Testing of Solar –Wind Energy Hybrid System Small Scale

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Abstract. Electrical energy sources are currently declining so that renewable energy is environmentally friendly as an alternative energy source. This paper aims to test the charging of a hybrid system based on the prototype of a hybrid solar power plant and wind/wind energy as an alternative energy source. The method of carrying out the activity is carried out by charging the system to the accumulator when the wind speed is capable of turning the turbine and filling the accumulator and at the wind speed that is not able to fill the accumulator with a hybrid system. This research was conducted at Akarena Beach Makassar in the dry season. The results showed that testing of hybrid generators with parallel solar panels totalling 4 pieces @ 50 Watt peak (Wp) to 200 Watt peak (Wp) was able to charge 4 accumulators connected parallel @ 18 Ah or 72 Ah for ± 10 hours in sunny conditions with a charging current of 7.39 Amperes at wind speeds of 1-3 m / s and at wind speeds of 5-7 m / s the magnitude of the charging current reaches 8.02 Amperes at 15:00 to 17:00, thus, the charging time becomes faster after the turbine works with wind speeds above 5 m / sec.

1. Introduction

Indonesia as an archipelago has many islands and is scattered so that electricity energy services from PLN are not yet affordable as a whole. This condition requires alternative energy sources that can serve people who live in rural areas, especially areas that are isolated by electricity but have energy that can be utilized as a source of electrical energy, including wind energy, solar energy, water energy and so forth.

The geographical location of Indonesia which is in the equatorial region is at latitude 600 LU - 1100 LS and 9500 BT - 14100 BT, and by observing the circulation of the sun in a year which is in the region of 23,500 NU and 23,500 LS then the territory of Indonesia will always be illuminated by the sun for 10-12 hours a day. This, of course, is a gift because this sunlight can be used as an alternative energy source. In addition to sunlight, wind can also be used as an alternative energy source. The use of wind energy in Indonesia has very good prospects, especially for coastal areas, which on average have quite large winds, so they are able to turn wind turbines as an environmentally friendly source of electrical energy. These two sources of energy, when working together, will produce quite large amounts of energy, which can thus be utilized for the needs of electricity in rural areas, especially those isolated by PLN electricity.
Solar Energy

The radiation intensity of the sun is almost constant outside the Earth's atmosphere. The solar constant Gsc is the energy from the sun per unit of time received at one unit of surface area that is perpendicular to the direction of solar radiation at the average distance of the sun-earth outside the atmosphere. World Radiation Centre (WRC) takes the value of the solar constant (Gsc) of 1367 W/m² with an error value of 1%. The effect of solar intensity on the power released by solar cells shows that the voltage is not too affected by solar radiation. Only the radiation intensity that is too low will affect the voltage.

Photovoltaic Solar Power System

Photovoltaic solar systems commonly used for lighting are individual systems or more commonly known as solar home systems (SHS).

![Simple PLTS system block diagram](image)

From Figure 1 it is explained that the energy from sunlight that is converted into electrical energy by the module will be distributed to the controller to regulate the charging of electrical energy in the battery. This charger controller can also be directly used for the direct current load (DC Load) or directly into the inverter to be converted into AC current voltage. Furthermore, the electrical energy produced by the battery will be converted by an inverter from the direct current voltage (DC) to alternating current voltage (AC) so that it can be utilized in alternating current loads (AC Load). The most dominant meteorological conditions in designing the SHS system are the amount of daily radiation (Wh/m² days), as well as the ambient temperature, while the humidity and wind speed/wind do not have much effect. [4].

Wind Energy

The wind is the air that moves in the natural world around us, because there is air movement that is not horizontal (vertical or tilted) to the surface of the land, the more precise formulation is due to the movement of air (relative) to the surface of the earth. The main cause of the wind is the temperature difference; this difference causes the pressure difference from high air pressure to lower air pressure. This movement of air is called wind which is leveling air pressure, so the higher the air pressure the stronger the wind flow.

In turn, the difference in air pressure is the result of solar radiation in relation to the nature of the earth's surface between one place and another, for example, the difference in the degree of reflection. Besides the earth's rotation on its axis also plays a role in the process of the occurrence of wind.

