system and savings on electricity bills, especially in the Electrical Engineering Department of the Medan State Polytechnic. The method used in this study is an experimental method, namely collecting data from measurement results, then conducting studies and analysis. The equipment used is NodeMCU ESP 8266, 3300wp photovoltaic module, PZEM 004T sensor, Triac BT 136, inverter, RTC DS 3231, contactor, electricity meter, temperature and light intensity meter, battery system, control panel and other supporting equipment. the internet of things as a load controller from a solar power plant can effectively contribute to saving electricity consumption because reluctance to turn off lights that are not used doesn't make sense because they can be controlled remotely or in close proximity practically using a cellphone via the blynk application. Full load is applied to the solar power plant by activating the four lighting load group buttons on the Blynk IoT app. The average battery voltage at loading is 51.6 volts from a normal battery voltage of 48 volts with the lowest battery voltage of 48.5 volts and the highest battery voltage of 54.31 volts. This rooftop solar power plant in Building C of the Medan State Polytechnic is capable of serving a load of 685 watts for a fixed load that is installed for 11 hours of loading.

This is an open access article under the CC BY-NC license.

Corresponding Author:

Suprianto,
Department of Electrical Engineering/Engineering/Electrical Engineering,
Politeknik Negeri Medan,
Jl. Almamater No. 1 Kampus USU, Medan 20155 Indonesia.
Email: suprianto@polmed.ac.id

1. INTRODUCTION

Rooftop solar power plants have two main advantages, namely they can be used to protect the roof from the sun so that the roof is more durable against weather and can be used to generate electrical energy. The advantage of a rooftop solar power plant that utilizes the width of the roof can generally meet the electrical energy in each building. Buildings with horizontally mounted PV roofs have the highest efficiency in summer, while buildings with inclined PV roofs have the highest efficiency in winter (Wang et al., 2020). Rooftop solar power plants are a useful source of electrical energy as a viable alternative to conventionally generated energy. Solar power plants can help people meet their electricity needs without depending on government electricity services, which sometimes occur several times when there are power outages. The potential that occurs when you only expect electrical energy from non-renewable sources such as oil, gas and others will result in an energy crisis. The investment costs for making solar power plants may be felt to be quite expensive at this time so there are still not many people who want to install solar power plants for their household electricity needs (Lan et al., 2021). Solar energy is highly available during daylight hours on earth. It is sustainable, renewable and green energy. Increasing the efficiency of using solar energy is a major concern for research because of its renewable nature(Gupta et al., 2021). An on-grid solar power plant for the needs of daily electricity consumption is built for the continuity of power services. From the measurement results, the solar module has a lower efficiency value compared to the efficiency value found on the solar panel nameplate. The surface temperature of the solar module is higher than the optimal operating temperature. On-grid solar power plants are used for the export and import of electric power.(Windarta et al., 2021). Rooftop solar photovoltaics (PV) systems are an attractive alternative source of electricity. The potential of solar PV at a particular location can be evaluated through software simulation tools to assess the feasibility of a rooftop photovoltaic system (Yadav & Bajpai, 2018). a large renewable energy installation will use a large area of land so that in terms of space it requires a large area. Placement of future solar power installations must be able to be placed to achieve the highest energy production with relatively limited land. Solar panel efficiency is affected by insolation, air temperature, wind speed and relative humidity (Adeh et al., 2019). The performance of solar panels and their lifetime depends on the quality of the photovoltaic cells, their soldering technology, the quality of the ethyl vinyl acetate film in which they are encapsulated, the encapsulation technology, and the backing sheet. Depending on the manufacturing technology, photovoltaic panels can be made from monocrystalline, polycrystalline and amorphous silicon cells(Mitiu et al., 2018). Solar power plant is a power plant that utilizes solar cells to convert solar radiation into electrical energy. Electrical energy is processed from non-moving parts such as diesel generators, steam, gas and others. Solar power plants are relatively simple compared to other types of generators. Solar energy is an environmentally friendly energy source(Ummah et al., 2021). Renewable energy as a solution to meet future and current energy needs. There are eight group maps around the world with collaborative researchers. the grouping of publications consists of renewable energy and solar panel literature, namely solar energy, renewable energy, management, power, technology, and the environment.(Choifin et al., 2021). Solar panels that are placed on the roof surface should be designed to provide an air gap between the roof surface and the bottom of the panel for air circulation so that overheating does not occur. The panels are pointed towards the sun and are not obscured by obstructions such as trees and buildings (Murat Ates & Singh, 2021). The use of solar energy has continued to increase significantly in installed capacity over the last few years. Most solar power plants are installed on the roof because it is the highest part of a building so that sunlight is not blocked by other parts of the building. The rapid development of photovoltaics makes it increasingly important to understand performance from reliability. One of the most

