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Low Speed Electric Machine Used for Electric Generating from Savonius Windmill

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Keywords: Savonius windmill, permanent magnet, electric generator

Abstract. Savonius windmill having advantages high starting torque and simple construction is applicable for Indonesia as a developing country with annual average wind speed 4,5 – 5,0 m/s. The purpose of the experiment is to identify characteristics of an electric machine used for low speed electric generator. The electric machine for the experiment is a permanent magnet electric motor usually used for electric bicycle. The electric motor is tested as an electric generator and rotated with variations of speed. Outputs of the generator are torque, voltage and current with 1) variation of lamps-load, 2) constant voltage-load for 12 volt and 24 volt battery charging and 3) combination of 12 volt battery charging and variation of lamps-load. The average efficiency of the generator is 59,8% and 65,4% for 12 volt and 24 volt battery charging. Battery charging starts at 95 rpm and maximum electric generating current is 20 Ampere at generator speed about 175 rpm.

Introduction

Indonesian Ministry of Research and Technology has defined a road map of wind energy development to guarantee supply of energy in the year 2025. Up to the year 2015, one of the main focus in research and development is low speed permanent magnet generator as well as advanced airfoil. As a developing country as well as an archipelago country located in equator which has electrification ratio less then 76% [1], Indonesia needs small scale electric generator to supply house hold needs. On the other side, Indonesia has annual average wind speed 4,5 up to 5,0 m/s., which is potential to be utilized as an enery resource. Eventhough the wind speed can be categorized as low, it is sufficient to be utilized as a small scale wind energy based electric generator unit [2].

Among several kinds of windmills (Fig.1), salt miner society in Madura and Java has utilized four arm Dutch and American multiblades windmills to pump water needed in salt production. Savonius windmill has low Cp (Coefficient of power) and low tsr (tip speed ratio), compared to other type of windmills. However, Savonius windmill is suitable for developing countries due to its three advantages, namely its simple construction, extremely low cost and acceptance of wind flow from any direction without disorientation [4]. Another important advantage is having high starting torque. This advantage is very competitive and almost ideally suited for pumping water [5].

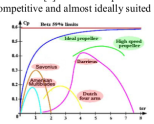

Figure 1: The relation of Cp and tsr of several windmills [3]

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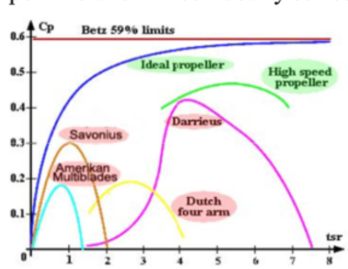


Figure 1: The relation of Cp and tsr of several windmills [3]

The purpose of this research is to find alternative utilization of Savonius windmill as electric generator by identifying the characteristics of electric machine which is able to work on low speed rotation. The electric machine used in the experiment is brushless DC (BLDC) electric motor usually used for electric bicycle. The electric motor can be utilized as electric generator by giving torque. Output expected from the experiment is the characteristics of the electric generator: the relation of efficiency and rotation speed, the relation of battery charging current and rotation speed, as well as the relation of battery charging current with load and rotation speed.

Experimet Equipments and Procedures

The main equipment of this experiment were electric generator and two testing support systems which consist of driving system and load controling system. Electric generator and electric machine on driving system were placed on a rigid frame.

Electric Generator. The tested electric generator was an electric machine which is commonly used in electric bicycle. The specification of electric machine were as follows: permanent magnet, brushless, 36 volt DC, 250 Watt, commonly used in SUN RACE electric bicycles.The wiring system consited of two wires. This type of electric machine might functioned as an electric motor which produces torque. When given torque, this type of electric machine might functioned as an electric generator which produces electric direct current (DC), as well. The chain gear of the electric machine was replaced by single lane about 40.64 cm (16 inch) diameter pully. The position of electric generator's shaft during the experiment was horizontal. Both ends of shaft were placed on bearings such that it can rotated freely. On the one of the end tip of the shaft, a 24 cm arm was placed horisontally to measure torque produced by the generator. A weight scale was placed on the other end tip of the torque arm to measure force of the end tip of the torque arm.

