Study of the Effect of Material Types on Output Voltage in the Permanent Magnet Generator Model with Simulation Using Magnet Software

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Abstract. The performance of the Permanent Magnet Generator is determined by the value of the voltage. The value of the voltage or waveform of the output of the generator is determined by the type of material used. The different types of material can be varied for core and permanent magnet material, namely 3 types of Core material and 2 types of permanent magnetic material to measure the output voltage using MagNet software. The results of simulation and data analysis show that the use of Carpenter type core material and Neodymium-Ferrite-Boron type permanent magnet material produces the maximum output voltage value compared to other material combinations which is equal to 67,625 Volts.

Keywords: *Permanent Magnet Generator, Simulation, Carpenter, MagNet.*

1 Introduction

The development of permanent magnet electric machines is widely used in various applications. Especially with the incessant campaign environmentally friendly in various sectors such as transportation, electronic equipment even in the energy sector. This is also supported by the development of better permanent magnet material technology. In addition, the use of software to design electric machines simplifies the design process, especially for the design and analysis stages. That way the implementation process to the actual design gets reliable results because the essence of design has been fulfilled since the initial stage.In a recent study an analysis design on electric machines, especially those based on permanent magnet, has been carried out utilizing the Finite Element Method (FEM). This method provides more accurate results on the results of calculation and analysis of data than other methods. Anam in 2017 has designed a 100W Permanent Magnet Generator with the help of Electromagnetic Software. The use of software makes it easy to do design and simulation, especially those based on FEM [1,2,3].

In addition, the design and simulation was also carried out on the Axial Flux Permanent Magnet Generator (GMPFA) type by varying the shape of the permanent magnet rotor, the

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design strategy as mentioned in the study previously was able to increase the efficiency of the engine designed. But one other important aspect is the selection of materials used [4,5,6]. While in this study a simulation was carried out on a permanent magnet generator model, where the model consisted of the main components, namely the stator and rotor. The rotor and stator are composed of special types of softmagnetic material, where the simulation uses three types, namely low carbon steel (CR10), silicon steel (Carpenter), and cobalt steel (Remko) [7,8,9]. Two types of permanent magnetic materials are used, namely Samarium Cobalt (SmCo) and Neodymium Ferrite Boron (NdFeB). The three types of core material or each core are combined using two types of permanent magnetic material. From the simulation results and calculation of the output voltage, it was found that the combination of the use of Carpenter core material with NdFeB permanent magnet produced the highest output compared to other material variations [10,11].

2 Material and Method

The object of the research is to find out the value of output voltage on several types of materials for core components and permanent magnets on the design of permanent magnet generators 12 8 pole slots. The tool used in this study is a PC computer or laptop that has MagNet software installed that is used to analyze the design of the generator. While data processing software and graphics are used Kaleidagraph.

Making a model that is simulated by changing the geometry of the existing generator design into the geometry form required in the MagNet software is used as a media design simulation. After the geometry is determined the design is then initialized. After various parameters are met, a rotor rotation simulation is performed by determining the rotor displacement angle. Simulation of rotor displacement at each of these points replaces the rotor rotation with respect to the time of displacement.

The rotor rotation simulation produces the linkage flux value at each specified position. Next, a calculation with a certain equation is carried out which will show the value of the voltage at each point or the whole. These results can also be seen in the form of graphs produced and comparisons of the values of each parameter given previously.

2.1 Model Form

The generator model analyzed is composed of the geometry of the stator, rotor, slot, width of the airgap, design drawings can be done directly using the MagNet Infolityca software, but in the form design of the stator, rotor, slot or magnetic layout usually use CAD software because the tools used for forming certain angles can be done using the software.

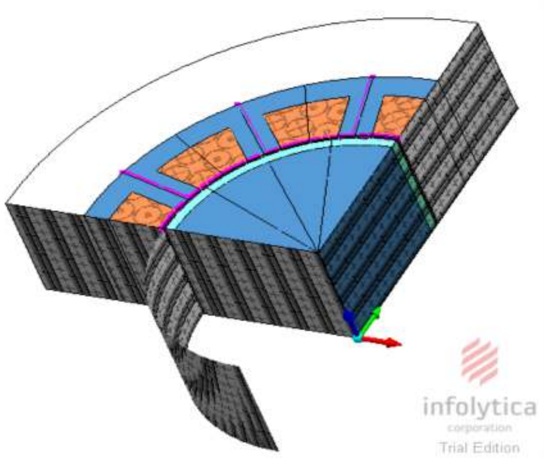

Fig. 1. Generator Design $^{1}/_{4}$ Model

2.2 Component Mesh Settings

Software based on Fenite Element Method (FEM) is a method that is one of the methods used in complex electromagnetic fields, so that it can be solved by an analysis model, especially in parts related to nonlinear properties of materials. This method basically discrete the cross section of the machine into a small area or volume called fenite element or mesh. The mesh settings for each part are different, for example in the stator core, rotor core, and permanent magnet using a 2 mm mesh, while for the airgap section both the rotor and stator parts are arranged using a mesh of 0.5 mm.