common problems encountered in solar power generation is non-uniform or partially shaded radiation. The consequences of such shading can be prevented by using a bypass diode (Vieira et al., 2020). The preference for types of renewable energy with green energy tariffs, namely solar panels on the roof, solar panels on the ground, heat pumps, wind turbines, has been measured in four tourist destinations. The positive attitude of tourists to the selected type of energy source has been confirmed. The highest preference was found for roof-mounted solar panels.(Navratil et al., 2019). Installation of residential solar photovoltaic cells realized for the utilization of renewable energy. This was followed by the establishment of a solar photovoltaic panel manufacturing company. public acceptance of residential solar panels, many respondents expressed interest in installing solar panels. However, challenges in purchasing and installing them, including capital, lack of information, and maintenance requirements are the main reasons why solar panels have not been widely used(Alsabbagh, 2019). Photovoltaics is a renewable energy technology that has the potential to replace non-renewable energy sources and has attracted worldwide attention in recent years due to the increasing demand for energy and concerns about climate change. Data analysis was applied to identify actual performance parameters based on solar irradiance, School buildings especially for roofs, is a unique and important asset for urban PV system implementation, as it provides a combination of relatively large, unused and suitable in use area, which enables power generation distributed and effective solar power for use nationwide(Al-Otaibi et al., 2015). Installing a rooftop solar panel system is the most promising option for reducing electricity costs and production costs for industrial use. The 1.43 MWp solar power plant has been built on the roof of the building, along with complete single line diagrams, technical specifications, interconnection diagrams of the rooftop solar power system connected to the network from the point of generation to the network point designedInstalling a rooftop solar panel system is the most promising option for reducing electricity costs and production costs for industrial use. The 1.43 MWp solar power plant has been built on the roof of the building, along with complete single line diagrams, technical specifications, interconnection diagrams of the rooftop solar power system connected to the network from the point of generation to the network point designed(Hore et al., 2022). During dry season and summer season, dust deposition significantly affects the performance ratio of solar panels. The performance ratio is reduced by 1.6% to 8%. After cleaning the surface of the solar panel, the performance increases and results in an increase in energy output of 10%. These improvements provide the economic and cost benefits of PV cleaning. The performance ratio does not change significantly during the rainy season, when the PV modules are relatively clean as dust is washed away by rainwater.(Sakarapunthip et al., 2017). More and more electricity users are generating their own electricity through rooftop solar panels. utility gain and social welfare are related. Mutually beneficial cooperation between utilities and rooftop solar panel user communities is based on the use of electric power measuring instruments, namely measuring instruments in the form of export and import of electric power(Sunar & Swaminathan, 2021). The use of rooftop solar power plants has been widely used in Australia, including in new housing estates that have installed solar power plants on each roof. Because of that, there is a difference in house prices for houses with solar power plants because they are indeed more expensive than ordinary houses in general(Best et al., 2021). The potential for electricity production from rooftop solar photovoltaic systems in residential areas with residential roof areas spread over 16 districts with an area of 412,987.50 m2 to 2,083,387 m2 has an average potential of solar energy annually of 44 to 222 MWh/year (Widodo et al., 2020). The rooftop solar power plant is a renewable energy technology that is environmentally friendly because of its ability to generate electricity without producing greenhouse gases when it generates electricity. application of the challenge-derived S-LCA framework for assessing the social impact of rooftop solar panels in the southeastern United States during their use and

end-of-life phases(Bonilla-Alicea & Fu, 2022). The rapid demand for electrical energy is proportional to the increase in population. Generating electricity using the sun will reduce the cost of electricity bills(Yadav & Bajpai, 2018). The off-grid roof solar photovoltaic system is adapted to optimal load service with planning that considers various aspects so that it is hoped that the main load requirement can be fulfilled for 24 hours. The off-grid solar power plant acts as the main source of electrical energy service and if there is cloudy weather for several days in a row or there is damage to the system, the service's electricity needs can be met from a backup power source, in this case electricity from the state electricity company(Winardi et al., 2021). The efficiency of solar modules depends on the weather and the configuration of the solar power plant. On cloudy and not hot weather, the efficiency of the solar module will be low. Apart from depending on the weather, the efficiency of the solar module also depends on the location where the solar module is placed against the sun's irradiation angle and also the effect of shading. Other technical matters such as the use of cable types and cable lengths also contribute to the efficiency value.(Windarta et al., 2021). The use of new and renewable energy related to the environment, global warming, energy conservation, and others needs to be socialized, including to the community and industry, including its interconnection with the state electricity company(Ohira et al., 2021).