Driving System. The driving system drove the generator by belt and pully transmission. In addition, the driving system also could adjust the rotation speed from 0 up to 450 rpm. Main power supply used 1 phase electric source. The scheme of experiment equipments was described in Fig. 2. The voltage regulator was used to stabilize voltage on 220 volt during the experiment. The specification of voltage regulator used in the experiment was KENIKA, Automatic AC Voltage Regulator AR-1200. A contoller was used to adjust the rotation speed of the driving motor. The specification of controller used in the experiment was TOSHIBA transistor inverter, VFS11-2055PM-WN (R5), 5.5 kW with 1 phase input and 3 phase output. The controller adjusts the speed of electric motor from 0 up to 1600 rpm. The electric motor used in the experiment was MEZ P55, 3 phase, 1.5 kW, 50 Hz, 1420 rpm. The position of electric motor's shaft was horizontal, parallel with electric generator which is driven. The foundation of the electric motor could be adjusted to adjust belt strength. The pully of the electric motor had 4 inch diameter and double lanes. The V-belt used in the experiment was BANDO brand, A-67.

Load Controlling System (LCS). The main load were lamps and a battery (YUASA 55D26R-N50Z, 60AH, 12 volt). The lamp load was divided into two groups. Each of them complemented by an ampere meter an a volt meter. The first group consisted of 21 lamps (STANLEE STAR, 24 volt, 25/10 Watt). Each lamp was 35 watt and possessed an ON-OFF swicth. The second group consisted of 4 lamps 220 volt (2 wolfram Philips lamps 40 watt and 2 wolfram Philips lamps 60 watt), and an inverter (TARGA Power Inverter M-666, 1000 Watt) to convert direct currect (DC) 12 volt into alternating current (AC) 220 volt. A 50 ampere diode was placed on the battery to prevent electric generator changes its function into electric motor during the experiment.

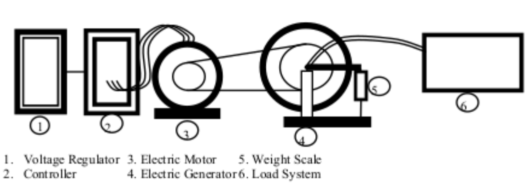


Figure 2: Schematic Diagram of Equipments

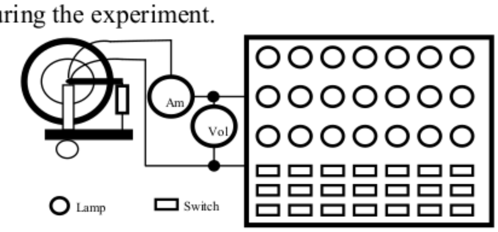


Figure 3: LCS with 21 Lamps

Experiment Procedure. The efficiency of electric generator was power input (Pin) divided by power output (Pout). The power input was shaft power as a function of n (rotation speed, rotation per minute, rpm) and T (torque, Newton meter, N m). The power output was electric power as a function of V (electric voltage, Volt) and I (electric current, ampere). The formula to calculate the efficiency of electric generator was as follows:

$$\eta = \frac{P_{in}}{P_{out}} \tag{1}$$

$$P_{in} = 2\,\pi\,n\,\left(\frac{1}{60}\right)\,T\,\left(\frac{1\,J}{1\,N\,m}\right) \tag{2}$$

$$P_{out} = V\,I \tag{3}$$

To get the relation of electric generator and its rotation speed on 12 volt voltage, the equipment was operated without load until the eletric generator got voltage about 12 volt. When load was given to the equipment, the voltage, the current produced, the rotation speed, as well as the result of the weight scale were recorded. Same experiment was performed using variation of load by adjusting the ON-OFF swtches (Fig. 3). The load was controlled in order to prevent the electric generator produced voltage less than 10 volt. Same experiements were performed for voltage about 13 volt up to about 20 volt.

To get the relation between the efficiency of electric generator versus rotation per minute (rpm) on 24 volt voltage, same experiments were performed without load on voltage about 25 volt up to about 31 volt. The load was controlled in order to prevent the electric generator produced voltage less than 20 volt.

To get the relation between battery charging current and speed, the data needed were battery voltage, electric current, electric generator voltage, as well as electric generator speed and torque. Fig. 4 showed the scheme. The experiment on baterry charging was performed for low, normal, and full condition as well. Initial voltage of low battery condition was 8.1 V, while the initial voltage of normal battery condition and full battery condition were 12,10 V and 13,44 V respectively. The electric generator speed was controlled until produced electric voltage about 10 V and then was connected to the battery. All data were observed and recorded. The battery was then disconnected from the system. Same experiments were done for electric voltage about 11 V up to about 26 volt. Similar procedure was performed for both in normal and full battery conditions as well. For these two conditions, the electric voltage started about 11 V up to about 27 V.

