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The Ferrite Effect on Magnetic Field Distribution with Two Rotors and One Stator Machine Topology

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Abstract

The study of axial flux permanent magnet machine (AFPMM) has been increasingly interesting to develop, since its construction is simple, easy to make, cheap, and portable. The application of NdFeB having high density, widely available in market and low cost maintenance was beneficial as this machine was brushless so that it didn't need routine maintenance. The results of many earlier researchers showed that there are still opportunities to improve engine performance. In this study, ferrite was used to collect and divert the magnetic flux, thereby reducing the magnetic flux leakage.This paper discussed ferrite installation technique in a cylinder and ring shape to direct magnetic flux circulation into closed circuit, and thus it could reduce leakage flux. This technique was performed on two rotors one stator topology using yhe finite element method for magnetic (FEMM) simulation. The simulation result presented magnetic field distribution on coil stator disc (1) without using ferrite having value of B = 364 to 379 mT (2) with ferrite core in coil having value of B = 399 to 419 mT (3) with ferrite core in each stator edges having value of B = 443 to 409 mT, and (4) with ferrite core both in coil and stator edges having the value of B = 467 to 446 mT.

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Keywords: two rotors one stator MMPFA, ferrite, FEMM, magnetic flux density.

1. Introduction

AFPMG (Axial Flux Permanent Magnet Generator) is one of the power plants to fulfill renewable energy need in terms of reducing global warming effect. The initial goal in developing AFPMG was to improve efficiency of traditional electrical machines, particularly on specific application: their compact and portable dimension. There are many kinds of generator construction designs to improve their performance. Axial flux configuration enables simple generator construction, easy to make, and relatively low cost [1-7]. In addition, axial flux machine configuration can be found by referring to stator towards rotor position and the winding structure [8]. The main characteristic of AFPMG is brushless, since it applies permanent magnet (NdFeB: Neodyminium-Ferry-Boron) having high density, and it is recently easy to get in the market; therefore, it can eliminate the routine maintenance cost [9-10]. Rotor and stator application from non-metal material can make it lighter and non-corrosive [9-13].

One of the ways to improve axial flux permanent magnet generator efficiency is by reducing magnetic flux leakage in rotor-stator with ferrite utilization. Ferrite is a component functioning to increase induction value and as a core of an inductor. Ferrite has low reluctance, thus it can facilitate to deliver magnetic flux. Moreover, it has high saturation (thin curve), easy to be influenced by a magnet, and it doesn't have magnetic remanence [14]. Ferrite powder is compacted, and it is processed through chemical synthesis, so that it has potential as renewable resources for nano magnetic particle. Ferrite is molded in cylindrical and ring shape. Cylindrical shape ferrite is installed in concentric shaped coil central, and it is called as the coil core. While ring shaped ferrites are installed at both stator and rotor outer edges.

2. AFPMG process simulation in five different topology

This study aimed to improve B magnetic flux density at MMPFA by reducing flux leakage to the rotor-stator by using ferrite. The relationship between flux density and permeability is:

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$$B = \mu H \quad (1)$$

Changes in the intensity of a magnetic field would affect the flux density that occurred in a magnetic material:

$$\mu = \mu_o \cdot \mu_r \quad (2)$$

where:
μ : material permeability (μ_f)
μ_0: free space permeability
μ_r: relative permeability (μ_{rf})
From equation (1) is substituted by (2), being:

$$B = \mu_0 \mu_{rf} H \quad (3)$$

If it used ferrite material, then:

$$B_f = \mu_0 \mu_{rf} H$$

$$B_f = \mu_{rf} B \quad (4)$$

Where:
B_f: magnetic flux density with ferrite
μ_{rf}: ferrite permeability
Electrical power for AFPMG with two air gaps or topology two rotors - one stator [15]:

$$P_{out} = K_a (D_o^2 - D_i^2)(D_o + D_i) n \quad (5)$$

Where:
K_a constant number of: 2,74 kB A 10^{-3} [14] in the condition without ferrite. After using ferrite, it can be expressed as $K_a = 2{,}74 \; k B_f A \; 10^{-3}$ Then the equation (5) becomes

$$P_{out} = 2{,}74 \; \mu_{rf} \; k B A \; 10^{-3} (D_o^2 - D_i^2)(D_o + D_i) n \quad (6)$$

Equation (6) showed that P is proportional to B magnetic flux density, so that it can be assumed that the increased in B value is equal to the increased in the electrical power generator. Since B measurement could not be conducted directly on stator coil disc, therefore, it was performed by applying FEMM (Finite Element Method for Magnetic) simulator, using the following steps:

a. AFPMM construction consisted of 2 disc types; they were rotor disc with 12 NdFeB permanent magnets, N 40 having 40 mm diameter dimension, 10 mm in thickness as shown in Fig. 1, and stator disc with 18 coils, 40 mm diameter dimension, 10 mm in thickness as shown in Fig. 2. Permanent magnet on rotor disc was arranged in such a way to make position of N-S-N-S and so on. For more than one rotor disc topology, each rotor disc was arranged face to face with the position of attracting each other. The distance between permanent magnet was optimum resulting in minimum magnetic flux leakage [16]. The distance between rotor and stator was 2 mm (air gap).

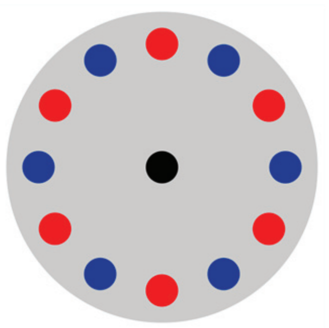

Fig. 1.A Rotor disc magnet

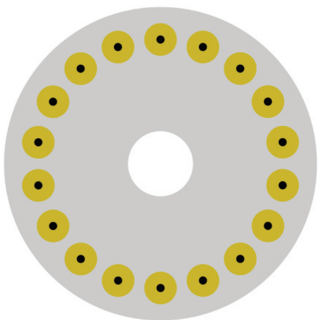

Fig. 2 A Coil stator disc with ferrite cores

b. Two kinds of ferrite were used, they were cylindrical shape as ferrite core installed in coil central, and ring shaped as ferrite ring installed in both outer edges of the rotor and stator disc, as showed in Fig. 3 and 4.

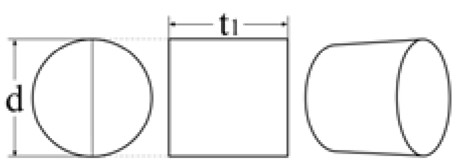

Fig. 3. Cylindrical ferrite core