Finite element modelling and design of the axial fluxsynchronous generator of permanent magnet for direct use in wind turbine

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***Abstract*— The purpose of this paper is to design a permanent annealing generator for use in small wind power plants. The permanent magnet synchronous machine uses a permanent magnet to replace the strings of excitation rotors in the rotor with a lower weight, higher efficiency, and better performance. On the other hand, Wind is renewable energy, free and clean. Therefore, the optimal design of a permanent magnet synchronous generator for use in a wind power plant provides low energy losses. Two-way Stator bidirectional AFPM rotor generator with no centralized slot interference and less winding stator and iron less. The PM rotor disk can be effective in connecting to a grid or small-scale independent wind power conversion systems.**

***Keywords*— Limited execution method, permanent magnet synchronous generator, optimal design, wind power plant,**

I. INTRODUCTION

Many micro-wind turbine manufacturers are considering the use of a direct axle generator [1], thus avoiding gearboxes, reducing system volume, reducing noise and maintenance costs in design. However, a wind-driven fly-axis generator is used to operate at very low speeds to match the wind turbine speed and generate power in a proper frequency range, hence a small wind generator with a number of poles. The permanent magneto-sync generator (AFPM) has been used extensively in the last decade to use small-scale direct drives in wind turbine applications [2, 3]. Compared to conventional radial flux machine PM, AFPM synchronous generators have more advantages and compact structure due to flat shape and short axis length, larger ratio of power to weight and torque density, armorer coil design, better cooling and construction Modular and ... The task of the low speed is to direct the AFPM synchronous generator, which requires a larger diameter that affects the cost of the machine material [4]. The topology of the two-way stator synchronous generator and AFPM rotor are non-interfacing. The centralized slot and less is the stator winding and the lower iron disk of the PM-rotor.

In permanent magnet synchronous machine, replacing permanent magnet instead of winding the rotors in addition to reducing the weight of the rotor and reducing losses, increases the efficiency, and increases the power density and the appropriate efficiency. A permanent magnet generator can be used in electric power stations. In a permanent magnet generator, the coil is located on the stator, which is induced by the rotor's rotation at that voltage. Figure. 1 shows the topology of the permanent magnet synchronous generator.

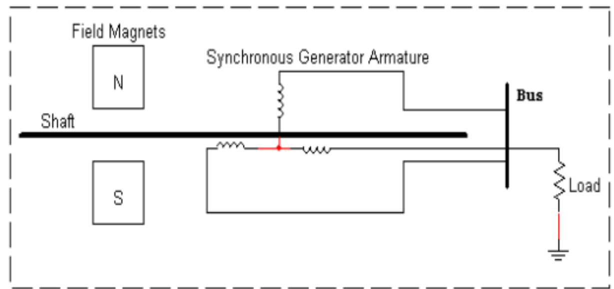

Figure. 1. Topology Synchronous Magnetic Permanent Magnet

The shape of the permanent rotor axis is effective in generating bond flux and magnetic field, which causes variations in the amount of torque ridge amplitude. Fig. 2 shows an example of the shape of this oven that is considered in the paper.

Figure. 2. shows the permanent magnet in the rotor

The energy of fossil fuels is not infinite and limited. And the pollution of the living environment, like greenhouse gases from fossil fuels, has forced humanity and humanity to devote to new energies. The use of wind energy was proposed in the 19th century, but did not grow much due to the use of a heater turbine. The 1973 energy injection caused human attention to use new energy, including wind energy, from which later on in the scientific centers, it has been more seriously pursued.

Wind energy is a clean and renewable energy, which can be used with the proper design of wind turbines. This energy has also attracted attention and high investment in order to be free of charge, high maneuverability and low operating costs compared to fossil fuels. The power generated by wind energy is given in equation (1)

$$P_{wind} = \frac{P_{wind}}{t} = \frac{1}{2} p \pi R^2 V_w^2 \qquad (1)$$

Where ρ is the air density, V_w^2 wind turbine, R^2 blade radius. The above equation shows that the energy of the wind depends strongly on the wind speed. This dependency is marked with a third wind speed. Therefore, a slight variation in wind speed will cause a significant change in wind power. It is also possible to receive more energy from the wind by increasing the radius of the turbine blades.