2. RESEARCH METHOD

A solar power plant designed to serve a lighting load of 45 units of lamps with a total power capacity of 686 watts spread across 8 rooms, namely 52 watts of lamps in the department head's room, 52 watts of lamps in the department secretary's room, 52 watts of lamps in the administration room , a 156 watt lamp in the study program room, a 36 watt lamp in bathroom 1, a 54 watt lamp in bathroom 2, a 54 watt lamp in bathroom 3, and a 230 watt lamp in the hallway on the 1st floor. Control of the lights can use connected IoT applications with an Android phone. The method used in this research is the experimental method, namely collecting data and designing and then testing the results of the design. Data collection is carried out by collecting equipment specification data and measurement results data, measurements in this case are measurements of electrical quantities such as current, voltage and electric power while measurements of other quantities such as temperature and solar intensity. The use of IoT is for electrical equipment control systems, in this case specifically for lighting using remote and short on-off control modes using the internet network. Switches for lighting using IoT are grouped into four light load groups, namely light group 1 which consists of lights in the department head room, department secretary, and administration room. Group 2 lights consist of lights in the study program room, group 3 lights consist of lights in the bathroom room and group 4 lights consist of lights in the hallway on the 1st floor. The equipment used consists of 4 units of 20 Ampere contactors, 4 units of Triac, DC power supply , 2 MCB units, 1 photocell unit, 1 CT unit, 1 PZEM sensor unit, 1 RTC unit, 1 NodeMcu ESP 8266 unit, 4 optocoupler units, 22 150 Wp solar panel units, 5000 watt inverter, 48 volt 100 AH battery and some other supporting equipment

Figure 1. Solar panel research equipment

Figure 2. lighting served by solar panels

Electrical equipment in the form of lighting that is supplied by a solar power plant can be controlled using IoT from a short or long distance. the program code embedded in the NodeMCU ESP 8266 is adapted to the blynk IoT application so that the control equipment can run as desired. Combined with hardware equipment such as MOC3021, BT136 triac, and ST10 contactor, PZEM004T sensor and others in one circuit, it makes a unified system with customized program code. The program code is as follows.

```
#define BLYNK_TEMPLATE_ID
#define BLYNK_DEVICE_NAME
#define BLYNK_AUTH_TOKEN
#define BLYNK_PRINT Serial
#include <PZEM004Tv30.h>
#include <SoftwareSerial.h>
#include <Wire.h>
#include <ESP8266WiFi.h>
#include <BlynkSimpleEsp8266.h>
```

```
#include <UnixTime.h>
#include <EEPROM.h>
UnixTime stamp(0);
#define PZEM_RX_PIN D3
#define PZEM_TX_PIN D4
char auth[] = BLYNK_AUTH_TOKEN;
char ssid[] = "Galaxy A131270";
char pass[] = "alhamdulillah21";
SoftwareSerial pzemSWSerial(PZEM_RX_PIN,
PZEM_TX_PIN);
PZEM004Tv30 pzem(pzemSWSerial);
const int pinSensor = A0;
const int pinL1 = D5;
const int pinL2 = D6;
const int pinL3 = D7;
const int pinL4 = D8;
byte addMode = 0;
byte addL1 = 1;
byte addL2 = 2;
byte addL3 = 3;
byte addL4 = 4;
BLYNK_WRITE(V1){
  int val = param.asInt();
  if(val == 1){
    EEPROM.write(addMode,2);
    EEPROM.commit();
    Mode = "MANUAL";
    Blynk.virtualWrite(V3, Mode);
    Serial.print("MODE : ");
Serial.println(Mode);
  }
}
BLYNK_WRITE(V8){
  int val = param.asInt();
  if(Mode == "MANUAL"){
    if(val == 1){
      L1ON();
    }else{
      L1OFF();
    }
  }
}
BLYNK_WRITE(V9){
  int val = param.asInt();
  if(Mode == "MANUAL"){
    if(val == 1){
      L2ON();
    }else{
      L2OFF();
    }
  }
}

BLYNK_WRITE(V10){
  int val = param.asInt();
  if(Mode == "MANUAL"){
    if(val == 1){
      L3ON();
    }else{
      L3OFF();
    }
  }
}

BLYNK_WRITE(V11){
  int val = param.asInt();
  if(Mode == "MANUAL"){
```

```
    if(val == 1){
      L4ON();
    }else{
      L4OFF();
    }
  }
}

BLYNK_WRITE(V18){
  int val = param.asInt();
    if(val == 1){
      pzem.resetEnergy();
    }
}
 BLYNK_CONNECTED() {
  Blynk.sendInternal("rtc", "sync");
}
BLYNK_WRITE(V13) {
WidgetLED Lamp1(V14);
WidgetLED Lamp2(V15);
WidgetLED Lamp3(V16);
WidgetLED Lamp4(V17);

void setup() {
  Serial.begin(9600);
  Blynk.begin(auth, ssid, pass);
  EEPROM.begin(512);
  pinMode(pinL1,OUTPUT);
  pinMode(pinL2,OUTPUT);
  pinMode(pinL3,OUTPUT);
  pinMode(pinL4,OUTPUT);
  cekEprom();
  delay(3000);
}
void loop() {
  Blynk.run();
  if (millis() - prev >= 1000) {
    prev = millis();
    float voltage = pzem.voltage();
    float current = pzem.current();
    float power = pzem.power();
    float energy = pzem.energy();
    float frequency = pzem.frequency();
      float pf = pzem.pf();
```

