Advances in Social Science, Education and Humanities Research, volume 528
Proceedings of the 7th International Conference on Research, Implementation, and Education of Mathematics and Sciences (ICRIEMS 2020)

Testing Low rpm BLDC Generator as Power Plant for Remote Areas

Bachtera Indarto[1] A. Wildan Ilhami[2] M. Arief Bustomi[3,*]

[1] *Department of Physics, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia*
[2] *Department of Physics, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia*
[3] *Department of Physics, Institut Teknologi Sepuluh Nopember (ITS), Surabaya, Indonesia*
[*]*Corresponding author. Email: a_bustomi@physics.its.ac.id*

ABSTRACT

BLDC generator can be an alternative solution for providing electricity to rural communities in Indonesia. In this research, a BLDC generator with a rotor and stator frame made from PETG material has been made using 3d printing. The dimensions of the generator stator section are 20 cm x 30 cm x 20 cm. On the inside, there is a magnetic wheel with a radius of 20 cm and a height of 3 cm. The coil used on the rotor is a coil of copper wire with a thickness of 0.4 mm and on each coil, there are 1250 turns. The research objective is to study the characteristics of generators at low speed for the application of electricity supply to rural communities. These characteristics are obtained from test results using a coupled generator and test motor. The test results show that at a low speed of 200 - 900 rpm, an increase in BLDC generator rpm will cause an increase in power. Testing the power load on the generator at 900 rpm with a variation of resistance of 0.25-15 Ω obtained the highest power of 13.17 W at a resistance of 6 Ω.

Keywords: *BLDC Generator, Low rpm, Power Plant, Characteristics of Generator.*

1. INTRODUCTION

The need for electrical energy in Indonesia is relatively high, while the supply of electrical energy is still inadequate. Based on Energy and Mineral Resources Ministry data, the achievement of electricity consumption in 2019 is only 1,084 kWh per capita from the target of 1,200 kWh per capita. Meanwhile, the target of electricity consumption in 2020 is 1,142 kWh per capita.

The need for electrical energy is closely related to the availability of various sources of electricity generation. The main element in the generation of electrical energy is the generator. Therefore, efforts to increase electricity production can be done by increasing the number of generators and increasing generator efficiency. One type of generator which is estimated to have a pretty good efficiency is a generator based on the Brushless Direct Current (BLDC) model [1 - 4]

The BLDC motor is a 3 phase AC synchronous electric motor [5]. Synchronous means the magnetic field generated by the stator and the magnetic field generated by the rotor are at the same frequency [6]. Compared to other types of DC motors, BLDC motors have a higher rotational speed and lower maintenance costs because they are without a brush. Compared to induction motors, BLDC motors have higher efficiency and higher initial torque because the rotor is made of a permanent magnet [7 - 9].

The BLDC generator is a modern energy generator, although the use of BLDC generators is not yet large. Research on the BLDC generator model needs to be done to meet the national electricity needs. Related to the potential of Indonesia's energy resources such as waterfalls, wind, coal, geothermal, solar energy, and others, the use of BLDC generators is quite promising [10 - 12]. The utilization of the potential of energy resources by people in rural areas or remote areas of Indonesia is very relevant to the work of BLDC generators at low rpm.

Considering the importance of utilizing BLDC generators for rural communities, this paper will discuss the results of the research on the determination of the characteristics of a BLDC DC generator at low speed. An important contribution from our results is in the form of additional knowledge about the characteristics of BLDC generators at low speeds. The characteristic measured is the optimal power of the generator at low speed in the range of 200 - 900 rpm.

2. METHODS

The stages in this research are (1) Designing a BLDC generator system, (2) Making a body frame using a 3d printing machine, covering the mainframe and coil of copper wire for the stator, (3) Configuring the configuration on the RPM Controller and rotary test equipment (4) Integration of all parts into one system, (5) Calibration and precision tests, (6) Data collection in the form of real voltage and rpm, (7) Testing through-loading experiments by giving variations of loading 0.25 - 15 ohms at one of the rpm set for determining the loading of power to the generator.

2.1. Equipment and Materials

The materials used in making the DC generator BLDC model are: (1) PETG (Polyethylene Terephthalate) is used to make a 3d-printer print base, (2) Copper wire is used for coil windings on the BLDC generator stator, (3) Neodymium Magnet is used as a magnetic field flux on the generator motor, (4) the diode is used as a voltage rectifier produced by the generator.

