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System development and performance test of 5 kW wind turbine

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Abstract

The paper presents development and performance of 5 kW wind turbine that already installed as one of renewable hybrid system in Tenjolaya village – sub district Malingping, Lebak – Banten Province. The renewable hybrid system consists of 5 kW wind turbine, 1 kW photovoltaic panels, water electrolizer and 300 W fuel cell. Monitoring and telemetry systems for measuring the performance of renewable energy generating equipment and energy consumption can monitor and record the performance of wind turbine in the field test . Data collection was performed with a range of every two seconds once and has done since June 2009, but data in June 2009 there is still much less than perfect because the data acquisition system has not been calibrated, whilst in July 2009 the data acquisition has gone well. In the case of wind power plants with capacity 5 kW, the observations in July 2009 produce data of wind speed on thre ranges 2-6 m/s, and generally only slightly above that reached more than 7 m/s. Correlation between wind speed turbine with output voltage, for the local wind speed 2-7 m/s, will produce the output voltage between 150-350 V. The above monitoring data will be used as a consideration in formulating the control system that will be designed. A concern in designing the control system because the output voltage of wind turbine fluctuative and has a very high range, i.e. between 0-400 V. From the monitoring result shows that the average wind speeds can reach 6.5 m/sec, and will produce a voltage of 340 V. Electric power generated will be used to charge the batteries by using a voltage of 130 -140 Vac (12 pieces serial batteries installed), so that the output voltage of the WT should be stabilized at a voltage of 130 - 140Vac. By installing the control system on WT output voltage can be obtained stable at 130-140Vac.

Keywords: Blade, energy, engineering, hybrid, Malingping, performance, rotor, solar, turbine, wind.

1. Introduction

The performance characteristics of wind turbine are needed in order to setup an annual performance model. This information is useful in comparing wind turbine performance at rating conditions, is inadequate to predict annual performance under typical operating conditions.

Analysis of wind energy potential is to compute large wind energy potential that can be utilized, to know the characteristics of the wind and to reap the way to convert wind energy into useful energy. The Weibull frequency distribution curves based on statistical data on average wind speed and standard deviation, and this curve can be used to predict the frequency distribution regulations. The theoretical distribution parameters can be used to express the characteristics and categories of wind energy output at a site. Based on aerodynamic theory, the maximum power that can be harvested by wind turbines is only 59%, even for windmill power coefficient ranges between 15%-47% [1]. From various libraries, the Weibull distribution is considered as one that that describes the distribution of wind speed [2]-[4].

Wind resource data is usually recorded from a tool that is installed at a height of 10 m (WMO

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standard), so the data must be extrapolated to the height of wind turbines hub to be installed.

Extrapolation of this data can be done based on data on average wind speed for long-term and short term or momentary.

Design engineering of wind turbine arranges the rotor blade system sizing, manufacturing and height extrapolation, control system and monitoring system. The data performance of wind turbine is acquisitive through web based monitoring system [5].

2. Methodology

Fluctuation of wind speed influences significantly to the output voltage of wind turbines, which at the time of high wind speeds will produce high output voltage, so it can cause damage to the equipment and the electrical energy generated had to be discarded. While at low wind speeds, the electric energy produced is not able to be stored in batteries due to low output voltages that have not been able to drive the battery charging system.

In this research project, a control system that is adapted to the parameters obtained from the data observation and monitoring in the field, so the electrical energy generated can be optimized as well the fluctuation of the existing wind speed no longer causes damage to the system existing equipment.

Assuming the output voltage of wind turbines in a range between 0-400 V. The results of the monitoring shows that the average wind speed may reach 6.5 m/sec, so that it will produce a voltage of 340 V, whereas the maximum allowed voltage enter the maximum system 130-140 V, and by using a step-down the voltage is lowered to half, so the voltage output of the wind turbine is 200 V, as shown in Fig. 1:

