Design of Radial Flux Permanent Magnet Generator (GMPFR) Types E_{NS}, E_N-I_N, and E_N-I_S

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Abstract. This paper focuses on radial flux permanent magnet generators with one stator and three types of rotors. The main objective of the research is to make a permanent magnet generator and to compare the best performance of the three types of rotors. Generator performance testing based on rotation that is maintained is the same for all types (250, 500, 750, 1000 RPM) both without load and with load (3 watts). There are 12 stator coils with 500 turns each (0.25 mm wire diameter). The E_{NS} type rotor uses 24 external pieces, 21 E_N-I_N types with an external arrangement of 18 north poles and 3 internal north poles and 24 E_N-I_s type types with an external arrangement of 21 north poles and 3 internal south poles. The results show that for variations in rotation, the GMPFR output voltage without load of the E_{NS24} type is greater than the other two types. This is because the magnetic flux density (Φ) and magnetic area (A_{mag}) are larger than the other two types with a voltage difference of above 10%. The same thing is also the result of testing with loads, where the GMPFR type E_{NS24} is greater than the type E_{N18}-I_{N3} and E_{N21}-I_{S3}. At 250 RPM rotation, the lights are not lit for the three types of rotors, because the power generated by the three types is not able to supply the light load (3 watts). For 500 RPM rotation, the E_{NS24} type is able to turn on the lights (dim) because the power generated is 1.94 watts, while the E_{N18}-I_{N3} and E_{N21}-I_{S3} types have not turned on at all because the power generated is below 1 Watt. For 750 RPM rotation, only the E_{N21}-I_{S3} type lights up in dim conditions (1.66 watts), while the other two types are bright (normal) because the power generated is above 3 watts. While the rotation is 1000RPM all types are capable of turning on a load greater than 3 watts.

Keywords: permanent magnet generator, stator, rotor type E_{NS}, E_N-I_N, and E_N-I_S

1 Introduction

Electrical energy conversion technology is increasingly innovative to make it easier for humans to do work. Innovative electrical energy conversion technology cannot be separated from the energy source used. Where energy must have a *flexible value* in the sense that it is energy that can be converted into various other forms of energy, this type of energy is called electrical energy. Electrical energy is energy that is produced from various types of energy. To produce the conversion of an energy into electrical energy requires a generator [1, 2].
Generators can be used as a solution to electrical problems where generators are able to

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generate electricity from permanent magnets. A generator with a simpler design and also an easier way to use it is the main requirement for this generator manufacturing solution [3].
Utilization of renewable energy such as water energy and wind energy as an alternative source of small-scale electrical energy requires an appropriate generator because the mechanical energy in the form of rotation produced by these energy sources is generally at low speed. Therefore it is necessary to develop a synchronous generator capable of producing the required voltage and frequency at relatively low rotation [4,5].
The difficulty of getting a low speed synchronous generator makes researchers continue to develop research to design and manufacture synchronous generators that can be used at low speed such as micro-hydro power plants using screw turbines and wind power plants. The development of research on low-speed generators that has been widely developed is the axial and radial flux method [6,7].
In this study, the design and development of a generator using a magnet instead of an anchor coil on the rotor as a source of magnetic flux and a coil of copper wire (email) as an anchor coil on the stator is known as a Permanent Magnet Generator (GMP). GMP designed and developed a single stator-three-rotor radial flux type E_{NS}, E_N-I_N, and E_N-I_S . This generator is designed for single-phase voltage output.

2 Research Methods

Axial flux permanent magnet generator (GMPFR) 1 phase one stator-three rotor type E_{NS}, E_N-I_N, and E_N-I_S is designed using the principle of Faraday's law which states that if the magnetic flux through a coil changes, then at the end of the coil will be a potential difference called Induction Electromotive Force (EMF Induction).

