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Design and Analysis of a Permanent Magnetic Bearing for Vertical Axis Small Wind Turbine

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Abstract

An interest toward zero frictional losses for small wind turbine is gaining popularity because of a considerable portion of the energy is lost due to friction in the ball bearing. The concept of levitation caused by repulsion of opposite pole in the permanent magnet reduced the friction between the stator and wind turbine rotor, so that the net power output of the turbine increases. The problem associated with usage of this kind of Passive magnetic bearing is its low load carrying capacity and low stiffness. To improve the load carrying capacity and stiffness, numerical simulation has been done for four different configurations. It is found that the stiffness is improved by stacking the magnet in the special combination of different radial cum axial direction of magnetization. The best configuration based on this analysis is fabricated and tested in the vertical axis wind turbine.

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Keywords: Permanent Magnetic Bearing (PMB); Vertical Axis Small Wind Turbine; Multiphysics; Zero Friction

1. Introduction

Due to friction between the moving parts of mechanical component, substantial amount of energy losses take place in the system, particular in the small wind turbine system. Usually, ball bearings are used to decrease the frictional losses. It is very important to minimize the losses in order to maximize the net output of the turbine. In order to achieve this, magnetic bearings are commonly used in this type of system, thereby eliminating mostly all

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the frictional losses. Recent advancement in rare-earth magnetic materials allows using magnetic bearings to a greater extent in mostly all mechanical systems [1]. The main reason to choose Permanent magnetic bearing (PMB) is very low frictional coefficient and its ease. Moreover, it is safe to use magnetic bearing as they do not require any additional power to control. However, the problem associated with the PMB is its stability. It is not stable because all six degrees of freedoms (dof) are freely allowed to move [2].

In order to integrate the PMB in any system, it is necessary to calculate the mechanical properties like stiffness and damping of the magnetic bearings. Moreover, equations have been developed to predict the above mentioned properties [3–4]. However, these equations will not predict the stiffness exactly as the actual parts are not perfectly built. The measured value deviates from the calculated value due to imperfections in the experimental arrangement and magnetization patterns. Moreover, according to Ravaud et al [5], analytical integration for ring magnet bearing is completely not possible to determine the axial forces of the radially polarization magnet. To improve the accuracy of the prediction, numerical methods using finite element methods (FEM) are also suggested in few literatures [6]. The analytical equation developed by Ravaud et al is used to predict the force and stiffness of the axially magnetized ring magnet. These equations are optimized to get the dimension of the ring magnet for the maximum stiffness and force. The effect of piling up of taper permanent magnetic bearing has been investigated using finite element method to check the stability [7]. It is suggested that the piling up of conical ring magnet would improve the stability. The effect of hydrodynamic and Magnetic properties in the bearing is studied to improve the damping characteristics. Experimental and numerical approach is adopted to validate this hybridization concept. The combined action of hydrodynamic and magnetic repulsion provides a greater damping characteristics than other configuration [8]. The radial and axial magnetization of the ring magnet plays a predominant role in the design of magnetic bearing for optimum design. In this paper, different possible arrangement of magnetization is analyzed using COMSOL Multiphysics software [9-10] to get the maximum stiffness in the arrays of ring magnet for Permanent magnetic bearing.

The main objective of this work is to document the design and analysis of the stacked ring permanent magnetic bearing that suits the small wind turbine to harness the low rated wind energy for domestic purpose power generation.

2. Design Configuration

The bearing made up of stacked ring magnet in both inner rotor and outer stator for different polarization like axial and radial direction. The different configuration of magnetization considered for the analysis is shown in Fig.1. Configuration 1 and 2 is the combination of radial and axial polarized ring magnet arranged in opposite direction. Configuration 3 and 4 consist of axially polarized ring magnet arranged in opposite direction. The rotor is Neodymium magnet and its inner radius is 10 mm and its outer radius is 20 mm. It is surrounded by ferrite magnet and its inner radius is 27.5 mm and its outer radius is 50 mm. In all the configurations, six Neodymium inner rotors and three ferrite ring magnet is used as the outer stator. This arrangement of magnetic bearing is achieved by placing the inner Neodymium magnet and outer ferrite magnet in concentric manners so that the repulsive reaction forces of these two magnets will center relative to each other in the magnet assembly. The other details about the model of permanent magnetic bearing and values of the boundary condition are given in the Table 1.

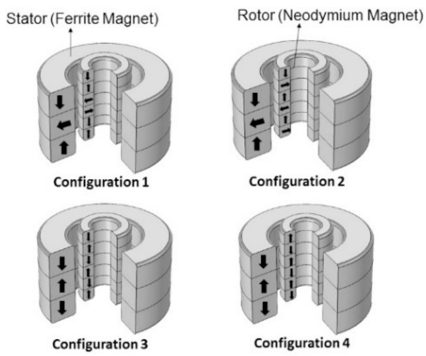

Fig. 1 Different configurations of PMB used for analysis.