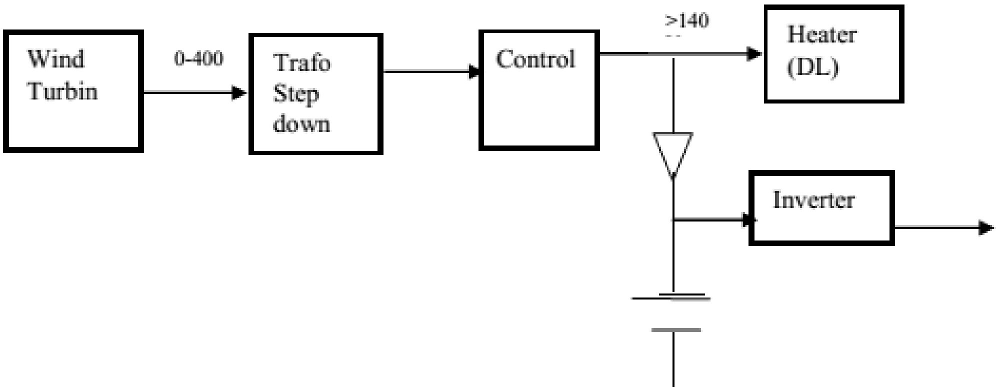

Fig. 1. A block diagram of the wind turbine control system.

As shown in Fig. 1. above, the output voltage of wind turbines derived using a step-down transformer fixed to half of the incoming voltage control system. The control system is used to control the output of the wind turbine so that the output voltage is not more than the desired voltage which is the incoming voltage inverter or battery charging does not exceed 140 V. If the voltage is 140 V, then the power is dumped through a dummy load in the form of heat.

The control system defines wind turbines have output voltage between 0-400 Vac at 0- wind speed of 10 m / sec, and the power supply voltage is expected to range between 130 - 140Vac which would be used to charge the batteries.

2.1. Rotor blade system sizing

Rotor blade size determination is based on the laws of physics in which power as a function of wind speed, rotor size and the efficiency of the system, which consists of a rotor, mechanical and electrical. A thermal power system is given by the equation (1),

$$P = \frac{1}{2}\rho V^3 S\, C_P \eta_e \eta_m \tag{1}$$

where:

P = output power turbine, kW
ρ = air density, 1.225 kg/m3, S.L, ISA.
V = wind speed, m/s.
S = cross section area "rotor disk" = πD2/4, m2
Cp = power coefficient
ηm = mechanical efficiency
ηe = generator efficiency

Power calculation as a function of wind speed and radius are given in Table 1. By assuming aerodynamic efficiencies CP = 0,43, mechanical and electrical ηm = 0.9, ηe = 0.9, it can be obtained by a configuration with each thermal power station rotor diameter is 3,50 m. It appears that the effect of a selection of design speed Vref = 7.1 m / s brings the consequence that the rotor radius will be greater than the design speed if used in other countries, which are generally designed at a speed of 10.5 m / s or achieving its by increased the height. It is intended to gain the ability to better energy extraction.

Table 1. Thermal power system of wind turbine

V [m/sc]	Power [Watt]	V [m/sc]	Power [Watt]
10.00	10578.06000	7.25	4031.06727
9.75	9804.37408	7.10	3786.00403
9.50	9069.36419	7.00	3628.27458
9.25	8372.03864	6.75	3253.24930
9.00	7711.40574	6.50	2904.99973
8.75	7086.47379	6.25	2582.53418
8.50	6496.25110	6.00	2284.86096
8.25	5939.74597	5.75	2010.98838
8.00	5415.96672	5.50	1759.92473
7.75	4923.92165	5.25	1530.67834
7.50	4462.61906	5.00	1322.25750

2.2. Height extrapolation

Wind resource data is usually recorded on the appliance which is installed at a height of 10 m (standard WMO), so the data must be extrapolated to the hub height of the wind turbines to be installed. Extrapolation of these data can be done based on the data the average wind speed long-term and short-term moment [2], [6].

$$\bar{V}_{(Z)} = \bar{V}_a \left(\frac{Z}{Z_Z}\right)^{\alpha} \tag{2}$$

$$\alpha = \frac{\left\{0.37 - 0.088 \ln \bar{V}_a\right\}}{\left\{1 - 0.088 \ln\left(\frac{Z_a}{10}\right)\right\}} \tag{3}$$

where, Za = high anemometer [m].

Projections Weibull parameters for height Z, when the design speed is increased about150% of the average speed, the smaller diameter can be about 2.40 m. This will be the basis of further calculations or object of sensitivity study to COE (cost of energy) and to perform optimization COE prices [8]-[11].

3. Rotor Blade Manufacturing and Installation

The rotor blade is manufactured in vaccuum casting process to increase the density and the strength of the blade as shown in the Fig. 2. The simple vaccuum mold is arranged from the combination of chicken wire mesh and reinforced plastic. The wind turbine installed as one of hybrid renewable energy system in Tenjolaya village-Malingping as shown in the Fig. 3.

Fig. 2. Rotor blade.

Fig. 3. Installation at malingping.