2.1 Block Diagrams

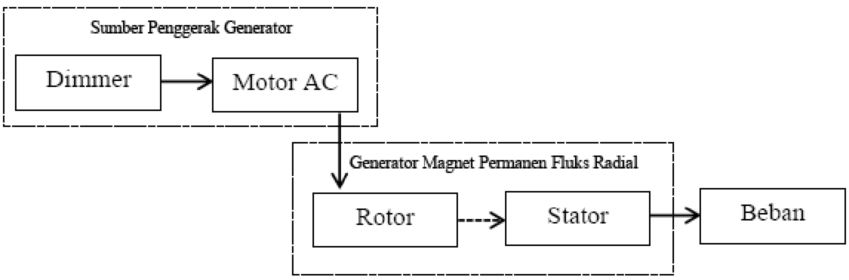

Figure 3.1 Block diagram of generator work testing

2.2 Radial Flux Permanent Magnet Generator (GMPFR) Construction Design

The design of the GMPFR is divided into two parts, namely the design of the stator and rator. In the design of the two components there are several specified quantities (*initial input*) as design references. The set values are shown in table 3.1 below.

Table 3.1. GMPFR Design Set Value

N	Initial	Mark	Unit

o	Input		
1	Frequency (*f*)	50	Hz
2	Number of Coils (N)	500	Coil
3	Number of phases (*Nph*)	1	Phase
4	Neomydium (N52) Magnet Dimensions	20 x 10 x 5	mm
5	Diameter of Enameled Wire *(d)*	0.25	mm
6	Air gap(δ)	4	mm
7	Internal Rotor Outer Circumference / External Inner (kr)	6.28 / 34.54	cm

Besides the fixed values in table 3.1 above, there are constant values for the design of the rotor, namely the number and variation/arrangement of magnets. This value is what will be tested for the GMPFR output. Table 3.2 and figure 3.2 show the arrangement of magnets and their arrangement.

Table 3.2. Number and arrangement of magnets on GMPFR

No	Number of Magnets (p)	Arrangement	Information
1	24	E_{NS24}	All Magnets are in an External position with the North (N)-South (S) magnetic arrangement
2	21	E_{N18} -I_{N3}	18 pieces in the North pole (N) External position and 3 North pole Internal (N) positions
3	24	E_{N21} -I_{S3}	21 pieces in the North Pole External position (N) and 4 Internal South Pole (S)

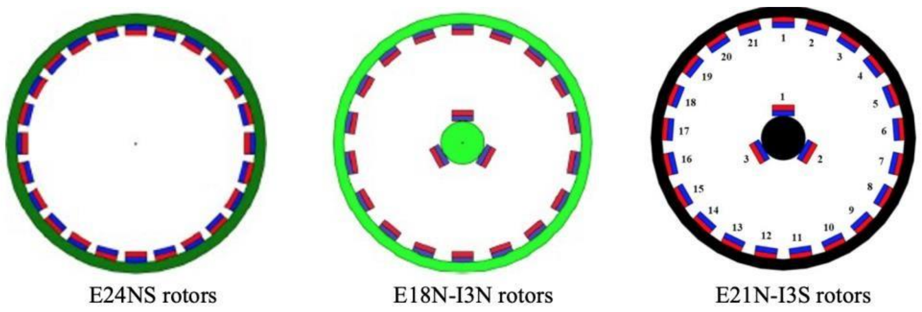

Figure 3.2. Design of the magnetic arrangement on the GMPFR rotor

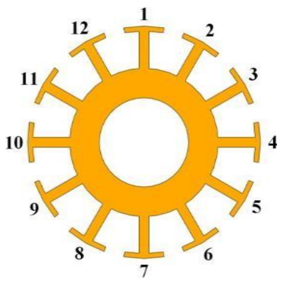

Figure 3.4. Stator design with 12 coils

The results of the overall design are shown in bold 3.3, table 3.4 and table 3.5

Table 3.3. The results of the parameter design GMPFR type E_{NS24}

No	The calculation results	Mark	Unit
1	Distance Between Magnets (Tf)	5,7	***mm***
2	Magnetic Area (Amag)	0.40	***cm2.***
3	Magnetic Flux Density (B)	0.81	***Tesla***
5	Number of Coils (Ns)	12	***Fruit***

Table 3.4. The results of the parameter design GMPFR type $E_{N18\text{-}IN3}$

No	The calculation results	Mark	unit
1	Distance Between Internal / External Rotor Magnets (*Tf*)	1.1/0.6	*cm*
2	Internal / External Rotor Magnet Area (A_{mag})	0.76 / 0.46	*cm2*
3	Magnetic Flux Density (B)	0.91	*Tesla*
4	Flux Density (Φ)	0.000027	*Webber*
5	Number of Coils (Ns)	12	Fruit

2.3 Design Results

The results of the design of the main GMPFR components are shown in Figure 3.5, Figure 3.6 andFigure 3.7.