Figure 2. Program Code.

3. RESULTS AND DISCUSSIONS

Measurements of electricity and other quantities in rooftop solar power plants will begin at 07.00 WIB until 18.30 WIB which is intended to find out how the performance of a solar power plant when serving lighting loads and how battery performance in charging and loading can be known through several the results of the measurement of electrical quantities. and other numbers in table 1. measurements are carried out once every 10 minutes so that a total of 700 measurements are taken. For this reason, in this article only the measurement results are displayed every 30 minutes to avoid the page limit in this article, the results of 700 measurements are displayed graphically in the discussion section.

Table 1. Results of measuring the performance of a solar power plant from 07.00 WIB to 18.30 WIB

Time	Vvp (Volt)	I Solar Cell	Power VP (Watt))	I Bat Charger	V Bat Supply	I Bat Supply	Watt Bat Supply	Intensity	Temperature	Power (Watt)
07:00	120	0	0	0	49,58	16,05	771,5	30,4	26,5	617,5
07:30	119	0	0	0	49,46	16,03	761,3	102,3	28,1	613,9
08:00	345	1	398	0	50,03	6,73	381,3	130,8	24,2	615,9
08:30	356	1,3	450	0	50,83	4,45	207	172,1	29,4	615
09:00	408	2,1	840	3,62	54,26	0	0	315,5	32,6	613,8
09:30	417	1,9	790	1,86	54,29	0	0	291,3	30,9	668,9
10:00	370	1,8	687	0	53,74	0,67	26,2	226,1	34,1	671,7
10:30	351	1,2	400	0	50,61	6,73	331,7	290,4	32,8	684,5
11:00	375	1,8	665	0	51,19	1,26	54,8	310,6	33,4	684,2
11:30	371	1,9	698	0	53,11	0,75	29,1	337	35,7	684
12:00	375	2,5	927	3,87	53,77	0	0	444,9	35,1	681,5
12:30	426	2,1	860	2,64	54,3	0	0	584,7	35,7	680,6
13:00	369	1,5	543	0	52	3,66	180,4	302,3	36,4	682,1
13:30	406	2	807	1,76	54,3	0	0	609,3	34,5	679,9
14:00	390	1,8	615	0	52,96	2,21	107,2	382,5	36,5	681,8
14:30	382	2,1	780	1,27	53,62	0	0	393,4	36,4	680,9
15:00	387	1,7	639	0	52,82	1,84	86	327,3	34,3	683,1
15:30	355	1,1	380	0	50,95	6,96	351,5	218,3	34,6	683
16:00	351	1,3	441	0	50,54	6,24	305,7	206,4	35,4	684,9
16:30	345	1,2	385	0	50,31	7,31	365,2	182,3	32,1	682,4
17:00	336	0,6	201	0	49,96	11,64	557	138	30,7	684,1
17:30	120	0	0	0	49,36	16,23	777,4	42,9	28,9	685,2
18:00	120	0	0	0	48,91	16,25	780,1	16,5	20,5	683,4
18:30	118	0	0	0	48,5	16,5	789,1	0,9	20,1	685,2