Because the wind speed is variable, a permanent magnet generator cannot produce constant frequency and power, so a converter and inverter are used before connecting to the network. Figure 3 How to connect a wind turbine with a permanent magnet synchronous generator to the grid Shows electricity.

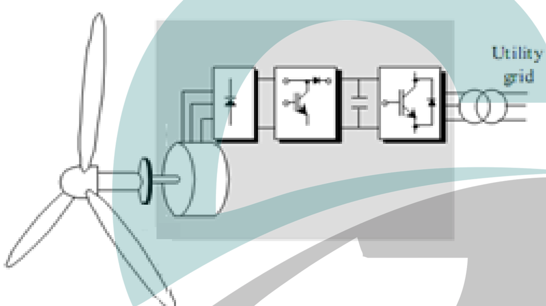

Figure. 3. How to connect a wind turbine with a permanent magnet synchronous generator to the network

II. AFPM SYNCHRONOUS GENERATOR DESIGN IN SMALL SCALE WIND TURBINES

An AFPM synchronous generator with eight pairs of internal axis rotor axis magnetic motors, NdFeB type rods, which have less iron replacement and a slotted external stator, made up of 24 coils, each of which is divided between 8 wire screws It may be possible to increase the air gap and reduce the flux density between the rotor and the stator. This decreases in the PM rotor, thus reducing the cost of the machine. On the other hand, the use of sliding armature and winding stator produces remarkable results in the harmonic and harmonic content behind the waveform of the EMF, with such effective electromagnetic design problems to be countered.

In this study, the power of the synchronous generator is 2.5 kw for a rotational speed of 200 rpm.

By applying the size of the AFPM small synchronous generator size equation, the outer surface of the diameter is obtained as follows:

$$D_0 = \sqrt[3]{\frac{120 P_{out}}{\pi^3 f_{LKG} K_f a K_w K_D n B_m A_s \eta}} \qquad (2)$$

The total outer diameter of the car is as follows:

$$D_i = K_d D_0 \qquad (3)$$

And the total axis of the car is as follows:

$$L_{tot} = L_r + 2L_s + 2g \qquad (4)$$

In which the axial length of the nuclear rotor and the rotor-PM are summed:

$$L_r = L_{r.core} + 2L_{PM} = B \frac{B_u}{B_{r.core}} \cdot \frac{\pi}{8} \frac{(1+\lambda)D_0}{p} + \frac{\mu_{r.PM} B_g}{B_{ren} - \frac{k_f}{k_d} B_g} g \qquad (5)$$

Relative permeability and residual flux The density of PM material rods are K_d and K_f respectively, K_w is the leakage flux factor which is the factor of the density of the machine, the number of turns per armchair phase N, f the frequency of the electric motor, p the number of pairs of car poles, and the diameter The internal and external surfaces of the machine are respectively D_0 and D_i, the inner diameter ratio, $\lambda = \frac{D_0}{D_i}$, the density at the peak of the magnetic flux B_m, and the pout output power of the P_{out} machine and the machine efficiency η.

The stator axial length sums the stator-core axial length

$$L_S = L_{s.core} \qquad (6)$$

Where

$$L_{s.core} = \frac{B_u}{B_{S.core}} \cdot \frac{\pi}{4} \frac{\alpha_p (1+\lambda) D_0}{p} \qquad (7)$$

$B_{S.core}$ is the flux density in the stator core, α_p is the ratio of the average current density.