On a large scale or general circulation (average wind circulation on earth), air circulation is generated by more warming on the surface of the earth in the equator than the poles, hot air from the tropics
becomes lighter and moves up to the lower layer. The wind speed that can be used as a wind power plant is class 3-8 wind with a speed of 3.4 - 20.7 m / s.

Figure 2: Form of Wind Power Plant

Wind Power Plant or often also referred to as Wind Power Plant is a renewable energy power plant that is environmentally friendly and has good work efficiency if compared to other renewable energy power plants.

The working principle of a Wind Power Plant is to utilize the kinetic energy of the wind that enters the effective area of the turbine to rotate the wind turbine, then this rotary energy is transmitted to the generator to generate electrical energy.

The conversion of electrical energy to this Wind Power Plant requires a continuous wind gust to turn a wind turbine. This rotating wind turbine will be connected with a mechanical transmission (optional) to produce a higher or lower rotation then rotate the generator.

Power in this Wind Power Plant system consists of several types which can be classified as [1]:

1. Wind Power (PW)
2. Wind Turbine Power (Pa)
3. Generator Power (Pgen)

Wind Power

Wind power is the amount of energy that can be produced by the wind at a certain speed that hits a windmill with a certain area. This wind power formula can be written by:

\[ P_w = \frac{1}{2} \times \rho_a \times A \times V^3 \]  
(1)

Where:
\( \rho_a \): wind density at a certain time (1.2 kg / m²)
\( V \): wind speed at a certain time. (m/s)
\( A \): broad wind sweep area (m²)

The area of wind strokes can be searched by the following formula:

\[ A = \pi r^2 \]  
(2)

Where:
\( A \): broad wind sweep area (m²)
\( r \): Turbine circle radius/turbine display (m)
Wind Turbine Power

Wind turbine power (PA) is the amount of mechanical energy that can be generated by wind turbine rotors due to the power obtained from wind gusts. Wind turbine power is not the same as wind power because wind turbine power is affected by the power coefficient. This wind power formula can be written by:

\[ P_A = \frac{1}{2} \times C_p \times \rho_a x A x V^3 \]  
(3)

\[ P_A = C_p \times P_w \]  
(4)

Where: \( C_p \): Power coefficient

The design of wind power plants usually has a power coefficient (CP) which has a value below the Constanta Betz law, due to losses such as copper loss, iron loss, hearing loss, and others. The amount of CP has a value between 0 - 0.6 and also depends on the type of turbine to be used.

Generator Power

Generator power (P_gen) is the amount of electric power that can be generated by a generator due to the spinning of the generator rotor coupled with a turbine shaft. The amount of power this generator depends on the efficiency of the generator and the efficiency that exists in the mechanical transmission so that the power that can be generated by the generator is calculated by:
\[ P_{\text{gen}} = \frac{1}{2} C_p \rho_a A V^3 \eta_{\text{gearbox}} \eta_{\text{gen}} \]  

(5)

Where:  
\( \eta_{\text{gearbox}} \): Gearbox / mechanical transmission efficiency  
\( \eta_{\text{gen}} \): Generator efficiency

From equations 3, 4 and 5 above it is explained that the electric power that can be generated by a generator, then used for electrical equipment is not proportional to the wind power obtained. The difference between the power generated by wind and the power produced by generators is very large. This is due to the power coefficient, gearbox efficiency, and generator efficiency.

**Hybrid Generating System**

The term hybrid is defined as the use of two or more power plants with different energy sources, generally used for captive wind power plants, so as to obtain synergies that provide benefits, economical and technical, which means the reliability of the supply system.

The main purpose of hybrid systems is basically trying to combine two or more energy sources (generating systems) so that they can cover each other's weaknesses and can achieve supply reliability and economic efficiency at certain load types. Type load (load profile) is an important keyword in a hybrid system. For each different load profile, a hybrid system with a certain composition is needed, in order to achieve the optimum system.

Therefore, system design and system sizing play an important role in achieving the target of hybrid systems. For example, a relatively constant load profile for 24 hours can be supplied efficiently and economically by a Wind Power Plant (with appropriate capacity), but a load profile where electricity usage during the day differs greatly compared to the night, making use of the Power Plant Wind power alone is not optimum.

