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Analysis of 1.2 kW Wind Power Generation using 24 V DC Bus with Energy Storage System for Hybrid Solar Thermal-Wind Power Generation

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Abstract: This study presents design of 1.2 kW wind power generation using 24 V DC bus system equipped with batteries as energy storage system to be installed in Purbalingga City, Jawa Tengah, Indonesia. Two 300 W wind Turbines and a 600 W wind Turbine are used to capture the wind energy to be converted into electricity. The wind power is designed to be integrated with thermal solar power generation as a hybrid power generation system. Battery charge controllers are applied to control the energy stored into the batteries. The 24 DC voltage of the batteries system are convert into Alternating Current (AC) to supply the AC power load by using power inverters. Some measurement and experimental test results of the wind power system installed in Purbalingga City, Jawa Tengah are presented in the study to explore the performance of the wind power system. The annual energy production analysis shown that the highest energy production was achieved on August with the total energy production 822 kWh/year.

Key words: Wind power, electricity, power converter, energy production, Indonesia, Purbalingga

INTRODUCTION

The energy demand in Indonesia increases because of the economics and populations increase. In Indonesia, the steam power plant and the gas power plant are still the most dominant of electric power generation supplying electricity in this country. These types of power plants uses fossil fuel which its availability is limitted. Furthermore, these power plants contribute negative impact such as pollutants to the environment (Herbert *et al*., 2007; Liu *et al*., 2010).

Indonesia is a country having a plenty renewable energy sources such as geothermal, solar and wind energy sources. As a tropical country, Indonesia has average daily irradiance 4.8-5.2 kWh/m^2. The solar irradiation are large and almost equally spread across Indonesia especially in coastal areas. As an archipelago, Indonesia has the world's longest coastal areas. In addition, the coastal area of Indonesia has a huge potential of wind energy which are available throughout the year amounted to 73 GW. Thus, the potential of solar and wind energy in coastal areas are very large and strategic to be developed as electric power plants.

Even so, the availability of renewable energy sources such as solar energy and wind energy is highly dependent on the environment, especially the weather. To improve the reliability of the power plants using renewable energy sources, hybridization is one way that can be applied (Lal *et al*., 2011; Madhav *et al*., 2012; Nehrir *et al*., 2011).

This study presents design of 1.2 kW wind power generation, incorporating batteries system as energy storage elements. The generated output power of wind power plant is connected to the DC bus 24 V throught battery charge controller. The power inverter is used to convert the DC power into AC power (Ng *et al*., 2008; Baroudi *et al*., 2007). In the future, the wind power plant is designed to be connected with the solar thermal power plants.

MATERIALS AND METHODS

System design and analysis: Wind speed data (Table 1) show the monthly wind speed data in Purbalingga area. In this research, the wind data in Purbalingga were obtained from BMKG station in Banjarnegara. Based on the this data, the average wind speed in the period of January to December varied from 2.994-3.08333 m/sec. The lowest average speed occured in June which is 2.4444 m/sec and the highest average speed was in March, namely 3.08333 m/sec. Figure 1 shows the profile of the wind speed data in Purbalinga.

To know the characteristics of wind energy in Purbalingga then it is needed to look the wind speed data, i.e., hourly, daily or monthly. However, due to the limitations of the obtained data the author assumes the characteristics of wind power is equated with the charging of the battery system which is observed on October 12,

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Table 1: Annual average wind speed

Months	Wind speed (m/sec)
January	3.006700
February	3.057000
March	3.083330
April	2.555600
May	2.833333
June	2.444440
July	2.750000
August	2.472220
September	2.500000
October	2.833333
November	2.805556
December	2.555560

Table 2: The wind power

Wind speed (m/sec)	Wind power (Wh/m^2)	Wind Turbine (W)
3.0067	16.648550	13.232480
3.057	17.498160	13.907760
3.08333	17.954200	14.270220
2.5556	10.223150	8.125487
2.833333	13.931530	11.072960
2.44444	8.946316	7.110644
2.75	12.738090	10.124400
2.47222	9.254809	7.355838
2.5	9.570313	7.606605
2.833333	13.931530	11.072950
2.805556	13.525800	10.750470
2.55556	10.222670	8.125106
Total	154.445100	122.754900

Table 3: Wind Turbine Aeolus 300

Models	Aeolus, 300
Specification of Aelous 300 wind Turbine	
Rated power (W)	300
Rated voltage (V)	24
Rotor diameter (m)	1.5
Start-up wind speed (m/sec)	2.5
Security wind speed (m/sec)	35
Rated wind speed (m/sec)	12
Shell material	Nylon
Blades material	Carbon fiber
Number of blades	3

