Analyzing Hybrid Systems for Railway Crossing Energy Generation

Santi Triwijaya[1]Natria Faisal[2]

[1,2] Politeknik Perkeretaapian Indonesia, 63129 Madiun, Indonesia

santi@ppi.co.id

Abstract. This research proposes an analysis of power requirements for the development of an optimal hybrid power generation system, especially for level crossings. Level crossings are critical points in transportation infrastructure that require a reliable power supply for train operations and traffic management. In overcoming this challenge, a hybrid approach that combines renewable energy sources. Technical and environmental analysis methods are used to produce the most efficient and environmentally friendly energy combinations. A detailed review of solar panel, wind turbine and energy storage technologies was conducted to determine the ideal combination according to the specific needs of the level crossing. This research contributes to a better understanding of the application of hybrid power generation systems using HOMER for level crossings which can be the basis for developing more reliable and environmentally friendly transportation infrastructure in the future. The average total energy produced by the Hybrid Power System in the research period was 9.38 kWh. Based on the average electrical energy production, the energy produced by solar panels is 92.25% and the energy produced by wind turbines is 7.74%. These results show that the production of electrical energy from solar panels is higher than from wind turbines

Keywords: Hybrid Power Plant, Level Crossings, Electrical Power.

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1 Introduction

Of all industrial systems, electrical systems are the most complex. The complexity is not only caused by the physical structure but also by social security because the electricity system has a direct impact on all daily socio-economic life, starting from industry, media, information, agriculture, daily life, transportation, entertainment, and trade [1] [2] [3] [4]. The good development of the electrical industry has made it possible to build large, reliable, and economical systems. The electricity industry does not stop designing systems, including conventional power plants such as hydroelectric power plants, steam power plants, and nuclear power plants, but is also aggressively developing renewable power systems such as wind power plants, solar power plants, and hybrids on a large scale globally. An increase in the number of loads, both industrial and residential, causes energy demand to increase. Meanwhile, most of the current power plants use fossil or non-renewable fuels. The increased operation of non-renewable power plants has resulted in negative impacts on the environment, such as increased pollution, CO2 emissions, and the greenhouse effect. To reduce the negative effects of energy generation on the environment, other alternatives for generating electrical energy that are environmentally friendly are needed. Apart from water energy, solar energy and wind energy are the most widely used energy alternatives. The advantage of utilizing renewable energy is that it is unlimited [5], [6]. However, this renewable energy has an intermittent nature; that is, its existence is not permanent. For example, the intermittent nature of solar energy means it is not available at night. To maximize the output of renewable energy, it can be done by combining more than one energy source (hybrid) [7]. For example, a combination of solar energy and wind energy can be used to supply residential and industrial loads.

2 System Description

2.1 Hybrid power plants

Hybrid power plants are a combination or integration of two or more power plants that use different energy sources [8] [9] [10]. The use of hybrid electric energy is very suitable for certain regions in Indonesia. This power plant is the most relevant renewable energy source to be developed in Indonesia because the potential for solar energy in Indonesia is very high, with an average radiation intensity of 4-5 kWh/m^2. The advantages of hybrid technology based on solar energy and wind energy are very important, especially during uncertain conditions, for example when it is rainy and windy. Even though the solar cells are not working, the windmill can still produce electrical energy, and vice versa. This system is suitable for use in areas with changing weather. Wind power plants combined with solar power plants or hybrid systems have advantages, because they can utilize sunlight when wind speeds are low and use wind energy when the weather is cloudy. However, the weakness is that hybrid technology based on solar and wind energy is only suitable for use in certain areas that have adequate wind speeds. This concept combines wind energy and solar energy, by placing a wind turbine on top of a solar panel array. These two clean energy sources produce

up to 380 W of power, and the energy is stored in batteries that are used to illuminate the LED lights at night.

2.2 Daily Load at level crossings

Planning the capacity of hybrid power plants as an alternative to providing electricity at level crossings can be done by calculating load requirements [11][15]. The average daily load at a railway level crossing consists of two DC motors, lighting and two sound signals in the form of sirens [4], [6], [16] [17] [18]. Total power requirement per operation of a level crossing showing on table 1.