The measuring instrument used in this research is (1) Multi-meter as a measure of current and voltage for the BLDC generator. The value of this voltage and current is used as a reference for the results of the generator test. (2) Tachometer as a real rpm meter for BLDC generator. This rpm value is used as a comparison to the rpm set on the test motor.

BLDC generator testing tools are: (1) Arduino UNO as an rpm control device on the test motor, (2) BTS7960 is an ACS712 current sensor module that functions as a current measuring instrument to measure the Heating Element in Muffle Furnaces, (3) DC Motor is used as a test motor on the BLDC generator to get the voltage and torque values, (4) the resistor is used as an additional input to the generator to determine the current value.

2.2. BLDC Generator Design

The BLDC generator design is shown in Figure 1.

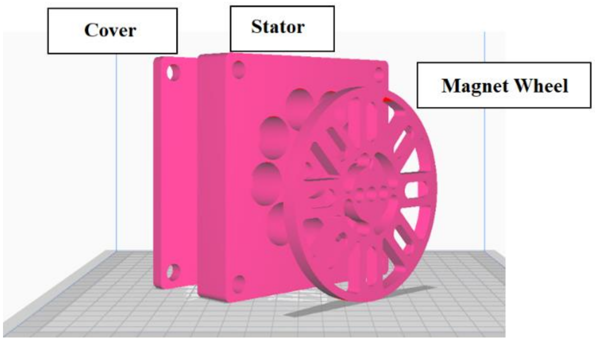

Figure 1 Design and construction of BLDC Generator.

In Figure 1 a part of the BLDC Generator is made of PETG plastic. PETG was chosen because it has a strong and heat-resistant structure. The body generator consists of 2 covers, 1 stator, and 2 magnetic wheels. The cover is made to support the roll and inner. The Stator section is made with holes as a copper coil. This section is designed with dimensions of 20 cm x 20 cm x 20 cm. Then the magnetic wheel part is used to install the Ne32 N32 Magnet. The magnetic wheel section is designed as a tube with a radius of 20 cm and a height of 3 cm.

The BLDC generator electrical circuit scheme is shown in Figure 2.

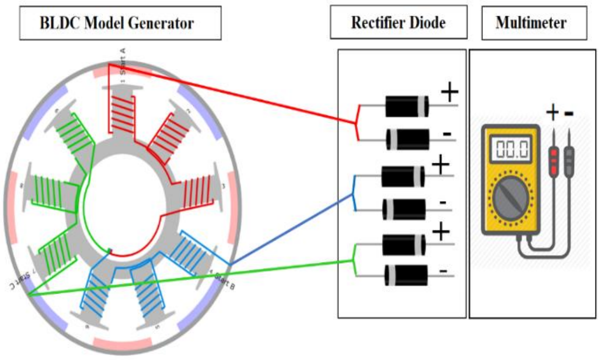

Figure 2 BLDC generator electrical circuit design.

Figure 2 shows the BLDC generator electrical circuit. The stator consists of a copper coil with a total of 1250 turns and a diameter of 0.4 mm. The coils on the body stator are arranged in 3 coil blocks in one phase. The BLDC generator uses 3 phases. Each phase is accompanied by a series of wyhe model. The wyhe model is a model of the arrangement of several coils for a motor phase [5]. Each phase is connected to the rectifier diode to produce a DC voltage. The generator is given a resistor variation from 0.25 ohms to 15 ohms. The generator is paired with a test motor so that the generator can be turned according to the set rpm set in the test motor system [13]. From the test results, we will get the value of voltage, current, and rpm so that the value of the power generated by the generator can be determined.

2.3. Generator Testing

To control the rpm on the test motor, several steps are needed, namely: (1) Setting the rpm configuration setting on Arduino using a computer, (2) Setting the rpm configuration using the rpm set on the conditional potentiometer, (3) Determining the setpoint value for data retrieval. Figure 3 shows the electronic scheme of the BLDC generator motor test.

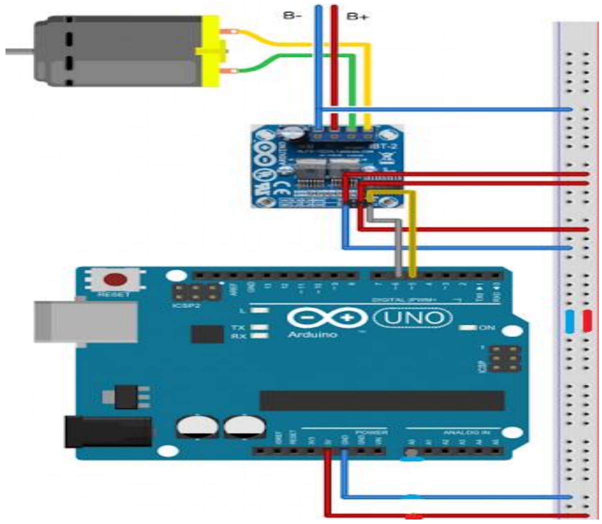

Figure 3 Electronic scheme of the BLDC generator test motor.

