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Design and Implementation of Substitution Power Supply at Base Transceiver Station (BTS) Using Hybrid Distributed Generator Wind Turbine and Solar Cell Powers

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Abstract

The availability of electric energy source in nature such as wind and solar power have not been explored and used significantly as electric power sources for human need of energy. Base transceiver station (BTS) sets a condition as uninterrupted power supply (UPS), which is currently supplied by the grid (PLN). However, that supplies is guaranteed inconsistent for consumer. Therefore, due to fulfil the need of BTS, the energy can be supplied by a substitution of distributed generator (DG) such as wind turbine and solar cell. This research conducts by designing a hybrid of wind turbine and solar cell energy modules. These modules are able to generate 50 Ampere-hour of electric energy. The result of this research shows that it needs 10.41 and 8 hours to fully charge 50-Ah battery for wind turbine and solar cell modules, respectively. Apparently, it is indicate that the designing of wind turbine and solar cell modules could result 100-Ah energy for 10 hours.

Keywords: Electric energy, wind power, solar cell, BTS

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1. Introduction

According to Indonesia BPPT Publish [1] the increasing of natural oil significantly impacts Indonesian economics. Moreover, it is also increasing the supply of petroleum and vehicles' fuel, including subsidies for PLN. This is an essential momentum of deploying the renewable energy resources. Indonesian government intends to hitch the enhancement of renewable energy rapidly. Several deploying alternative energies are solar and wind energy. Both energies are massive widely along Indonesia archipelagos. Vereeen et al [2] explain that over 90 % of wireless networks energy consumption is part of the operator's operating expenses. There are approximately four millions installed Base Transmitter Station (BTS) in the world today. Unfortunately, this trend of renewable energy still barely used, unlike government tendency that previously mentioned. The advantages of both energies are free and environment friendly. By combining these two energy sources, the uncertainties needs of electric energy can be overcome. The middle scale use of these tow resources are the possible way to deploy.

Others experts, such as Nema et al [3] stated that renewable energy, such as wind and solar is also used to reduce the operation costs in BTSs. These energy sources are intermittent, naturally available, environmental friendly and can be used to provide virtually free energy. Thousands of BTS all over Indonesia require approximately 3kW electricity (including the air conditioning system and lightings). Recently the electric power for BTS supplied from grid or generator set. The drawback of these kinds of supplies is the operational and maintenance high costs. In addition, the widely open access locations and high towers made BTS optimally receive solar radiation and wind energy.

In the typical BTS, radio equipment and cooling are two major section where the highest energy savings potential resides 4]. As mentioned earlier, there are thousands of BTS around Indonesia, at cities, suburbs; even villages, coastal area, mountains and valleys, with the height of the towers reach 40 meters. The power supply for electronics equipment at BTS is very limited. Thus, wind and solar energy can be used to overcome this problem. However, the issues are: i) How to design and assembly the system of solar cell and wind turbine to be used as power supply for BTS continually. ii). How to design the propeller of wind turbine optimally that can work though it is low speed wind, and how to apply the solar cell as the BTS tower is 80 meters height from the surface. iii). How to design the controllers that can both adjust and regulate wind and solar irradiance, thus the produced energy can be stored and used optimally at night time or when the day with no wind.

The contributions of this research are:

1. The result of this research is a prototype, which is designed to generate electronic equipment at the BTS.

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2. The designed prototype can be used as students' practice module at the laboratory of Electrical Engineering Department.
3. The designed prototype can also be used to support lecturers and students' research.

2. Literature Review

Zhow et al [5] argued that hybrid solar-wind system use two renewable energy sources, improving the system efficiency and reducing the the energy storage requirement. A solar-wind hybrid power generation system for remote BTSs is also proposed in Naikodi [6]. However, in the main problem of the renewable energy installation is that the generation of electricity cannot be fully forecasted and may not follow the trend of the actual energy demand. Solar cell power plant in Indonesia mostly implemented in rural un-electricity area. It is popular known as solar home system (SHS). SHS is commonly using small-scale solar cell module, 50-100Wp (Watt-peak) and produce small amount of daily electric energy, and 150-300Wh. Since it is a small scale, the system is direct current (DC) to avoid losses and self-consumption that caused by inverter.