Table 1 shows that the loading for 11 hours shows several variations in the electrical quantities that occur from time to time, even from minute to minute. this is caused more by fluctuations in the state of the intensity of the sun which tends to change from the morning to the afternoon. The intensity of the sun in the morning and evening is lower than during the afternoon. the consequence of the intensity in the morning and evening is that it generates low electric power so that the use of batteries is needed to support the demand for electric power which cannot be fully supported by solar power plants. compensation for battery energy used during the day is provided by the solar power plant during the day, which is around 09.00 WIB to 16.00 WIB. at that time the battery energy that is drained in serving the electric load is given back through the solar power plant by providing charging of electrical energy into the battery until the battery is fully charged. by fully charging the battery during the day, the battery can again supply the load at full power to supply electrical power in the afternoon from 16.00 WIB to 18.30 WIB. at 18.30 WIB the battery will be in a no-load condition as well as solar panels which have no electricity because there is no sunlight. in the morning the power of the battery in supplying the load from 07.00 WIB to 08.00 WIB relies on the remaining battery energy in the previous afternoon which is also able to supply electric power in the morning because it only lasts for approximately one hour the rest of the loading is carried out by

the power plant solar which when supplying the load is also capable of charging the battery..

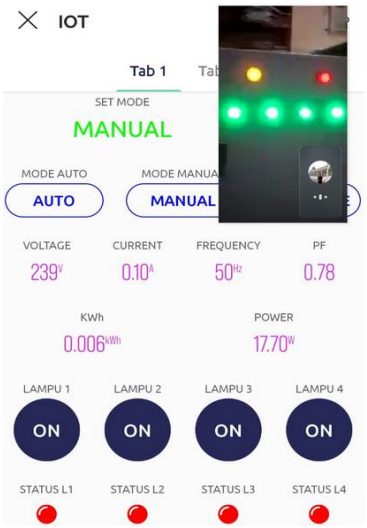

Figure 3. IoT display on handphone

Testing for IoT applications in controlling the electric load of lighting lamps is carried out remotely under no-load conditions from the Labuhan Batu district, Panai Hulu sub-district, Ajamu village, which is about 317 km from the city of Medan. the results of these tests indicate that through the blynk IoT application controlling the electric load of lighting lamps has succeeded in turning off and on the four groups of switches that represent the loading group remotely. There are four buttons in the blynk application that are used to turn load groups off and on. light button 1 represents the lighting load group in the chairperson and secretary room of the department and administration room. light button 2 represents the light load group in the study program room. light button 3 represents the light load group in the bathroom room and light button 4 represents the light load group in the first floor hallway of the building c.

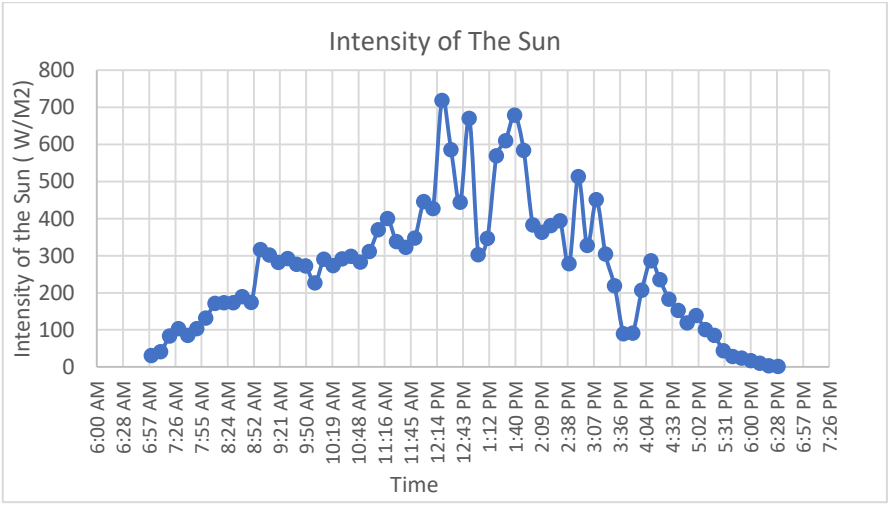

Figure 3. Intensity of The Sun

The intensity of the sun fluctuates every day depending on weather conditions, Figure 3 shows a picture of fluctuations in the intensity of the sun in one day on December 28. It can be seen that the high intensity of the sun occurs from 09.00 to 15.20, and between these times the intensity of the sun shows high intensity even though it fluctuates.