3. RESULTS AND DISCUSSION

The characterization of the BLDC generator was carried out to determine the characteristics of the BLDC generator loading at low rpm.

3.1. Analysis of Loading Results

was carried out at 900 rpm, with variations in resistance of 15 - 0.25 Ω. Current and voltage measurements were carried out with a multi-meter. Then the current and voltage values were used to get the power value. The analysis of loading in this study is shown in Table 1.

At a resistance of 15 Ω has a voltage value of 5.665 V, at 2 Ω a voltage value of 2.865 V, and at 0.25 Ω a voltage value of 1.669 V. This is because the loading of a resistor against a BLDC generator will cause the voltage value to decrease, but the current value will increase. The current value at resistor 0.25 Ω is 4521.4 mA and the current value at resistor 15 Ω is 1892.7 mA.

3.2. BLDC Generator Test Results

This test is carried out to determine the characteristics of the BLDC generator. Also, this test is carried out to get the results in the form of a voltage (V), current (mA), real rpm, power (W), and torque (Nm) to real rpm displayed in graphical form. Tests carried out at rpm 200, 250, 300, 350, 400, 450, 500, 550, 600, 650, 700, 750, 800, 850 and 900 at a resistance of 10 Ω. The results obtained in this study are shown in Figure 4 in the form of graphs of measurement results, namely: (1) Large rpm set to real rpm, (2) Voltage (V) to real rpm, (3) Current (mA) to real rpm, (4) Power (W) to real rpm, (5) Torque (Nm) to real rpm.

Table 1. BLDC Generator Charging Analysis Table

Resistance (Ω)	Voltage (V)	Current (mA)	Power (W)
15	5.665	1892.7	10.72
14	5.643	1923.6	10.85
13	5.652	1984.9	11.22
12	5.636	2103.6	11.86
11	5.667	2149.4	12.18
10	5.473	2215.3	12.12
9	5.167	2365.3	12.22
8	4.749	2619.6	12.44
7	4.326	2896.3	12.53
6	3.964	3326.6	13.17
5	3.731	3483.8	13.00
4	3.419	3735.6	12.77
3	3.159	3947.4	12.47
2	2.865	4175.6	11.96
1	2.643	4256.3	11.25
0.5	2.344	4364.3	10.23
0.33	2.056	4452.6	9.15
0.25	1.669	4521.4	7.55

Loading analysis was carried out to determine the amount of current, voltage, and power generated when the BLDC Generator work. The loading analysis process

The results of observing the graphs in Figure 4 until Figure 8 show that: (1) The difference between set rpm and real rpm is relatively constant, around 2-7 rpm, (2) the voltage value increases with increasing rpm value, (3) the current value increases with increasing rpm value. This proves that the BLDC generator is strongly influenced by the rotation or rpm.

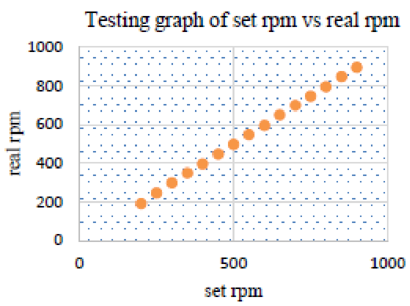

Figure 4 Testing of rpm set vs. real rpm.

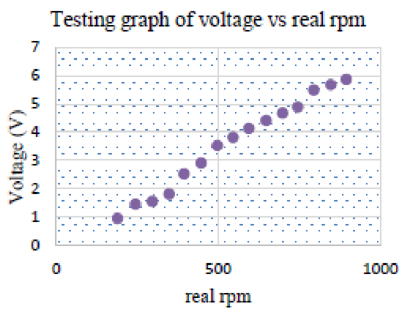

Figure 5 Testing of voltage vs. real rpm.