Research conducted by Hashimoto et al [7] described a stand-alone hybrid power system, wich is consisted of wind generator and photovoltaic module for a BTS, comparing the produced energy during the worst month of the year with the consumed energy. One of the main objectives of Ekren et al [8] is to show the use of the response surface methodology (RSM) in size optimization of an autonomous PV/wind integrated hybrid energy system with battery storage. Furthermore, Ekren et al [9], developed a Simulated Annealing (SA) algorithm to optimize the size of PV/wind integrated hybrid system with battery storage. Hongxing et al [10] proposed an optimal for designing hybrid solar-wind system employing battery bank for calculating the system optimum configuration and ensuring that the system's annualized cost is minimized, while satisfying the custom required loss of power supply probability. Although there is unclear boundary, the power plant that used solar cell module more than 100Wp (output energy > 400Wh), and then the ideal condition is to use alternating current (AC) system, since the used electric power has been subscribed from losses and self-consumption of inverter is sufficient. This scale of solar cell power plant usually no longer used decentralized system, but vice versa (using distribution line), and combined with other distributed generator (DGs).

Grid-tied photovoltaic (PV) is mostly used in urban area, off grid PV and generator set, mostly used as stand-alone PV, PV and micro-hydro, and PV-wind turbine are hybrid system applications. The last sample is the one that mostly used as hybrid system in the rural area. The most advantages of using solar cell power plant are: 1) Inclusion as friendly environment renewable energy technology. 2) Low costs of operations and maintenances. 3) More than 30 years of technical lifetime.

Hybrid system can involve two or more power plants; generally the one that has been developed is generator set, solar cell module, micro-hydro, and wind turbine.

Wind turbine power plant is a power plant that used the strength and speed of wind as electric energy. The main gear is generator, using blade that moves because of the wind. This power plant is more efficient than solar cell. The capacity in Watt –hours are 200, 400, 500, 1000, 2000 and 3000. The electromagnetic field of wind turbine must have high speed and stability of the wind. To swing the blade then produce 2m/second wind speed and stabled electric energy with the average capacity 6-10m/seconds. Coastal and mountain are the proper zones to place the wind turbine and its blade.

For wind energy conversion system, the carbon footprint is taking into account covering the process of turbine installing, generator constructing and the operation of the conversion system. The generation of wind turbine occurred based on the principle of kinetic energy before and after the wind flow into the wind turbine. As the wind circulates into the turbine, the loss of kinetic energy occurred. The loss of kinetic energy is conversed into mechanical energy that rotates the turbine, which is connecting to rotor of the generator. Generator converts mechanical into electrical energy. The actual power of the mechanical from the turbine is defined as (1).

$$P_m = \frac{1}{2} \cdot r \cdot C_p \cdot A \cdot v_1^3 \quad (1)$$

Where ρ is the water mass (kg/m3), Cp is coefficient of wind turbine performance, A is the area of wind turbine (m2), and vl is the velocity of the wind before flowing into the turbine (m/s).

From equation (1), it can be concluded that the power can be convert by the conversion system depends on the wind speed (cubical of the speed). For example, from a certain conversion system, which has nominal power or known as rated power (Prated) 1000W at the 10m/s wind speed (Vrated), when the wind is on the area of conversion system, then the power can be defined as:

$$P_{WT} = \left(\frac{V}{V_{rated}}\right)^3 \times P_{WT(rated)} \quad (2)$$

Thus, for V = 9m/s, then the power that the wind turbine produced is 0.729 times P_{rated}, in this case, the power is 729W. So, it can be concluded that the wind speed affects the conversion system. Basically, the conversion system that common used can be seen in Figure 1. Wind is the energy that can be controlled its existence and has fluctuation that can be approach using probabilistic approach. Due to predict the wind existence in certain area, can be done by using Weibull distribution.

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3. The Hybrid Configuration

3.1 Wind Turbine

The main factor that determines the power output of a wind turbine is the wind speed. Absolutely, choosing a suitable model is very important for wind turbine power.

Figure 1 indicates that the wind speed can be probably massive and/or less, every value has the chance to occur. Commonly in the wind turbine design, several parameters must take into account, such as cut-in velocity (V_{cutin}), rated velocity (V_{rated}), and cut-off velocity (V_{cutoff}). Cut-in velocity is the speed of wind that starts the turbine to rotate; cut-off velocity is the limit speed where the turbine has not yet broken. Practically, to avoid the broken turbine, then it designed to have maximum velocity, which relatively huge to anticipate massive wind though when the Weibull distribution curve has the small chance, but stil has chance to occure. Mechanically, the compensation of the wind turbine design with maximum speed (V_{cutoff}) is V_{cut} and V_{rated} that relatively massive.