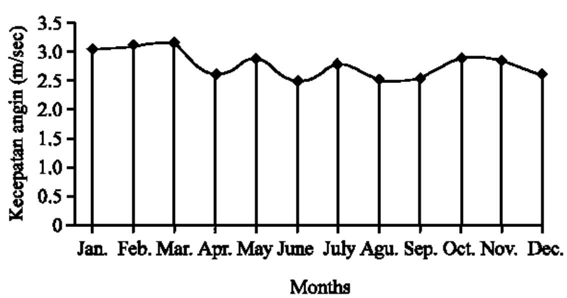

Fig. 1: The average velocity of wind

2015 from 08.00 a.m. to 16.00 p.m. Figure 3 shows the data charging of the battery observed from 08:00 a.m. until 16:00 p.m. By using Eq. 1 the wind power were calculated as shown in Table 2 and 3:

$$P = 0.5\,\rho v^3 \tag{1}$$

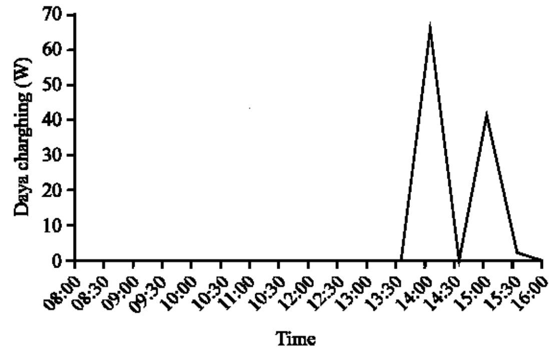

Fig. 2: Daily charging profile

Where:

- P = Wind power (W/m^2)
- ρ = Air density (kg/m^3)
- v = Wind speed (m/sec) (Fig. 2)

Wind power system design: Figure 3 shows the design of the 1.2 kW wind power system. This system uses two 300 W Aeolus models of wind Turbines and a single 600 W wind Turbine, FD2.6-600 Model. These wind Turbines are horizontal axis wind Turbines (Tash) with 3 blades and has a capacity of 300 and 600 W.

The batteries used in this system is Rocket battery SMF N150 type with a capacity of 12 V, 150 Ah. The total batteries are 12 units. Two batteries are conected in series to generate a 24 V output voltage. There are six parallel batteries connetions to store the energy generated by the wind power.

RESULTS AND DISCUSSION

In this system, the inverter is used to convert the DC power generated by the wind power into 220 V 50 Hz AC power supplying the AC power load. The specificatiion of the wind Turbines and the battery controller are listed in Table 3-5 and Fig. 4-8.

The wind power system is simulated by using HOMER Software to analysis the system performance, instead of the measurement test. Figure 9 shows the energy production of the wind power system per year. The maximum energy production will be obtained around in August. Figure 10 presents state of charge of the battery system. The highest frequency of the charging state are occurred in July and August. Figure 11 and 12 show the profile of the wind Turbines output power both the 300 and 600 W wind Turbines.

