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Design of Low Speed Generator 1 Phase Using Permanent Magnetic Type Neodymium

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Abstract. The need for electricity in Indonesia and throughout the world is increasing, while most of the energy sources for electricity generation are still using fossil fuels such as oil, natural gas and coal. Fossil energy has a high level of pollution which is the cause of global warming, it is necessary to replace fossil energy that is environmentally friendly, namely renewable energy. The construction of power plants such as micro hydro power plants (PLTMh) which are located in irrigation canals or rivers with relatively small water discharge will result in low wheel rotation. The waterwheel rotation in this PLTMh system has a low rotating speed of around 200 rpm, and has a low torque or no cogging torque effect. Based on the needs in the field, a permanent Neodymium Type (NdFeB) Permanent Magnet Axial Flux Generator is built, which is specifically designed for low speeds of 200 rpm and has no cogging torque or low rotational torque effects. And it is hoped that the design of this generator can be used according to the needs of PLTMH. The results obtained in this study are, the generator can produce a voltage at a rotational speed of 200 Rpm and a frequency of 50 Hz is 100 VAC.

1. Introduction
Energy is one of the main problems faced by almost all countries in the world. This is because energy is one of the main factors for the economic growth of a country. Energy problems are becoming increasingly complex when the increasing need for energy from all countries in the world to sustain economic growth actually makes the supply of conventional energy reserves less and less. Indonesia is one of the countries with the largest growth rate in energy consumption in the world. Based on data from the Directorate of New-Renewable Energy and Energy Conservation, Ministry of Energy and Mineral Resources (ESDM), Indonesia's energy consumption has increased by seven percent per year in recent years. Cumulative global renewable electricity installed capacity grew by 8% in 2014 (from 1,579 GW to 1,712 GW), growth which has remained stable (6.6% per year from 2004-2014) in recent years. The addition of global renewable electricity capacity grew by 24% compared to 2013 (from 108 GW to 134 GW in annual capacity additions), a rate higher than in recent years. Renewable sources accounted for almost 24% of all electricity (5,507 TWh) worldwide in 2014. Global solar PV (Photovoltaic) and CSP (Concentrating Solar Power) increased by 28% and 29% in 2014, each installed capacity. Wind Power Generation installed capacity grew by 16% globally [1].

The total percentage of use of electricity production in the world until the end of 2015, fossil or non-renewable energy is still used for electricity production in the world, namely 76.3% and renewable

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energy at 23.7%. Hydropower still has the largest capacity in renewable electricity, which is 16.6% [2]. To overcome the threat of future energy deficits, the development of new and renewable energy (renewable energy) in Indonesia is a necessity. Moreover, the potential of the "Thousand Islands" is very abundant. Indonesia's energy consumption pattern also needs to shift from fossil energy to new-renewable energy. This is because, in the midst of declining production levels, national energy consumption is still dominated by non-renewable energy, aka fossil energy. Indonesia plans to increase renewable energy consumption by 25% by 2025 and 31% by 2050 [3]. Figure 1 below shows the share of power plant capacity from NRE and fossil energy.

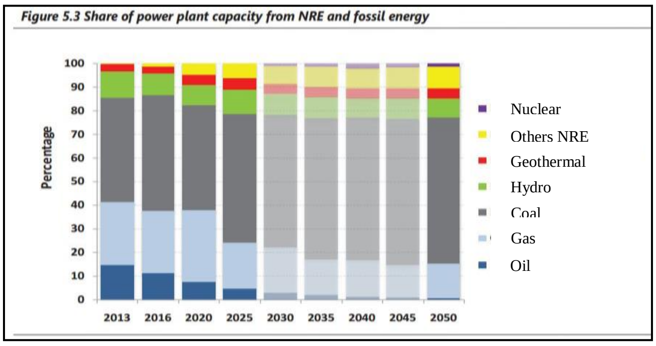

Figure 1. Share of power plant capacity from NRE and Fossil energy.