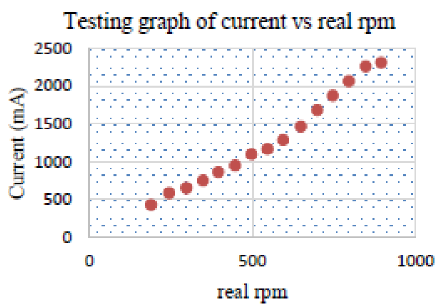

Figure 6 Testing of current vs. real rpm.

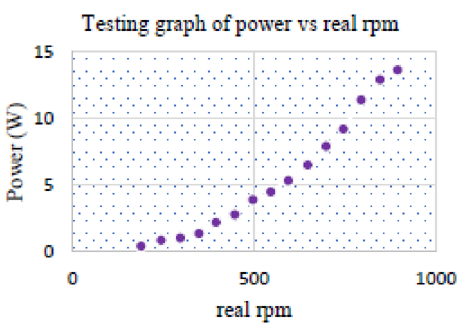

Figure 7 Testing of power vs. real rpm.

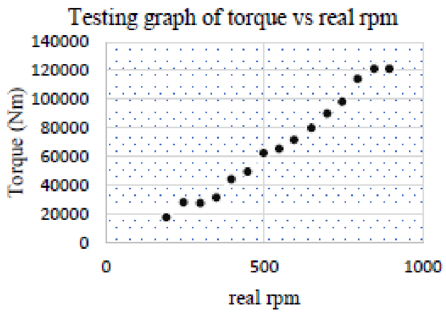

Figure 8 Testing of torque vs. real rpm

3.3. Discussion

The BLDC generator made is the Brushless DC Motor system composed of stator 9 copper coil with a 0.4 mm diameter and 1250 coils. On the magnetic wheel, there are 8 rows of neodine magnets, wherein in one row there are 5 layers of magnets. The stator is flanked by 2 magnetic wheels to obtain optimal magnetic field fluctuations. The generator applies a 9 stator line wyhe model where every 3 coils represent 1 phase motor. There are 3 phases in one motor, where each phase has an end and base phase, namely the first phase A start and A end, the second phase B start and B end, and the third phase C start and C end. In the wyhe model, A, B, C end are united in one line/grounding, while A, B, C start is put together using a diode to produce a DC voltage [14].

The magnetic flux generated by the main poles of the generator at no load is the main field flux. This flux cuts the stator windings so that the induced voltage arises. When the generator is loaded, the stator current arises. This stator current causes a flux in the stator conductor and is called the stator field flux. The emergence of the stator field will weaken the main field located to the left of the north-pole and will strengthen the main field located to the right of the north pole. The effect of this interaction between the main field and the stator field is called the stator reaction. This stator reaction results in the main field not being perpendicular to the neutral linen but shifting at an angle α. The neutral line will shift and can cause an electric spark. Shifting the neutral line will weaken the nominal voltage of the generator. To return the neutral line to its original position, a magnetic field is installed. If the heat that arises in the coil is too high, then the coil diameter is added to prevent sparks or fire [15].

In this study, the generator speed was made to vary from 200 to 900 rpm at 10 Ω resistance. It can be seen in Figure 4, that an increase in rpm or generator speed will cause an increase in voltage and current. The increase in voltage and current is caused by the speed change factor on both magnetic wheels. Changes in the speed of the two magnetic wheels cause the flux / magnetic field will reach faster windings resulting in voltage and current surges due to the use of N32 type neodine magnets. Thus in the range of 200-900 rpm rotation variations, the greatest power generator will be obtained at 900 rpm rotation. Tests for determining the power characteristics of a BLDC generator at 900 rpm are carried out by loading the variation of resistance 0.25 - 15 Ω. Thus the results of the BLDC generator research at a low rotation of 900 rpm obtained that the peak power occurs at a resistance of 6 Ω with a power of 13.17 W.

4. CONCLUSION

The BLDC generator used in this study has a range of differences between the set rpm and the real rpm ranging from 2-7 rpm. At a low speed of 200 - 900 rpm, an increase in generator rpm will cause an increase in power. Testing the power load on the BLDC generator at 900 rpm with a variation of resistance of 0.25-15 Ω obtained the highest power at a resistance of 6 Ω. At the 6 Ω resistance value, the voltage (3.964 ± 0.01) V and current is (3326.6 ± 0.01) mA or the power is 13.17 W.

AUTHORS' CONTRIBUTIONS

The first author contributes as the author of research ideas, the second author contributes as executor of research work, and the third author contributes to publish the research results.

ACKNOWLEDGMENTS

We are gratefully expressing our appreciation to our colleagues at the Department of Physics Institut Teknologi Sepuluh Nopember (ITS) for their supporting work.