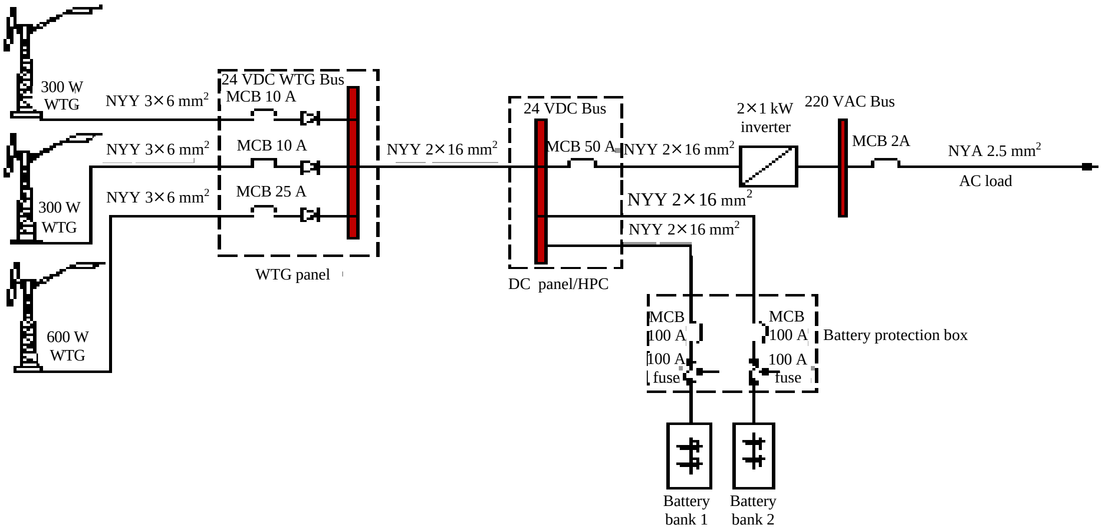

Fig. 3: Design of wind power power system

Fig. 4: Wind Turbine Aeolus 300

Fig. 5: Baterai rocket SMF N150

Fig. 6: Battery controller unit solar thermal power plant

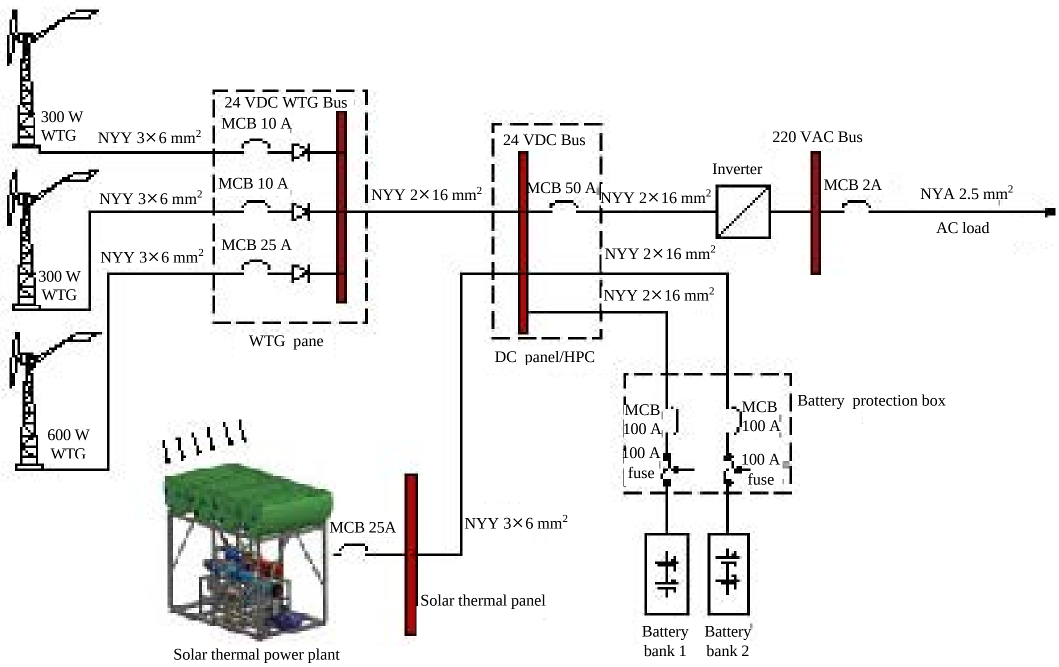

Fig. 7: Design of hybrid solar thermal-wind power power system

Fig. 8: The installed 1.2 kW wind power system

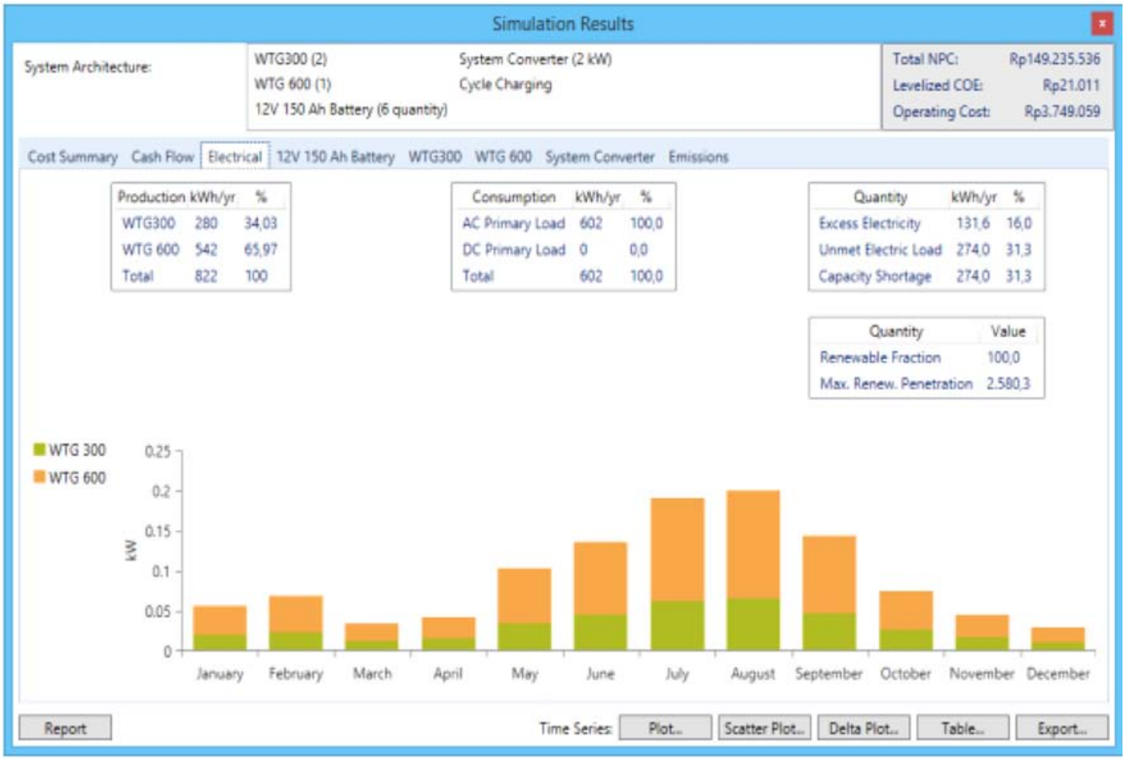

Fig. 9: Wind energy production per year

Fig. 10: State of charge of the battery system

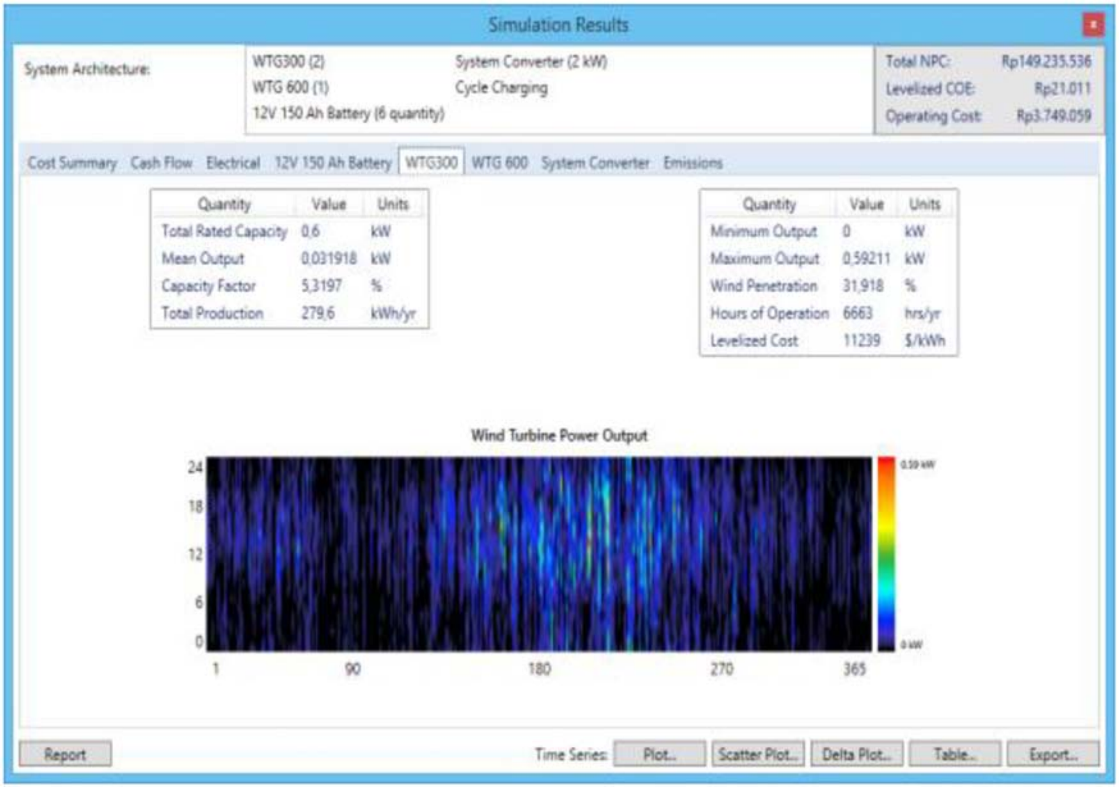

Fig. 11: Power output of the 300 W wind Turbine

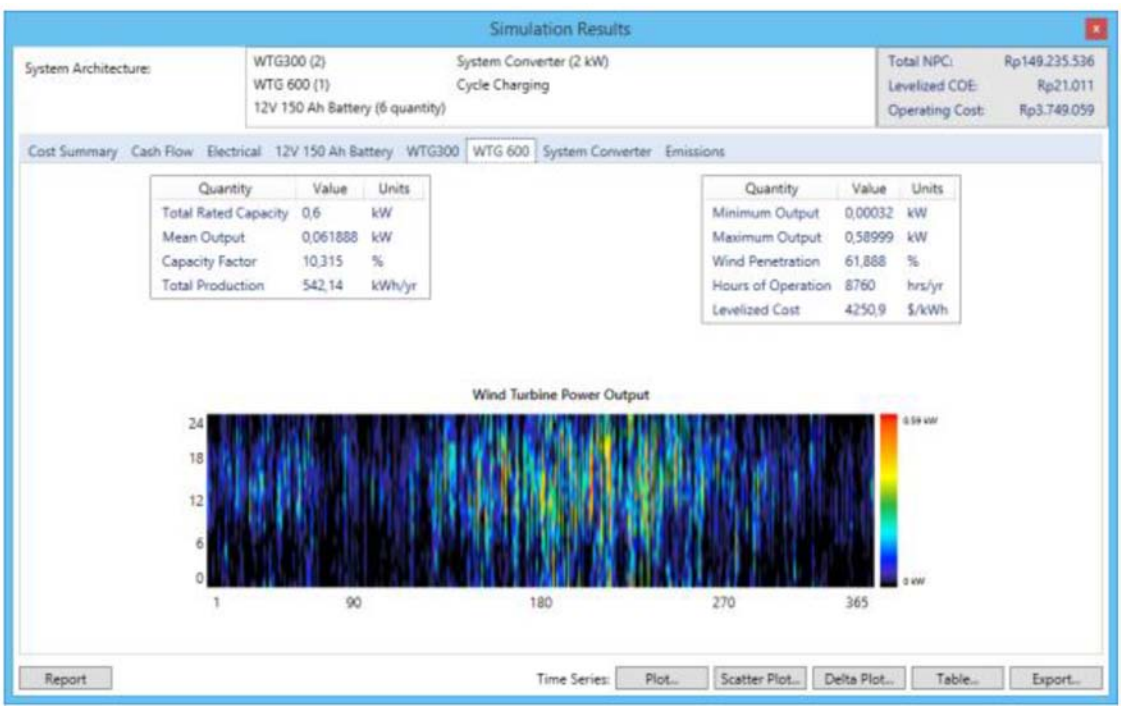

Fig. 12: Power output of the 600 W wind Turbine

Table 4: Wind Turbine FD2.6-600