Electricity needs in Indonesia and the rest of the world are increasing while some of the energy for electricity generation still uses fossil energy such as oil, natural gas and coal. Until now, Indonesia has not been able to meet the electricity needs of the community. For that, a smart solution is needed to overcome these problems. The Microhydro Power Plant (MHP) is an alternative solution to address these problems. Microhydro is a term used for small-scale hydropower plants. The working principle of the MHP itself is basically the same as the hydropower plant; it is only different in capacity or size. MHP in principle utilizes height or slope differences and the number of debits per second in irrigation canals or rivers.

In this study the use of Neodymium (NdFeB) Axial Permanent Magnetic Flux Generator without Core Stator, which is specifically designed for low speeds of 200 rpm, because it uses permanent magnets it is not necessary to direct current reinforcement from the outside and does not have a cogging torque effect or swivel torque low. And it is expected that the design of this generator can be used according to the needs of the MHP.

Excitation is a part of the system of a generator that functions to form / produce flux that changes with time, so that it produces one GGL induction [4].Operating performance in a low speed range and is being studied. A new design method based on a multi-speed design strategy (MSD) is proposed. Using this method with stateless type without core, the efficiency of the total AFPM engine in the HEV operating cycle can be increased. Analysis of the performance of the AFPM in-wheel engine is done using the finite element method (FEM). FEM analysis from a single speed design method (SSD) is also done. Machines designed by MSD and SSD are applied in HEV and simulated using urban cycles and highways. The results obtained show better HEV performance, using machines designed based on MSD in all operating cycles. The experimental results were obtained from practical prototypes of samples, confirming analytical methods [5]. a novel design of axial flux permanent magnet generator using torus construction of stator with plastic material for wind energy generation system. In this Generator the stator is sandwiched between rotor discs where north pole of one rotor disc faces south pole of opposite rotor disc. In this arrangement as the flux does not pass radial in the stator disc, hence does not require magnetic material. This in turn means no iron losses in the designed machine. Designs were prepared for various ratings with same value of design parameters and comparison was made between Axial Flux Permanent Magnet Generator (AFPMG) and Radial Flux Permanent Magnet Generator (RFPM) [6].

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Design and manufacturing process for axial flux permanent magnet generators is explained for low-cost rural electrification applications, where local production of small wind turbines is considered. This process is based on existing open source designs and construction manuals, while a systematic approach to designing generators with a nominal power range and for network connections or battery charging schemes is immediately explained. The process of making a 3 kW small wind turbine generator for network connections is used as a case study. Emphasis is placed on using simple tools and techniques to achieve lower costs, while the complex steps in the manufacturing process are explained in more detail. The design of the generator is simulated and the engine built is tested in the laboratory [7]. Design of axial flux permanent magnet generator is using torus construction of stator with plastic material. To maximise the efficiency of the generator, the losses are to be minimized in proposed N-S Arrangement iron loss is absent and only copper losses are present. To minimise the copper loss for a given rating, the per phase stator resistance is to be minimised. The relation between Internal Diameter (ID) to Outer Diameter (OD) Ratio and the per phase resistance has been developed and optimal value is worked out. Also the designs were prepared for various ID to OD ratios to verify the optimal results [8].

Reuse the used stator core and frame from a three-phase induction motor (3Φ) through reconditioning the stator frame and core for the acquisition of a single-phase alternator. The structure of the stator winding is used to fabricate rotor structures with radial flux permanent magnets. The existence of a rotor structure with a radial flux permanent magnet on a single-phase alternator is used as the basis for calculating the theoretical mechanical power required from the starting drive. The structure of the stator winding is formed by six groups of coils (lap) type one lap (lap winding) in the range of 6 (six) channels connected in series. Hollow cylindrical rotor structure with dimensions of 60 mm, 30 mm and 85 mm equipped with 12 permanent magnets. The value of the theoretical electrical power produced by the alternator is 81VA, while the theoretical mechanical power required from the initial drive is 350 watts [9]. The axial flux (disc shape) permanent magnet machine is an attractive alternative to radial flux (cylindrical shape) machines in wind turbine applications. The axial flux configuration is amenable to the low-speed, high-torque operation of a direct drive wind energy system, Direct drive wind energy conversion tends to decrease the system size, weight, and noise, while increasing overall efficiency and reliability [10].