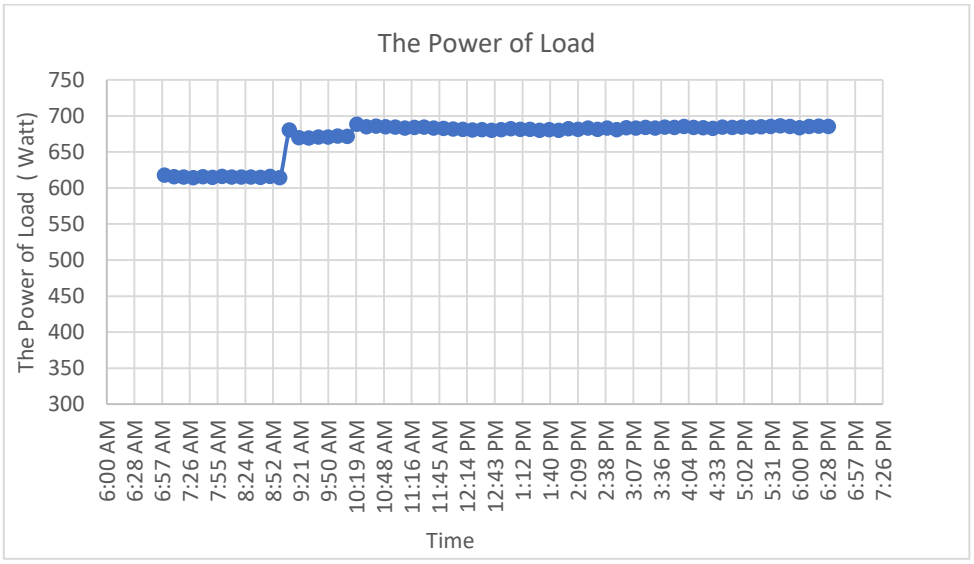

Figure 4. The Power of Load

the power used in the morning and evening consists of a total power of 600 watts to 700 watts. The load consists of lighting in the department office, study program office, 1st floor hallway and 3 bathrooms which are always on from morning to evening. This power service can be served using a solar power plant without involving a PLN power source.

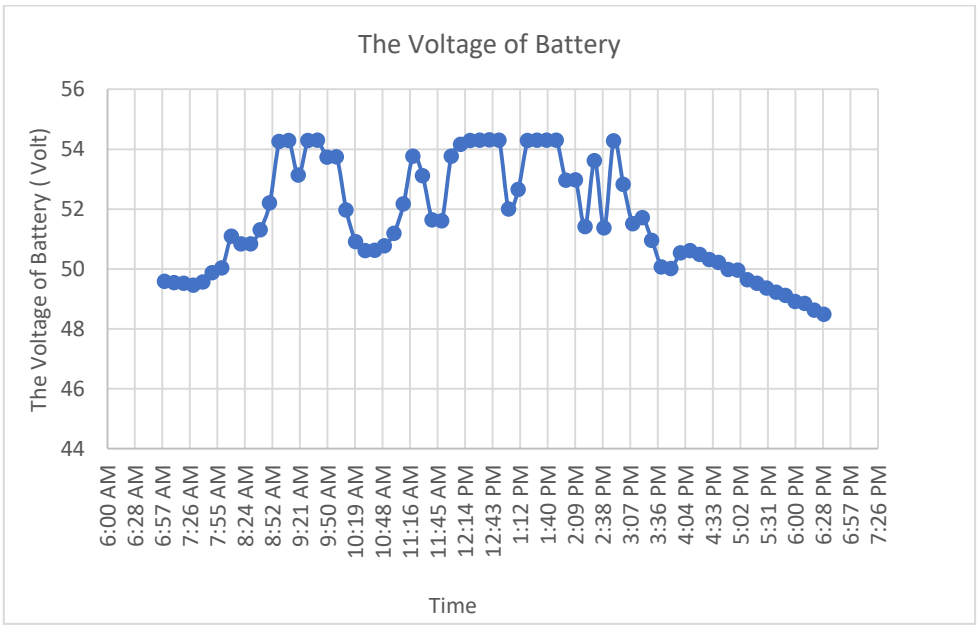

Figure 5. the Voltage of Battery.

normal battery voltage is in the range of 48 volts, the battery consists of 4 pieces consisting of a 12 volt 100 Ah battery strung together to 48 volts. even though the battery provides maximum power service in the morning, it does not cause the battery voltage to drop below 48 volts but on the contrary it does not drop to its nominal voltage. which has been fully charged steadily returns to serve the load until 18.30 and this can be served by the battery