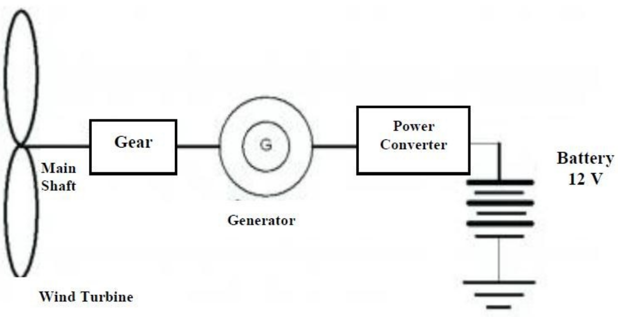

Fig.1. Scheme of the conversion system of wind turbine

The correlation between speed rotation and output voltage of the conversion system can be formulized by theoretically relate it to the conversion of mechanical into electric of the synchronous generator. Whereas at the synchronous generator the inducted voltage by the electromagnetic field at armature, E_A, is:

$$\mathbf{E_A = K.\ \Phi.\ \omega} \qquad (3)$$

3.2. Photo Voltaic Generator

There are three main factors that determines the power output of solar cell generator, it is the cell material, the cell temperature and the solar radiation. Nema et al [11] describe that the solar radiation is usually measured only at horizontal plane. Thus, a technique to transfer the radiation measured at horizontal plane to the desired slope angle of the photo voltaic module is needed. Such a technique is described in detail.

The solar cell module as can be seen in Fig. 3, is a device to convert sun radiation into electricity for the purpose of BTS battery charging. To ensure and verify that the module works properly as it was designed, then the test to recharge the BTS battery needs to be done. Firstly, module is assembled and placed at unshielded area, which the sun directly is able to go through the cell, thus it fulfilled the battery.

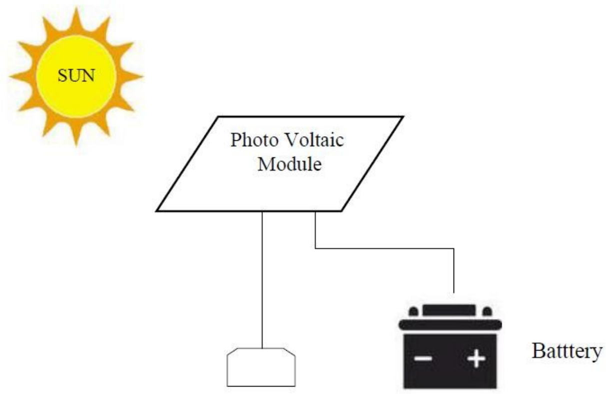

Fig. 3. Diagram Block of solar cell proposed system

3.3. Battery System

According to the previous section, the cooling power (AC load) is not only a function of the power that consumes the radio equipment (DC power), but it also depend on the operation of passive cooling. For this reason, it has to be considered as the different part of consumption during the simulation. Note that during discharging process, the energy that the batteries can offer is around 20% of their normal capacity, and the maximum depth of discharge is around 30-50%, according to the specification of the manufacturer [10].

4. Research Method

The developed method is by building up a prototype of hybrid power plant, combined solar cell and wind turbine. The step is clearly explained by firstly conducting preliminary survey, searching and input data regarding the characteristic of all included components. Secondly, designing the system. In this step, the blade, and turbine type are defined. The turbine must be from light material. This step also included the solar cell determination. The third step done by both designs included in the controller system. In this step, using certain microcontroller made the system more accurate. Then the generated voltage is stored into battery, at BTS this voltage is converted using inverter then finally supplied other supporting components at BTS.

The algorithm in making process of substituted power supply for charging the battery wind turbine-based, can be seen as follow:

1. Determine the wind turbine design
2. Determine the wind turbine size
3. Build up and test the wind turbine
4. Determine the generator specification

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5. Determine the installation and test of generator
6. Determine the voltage regulator
7. Test the voltage regulator
8. Determine charging circuit of battery
9. Assemble and test the charging circuit of battery
10. Run and test all the integrated components

The used generator at wind turbine is charged generator of battery with excitation field 12Vdc, 6 poles, 600rpm, and maximum output current is 35A. This generator is suitable for wind turbine since it is only used for 600rpm speed. The output voltage of generator is not always constants values, since the generated voltage depends on the wind speed. The stronger the wind speeds, then the faster the rotor of generator speeds as well, and vice versa. The rotor functioned as magnetic flux, then by adding or eliminating the input current into rotor coil, it influences the magnetic flux then the stator coil influences as well. Thus, the output voltage of generator depends on the input current into the rotor coil.