Models	FD2.6-600
Rated power (W)	600
Rated voltage (V)	24
Rotor diameter (m)	2.6
Start-up wind speed (m/sec)	2
Cut-in wind speed (m/sec)	3
Safety wind speed (m/sec)	35
Rated wind speed (m/sec)	8
Yawing type	Mechanism
Rated rotating rate (r/m)	380
Generator material	Aluminium alloy
Blade material	Fiber glass
Blade quantity	3

Table 5: Battery controller specification

Models	WSH30-12/24	WSH60-24
Rated battery Voltage (V)	24 V	24 V
Rated wind Turbine power (W)	300 W	600 W
Max. wind Turbine input current	13	25
Unload start voltage (default) (V)	28	28
Max. unload current (default) (A)	15	25
Battery over-discharge voltage shutoff (V)	21.6	21.6
Battery over-discharge voltage recovery (V)	24	23
Output protection Voltage (V)	32	32
Rated output current (A)	25	25
Quiescent current	≤20 Ma	-
Working temperature and humidity	Ordinary: -20 to +55°C/35-85% RH (with condensation)	
Temperature compensation function (optional)	-4 mV/°C/2V, -35°C to +80°C, precision	
Communication function (optional)	RS232, RS485, RJ45, GPRS	

CONCLUSION

In this study, the design of a 1.2 kW wind power system in Purbalingga area was presented. Two 300 W wind Turbines and a 600 W wind Turbine are used to generate the electric power. From the simulation results, it can be obtained that the highest energy production will be obtained in around August and July.

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