2.3 Making a Coil series

The stage of making a circuit, is the stage for making a circuit that is in generator windings, because every generator test or simulation that uses MagNet Infolityca software has different circuits, both for testing loaders and generators without load.

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2.5 Rotor Rotation Simulation

Retrieving data in the simulation is obtained by rotating the rotor. The magnetic field produced in the rotor will induce the coil in the stator so that at any time it can change due to differences in the direction of the magnetic field from the polar difference. This means that in certain positions the magnetic field density distributed to the stator will also vary. The rotational rotation simulation aims to determine how much linkage flux is produced in a particular position.

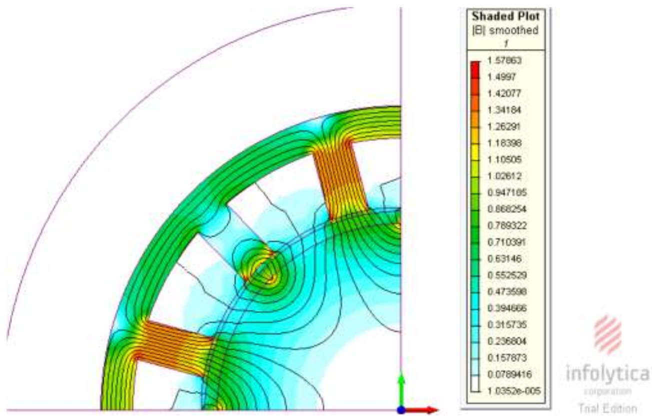

Fig. 2. Model Simulation

Because the model is used in the form of ¼ from the original shape, the rotating motion of the rotor is divided into 30 points from the origin. This means that the rotor will move radially by 3 degrees. Every time the rotor rotates 3 degrees the value of the linkage flux is taken periodically to be processed and the data is obtained. After getting the flux linkage data at each of these points on each coil which represents the magnitude of the linkage flux at each phase. The data is then processed in the Microsoft Excel application to calculate the magnitude of the series voltage on each coil. Furthermore, because the simulation uses the form ¼ model, then the voltage is measured on each coil in the form of a full circle. Only after that can be determined the amount of voltage between the phase produced and the output voltage.

3 Results and Discussion

Analysis Design of permanent magnet generator 12 8 pole slots that have been simulated using tools in MagNet software and simulation data is processed using Microsoft Excel software. The data obtained from processing the data, namely the voltage of each coil, 4 coil series phase voltage and inter phase voltage.

Data The simulation results obtained in the form of linkage flux data in a particular rotor position which represents the rotor rotation of 360 in the original model. Because the parameters used use 3 types of softmagnetic material for core components and 2 types of permanent magnet material, then 6 linkage flux data are obtained from rotor rotation simulation results.

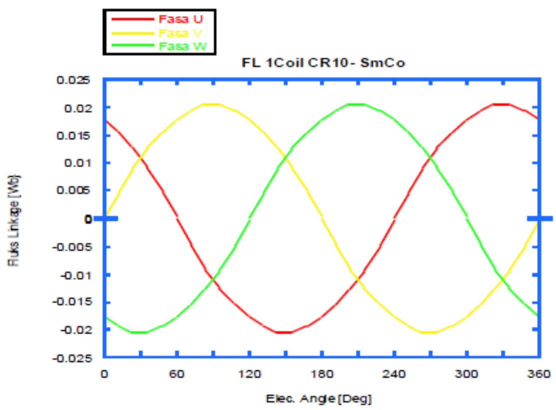

Figure 3 Graph of linkage flux of CR10-SmCo material

The sinusoidal form as shown states that the simulation process is carried out well and as expected. Changes in core material with the type of material Remko and Carpenter give results that are close to each other at each point of its simulation. Although there are differences in the value of the graphs that are produced, it shows plots that coincide with each other between other types of material when material changes are made.