Functioned of voltage regulator is to adjust the input current into rotor, then the output current of stator coil is stable. Moreover, the voltage regulator also turns on and off the indicator light of charging circuit. This voltage regulator contains contact coils, magnetic coils and resistor. For the battery charging system, it depends deeply on the voltage regulator. The energy to generate magnetic flux at rotor of generator supplied from F terminal, this current regulates by adding or eliminating it refers to the voltage of B terminal. It then used to supply headlight, wiper, radio, etc., and the remains used to charge the battery. The light indicator is on when generator insufficiently flow the current. This occurred if the N terminal voltage is less than the determined one.

Based on diagram block Fig. 2, we discovered that whenever the wind blade rotates, generator excites the energy into battery. The DC voltage then runs to the regulator and stabilizes the coils. A solar power plant must have a proper design regarding the dimension, the series and parallel cell connections, which has the voltage 1-1.1V, width 50cm, and length 1m. After calculated it total cells of the designed solar cell panel is 40 cells, either connected series or parallel with the output power 100W.

The batteries used for the purpose of store the energy from solar panel at daytime, and use it at night. The battery capacity is 50Ah/12V. It means that the battery can be used for 2 hours with supplies 600W loads. To maintain the battery lifetime, it is necessarily to check the battery regularly.

$$\mathbf{Ta} = \frac{\mathbf{50}}{\mathbf{6.25}} = \mathbf{8\ hours} \qquad (5)$$

5. Results and Discussions

The result of the test can be seen in Table 2, and the load over excited current is illustrated in Fig. 6(a), and load current over excited current is illustrated in Fig. 6(b). The average of solar cell output within six hours is 10.23V, and 8 Amps. The excited current stepped its value within the three minutes period (Fig. 6(c)), then in Fig. 6(d) we can see the voltage and currents though they are within the similar range, but their values are different.

Table 1.
Measured excited current of generator

Excitation Current (IF) (A)	Charging Current (IL) (A)	Charging Voltage (VL) (Volt)
0,2	3,2	6
0,4	3	6,8
0,6	2,8	7,4
0,8	2,6	8,2
1,2	2,4	8,9
1,4	2,2	9,3
1,6	2,1	9,7
1,8	2	10
2	1,8	10,2
2,4	1,5	10,7
2,6	1,3	11,2
3	0,7	12,2

Table 2.
Measured battery charging system using voltage regulator

Time (minute)	Excitation Current (IF) (A)	Charging Voltage (VL) (Volt)	Charging Current (IL) (A)
15	2,8	10	3.6
30	2,8	10,3	3,5
45	3	10,5	3,3
60	3	10,8	3,1
75	2.8	11,2	2,9
90	2,8	11.6	2,5
105	2,8	11.8	2,1
120	2,8	11,8	1,7
135	2,8	11,9	1,2
150	3	12	0,8
165	3	12,2	0,4
180	3	12,6	0,1

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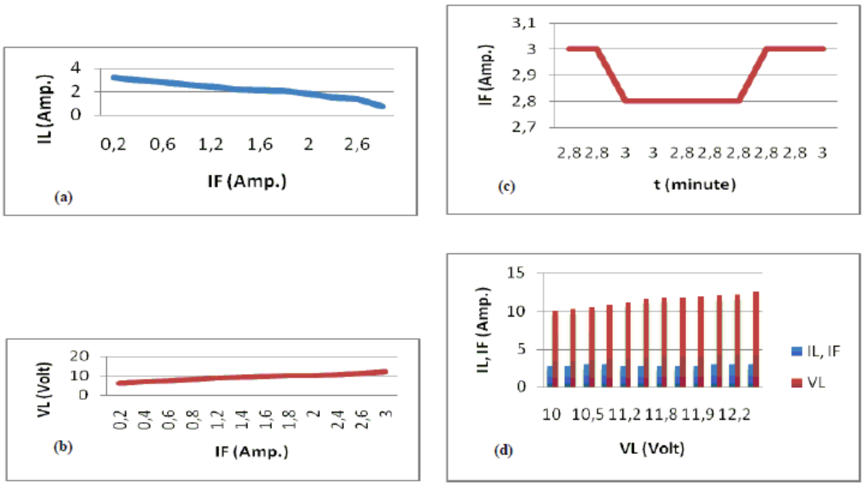

Fig. 6. Current and voltage measured from generator; (a) load current over excited current, (b) load voltage over excited current, (c) excited current over time, and (d) load and excited current over load voltage

Table 3
Test result of battery charging

No	Hours	IL (Amp)	VL (Volt)	Brightness
	10.00	4.7	8.2	Bright
2	10.30	4.2	8.5	Bright
3	11.00	3.8	8.9	Bright
4	11.30	3.3	9.3	Bright
5	12.00	2.9	9.7	Bright
6	12.30	2.6	10	Bright
7	13.00	2.3	10.4	Bright
8	13.30	1.8	10.7	Bright
9	14.00	1.5	11.2	Bright
10	14.30	1.1	11.6	Bright
11	15.00	0.9	11.9	Bright
12	16.00	0.5	12.4	Bright