The analytical preliminary electromagnetic design has been used for determining the main data of rotor and stator components for the small three-phase AFPM synchronous generator, listed in Table I

Table I Main Data Design of Two-Sided Stator AFPM Three Phase Synchronous Generator

Design data	Value
Turns per stator-winding phase	2500
Turns per coil	312
Wire diameter [mm2]	20
Slot-fill factor (gross)	0.5
Stator phase-winding resistance [Ω]	12
Rotor-PM thickens [mm]	20
Air gap clearance [mm]	2
Number of PM-rotor poles	16
Outer radius [mm]	295
Rated rotational speed [rpm]	200
Rated output power[w]	2500
Magnet height	20

III. Limited Elements of the AFPM 3D Synthesis Analyser Area

Due to the rapid advances in computational methods, a number of 3D finite element (FEM) is available in the packet field analysis software, so that a underlying problem may be solved by a conscious measurement of software tools has been. In this paper, the evaluation of the design of the three-phase AFPM synchronous generator design for two-way stator was performed and analysed by three-dimensional FEM field analysis using Maxwell 16.0 Maxwell 16.0 software.

The stepped FEM time in the method and solution of this circuit field requires the following steps: (a) constructing the right geometric model and the associated circuit model of the AFPM wind generator. (B) constructing the slip surface for step analysis; (c) selecting the solver, the boundary conditions, and increasing time; (d) executing the program to obtain the correct circuit of the FEM.

An overview of the single-rotor stator axial flux synchronous generator is shown in Figure. 4.

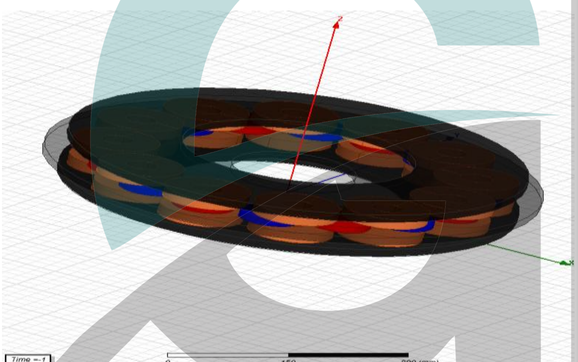

Figure .4. Overview of the synchronous generator of the internal rotor axial flux

The PM rotor and the density distribution of three-dimensional FEM analysis of two-way stator FEM and synchronous wind generator AFPM are presented in Figure. 5, which proves that the magnetic saturation of the PM rotor does not cause concern.

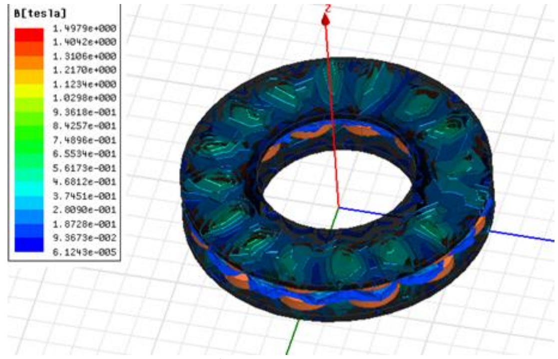

Figure. 5. Distribution of Flux Density in Two-way Stator AFPM Synchronous Generator.

In this case, the unloading of the stator terminals will be opened and the current will be zero. Normally, due to the circuit's openness, the flow of the wiring is not shown, as shown in Fig. 6.

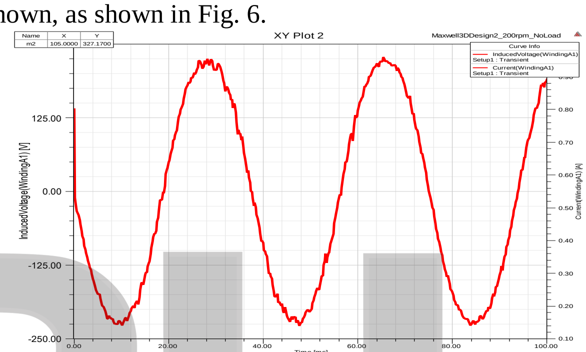

Figure .6. Voltage waveform in idle mode

The performance of two-way stator operation in an AFPM three-phase synchronous rotor with isolated supply and a load resistance of 85 [Ω / phase] is calculated using three-dimensional FE time step analysis. Figure.7. presents the calculation of the FEM electromagnetic torque dynamic. Considering the power output of the machine and output, naturally, when the generator is not pulled, so the torque is not applied to the shaft.