Design of an 8-pole, single-phase permanent magnetic synchronous generator using Neoflux-30 type Neodynium Ferrite Boron (NdFeB) magnet which is operated at a speed of 750 rpm. The test results show that when the generator is not loaded it produces a voltage of 7.91 Volt and when loaded, the voltage generated by the generator is 6.11 Volt with an efficiency of 32.84% [11]. Axial flux permanent magnet synchronous generators (PMSG) are designed as double stators and three rotors and their electromagnetic and structural characteristics are analyzed. The design aimed at the axial flux generator is placed to the single end of the inner rotor of the engine and a permanent magnet is placed into the double end of the middle rotor. One rotor more than the number of stator here is used. Cores are not used in the stator of the machine intended to be designed. The purpose of this study is to provide a reduction in both iron loss and making the engine lighter by reducing the number of rotors to be used. The new axial flux generator is designed to move as a permanent speed of 500 rpm so that the maximum voltage is around 120 V per phase [12].

Microhydro power plants that use irrigation channels or river flow require low-speed generators. At this time in the market it is very difficult to find low-speed ac generators, so that in this study researchers tried to plan low-speed generators, where the stator planning was made from epoxy resin material and the rotor is made of white acrylic material with a thickness of 5mm, with a rotation plan of 200 rpm, with an output voltage of 220 volts at a frequency of 50 Hz.

2. Experimental set up

2.1. Design Generator Axial.

In the research carried out concerning low-speed permanent magnet generator 1 axial type using a permanent magnet type Fe. The faster the rotation the greater the voltage produced. In this study a permanent magnet generator was designed, with the design of a generator in the form of an axial flux type 1 phase generator using 15 pairs of permanent magnet NdFeB type and comparison of results and generator performance will be carried out. Figure 2 below shows the design of axial generator permanent flux.

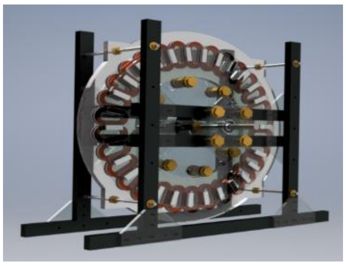

Figure 2. Design axial generator permanent flux

2.2. Magnet neodymium

Neodymium magnets known as NdeFb, NIB or Neo magnets, which are the most widely used types of rare-earth magnets are permanent magnets made of alloys from Neodymium, iron and boron to form Nd2Fe12B tetragonal crystalline structures. The neodymium magnet is shown as in Figure 3.

Figure 3. Neodymium magnet

2.3. Axial flux generator stator

Looking from the stator, this axial flux generator can be seen from a variety of variations including: Stator with iron core, stator without iron core, and number of coils. The number of coils in the stator depends on the number of phases and poles that you want to produce and the power produced. An iron-core stator is usually used for low speed and low load torque. Of course this is caused by the absence of an iron core inside. At the stator without an iron core the arrangement of the coils is divided into two types, some are arranged in overlapping and non-overlapping. The design of the stator is shown in Figure 4.