Figure 3.5. GMPFR Stators

$_{NS24}$ rotors Rotor E $_{N18-IN3}$ Rotors E $_{N21}$ -I $_{S3}$

Figure 3.6. GMPFR Stator Models

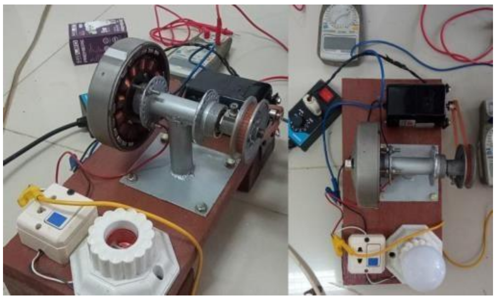

Figure 3.7. GMPFR

3 Results and Discussion

Generator testing is carried out by simulating the rotor speed using a speed-controlled AC motor. Generator rotor rotation varies from 250, 500, 750 and 1000 RPM . Generator testing is carried outat no load with measurement data on the voltage values between the lines. While testing when loaded will be taken measurement data on the value of the voltage between the channels. The load is in the form of a led lamp with a power of 3 W for each type of generator. The test results are as follows:

Table 4.1. GMPFR Output Voltage Test Results without load

No	Spin Speed (RPM)	GMPFR Output Voltage (Volts)			Voltage Difference (%)	
		E_{NS24} rotors	Rotor E_{N18} - I_{N3}	Rotor E_{N21}-I_{S3}	E_{NS24} : E_{N18} -I_{N3}	E_{NS24} : E_{N21} -I_{S3}
1	250	21,8	17.5	13.5	19,72	38.07
2	500	36	32	24.5	11,11	31.94
3	750	65.7	52	39,4	20.85	40.03
4	1000	87.9	69.5	52.5	20.93	40.27

Table 4.1. shows that for variations in rotation, the output voltage of the GMPFR type E_{NS24} is greater than the other two types. This is because the magnetic flux density (Φ) and magnetic area (A_{mag}) are larger than the other two types with a voltage difference of above 10%.

Table 4.2. GMPFR Output Voltage Test Results with load (3 Watts)

No	Spin Speed (RPM)	rotors E_{NS24}			Rotors E_{N18} -I_{N3}			Rotors E_{N21} -I_{S3}		
		Voltage)	Current (mA)	Power (Watts)	Voltage)	Current(m)	Power (Watts)	Voltage)	Current (mA)	Power (Watts)
1	250	22,6	6,7	0.14472	17.5	0.2	0.0035	13.5	3	0.0405
2	500	36	53,8	1.9368	32	26	0.832	24.5	16	0.392
3	750	53,2	58.5	3.1122	72	42.5	3.06	33.5	49.5	1.65825
4	1000	83.3	37.5	3.12375	60,4	57,8	3.49112	45.5	60,7	2.76185

The same thing applies when testing with a load (table 4.2), the rated load voltage on the GMPFR type E_{NS24} is greater than the type E_{N18} -I_{N3} and E_{N21} -I_{S3} . At 250 RPM rotation, the lights are not lit for the three types of rotors, because the power generated by the three types is not able to supply the light load (3 watts). For 500 RPM rotation, the E_{NS24} type is able to turn on the lights (dim) because the power produced is 1.94 watts, while the E_{N18} -I_{N3} and E_{N21} -I_{S3} types have not turned on atall because the power generated is below 1 Watt. For 750 RPM rotation, only the E_{N21}-I_{S3} type lights up in dim conditions (1.66 watts), while the other two types are bright (normal) because the power generated is above 3 watts. While the rotation is 1000 RPM all types are capable of turning on aload greater than 3 watts.

4 Conclusion

From the test results it can be concluded as follows:

1. The area of the magnet and magnetic flux density are very influential in the manufacture ofradial flux permanent magnet generators.
2. $_{NS24}$ radial flux permanent magnet generator is greater than that of the E_{N18} -I_{N3} and

E_{N21} -$I_{S3\ types}$

with a difference of above 10%.

3. There are no lights on at 250 RPM, only the E_{NS24} type is able to turn on the lights at 500 RPM. Whereas for 750 RPM and above the three types are already able to turn on the lights, even greater than 3 watts.
4. The output voltage of the three types is strongly influenced by the dimensions of the magnet used.

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