To identify battery life time while being loaded (in this experiment the load was 200 watt consisted of 4 lamps), electric wiring diagram in Fig. 5 was adopted. The power input given to the electric generator was about 330 watt by adjusting electric generator speed without load on about 160 rpm (based on previous experiments). The initial battery voltage was 13,1 V. The data acquisition were performed from the begining until the end of the observation, every 10 minutes.

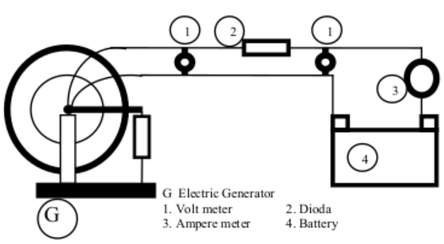


Figure 4: LCS with Battery

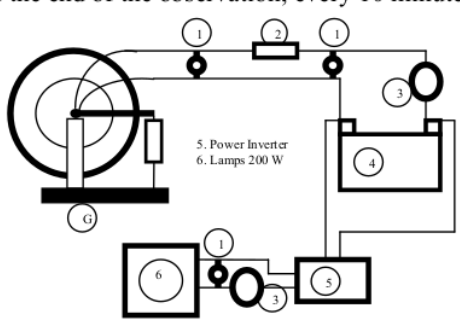
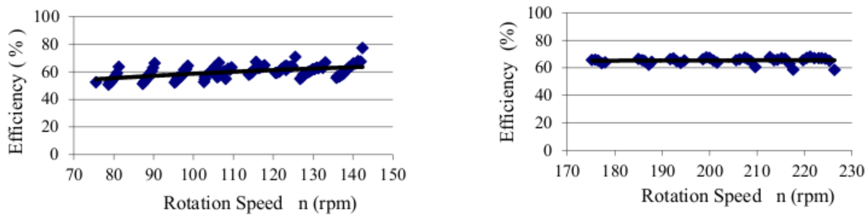


Figure 5: LCS with Battery and Lamps

Experimental Result

The recorded data were processed using Microsoft Office Excell 2007. The results are described in Fig. 6 to Fig. 10.



(a) (b)

Figure 6: Relation fo efficiency and rotation speed for (a) 12 volt and (b) 24 volt

Fig. 6 shows that average efficiency of the electric generator for 24 volt (65.4%) is larger than of the electric generator for 12 volt (59.8%). Rotation speed ranges for 24 volt and 12 volt was 175.2 rpm up to 228.2 rpm and 75.5 rpm up to 143.7 rpm, respectively.

In the following experiment, the voltage was set into 12 volt considering fact that it is easier and cheaper for common people to get 12 volt batteries rather than 24 volt ones.

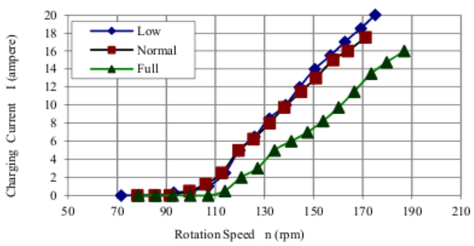


Figure 7: Relation of battery charging current and rotation speed

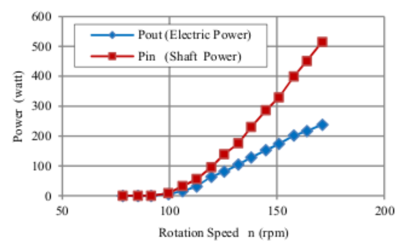


Figure 8: Relation of power normal battery charging and rotation speed

Fig. 7 shows that normal and low battery conditions have no significant effect on the charging current. Both battery conditions have different significant effect compared to full battery condition. Charging current of full battery condition is lower than other battery conditions on any rotation speed. Battery charging starts from the rotation speed of electric generator about 95 rpm. Data collecting was stopped when electrical power output was about 250 watt. On the observation of full battery condition, the temperature of the battery was higher than the others and the battery fluid was boiling and evaporating. Fig. 7 above can be used to predict time which is needed to charge the battery on a certain generator rotation speed.