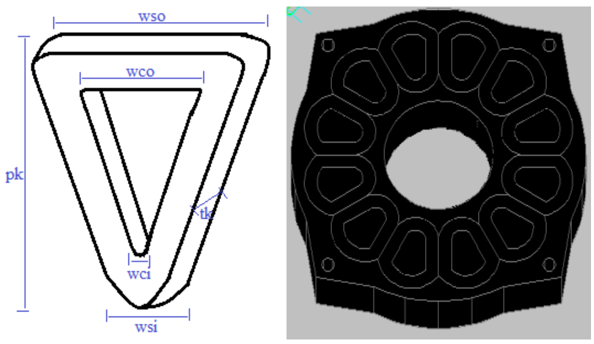

Figure 4. Stator design

2.4. Rotor

The rotor on the axial flux generator is a rotating part, the rotor consists of two parts that flank the stator, the rotor in this generator does not require external reinforcement to produce a magnetic field because it uses neodymium iron boron (NdFeB) permanent magnet. Permanent magnets use these materials which are basically the strongest magnets today compared to other types of magnets. The amount of magnetism in the rotor depends on the number of phases and the poles on the stator; the magnetic arrangement of the rotor is opposite the poles. Figure 5 shows the design of the rotor.

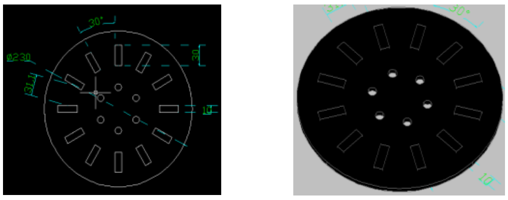

Figure 5. Design of rotor axial flux generator.

In order to find out the maximum flux density that can be produced by a rotor in the air gap equation 1 can be used.

$$B_{max} = B_r \frac{lm}{lm+\delta} \tag{1}$$

where B_{max} is the maximum flux density (tesla), B_r is the magnetic flux density (tesla), lm is the high, and δ is the air gap distance (meter). The maximum magnetic flux value produced can be calculated by using equation 2.

$$\Phi_{max} = A_{magnet} \cdot B_{max} \tag{2}$$

where Φ_{max} is the maximum magnetic flux (Wb), A_{magnet} is the extent of magnetic fields (m^2), and B_{max} is the maximum magnetic field (tesla). Figure 6 shows the measurement in the magnet.

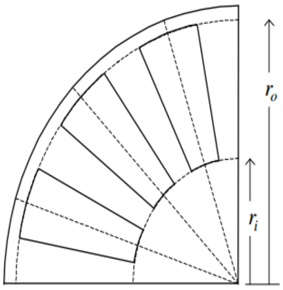

Figure 6. Radius in a magnet (ri), magnetic outer radius (ro).

2.5. Design Stator Generator Flux Axial

The stator of the axial flux generator can be seen from a variety of variations including: Stator with iron core, stator without iron core, and number of coils. The number of coils in the stator depends on the number of phases and poles that you want to produce and the power produced. The shape of the stator on the axial flux permanent magnet generator can be seen in the following figure:

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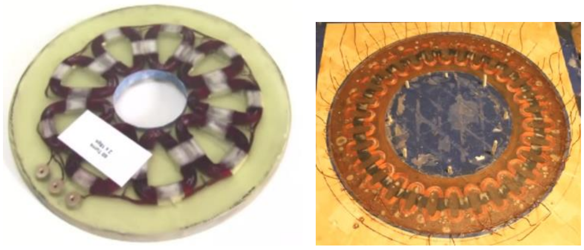

Figure 7. The form of the stator axial flux generator

2.6. Design

The axial flux generator that is to be created has specification as shown in Table 1 below.

Table 1. Generator specification

Specification	Description
Phase:	1
Pole:	30
Frequency	50Hz
Speed	200 rpm
P	74.4 VA
Magnet	Neodymium (NdFeB) grade 50
	Size (L×W×H): 3×1×4 cm

2.7. Result

At the measurement of the generator without load, measurements of frequency, voltage and rotation speed of the generator are carried out. Measurements were taken in eleven measurements, namely the frequency of generators from 10Hz to 110. The measured data is tabulated as shown in Table 2 below.