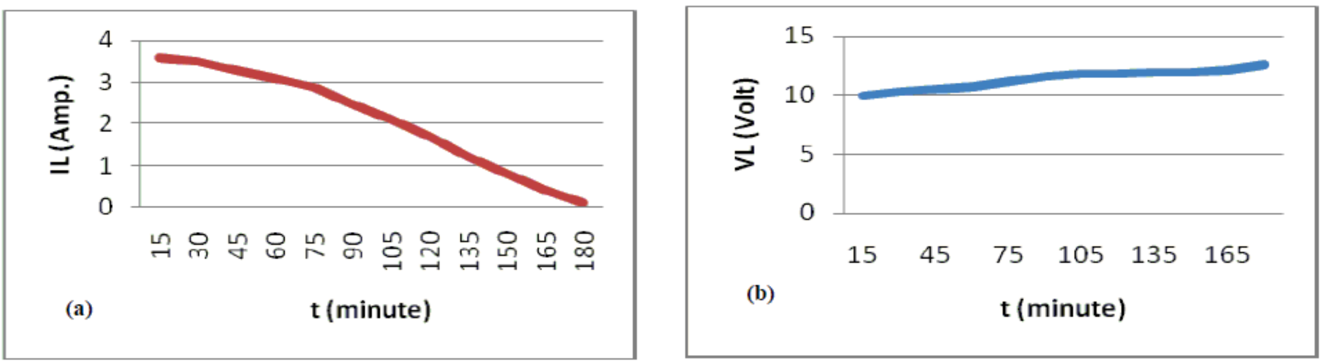

Fig. 8. Battery charging measurement using voltage regulator; (a) load

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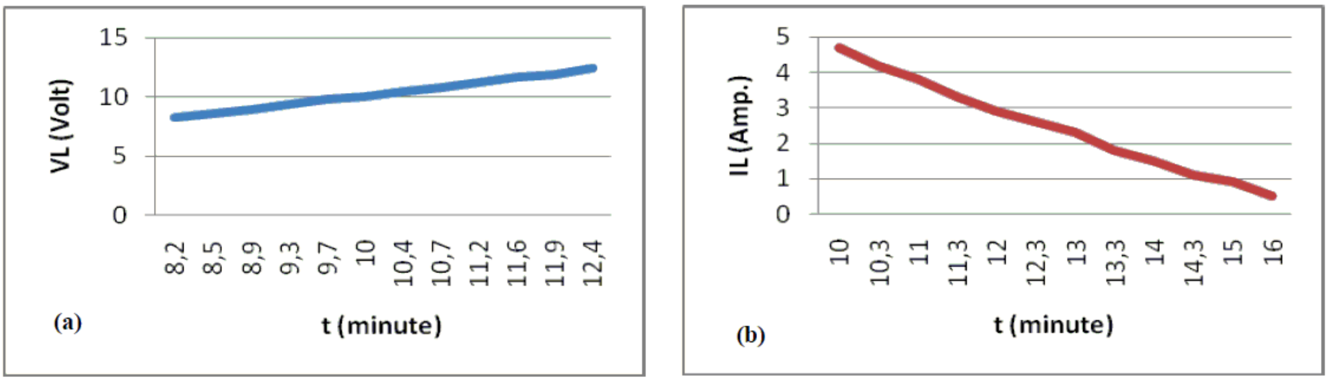

Fig. 9. Battery charging test; (a) load voltage over time, (b) load current over time

6. Conclusion

The wind speed at certain area (the test is conducted at the coast of Lhokseumawe, Aceh), which has wind speed that relatively strong whole day long, can generate electric energy of 50Ah, and charged the battery within 10.41 hours. It is shown that the wind energy can be used as power supply for BTS.

The available of sun radiation for 12 hours at daytime, can be used as energy of 50Ah within 8 hours of battery charged. Both power generation systems if hybrid can produce electric energy, which can supply the transceiver of BTS with the energy of 100Ah within 10 hours whenever grid connection is out.

The result of the design and implementation of the hybrid system of solar cell and wind turbine proved that the energy produced within 10 hours that stored in the battery can be implemented into BTS. Further research can be developed to produce massive energy, which can generate electric power in longer time as in case the grid is blackout for long period. The location of the research development can be enlarged to bigger area of Aceh coastal area.

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