PLTS Design as Secondary Power Supply of Tower R.67 Mount Gending Resort Sintelis Kalibaru Banyuwangi

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Abstract. Electricity plays a crucial role for a better operation in railways. Therefore, it is necessary to maintain the electricity to run continuously without disrupting the network. Tower R.67 of Mount Gending serves as the base station tower, located in the area of Sintelis Kalibaru Resort, which utilized to connect telecommunication activities in train operations. This tower is located in a mountainous area that often experience power outages by the PLN authorities. When frequent power outages occur, the generator set installed as a backup power supply will have to work continuously. This concern causes the generator set to experience technical error due to its continuous work. On the other hand, Mount Gending is the region that has the potential access to the sunlight as one of the renewable resources. Sunlight can be an alternative to support PLN's electricity source as the main power supply of Tower R.67 of Mount Gending. The alternative of utilizing the solar power plant (PLTS) is chosen due to avoid technical error with the generator set which run continuously. Additionally, the writer compiled the PLTS and PLN design by calculating the energy consumed in 1 h or its peak load as the first step which then followed by calculating the needs for batteries, solar panels and inverters. Meanwhile, the generator set can only be turned off for a maximum of 2 h, thus the total peak load is 3811.5Wh and is multiplied by 2, which is 7623Wh. Moreover, 7 batteries, 17 pieces of solar panels, and inverter with 8Kw output are required to perform this calculation.

Keywords: PLTS · PLN · inverter · battery · electrical load

1 Introduction

Maintaining the dependability of the railway infrastructure is a necessary activity done in order to maintain it suitable for operation (Ministerial Regulation Number 32 of 2011). The maintenance operation is conducted by the railway operating facility, and generation set maintenance is carried out within the monthly activity. It is also beneficial for optimizing the performance of generator set as to work at its best. Tower R.67 of Mount Gending is within the work area of Resort Sintelis 9.5 Kalibaru, which functions as the base station for the train dispatching telecommunication operation. In performing

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its function, Tower R6.7 of Mount Gending went through interference with the generator set as the power supply tool. The tower is located in the mountainous area where power outrage often occurred nearly every day by the PLN authority. According to this concern, the generator set have had experienced technical error due to its continuous work, despite the fact that Mount Gending is the region that have access to the sunlight as one of the alternative source of energy with significant energy reserves. Sunlight is a renewable energy resource which is produced by the sun and its existence will never completely run out.

2 Theoretical Aspects

Several theoretical aspects are required to support in compiling this research. These theoretical aspects includes renewable energy resources, PLN electricity sources, potential solar energy, PLTS, electrical loads, batteries, inverter, automatic transfer switch (ATS), and solar charge controller (SCC).

2.1 Renewable Energy Resources

Renewable energy resources are those energy derived from the nature which will never run out its supply due to its ability in regenerating itself. It is expected that renewable energy resources to be the primary source of energy in the future. Sun, wind, water, geothermal and others are examples of renewable energy resources.

2.2 Potential Solar Energy

Weather is a variation of temperature, wind, rainfall, as well as sunlight. Weather changes are caused by the existence of different temperature and humidity of the place. Therefore, weather is one of the key factors in creating the PLTS. The research location is at the Tower R.67 of Mount Gending, Village Lekab, Banyuanyar, District of Kalibaru, Regency of Banyuwangi, located at the coordinates - 8.252014, 113.936992.

2.3 Loads

Electrical load refers to anything that is supported by the power plant and anything that requires energy (Rofifah 2020). Within an electrical circuit, electrical load is also referred to resistance which is related to electric current and voltage as mentioned in the Ohm's law.

2.4 Solar Panel

Solar panel is a mandatory component in compiling the PLTS, which works by utilizing the sunlight and processes it through the photovoltaic system. PLTS generates DC electricity and can be transformed into AC electricity by utilizing the inverter. Moreover, PLTS is an environmentally friendly renewable energy resource and does not produce pollution such as exhausting waste or gases.

2.5 Battery

Battery functions to store electrical energy as the form of DC electricity which is produced by solar panels. Due to the absence of sunlight at night, solar panel stops producing electricity; yet, batteries help store electrical energy which keeps the electricity available. In general, the unit capacity of battery is Ampere Hour (Ah).