Table 2. Data comparison of frequency to voltage and rotation

Frequency of generator (Hz)	Voltage of generator (volt)	Rotation speed of generator (Rpm)
10	22,5	40
20	40	80
30	60	120
40	85	160
50	100	200
60	134	240
70	150	280
80	171.6	320
90	193.4	360
100	215.2	400
110	236	440

From the data shown in Table 1, the frequency generator characteristics obtained from generator voltage indicate that the higher the voltage increase in the generator, the frequency will also increase; this is to be able to see the generator frequency characteristics of the voltage at 50 Hz at 100 volts. This can be seen in the following graph in Figure 8 below:

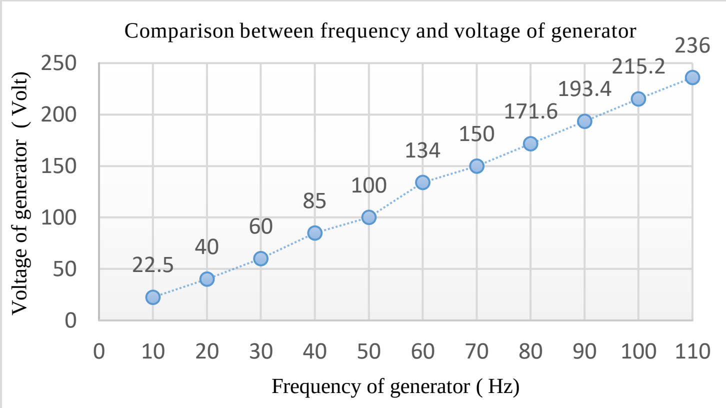

Figure 8. Comparison of Analysis Generator Frequency and Voltage

Also from Table 1, it can be seen that the increase in speed at the generator is linear with an increase in the frequency value, so that the characteristics of the generator at a frequency of 50 Hz are obtained at 200 rpm which is as shown in Figure 9 below.

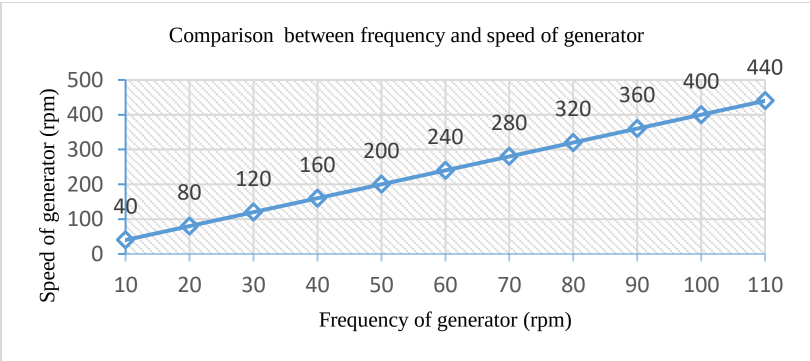

Figure 9. Comparison of speed to generator frequency

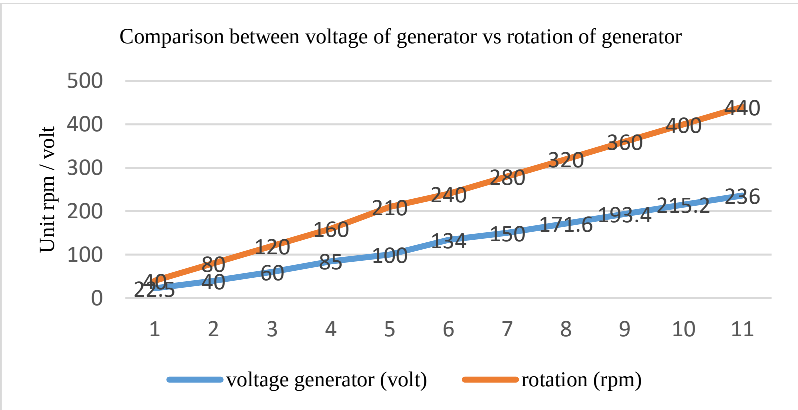

Figure 10. Comparison of generator speed to voltage generator

Figure 10 shows that the rotation of the generator increases as the voltage increases in the generator. This shows that the increase in rotation will increase the magnitude of the magnetic flux that is generated so that it affects the voltage generated by the generator.