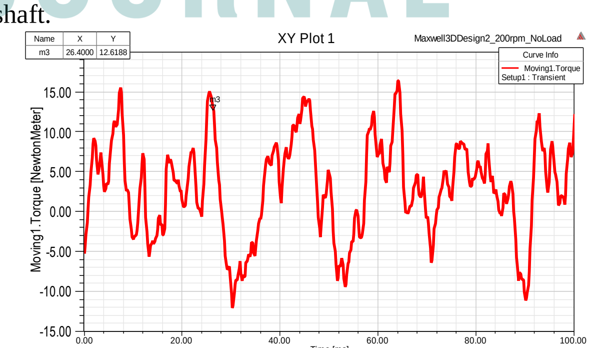

Figure. 7. Electromagnetic torque of the two-way stator in the AFPM synchronous rotor under unlade conditions

In this case, the pure resistive load simulation is performed with the resistance connected to the terminals of each phase. This resistance is entered for each phase of 85 ohms. As shown in the diagram, the current and voltage with each other have a phase difference of 180 degrees. This phase difference represents the state of the machine's generator and power injection. It is shown in Fig. 8.

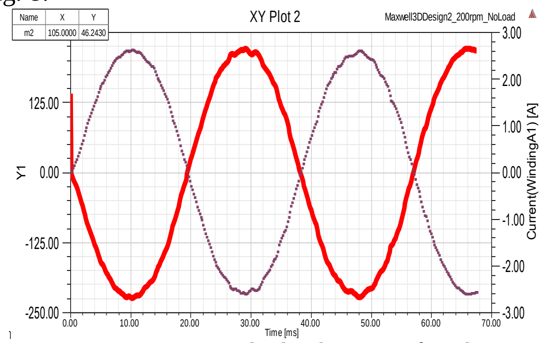

Figure .8. A pure resistance load with a rating of 85 ohms

Given the fact that pure resistive load produces the most active power from the generator, this state represents the maximum negative torque of the generator, as shown in Fig. 9, showing mechanical input power.

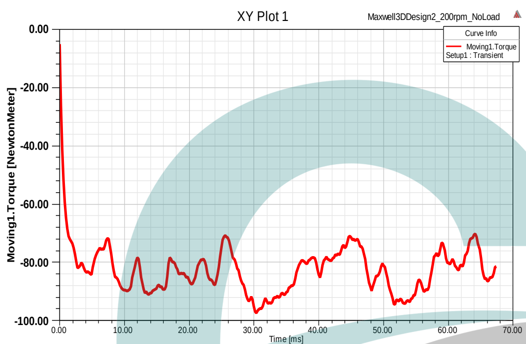

Figure .9. Torque caused by pure resistive load

By assigning the combined load of the inductor and the resistor with a magnitude of impedance of 85 ohms as in Fig. 10, the phase of each phase has a fuzzy difference with the voltage diagram. This phase difference is the function of the inductor and the load resistance and represents the load factor coefficient.

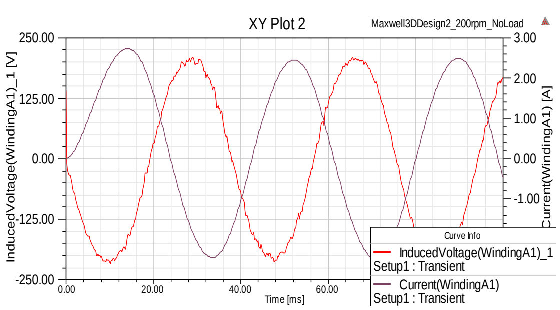

Figure .10. shows the voltage and current in a resistive self-acting load

In this case, the torque of the car has a negative effective value of 50 Nm, which is less than the value of the state where the pure resistance load has been allocated to the generator. This reduction is due to the reduction of active power consumption, as shown in Figure .11.