REFERENCES

[1] E. Afjei, O. Hashemipour, M. A. Saati, M. M. Nezamabadi "A New Hybrid Brushless DC Motor/Generator without Permanent Magnet" IJE Transactions B: Applications 20(1) (2007) 77-86.

[2] A. H. Niasar, A. H. Sabbaghean "Design and Implementation of a Low-Cost Maximization Power Conversion System for Brushless DC Generator" Ain Shams Engineering Journal 8 (2017) 571–580. DOI: http://dx.doi.org/10.1016/j.asej.2015.11.001

[3] S. R. Gurumurthy, V. Agarwal, A. Sharma "Optimal Energy Harvesting from a High-Speed Brushless DC Generator-Based Flywheel Energy Storage System" IET Electr. Power Appl. 7(9) (2013) 693-700. DOI: 10.1049/iet-epa.2013.0134

[4] A. Kochan, T. Trawiński "Simulation Research on Hybrid Electromechanical Device - BLDC Motor, Torsion Torque Generator - for Torsional Vibration Spectrum Identification of Drive Systems" Przegląd Elektrotechniczny, R. 90 NR 7 (2014) 60-64. ISSN 0033-2097

[5] R. Shivarudrswamy, D. N. Gaonkar, S. K. Nayak "Coordinated voltage control in 3 phase unbalanced Distribution system with multiple regulators using Genetic Algorithm" Energy Procedia 14 (2012) 1199-1206. DOI:10.1016/j.egypro.2011.12.887

[6] B. Naas, L. Nezli, B. Naas, M. O. Mahmoudi, M. Elbar "Direct Torque Control Based Three Level Inverter-fed Double Star Permanent Magnet Synchronous Machine" Energy Procedia 18 (2012) 521-530. DOI: 10.1016/j.egypro.2012.05.063

[7] I. Janpan, R. Chaisricharoen, P. Boonyanant "Control of the Brushless DC Motor in Combine Mode" Procedia Engineering 32 (2012) 279-285 DOI:10.1016/j.proeng.2012.01.1268

[8] H. S. M. Widodo, S. Madenda, S. Harmanto, L. Hermanto "Approaching the Ideal BLDC Motor a Novel Electronic Speed Controller System for a Generator-Converted BLDC Motor with Field Weakening Feature" Modern Applied Science 14(3) (2020) 90-107. ISSN 1913-1844 E-ISSN 1913-1852

[9] P. Bajec, B. Pevec, D. Voncina, D. Miljavec, J. Nastran "Extending the Low-Speed Operation Range of PM Generator in Automotive Applications Using Novel AC–DC Converter Control" IEEE Transactions on Industrial Electronics 52(2) (2005) 436-443. DOI: 10.1109/TIE.2005.843912

[10] J. Werner, T. Heß, P. Scheiner "Flexible Test Facility for Evaluation of the Static and Dynamic Parameters of Micro Combined Heat and Power Plants" IFAC-Papers Online Proceedings 8 (2012) 260-265.

[11] K. Suresh, M. V. Raghavendra "Speed Control Scheme for Wind Based On PFC of BLDC Drive Applications" International Journal of Research and Analytical Reviews 6(2) (2019) 30-38. www.ijrar.org E-ISSN 2348-1269, P-ISSN 2349-5138

[12] A. A. Laczko (Zaharia), S. Brisset, M.V. Zaharia, M. M. Radulescu "Modeling and Simulation of a Brushless DC Permanent-Magnet Generator-Based Wind Energy Conversion System" 2015 Tenth International Conference on Ecological Vehicles and Renewable Energies (EVER). 978-1-4673-6785-1/15/$31.00 ©2015 European Union

[13] Iswanjono, Y. B. Lukiyanto, B. Setyahandana, Rines "A Couple of Generator and Motor as Electric Transmission System of a Driving Shaft to Long Distance Driven Shaft" 2018 E3S Web of

Conferences 67 01013 (2018) 1-4. DOI: https://doi.org/10.1051/e3sconf/20186701013

[14] A. Abu-Siada, C. Karunar "Transmission Line Power Transfer Capability Improvement, Case Study" IFAC-Papers Online Proceedings 8 (2012) 495-499.

[15] P. Maya, S. V. Shree, K. Roopasree, K. P. Soman "Discrimination of Internal Fault Current and Inrush Current in a Power Transformer using Empirical Wavelet Transform" Procedia Tech. 21 (2015) 514-519. DOI: 10.1016/j.protcy.2015.10.038