On the other hand, the measurement of the loaded generator, generator and current measurements are made. Different generator setting were used. For generator settings at 200Rpm, 50Hz, 100V, the measured data are flow and power. The load used is in the form of 3 led lights arranged in parallel. For setting the generator 420Rpm, 105Hz, 220V, the measured data are flow and power. The load used is in the form of 1 18W LED lamp. Measurement with Generator Settings 200Rpm, 50Hz, 100V is taken 2 measurement parameters including: current and power. Measurement data can be seen in the following Table 3 below.

Table 3. Measurement Data with Generator Settings 200Rpm, 50Hz, 100V

Load	I (ma)	P (w)
1 pcs led 18w	20	2
2 pcs led 18w	51	5.1
3 pcs led 18w	90	9

On the other hand, the measurement with Generator Settings 420Rpm, 105Hz, 220V, there are 2 parameters used in this measurement, namely: current and power. Measurement data can be seen in Table 4 below.

Table 4. Measurement data with Generator Settings 440 Rpm, 105Hz, 220V

Load	I (ma)	P (w)
1 pcs led 18w	120	26.4 w

Comparative analysis is used to determine the characteristics of the current and power that the generator generates against the load can be seen in the graph as shown in Figure 11 below.

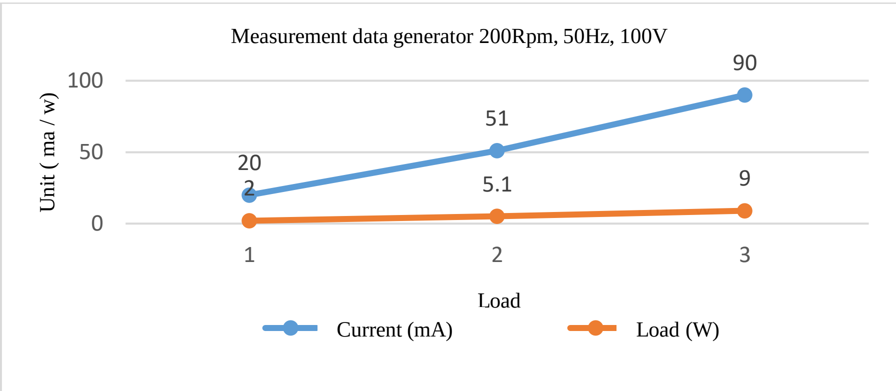

Figure 11. Load characteristics testing (generator settings: 200Rpm, 50Hz, 100V)

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The waveform generator is also analyzed using an oscilloscope and viewed the waveform. An oscilloscope (see Figure 12) is used using analog and digital types, how to connect it is a probe on an oscilloscope connected directly to the generator voltage terminal.

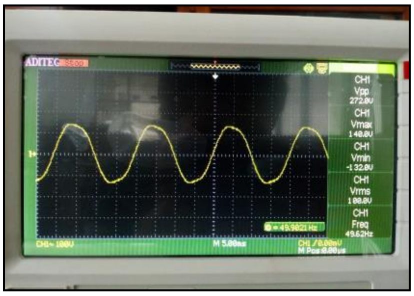

Figure 12. Waveform Generator

3. Conclusion

In planning this axial flux generator can produce 100 volt generator voltage, at a rotation speed of 200 Rpm with a frequency of 50 Hz, the level can rise according to the rotation speed of the generator, as in Figure 10 Rpm and 50 Hz frequency, axial flux generator output voltage is influenced by several parameters, including: rotation speed, magnet type, magnetic volume size, coil shape and size, many turns in one coil and air gap or air gap between the rotor and stator. The output of axial generator flux is influenced by the size of the copper wire email used. The choice of the type of permanent magnet is very influential on the output voltage of the generator. This is very influential, where the volume of the magnet is proportional to the generator voltage.

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