Fig. 8 shows more detail battery normal charging to identify input and output power of electric generator. The diagram can be used to determine the rotation and power provided as well as the resulted electric power.

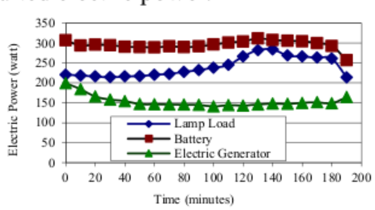


Figure 9: Relation of electric power and time

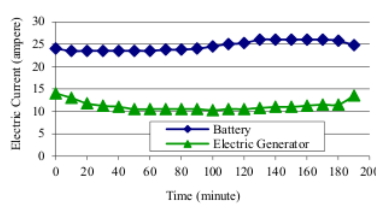


Figure 10: Relation of electric current and time

Fig. 9 shows the description of battery life time with nominal total load 4 lamps 200 watt, electric generator rotation speed 150 rpm and battery normal condition. The power of the battery always higher than the power needed by the lamps due to the energy losses on the inverter. Electric power input on the lamp load is also greater than the nominal power due to the energy losses. This energy losses are physically converted into heat. The battery life time will be longer when the nominal total load are reduced since the power of the battery are reduced. When the power of the battery is smaller than the power of electric power output of electric generator, then the battery is charged. Fig. 10 shows that battery charging will happened when electric current of electric generator is greater than electric current needed by the load.

Discussion

P.N. Shankar [6] found that two bladed Savonius windmill have much higher peak power output (almost 50 %) than three-bladed Savonius windmill. R. Gupta [4] showed that air gap with 20% overlap between blades increased the performance up to 21%. YB. Lukiyanto [7] showed that air gap with 12,5% overlap gave better performance compared to 25%, 37,5% and 50% overlap. Using the best configuration Savonius windmill of [7] (80 cm diameters, 1 m height, 2 stages, 2 blades per stages) and by assumption that the rotor height is 5 meters (80 cm diameters,10 stages, 2 blades per stages), the relation of power and rotation speed can be described as in Fig. 11.

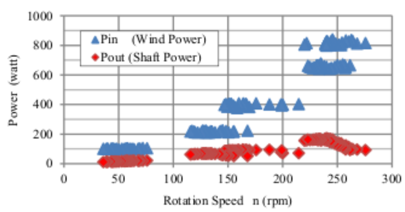


Figure 11 : Relation of power and rotation speed of the Savonius windmill

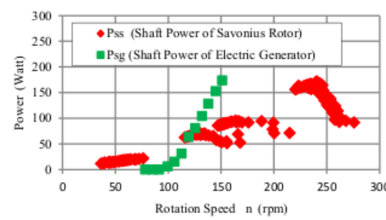


Figure 12: Relation of power and rotation speed of the Savonius and the electric generator

When electric generator input is coupled directly with the shaft and without any losses, while electric generator output is coupled with battery charger at normal condition, the relation of power and rotation speed of the Savonius as well as the electric generator can be described as in Fig. 12.

Fig. 12 shows that on rotation speed up to 125 rpm the windmill is still able to produce electric current about 6 amperes. On the rotation speed more than 125 rpm, the windmill are not able to produce power to drive electric generator proportionally to its shaft rotation speed. To overcome this problem, a gearbox with transmission ratio about 5 : 3 can be used to reduce rotation speed of electric generator. Using this gearbox, the windmill on rotation speed about 150 rpm is still able to supply the power for electric generator.

Conclusion

An experiment of utilization of Savonius windmill for electric generating has been accomplished by studying an electic motor. The electric motor commonly used in electric bicycle was functioned as an electric generator. From the experiment, it can be concluded that the electric generator has average efficiency 59,8% for 12 volt target and 65,4% for 24 volt target. In normal battery condition, battery charging starts at electric generator rotation speed about 95 rpm, similar to low battery condition, but lower than full battery condition which starts at about 110 rpm.

Normal battery condition and electric generator that rotate constantly on rotation speed about 150 rpm is abel to supply electric power for nominal load 200 watt. Simulation study shows that shaft power output of a Savonius windmill with 5 meters height and 80 cm diameter is able to supply the need of shaft power input of electric generator, by applying a gear box with transmission ratio about 5:3.

Acknowledgment

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