4. Wind Turbine and Monitoring System

4.1. Wind speed & direction

Table 2. Specification anemometer

Sensor	: Davis 7911
Controller	: KTA-250
Module	: Monita 4-20 mA / Monita RS-485
Power	: 12 V DC
Other	: Card holder untuk KTA-250

Anemometer was specified in Table 2 and Sensor Davis 7911 will be installed on the pole which brought near to the house of battery, with a height of approximately 2 m from the end of the house battery, following the installation scheme. Signal can also be taken within 4-20 mA from the KTA-250 which indicates wind speed & direction. It should be noted that the cable from the sensor to the KTA-250, if too long, it needs to be made boxes to install the KTA-250 on the pole. So between the KTA-250 to the main panel will use the RS-485 / 4-20 mA which can use long cables.

4.2. Rotation wind turbine

Table 3. Specifications of Sensor and controller

Sensor	: Autonics proximity probe
Controller	: Monita proximity receiver
Power	: 12 – 24 VDC

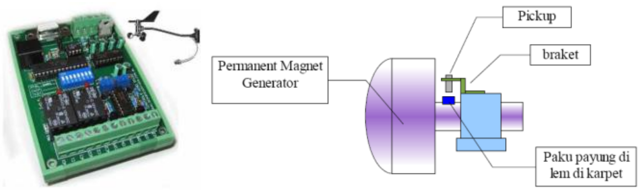

Fig. 4. Wind direction and speed controller and monitor system wind turbine rotation.

Rotation Meter was equipped with sensor and controller and specified in Table 3. Installing rotation meter should be made bracket for proximity probe as shown in Fig. 4. Bracket will be paired in such a proximity sensor so that the tip distance approximately 5 mm near the marker / tack.

Then installed the cable from the proximity probe to the controller, and supplied the power by limiting the current in proximity. And installed LED probe as a marker activity in the main panel.

5. Concept Design and Reconfiguration of Control System

The modified control system [11]-[14] will maintain the output voltage in the range of 130 -140 V accordance to the input voltage inverter. The voltage of the wind turbine will be used as a reference to drive the relay system / switching system that will enable the transformers produce stable voltage at 140V_{ac} accordance with the voltage output of wind turbines. Subsequently, electricity is inverted to DC power by using rectifier (diode), and filters are installed to attain better power quality for charging the battery. Transformer is basically equipped with a primary coil and a secondary coil produce a fixed voltage output between 130 -140 V, in accordance with the output voltage of wind turbine, Fig. 5.

The system stabilized the voltage between 130 – 140 V through a voltage stabilizer, then the voltage output is used for charging the battery or inverted through an inverter to voltage 220 V_{ac} and transmits to residents / users.

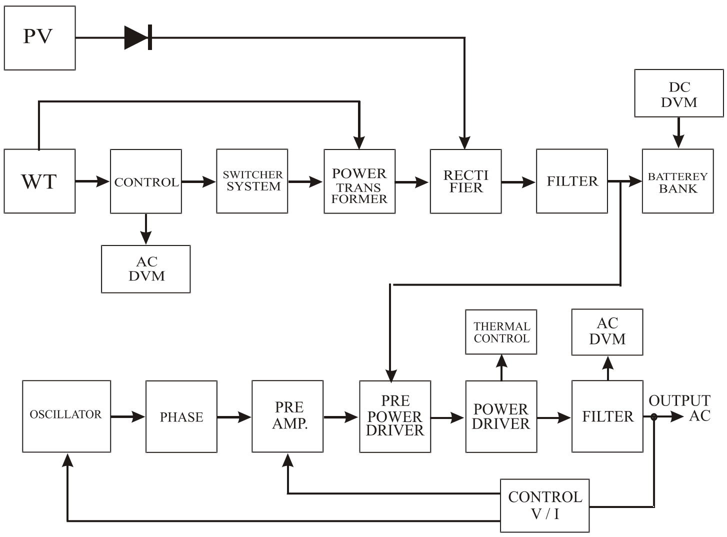

Fig. 5. Hybrid control system block diagram.

6. Assembly and Installation

The design of electronic circuits is implemented and assembled in a PCB (printed circuit board) as shown in Fig. 6 and constructed as shown in Fig. 7

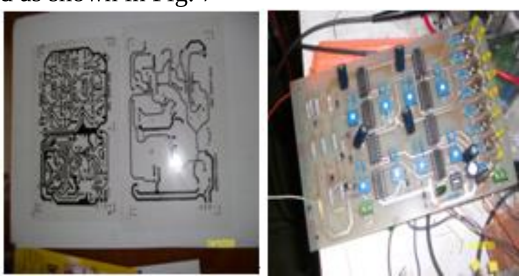

Fig. 6. PCB of hybrid control system.