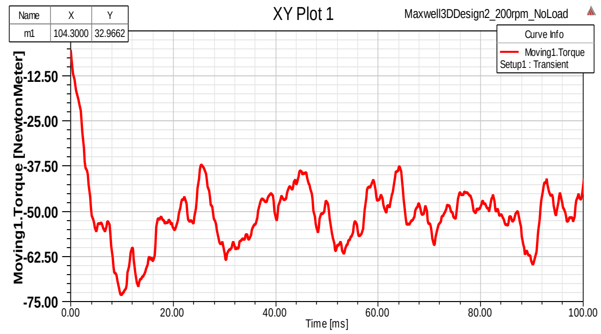

Figure. 11. Torque caused by resistive self-lift

Short-circuit models are modeled by short-circuiting a coil of phase A and a coil of short-circuit B phase. Also, the short-circuit strength is determined to be one tenth of ohm First, the voltage induced in phases with a short-circuit coil is much lower than in normal phases, as in the waveforms induced in phases. The same is true of the short circuit occurrence and a method for detecting the shortening of the windings in the generator. It is shown in Figure. 12.

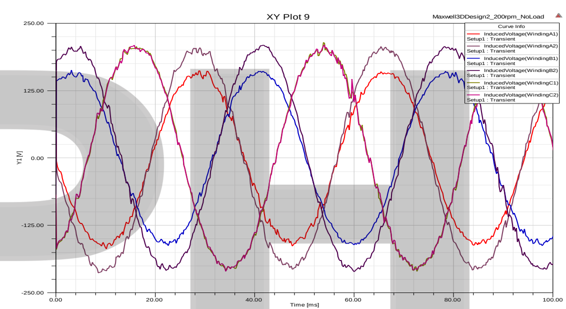

Figure.12. Short-circuit induced voltage in 3-phase winding

In addition to the voltage difference created in the coils, torque fluctuations are also important in the machine. In the form of 13 torque, the car is displayed in the short circuit mode of the machine.

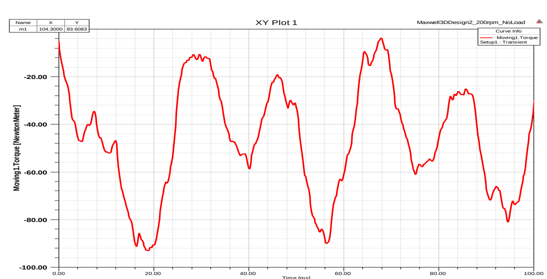

Figure. 13. Torque of the car in short circuit mode

The FE results are calculated, as well as the active mass of the masses as a two-way static analysis design within the AFPM synchronous generator rotor, which is presented in Table II.

Table II Results of FE Analysis for Two-way Stator AFPM Synchronous Generator

Design FE-analysis result	Value
Copper mass of the stator winding [kg]	35

Mass of rotor PMs [kg]	10
Iron mass of stators [kg]	30
Total mass [kg]	60
U_{rms} [V]	240
I_{rms} [A]	1.85
Torque [Nm]	75
Stator-winding copper losses [W]	135
Active materials estimated cost [Euro]	340
Manufacturing cost factor	1.5
Total estimated cost [Euro]	525

CONCLUSION

The purpose of this paper is to design a permanent magnet stator and single-rotor magnet synchronous generator for use in small wind power plants. Permanent magnet synchronous machines use a permanent magneto instead of an induction coil in the rotor to produce less weight, high efficiency and efficiency Are suitable. The car is intended to be designed based on the description of the methodology and the accuracy of the design results is confirmed on the basis of finite element method. The design of these types of machines will expand their application in new industries, including wind power plants.

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