2.6 Inverter

Inverter is a component which converts DC voltage into AC voltage at frequency of 50 Hz/60 Hz. It is also utilized to boost energy security to provide reserved energy when power outage occurred by the authority of PLN as well as to maximize the energy generated by the solar panels. There are three inverters which include square wave, modified sine wave, and pure sine wave.

3 Method

3.1 Flow Diagram

This research follows the flow diagram as presented in Fig. 1

In compiling this final project, the writer prepares to collect primary and secondary data as a theoretical foundation in conducting this research as presented below:

Fig. 1. Flow diagram

Table 1. Process of data collecting

Name of Tool	**Amount**	**Time (Power on)**	**Electricity Power**	**Electricity Power**	**Total of Electricity Power**
(1)	**(2)**	**(3)**	**(4)**	**(5) = (2) * (4)**	**(6)**
Power One Rectifier Module	1 item	24 h	220 W	220 W	5.28 Kwh
AC Split	1 item	24 h	746 W	746 W	17.904 Kwh
TL Light	8 items	1 h	320 W	2560 W	2.56 Kwh
XL Light	4 item	12 h	40 W	160 W	1.92 Kwh
Tower Light	1 item	12 h	100 W	100 W	1.2 Kwh
Minilink Radio	3 items	24 h	8.5 W	25.5 W	0.612 Kwh
Amount of Total Energy			1434.5 W	3811.5 W	29.476 Kwh

1. Primary Data

   a. Existing condition of the Tower R.67 of Mount Gending
   b. Interviews with railway facility operation officers or specialists

2. Secondary Data

   a. Data of the electrical energy at Tower R.67 of Mount Gending
   b. Data of the radiation at the Kalibaru Region

c. Data of interference occurred to the generator set at Tower R.67 of Mount Gending

3.2 Method of Data Collection

There are several steps included in the process of data collecting, as follow:

a. Data of Electrical Load Energy

The Table 1 presents the data of electrical energy consumed in Tower R.67 of Mount Gending. According to the table, 29.476 Kwh is the total amount used daily. Tower R.67 of Mount Gending is utilized for the train dispatching telecommunication operation. Certainly this role is essential to support railway traffic. Therefore, in order for the tools to frequently function, power supply at Tower R.67 must operate continuously and never to be turned off. There are three (3) trains travel through the area of Tower R.67 of Mount Gending from Kotok – Sumberwadung at around the hours of 06:00–07:00, 10:30–11:30, and 18:00–19:00. This tower utilized *PLN* as its main power supply and generator set as their reserved power supply, and in this case the *Yanmar* generator YDG5001se series is used. As the location of this tower is in mountainous area, power outage often occurred by the authority of *PLN* due to their activities, consequently the generator set runs non-stop every day. In each day, power outage last at an average of two hours.

4 Results and Discussion

4.1 Method and Process of Designing *PLTS*

In this research entitled "PLTS Design as Secondary Power Supply (Generator Set – PLN) of Tower R.67 Mount Gending" includes the stages of production and procedure for its implementation. There must be components utilized in designing *PLTS* such as solar panels, battery, and inverter. In addition, it is required to identify the energy of Tower R.67 of Mount Gending in order to determine each of the components. To determine each component, it is necessary to identify the total of energy consumed. Therefore, below are the determinations of tools utilized:

1. Battery

Battery is one of the components of *PLTS* which purposes as to store electrical energy generated from the solar panel during the day, which then can be used at night or when the weather is cloudy. In this design, battery with the capacity of 12 V 100 Ah is used as the second tool. Furthermore, to calculate the battery it is required to divide the energy loads of Tower R.67 by the battery capacity needed.

2. Power Plant (*PLTS*)

PLTS is a power plant which utilizes the sunlight through solar cells (photovoltaic) and converts solar photon radiation into electrical energy. The solar panel utilized for this design are those polycrystalline type with the capacity of 100 Wp, a maximum power of 100 w, an efficiency of 16.93%, a maximum power voltage of 17.8 V, and a maximum power current of 5.62 A.