Fig. 7. Hybrid control system.

The control system was developed is a modification of the standard control that is supplied by the vendor. Usually the vendors supply a control system which is not compatible with the wind speed fluctuation and condition in certain areas. If there is an excessive load, the control system will waste the load by converting it into heat using a dummy load. In this work, the control system is modified as such that it will divert the peak load into the electrolyser to generate hydrogen gas.

The modification is based on wind speed data during July 2009. The objective is to change the voltage from 0-380 VAC at wind speed 0-7 m/s, into a stable voltage at 0-135 VAC, which is then converted into a DC current to charge the accumulator and into the inverter to be used directly by the people in the village at the voltage of 220 AC.

7. Laboratory Test

The control system has been functioning well in laboratory test that is the fluctuation of voltage input can be control on a stable condition, i.e. 139 V, as shown in Table 4.

Table 4. Laboratory test of hybrid control system

Run	Input Voltage (V)	Output Voltage (V)
1.	180	139
2.	200	139
3.	220	139
4.	249	139
5.	260	139
6.	280	139
7.	300	139
8.	320	139
9.	340	139
10.	360	139

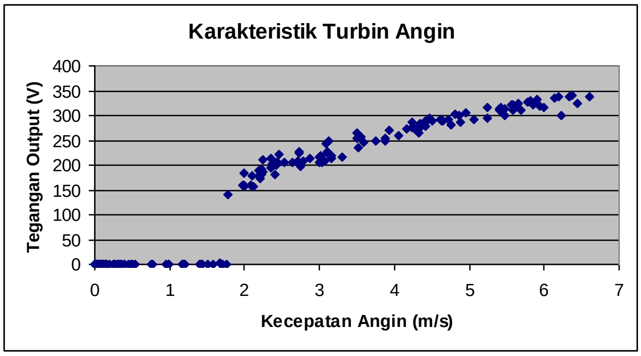

Fig. 8. Effect of velocity on the output voltage.

8. Wind Turbine Performance

Power curves were following the IEC 61400-12-1 standard might lack consistency [15] and should be generated based on measured wind speed and power output data [16]. After improvement, the system been able to work again, so it can be measured several parameters by using monitoring equipment and telemetry systems, data measurement equipment. The existing energy consumption can be monitored either on line or recorded on a hard disk that is in the field. Data were collected once every 2 seconds. Data collection has been conducted since June 2009, but data in June 2009 was still much less than perfect because the data acquisition system is not calibrated, and in July 2009 data is running well.

Fig. 8, shows the relationship between speed wind turbine with the output voltage, where the local wind speed 2-7 m / s, will produce the output voltage between 150-350 V, while the cut-in of the wind turbine is 2 m / s.

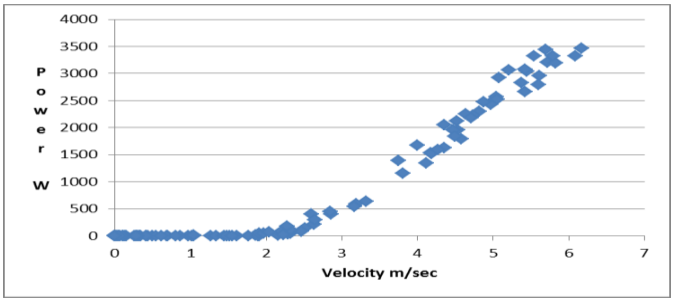

Fig. 9. Power curve of 5 kW wind turbine.

The relationship between wind speed and power generated by wind turbines are shown in Fig. 9. The characteristic of wind turbine in Fig. 7 and Fig. 8 will be used as the basic design of the control system.

9. Conclusion and Suggestions

Data acquisition from the monitoring system will be used as a basic consideration in formulating the control system that will be designed. Relationship between wind speeds with output voltage are the local wind speed 2-7 m/s, wind turbine will produce the output voltage between 150-350 V. It is the concern in designing the control system, because the output voltage of wind turbine has a very high range, i.e. between 0-400 V. From the monitoring result shows that the average wind speeds can reach up to 6.5 m/sec, and will produce voltage of 340 V. The maximum voltage allowed in the maximum system is about 130-140 V, by using step-down caused the voltage reduced to half, so the voltage output from wind turbines is 280 V.

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