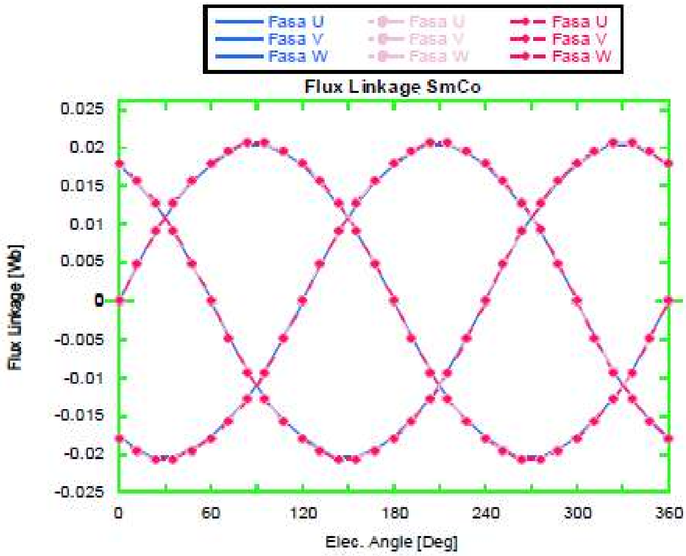

Fig. 4. Graph of linkage flux values using Samarium Cobalt (SmCo) permanent magnet with 3 different types of core material

The plot of each linkage flux in terms of value does not appear to change in each phase, but if observed from the data obtained there is an increase in value when compared to the use of the initial material.

3.1 Voltage of Each Coil

Changes in Core material in the type of Samarium Cobalt (SmCo) permanent magnet increase in each phase. In Remko and Carpenter material, the changes that occur are equal to 1% in phase U, 1% in phase V and 2% for phase W. Whereas in the Neodymium Ferrite Boron material there are changes that occur in both types of Core material. In Remko material there is a change of 2% in phase U, 1% in Phase V and 1% in phase W. While Carpenter material changes by 2% in phase U, 2% in phase V and 3% in phase W. Maximum increase which can be achieved from changes in the type of material in the model is the use of Carpenter type Core material with a Neodymium Ferrite Borron type permanent magnet.

Table 1. The average stress value of 1 Coil of each Phase

Material *Softmagnetik*	Fasa *Coil*	Magnet Permanen	
		Smco	NdFeB
CR10	U	0.14314	0.1685
	V	0.29673	0.34869
	W	0.10768	0.12639
Remko	U	0.14482	0.17103
	V	0.29991	0.35353
	W	0.10939	0.12912
Carpenter	U	0.1451	0.17152
	V	0.30048	0.3545
	W	0.10973	0.12976
Rata-rata		**0.184109**	**0.217004**

The graph shows the same results in terms of the trend of voltage changes for each phase when the core material changes. This is directly proportional to the trend of the graph of the linkage flux value previously obtained. Also when changes to permanent magnetic material using NdFeB types are seen in terms of the size of the output value shown shows a greater value than when using permanent SmCo type magnets. This means that all results will be influenced by the linkage flux graph because it is one of the important aspects in calculating the stress value.

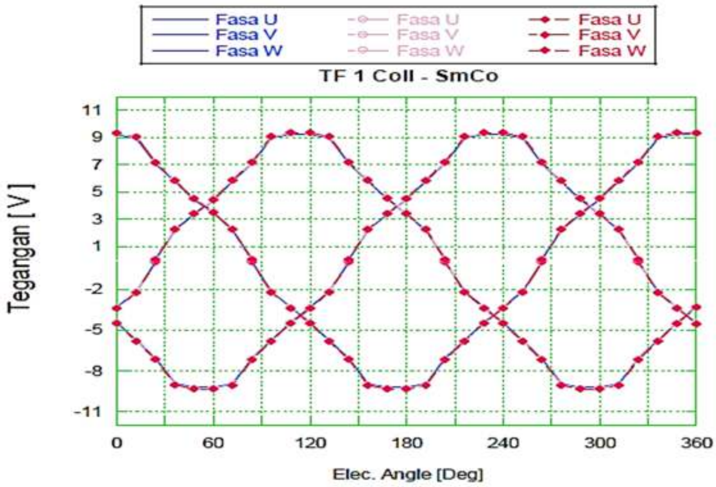

Fig. 5. Smco 1 coil stress graph with variations in the three types of core material

3.2 Series 4 Coil Phase Voltage

The magnitude of the change in the value of the series phase voltage at 4 Coils that occurs in each type of material in each phase will be the same as the change in the value of 1 coil voltage in each phase. Likewise, the trend changes in the graph will also be the same.