Table 1 load power requirement of level crossing

No	Load	Power (Watt)	Quantity	Time of use (hours)	Total Power (Watt)
1	DC Motor	75	2	8	1200
2	CFL Lamps	19	1	12	228
3	Level crossing siren	30	2	8	480
Total Usage					1908

2.3 The Duration of Sunlight

When implementing solar panels, it is important to know the duration of solar radiation in order to maximize the use of irradiation during the day. Solar radiation data was collected from June 2022 to December 2022 in Madiun city via the BMKG website. This aims to analyze rainfall and duration of solar radiation to predict planning for the construction of a Hybrid Power Plant. The research results show that the average duration of sunlight is 5.65 hours, while rainfall is classified as moderate with an average of 21.04313 mm.

2.4 Wind Speed

In implementing wind turbines, it is necessary to consider wind speed for planning at a location, with the aim of determining a wind turbine that is efficient in producing power. To get this data, the author took data from the BMKG page regarding average wind speed in Madiun. Wind speed data was collected over a period of 6 months, namely from July to December 2022. From the data that was collected over a period of 6 months, in July the maximum wind speed was reached, namely 3.4m/s. This speed is included in the Class 3 wind category, which is the minimum wind speed limit that can be used to produce electrical energy.

3 Homer Simulation Model

In this research, HOMER software is used in the design of a hybrid generating system. The selection and size of components has been carried out using previous calculations taking into account the load requirements. The input data required for running the HOMER software includes electricity loads (one year's load data), renewable resources, technical details and component costs [19], [20]. With HOMER the power system can be designed optimally according to the needs of the load.

In this developed model, the design of a hybrid energy system connected to the grid using HOMER, which includes solar panels, wind turbines, inverters, loads at level crossings, and batteries. The schematic of this hybrid power system is shown in Figure 1. Verification of the performance of the planned system is carried out by providing input (sunlight radiance and wind speed) with different variation values from July to December 2022 according to real conditions. The variables are controlled by the system designer and HOMER can consider several values that can influence the output results. Variables considered in this planning include solar panel specifications, wind generator sizing, battery capacity requirements and inverter requirements

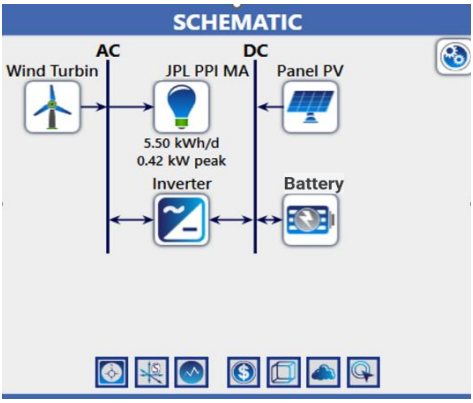

Fig. 1 schematic system hybrid

Table 2. Solar Panel Specifications

Cells Type	Mono 166 x 166 mm
Max Power	340 Wp
Maximum System Voltage	800 VDC
Operating Temperature	-40°C ~ +85°C
Nominal Operating Cell Temperature	45°C ± 2°C
VOC (Voltage Open Circuit)	50 V
ISC (Short Circuit Current	10 A

Table 3. Wind generator specifications

Generator type	3-phase AC PM
Generator Efficiency	0.96
Rated voltage	DC 48-220V
Suggested battery capacity	4pcs 200AH/12VDC
Tower type	6-12m guyed cable / 7-15m free standing
Working temperature	-20-50°C

Table 4. battery specifications

Type	Deep-cyle floaded/advanced lead acid battery
Capacity	708Ah
Rating voltage	6V
Live time	17 years

Table 5. Inverter specifications

Continuous Power	2000W
Peak Power	6000W
Battery Type	Lead Acid Battery
Input Voltage	DC 24V
Charging Current	3-60A Adjustable
Output Voltage	AC 220V
Output Frequency	50Hz ± 2.5Hz
Waveform	Pure Sine Wave (Low Frequency)
Transfer Time	4ms
USB Output	N/A
Efficiency	83% (Battery), 93% (AC Grid)

4 Simulation Results and Discussion

The combination of components specified in the input will influence the system configuration that will be produced by HOMER. The input specifications are known by carrying out calculations first, so that the data in table 2 to table 5 are obtained. The amount of electrical energy produced by solar panels is very dependent on the radiation at the research location. In this research, the Solar Power Plant will fulfill 95% of the total daily electrical energy load requirements.