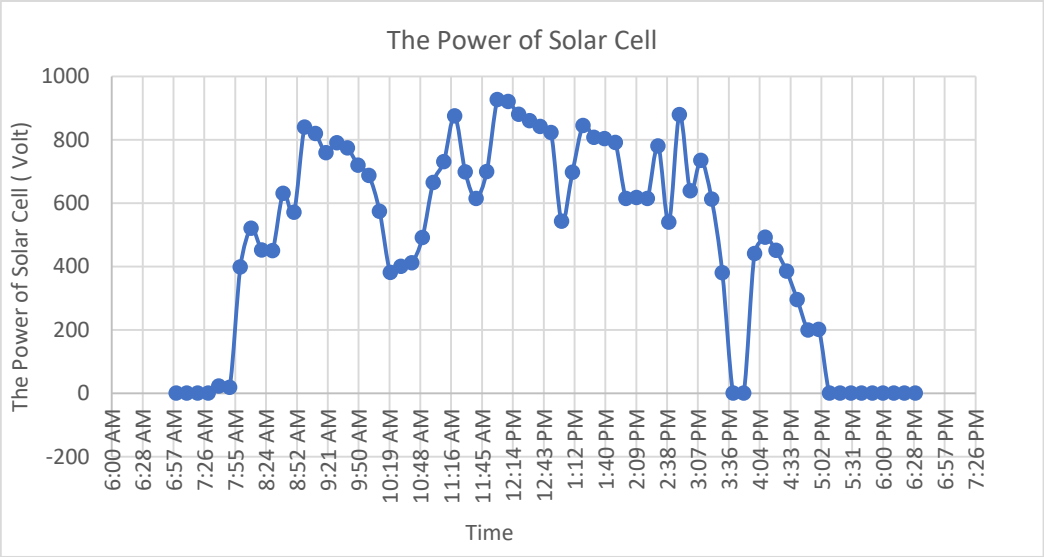

Figure 6. The Power of Solar Cell

The power generated by solar panels occurs from 08.00 to 17.00 in the afternoon. maximum power on solar panels is 3300 watts, but this power can be generated depending on weather conditions, for sunny weather this can be achieved but in cloudy weather power production will decrease by several percent depending on the weather at that time. but in conditions when the weather measurement includes not cloudy and not sunny. the weather was not hot but not raining or drizzling. electric power production at that time was able to serve the load normally while charging the battery.

4. CONCLUSION

The use of the internet of things as a load controller from a solar power plant can effectively contribute to saving electricity consumption because reluctance to turn off lights that are not used doesn't make sense because they can be controlled remotely or practically from a short distance using a cellphone via the blynk application. Full load is applied to the solar power plant by activating the four lighting load group buttons on the Blynk IoT app. The average battery voltage at loading is 51.6 volts from a normal battery voltage of 48 volts with the lowest battery voltage of 48.5 volts and the highest battery voltage of 54.31 volts. The difference in electrical energy consumption that occurs in rooftop solar power plants is due to the user's need for fluctuating lighting needs. Determining the design of the solar panel voltage source affects the variable battery voltage, inverter voltage, and system equipment selection. This rooftop solar power plant in Building C of Medan State Polytechnic is capable of serving a load of 685 watts for a fixed load that is installed for 11 hours of loading. the loading of solar power plants is carried out from 07.00 WIB to 18.30 WIB because it is adjusted to lecture activities. the next research is planned to be able to design and add a solar power plant with an even

greater capacity so that it is able to serve all electricity needs and can even export electricity to the state electricity company.

REFERENCES

Adeh, E. H., Good, S. P., Calaf, M., & Higgins, C. W. (2019). Solar PV Power Potential is Greatest Over Croplands. *Scientific Reports*, *9*(1). https://doi.org/10.1038/s41598-019-47803-3

Al-Otaibi, A., Al-Qattan, A., Fairouz, F., & Al-Mulla, A. (2015). Performance evaluation of photovoltaic systems on Kuwaiti schools' rooftop. *Energy Conversion and Management*, *95*. https://doi.org/10.1016/j.enconman.2015.02.039

Alsabbagh, M. (2019). Public perception toward residential solar panels in Bahrain. *Energy Reports*, *5*. https://doi.org/10.1016/j.egyr.2019.02.002

Best, R., Burke, P. J., Nepal, R., & Reynolds, Z. (2021). Effects of rooftop solar on housing prices in Australia. *Australian Journal of Agricultural and Resource Economics*, *65*(3). https://doi.org/10.1111/1467-8489.12431

Bonilla-Alicea, R. J., & Fu, K. (2022). Social life-cycle assessment (S-LCA) of residential rooftop solar panels using challenge-derived framework. *Energy, Sustainability and Society*, *12*(1). https://doi.org/10.1186/s13705-022-00332-w

Choifin, M., Rodli, A. F., Sari, A. K., Wahjoedi, T., & Aziz, A. (2021). A STUDY OF RENEWABLE ENERGY AND SOLAR PANEL LITERATURE THROUGH BIBLIOMETRIC POSITIONING DURING THREE DECADES. *Library Philosophy and Practice*, *2021*.