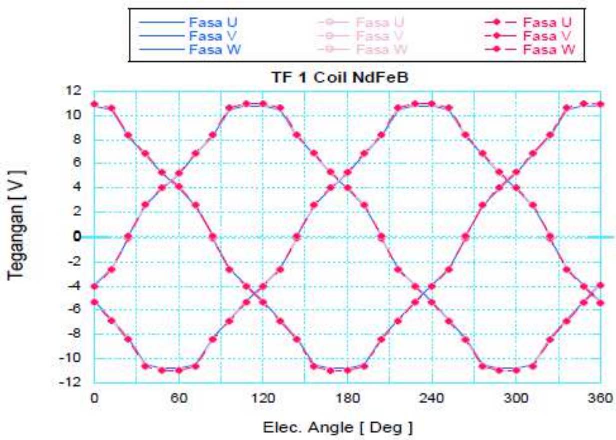

Fig. 6. Graph of 4 coil series voltage material PM SmCo

3.3 Inter Phase Voltage

Calculate the voltage between phases by reducing the 4 coil series voltage in each phase you want. After the value between the phases is obtained then the output voltage can be found in each rotor position or at each specified time.

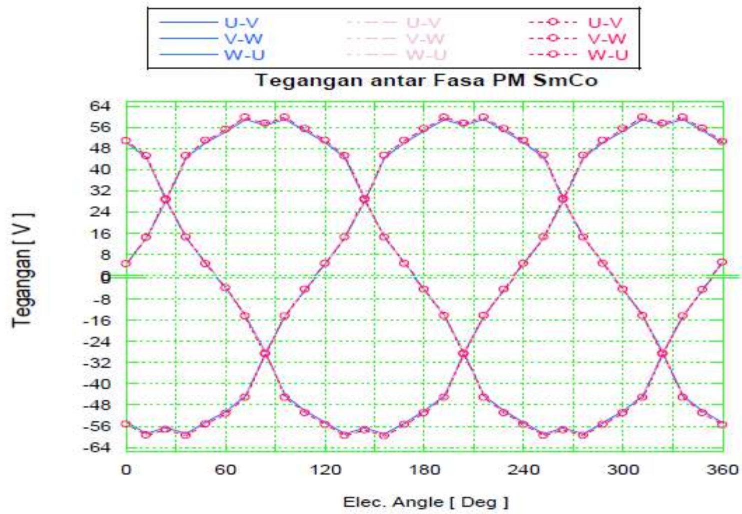

Fig. 7. Material inter phase phase graph of PM SmCo

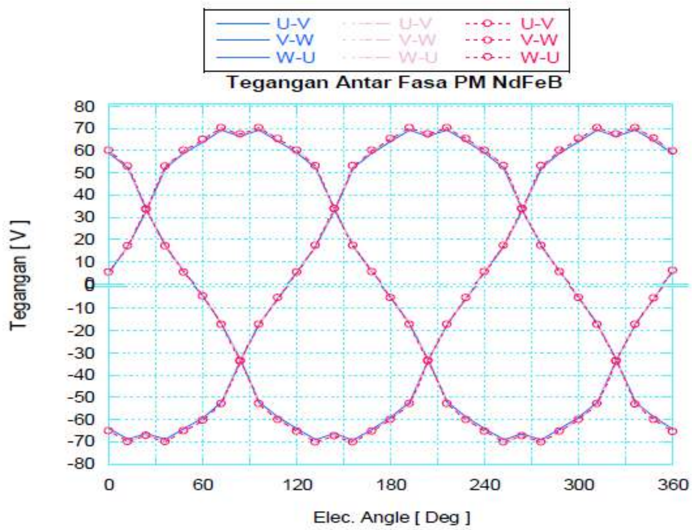

Fig. 8. Inter phase voltage graph of PM NdFeB material

The graph change trend shows the same characteristics in the previous graph graph. The value of each change in core material always shows plots attached to each other. To determine what DC voltage is generated from the simulation results in each material, it is determined after the inter-phase voltage is obtained, the output voltage is determined by calculating the maximum absolute value of the inter-phase value in each rotor position. So that it is known the voltage produced by the three coil phases.