4.1. Electrical energy is produced by solar panels

Solar panels are devices that can convert sunlight energy into electrical energy. Photovoltaic technology is a technology used to convert solar irradiation into electrical energy. The peak watt value of a solar panel is influenced by several important factors, including weather conditions, panel orientation, and surface cleanliness. Data collection was carried out from July to December 2022. These months represent the results of solar panel generation from the rainy and dry seasons.

From the results of research conducted from July 2022 to December 2022, it can be seen that the production of electrical energy from solar panels is best in July. Where the peak value of electricity production reaches 8.34 kW with daily production reaching 7.66 kW. Meanwhile, in December 2022, production generated from solar panel plants was at its lowest point with the lowest production of 0.85 kW, maximum generation of 6.9 kW and average production of 4.36 kW. This is in line with the change in season from dry to rainy, so the process of converting solar energy into electrical energy cannot be maximized. The results of the solar panel power production simulation using the HOMER application in July and December are in figure 2 and 3.

Table 6. Electrical production by solar panel from July to December 2022

Electrical Energy Production	Month Of Observation					
	July	August	September	October	November	December
Lowest	6,84 kW	6,41kW	5,28 kW	1,08 kW	1,23 kW	0,85 kW
Maximum	8,34 kW	8,31 kW	8,31 kW	7,43 kW	8,1 kW	6,9 kW
Average	7,66 kW	7,53 kW	7,53 kW	5,08 kW	5,008 kW	4,36 kW

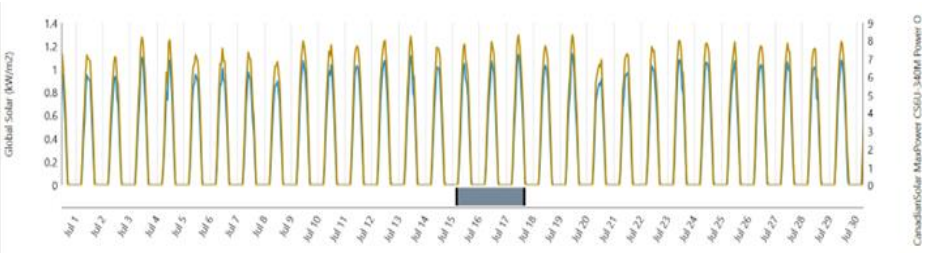

Fig. 2. Solar Panel Output Power Results for July 2022

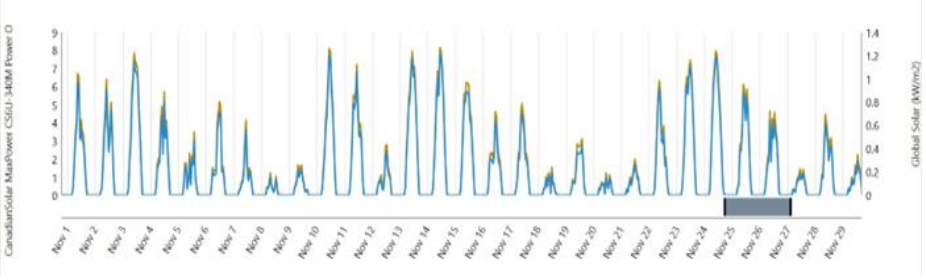

Fig. 3. Solar Panel Output Power Results for December 2022

4.2. Electrical Energy from Wind Turbines

Wind Power Plants use wind gusts as a source of electricity. The main tool is a generator. The rotating wind turbine will drive the generator. The generator is tasked with converting kinetic energy from turbine rotation into electrical energy. The energy produced by wind turbines in the rainy season is generally greater than in the dry season. The electrical energy produced by wind turbines varies every day depending on the wind speed at that time. From July to December 2022, it is known that the lowest energy production was on October 8 2022, namely 0.04 kW. Meanwhile, the highest energy production was on November 13 2022, namely 2.21 kW. Meanwhile, the highest average production will be in December 2022 with an average generated energy value of 0.78 kW. Data on energy results generated by the wind power plant are in table 7.