3. Inverter

Inverter is a circuit which converts DC into AC voltage; it specifically transfers voltage from a DC source into AC loads. The source of inverter voltage can be solar panel, battery, and others. An additional function of inverter is to control and maintain the stability of voltage at the generated electrical output. Moreover, note that in this design of *PLTS* system, inverter must be able to be both connected and disconnected from the solar panel to the load in order to operate with the electrical energy of *PLN* which also connects to the inverter.

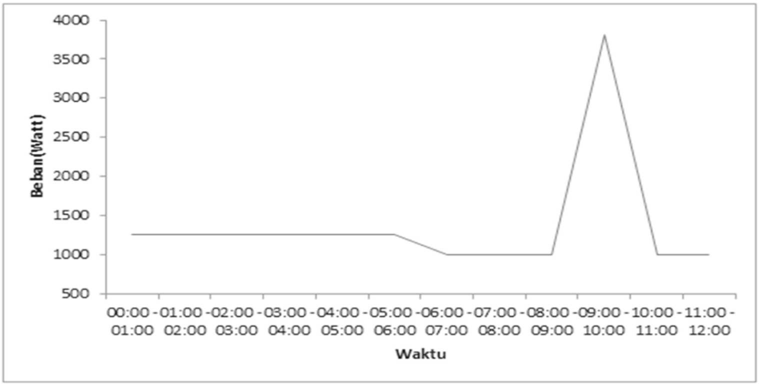

Fig. 2. Graph of energy at the hours 00:00–12:00

4.2 Results and Discussion

The graph above presents the illustration of the energy used per hour, the 'x' axis represents time, while the 'y' axis represents load in watts. The overall load from 00:00 to 06:00 is the same, at 1251 Wh. At these hours, a power one with a 220 Wh capacity, AC split with 746 Wh, 40 Wh XL light, 100 Wh tower light, and an 8.5 Wh radio minilink are the current operating tools. There is a decrease in energy at 06:00 to 09:00 due to the absence of the XL and tower lights. The total load during this time period is 991.5 Wh, and the operating tools at this period are a power one, AC split, and radio minilink. There is a peak load from 09:00 to 10:00, where all operating tools are turned on, and the peak total load of this tower is 3811.5 W. Facility operation authorities also conduct maintenance on Tower R.67 of Mount Gending at 09:00 to 10:00, the authorities would turn on all the equipments when carrying this maintenance activity to indicate the functionality of each tools. It is 4400VA for membership purchased directly from PLN. Tools operating at 10:00 to 12:00 are the same as at 06:00 to 09:00, with the total load of 991.5 Wh.

The Fig. 2 presents further information from the previous figure. This graph shows the load at 12:00 to 24:00. Between 12:00 to 18:00 the amount of load is 991.5 Wh, whereas there is an increase of energy from 18:00 to 24:00 the amount of load is 1251.5 Wh since more electricity is used at night when the lights are on. The peak load in the previous graph is 3811.5 Wh. Two hour are the maximum power outage at Mount Gending, therefore, to determine the demand for *PLTS* equipments, multiply the peak load by two hours (Fig. 3).

$$3811.5\ \text{Wh}\ \times\ 2\ \text{h}\ = 7623\ \text{Wh}$$

Description:

1. Peak Load = 3811.5 Wh
2. Maximum of PLN power outage = 2 h

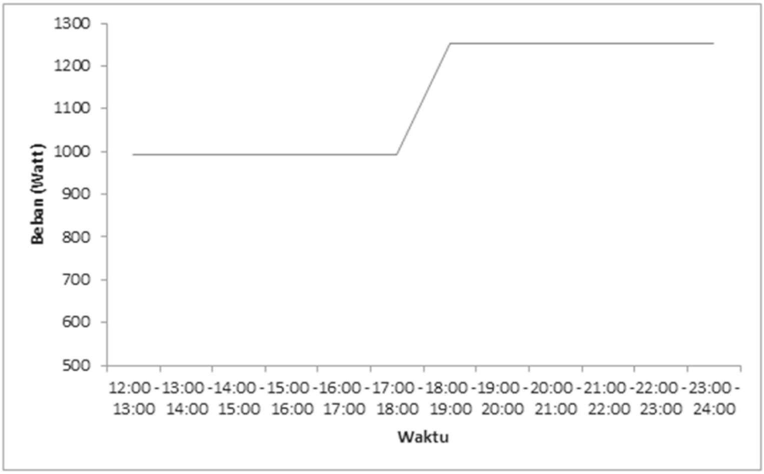

Fig. 3. Graph of energy at the hours 12:00–24:00

4.3 Battery Calculation

At daylight, the battery charges with electricity from the solar panel while being directly used by the load. It is intended that the battery can be utilized at night time without requiring the access to the PLN energy network. Assuming a VRLA battery with a capacity of 12 V 100 Ah, therefore the calculation of total capacity is as follow:

$$Cb = \frac{7623\ \text{Wh}}{12v \times 100\ \text{Ah}} = 6,3525\,\text{Ah}$$

Description:
Cb = the required battery capacity (Ampere Hour)
7623 Wh = energy within 2 h
12 V 100 Ah = consumed battery capacity
Following the identification of total battery capacity, the amount of battery that will be used is the next calculation, as follows:

$$6,3525 \approx 7 batteries$$

4.4 Solar Panel Calculation

The purpose of solar panel calculation is to determine the value quantity used in solar panel, namely Watt Peak (WP). Watt Peak is the highest possible nominal Watt that can be generated from the solar panels. It is first to calculate the total amount of battery capacity, then determined to requiring a total battery of 7 with a capacity of 12 V 100 Ah. Therefore, the following formula is used to calculate the total battery capacity consumed:

$$\in Cb = 1200\,\text{VAh} \times 7 = 8400\,\text{Wh}$$

Table 2. Inverter calculation

Input Voltage	DC 12 V
Output Voltage	AC 220 V
Peak Energy	8000 W
Wave	Pure Sine
Size	37 × 16.5 × 9 cm

Description:
Cb= Battery Capacity
1200Ah = Capacity in 1 battery
7 Batteries= 7 batteries used
8400 Wh = Battery capacity needed to catered 2 h energy

The process of photovoltaic or the absorption of thermal energy from the solar cell components in Indonesia optimally lasts for 5 h. According to the above calculation, it is determined that total battery capacity is 8400 Ah, and therefore solar panels need to be charged 8400 Ah within 5 h. If this *PLTS* design utilizes solar panels with a 100 WP power arranged in series, then:

$$\in ps = \frac{8400\,\mathrm{Ah}}{5 \times 100\,\mathrm{Wp}} = 16,8 \approx 17 Pieces$$

Description:
$\in$ ps = the amount of required solar panel.
8400 Ah = Battery capacity needed to catered 2 h energy
5 h = assumption of the optimal time for solar panel to operate
100 Wp = consumed battery capacity

4.5 Inverter Calculation

Inverter is a tool functions to convert DC voltage into AC voltage. Moreover, note that in this design of *PLTS* system, inverter must be able to be both connected and disconnected from the solar panel to the load in order to operate with the electrical energy of *PLN* which also connects to the inverter. According to the table on load energy above, it shows Tower R.67 requires 7623 W. The inverter is therefore determined to use an output of more than 7623 W. As a result, it is required to use inverter with 8000 W or around 8 kW (Table 2).

4.6 Estimation of Annual Energy

It is possible to estimate how much energy is produced by the constructed *PLTS* by observing the sunlight data in Cikarang. The formula below is to calculate the amount of generated daily energy (Nugroho, 2016):

Estimated energy= 1700 Wp × 5.5 h

Table 3. Total cost

No	Equipment	Qty	Unit	Price per Piece (Rp)	Total Price (Rp)
1	Solar panel	17	Pcs	1.000.000	17.000.000
2	Inverter	1	Pcs	15.100.000	15.100.000
3	4 mm^2 cable	250	Meter	2.000.000	2.000.000
4	kWh meter	1	Pcs	149.900	149.900
5	Batteries	7	Pcs	1.250.000	8.750.000
6	Installation service	1	Package	15.000.000	15.000.000
7	SCC	1	Pcs	135.000	135.000
8	Light steel	1	Package	587.000	587.000
Total					**58.721.900**