Table 2. Average output voltage data produced by all types of material

VOLTAGE OUTPUT					
Samarium Cobalt (SmCo)			*Neodymium-Iron-Boron (NdFeB)*		
CR10	Remko	Carpenter	CR10	Remko	Carpenter
56.680244	57.287475	57.387672	66.585646	67.463013	67.625211

Changes that occur when changes are the same as before at a voltage value of 1 Coil Core material changes when using SmCo permanent magnets of 1% in remko and Carpenter materials. While the use of permanent magnets NdFeB changes that occur at 1% in Remko material and 2% in Carpenter material. A significant change in value occurs when the replacement of permanent magnetic material used from SmCo is changed with NdFeB. From these data changes in value occur at 17% in CR10 core material and 18% each in Remko and Carpenter materials when changing to NdFeB permanent magnets.

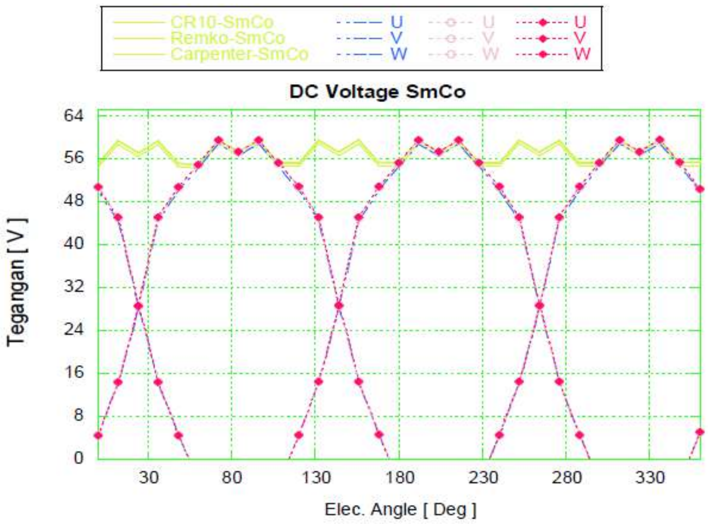

Fig. 9. Output voltage in PM SmCo material

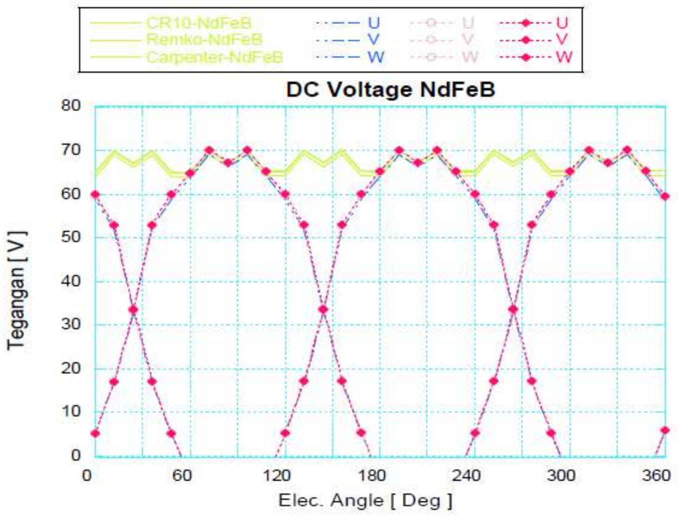

Fig. 10. Output voltage in PM NdFeB material

The difference in values found in Figure 4.12, which represents the use of NdFeB permanent magnetic material, shows higher output compared to the SmCo type. The results show that the simulation carried out goes well in the arena of the DC voltage output waveform forming waves whose intervals are balanced at each point from the beginning to the end.

4 CONCLUSION

The conclusions obtained from this study are as follows:

1. Material changes in the core or electromagnetic core components in the simulated generator model indicate a change in the Linkage and Voltage flux results in each phase. In material changes Core changes to phase U of 1%, in phase V of 1%, in Phase W of 2%. The Linkage Flux results show the maximum value in the core material type Carpeter: Silicon Steel. Flux Linkage results affect the value of the output voltage produced so that the output voltage of the material shows a higher value than the two other types of core material.
2. Changes in the material on the permanent magnet component show changes in the value of Linkage Flux and phase voltage to the type of permanent magnetic material with an average value of 0.000157 Wb when using the type Samarium Cobalt (SmCo), and 0.000229 Wb on permanent magnets Neodymium-Ferrite-Boron (NdFeB) Material changes provide a value of 18% higher output voltage when using Neodymium Ferrite Borron permanent magnet material.
3. From the simulation and processing of linkage flux data, the combination of the use of material in the permanent magnet generator model which is able to provide optimum voltage output is 74 Carpenter core material: Silicon Steel and Neodymium-Ferrite-Boron permanent magnet with a voltage output value of 67,625 Volt.

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