Tabel 7. Power generated by Wind Power Plants

Electrical Energy roduction	Month Of Observation					
	July	August	September	October	November	December
Lowest	0,11 kW	0,05 kW	0,07 kW	0,04 kW	0,07 kW	0,06 kW
Maximum	1,52 kW	1,03 kW	2,22 kW	0,91 kW	2,21 kW	1,04 kW
Average	0,448 kW	0,31 kW	0,5573 kW	0,26 kW	0,559 kW	0,78kW

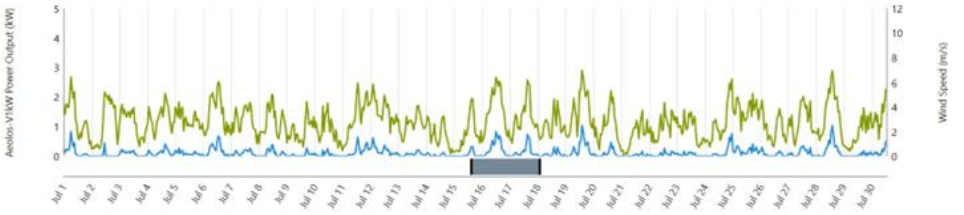

Fig 4. Wind Turbine Power Output Results for July 2022

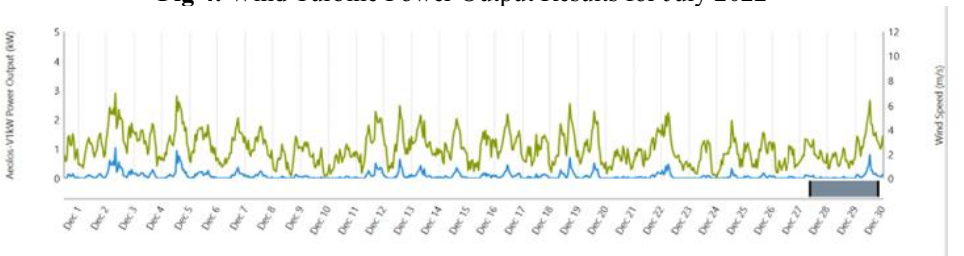

Fig 5. Wind Turbine Power Output Results for December 2022

4.3. Electrical Energy Produced by Hybrid Electrical Power

Wind energy and solar energy are renewable energies that are now being developed to meet energy needs. The total amount of electrical energy produced by the hybrid power generation system from July to December 2022 can be seen in Figure XXX below

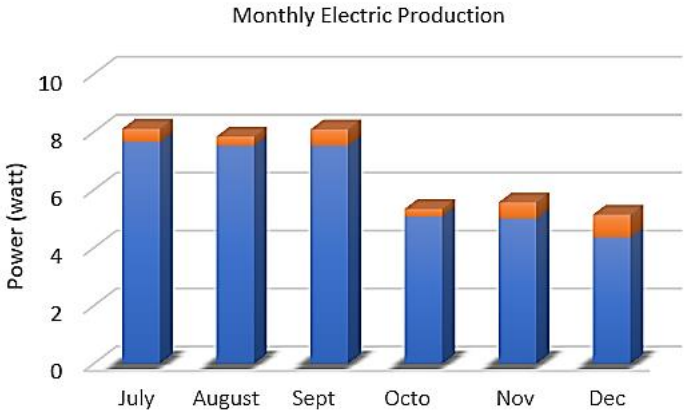

Fig 6. Power Production of Hybrid Power System

Electrical energy production from solar panels reached its maximum in July with a total of 9.86 kWh and the average production produced by the Hybrid Power System in this period was 7.27 kWh. Based on the total electrical energy production, the energy produced by solar panels is 92.25% and that produced by wind turbines is 7.74%. These results show that the production of electrical energy from solar panels is higher than from wind turbines.

5 Conclusion

Research on analyzing power requirements and designing a Hybrid Power System has been successfully carried out. The average total energy produced by the Hybrid Power System in the period July to December 2022 was 9.38 kWh. With a load requirement of 1.908 kWh, it is known that the Hybrid Power System design that has been created can meet the load requirements at level crossings. Further research that can be carried out to develop this research is to consider the initial investment costs for building a Hybrid Power System and the possible payback period. So, we know the benefits of investing in a Hybrid Power System that will be carried out at level crossings. So, it can be consideration by technicians for construction.

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