The following is a typical load profile for rural electricity consumers that is during peak load, the use of Wind Power Plants reaches its optimum point, but at the base load, the efficiency of Wind Power Plants is greatly reduced. In load profiles like this, the hybrid system is very useful. Hybrid systems can involve 2 or more power generation systems, such as PLTS-Wind Power Plants, PLTS-Microhydro, Micro-Hydro-Wind Power and so on. This system is generally used in captive wind power plants / isolated grid (stand-alone), ie wind power plants that are not interconnected.

Combination or Hybrid PV-Wind Power Plant will increase the storage of electrical energy to ACCU in order to be able to provide sufficient electrical energy, so it is necessary to design the battery needs that are tailored to the needs of this hybrid system, however a large initial investment is needed when compared to the plant others such as generators, but in the long run, the Hybrid PV-Wind Power Plant system saves more O&M costs and no fuel costs.

**2. Research Methods**

For testing prototypes of wind energy hybrid plants with solar energy, it is carried out as shown in Figure 5 below.
3. Results And Discussion

Figure 6. Block Model of Solar Energy and Wind Energy Hybrid Power Plants

Figure 7. Prototype Panels for Solar Energy and Wind Energy Generation
Test Results accumulator charging current in sunny conditions with wind speeds of 1-3 m/s.

### Table 1.
Current accumulator charging in bright conditions with wind speeds of 1-3 m/sec

| Number | Time (hour) | Voltage (Volt) | Current (Ampere) |
|--------|-------------|----------------|------------------|
| 1      | 8.00        | 13.2           | 6.3              |
| 2      | 9.00        | 13.4           | 7.1              |
| 3      | 10.00       | 13.6           | 8.5              |
| 4      | 11.00       | 13.9           | 8.2              |
| 5      | 12.00       | 14.1           | 8.8              |
| 6      | 13.00       | 14.0           | 8.4              |
| 7      | 14.00       | 13.8           | 8.2              |
| 8      | 15.00       | 13.2           | 7.8              |
| 9      | 16.00       | 12.2           | 5.6              |
| 10     | 17.00       | 12.05          | 5.0              |

The average is 13.35 and 7.39.

The results of the charging test in sunny conditions with wind speeds between 5-7 m/sec at 1500 - 17.00.

### Table 2.
Current accumulator charging in bright conditions with wind speeds of 5-7 m/sec

| Number | Time (hour) | Voltage (Volt) | Current (Ampere) |
|--------|-------------|----------------|------------------|
| 1      | 8.00        | 13.2           | 6.3              |
| 2      | 9.00        | 13.4           | 7.1              |
| 3      | 10.00       | 13.6           | 8.5              |
| 4      | 11.00       | 13.9           | 8.2              |
| 5      | 12.00       | 14.1           | 8.8              |
| 6      | 13.00       | 14.0           | 8.4              |
| 7      | 14.00       | 13.8           | 8.2              |
| 8      | 15.00       | 13.4           | 8.0              |
| 9      | 16.00       | 13.2           | 8.3              |
| 10     | 17.00       | 13.05          | 8.4              |

The average is 13.565 and 8.02.
Discussion

From the results of testing wind and solar energy hybrid systems can be explained that:

1. In sunny conditions around the coast, the wind speed is between 1-3 m/sec from 08.00 - 17.00 (table 1) so that the turbine in the wind power plant spinning but has not been able to fill the accumulator because the voltage generated is still below the nominal voltage accumulator. Thus, the accumulator charging current from the solar panel.

2. In sunny conditions around the coast wind speeds between 5-7 m/sec at 15:00 to 17:00 (according to observations), the turbine in the wind power plant rotates with normal speed so that it fills the accumulator together with solar panels.

Based on this explanation, the charging current to the accumulator at point 1 will be longer than the charging current to the accumulator at point 2.

4. Conclusion

Based on a prototype system for wind energy and solar energy hybrid power plants, it can be concluded that the hybrid power plant test with parallel solar panels totaling 4 pieces @ 50 Wp to 200 Wp is able to fill 4 accumulators connected parallel @ 18 Ah or 72 Ah for ± 9 hours from at 08.00 - 17.00 in sunny conditions with a charging current of 7.39 Amperes at wind speeds of 1-3 m/sec and at wind speeds of 5-7 m/s the magnitude of the charging current reaches 8.02 Amperes at 15.00 - 17.00. Thus, the charging time becomes faster after the turbine works with wind speeds above 5 m/s

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