Gupta, M., Dubey, A. K., Kumar, V., & Mehta, D. S. (2021). Experimental study of combined transparent solar panel and large Fresnel lens concentrator based hybrid PV/thermal sunlight harvesting system. *Energy for Sustainable Development*, *63*. https://doi.org/10.1016/j.esd.2021.05.008

Hore, S., Sakile, R., & Sinha, U. K. (2022). Design and Implementation of 1.43 MWp Grid-Connected Rooftop Solar PV Power Plant. *Lecture Notes in Electrical Engineering*, *812*. https://doi.org/10.1007/978-981-16-6970-5_41

Lan, T. T., Jirakiattikul, S., Niem, L. D., & Techato, K. (2021). The intention of households in the Daklak province to instal smart grid rooftop solar electricity systems. *Energy, Sustainability and Society*, *11*(1). https://doi.org/10.1186/s13705-021-00297-2

Mitiu, M. A., Olteanu, M. V, Raischi, N. S., Balaceanu, C. M., & Cociorva, D. (2018). Efficiency of polycrystalline photovoltaic parks in Romania: Possibility of using renewable energy. *Thermal Science*, *22*. https://doi.org/10.2298/TSCI170720051M

Murat Ates, A., & Singh, H. (2021). Rooftop solar Photovoltaic (PV) plant – One year measured performance and simulations. *Journal of King Saud University - Science*, *33*(3). https://doi.org/10.1016/j.jksus.2021.101361

Navratil, J., Picha, K., Buchecker, M., Martinat, S., Svec, R., Brezinova, M., & Knotek, J. (2019). Visitors' preferences of renewable energy options in "green" hotels. *Renewable Energy*, *138*. https://doi.org/10.1016/j.renene.2019.02.043

Ohira, Y., Kartika, B. T., & Sarono, T. (2021). Company participation in supporting national energy security through collective installation of rooftop solar panel of employees' houses as an effort to accelerate increased utilization of solar energy. *IOP Conference Series: Earth and Environmental Science*, *753*(1). https://doi.org/10.1088/1755-1315/753/1/012047

Sakarapunthip, N., Chenvidhya, D., Chuangchote, S., Kirtikara, K., Chenvidhya, T., & Onreabroy, W. (2017). Effects of dust accumulation and module cleaning on performance ratio of solar rooftop system and solar power plants. *Japanese Journal of Applied Physics*, *56*(8). https://doi.org/10.7567/JJAP.56.08ME02

Sunar, N., & Swaminathan, J. M. (2021). Net-Metered Distributed Renewable Energy: A Peril for Utilities? *Management Science*, *67*(11). https://doi.org/10.1287/mnsc.2020.3854

Ummah, H. F., Setiati, R., Dadi, Y. B. V., Ariq, M. N., & Malinda, M. T. (2021). Solar energy as natural resource utilization in urban areas: Solar energy efficiency literature review. *IOP Conference Series: Earth and Environmental Science*, *780*(1). https://doi.org/10.1088/1755-1315/780/1/012007

Vieira, R. G., de Araújo, F. M. U., Dhimish, M., & Guerra, M. I. S. (2020). A comprehensive review on bypass diode application on photovoltaic modules. In *Energies* (Vol. 13, Issue 10). https://doi.org/10.3390/en13102472

Wang, D., Qi, T., Liu, Y., Wang, Y., Fan, J., Wang, Y., & Du, H. (2020). A method for evaluating both shading and power generation effects of rooftop solar PV panels for different climate zones of China. *Solar Energy*, *205*. https://doi.org/10.1016/j.solener.2020.05.009

Widodo, D. A., Purwanto, P., & Hermawan, H. (2020). Potential of solar energy in residential rooftop surface area in Semarang City, Indonesia. *Advances in Science, Technology and Engineering Systems*, *5*(4). https://doi.org/10.25046/aj050446

Winardi, B., Sinuraya, E. W., Nugroho, A., & Denis. (2021). Design and Implementation of Rooftop off Grid Solar Panel for Household Electricity Loads. *2021 8th International Conference on Information Technology, Computer and Electrical Engineering, ICITACEE 2021*. https://doi.org/10.1109/ICITACEE53184.2021.9617551

Windarta, J., Denis, Silaen, J. S., & Satrio, D. A. (2021). Analysis of performance and testing of 1215 WP rooftop solar power plants with on-grid system household scale with the case study of Sambiroto Asri Housing Semarang City. *IOP Conference Series: Earth and Environmental Science*, *623*(1). https://doi.org/10.1088/1755-1315/623/1/012011

Yadav, S. K., & Bajpai, U. (2018). Performance evaluation of a rooftop solar photovoltaic power plant in Northern India. *Energy for Sustainable Development*, *43*. https://doi.org/10.1016/j.esd.2018.01.006