Table 4. Operational and maintenance costs

Components	20 years Escalation
Variable Cost	
Battery (per 5 years)	6.250.000
Inverter (per 15 years)	15.100.000
Total Variable Cost	**21.350.000**
O&M/Year	**1.067.500**

= 9.35 Kw/day
= 9.35 Kw × 365 days
= 3412.72 Kwh (Table 3)

4.7 Total Cost of *PLTS* Demand

Following the calculation of *PLTS* components arrangement, the writer determines the cost of each item of *PLTS* components above. Additionally, the author compiles lists of operational and maintenance costs. Therefore, on Table 4 presents operational and maintenance costs of *PLTS* design at Tower R.67 of Mount Gending:

LCC = II + MPW
= 58.721.900 + 8.529.623
= Rp 67.251.523

Furthermore, the writer calculates the cost of energy of a *PLTS* which determined by the Life Cycle Cost (LCC), capital recovery factors (CRF), and the total amount of generated energy in a year. The following formula is applied in order to determine the capital recovery factors in converting cash flow from Life Cycle Cost into a list of annual costs:

$$\mathrm{CRF} = \frac{i(1+i)^n}{i(1+i)^n - 1} = \frac{0,1095(1+0,1095)^{20}}{(1+0,1095)^{20} - 1} = \frac{0,8748}{6,9899} = 0.1251$$

Based on the findings in the calculations of LCC, CRF, and estimated energy in a year, the cost energy for *PLTS* that will be developed at Tower R.67 Mount Gending for hybrid solar panel is presented as follow:

$$\mathrm{CEO} = \frac{LCC \times CRF}{AkWh} = Rp\frac{67.251.523 \times 0,1251}{3412,72} = \mathrm{Rp}\ 2.465/\mathrm{kWh}$$

5 Conclusion

5.1 A Subsection Sample

According to the results of calculation and evaluation data, the followings are several conclusions that are obtained:

1. Matters such as the peak load of Tower R.67 of Mount Gending, the calculation of solar panel requirements, calculation of battery needs, and the determination of inverters are included in the calculation of PLTS and PLN system equipment requirements at Tower R.67of Mount Gending. In order to generate 7623 Wh of energy, the total amount of electrical energy load, which is 3811.5 Wh, is to be multiplied by 2 h, which is the maximum period of power outage. Therefore, with the acquired energy, calculations are done in order to estimate the suitable tools that can back-up the existing tools. It may be determined through the calculations that 7 batteries are required, because battery capacity of 12 V 100 Ah is divided with 2 h of energy. Additionally, 17 pieces of solar panels are needed based on the calculation of solar panels with a capacity of 100 Wp, which is the calculation of 5 h of optimal sunlight divided by the amount of 2 h of energy. Moreover, to determine the inverter with energy of 7623 Wh, it is necessary to use an inverter with an output greater than 7623 Wh, such as an 8Kw inverter. These calculations are considered to the daily power requirements for the entire tools at the tower.
2. The overall PLTS design at Tower R.67 of Mount Gending has been determined to be practicable based on the results of the Practical Investment Analysis due to the achieved NVP (Net Present Value) value by Rp 47.869.548, PI (Profitable Index) by 1.8151, IRR (Internal Rate of Return) by 12.51%, and (DPP (Discounted Payback Period) by 2.7918 years.

5.2 Suggestions

Based on the aforementioned research, the writer offers some several suggestions for the advancement of more studies.

1. In the future, it would be best to look for calculations in 24 h or in a day as the main power supply requirement as this research applies the total load to calculate the power requirements for 2 h. Additionally, it is possible to incorporate into the tool's design.
2. Only a few components, including solar panels, batteries, and inverters were calculated in this research, therefore it would be better to add more components in the future such as solar charge controller and loads.
3. In order to achieve higher or better investment practicable value, the company can use more cost-effective *PLTS* component tools and recalculate the operational and maintenance cost required to increase efficiency.

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