FABRICATION OF A PROTOTYPE LOW POWER MOTOR FOR INDOOR VENTILATION

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This thesis is dedicated to God almighty, my beloved wife, my daughter Janiel and Janita

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ABSTRACT

This thesis focuses on the fabrication of a prototype Low Power Motor (LPM) for indoor ventilation. The proposed motor consists of electromechanical system (actuator), spring, motion translator, position controller and proximity sensor. The principle of the LPM is based on the integration of the mechanisms of the solenoid actuator which produces linear motion further converted to rotational motion by using a motion translator. The motion translator consists of oscillating stator magnet and permanent magnet array. Power delivery is controlled by using the position control approach. With this prototype, the circulation or movement of air for indoor ventilation is suitable for rural dwellers. This is achieved by utilizing a limited power resource over an extended period of time. This research begins with a review of electromechanical system (actuators/motors) and permanent magnet arrays. Simulations of electromechanical system were performed by means of model developed in Matlab/Simulink environment. Experimental tests of the prototype were carried out to compare with simulation results. The developed prototype was tested on a commonly sized blade normally used for ventilation. It is able to produce a rotational speed of 350 rpm at 4.4 W of power, which should be sufficient for indoor ventilation and cooling of simple homes and buildings.

ABSTRAK

Fokus tesis ini adalah fabrikasi prototaip Motor Berkuasa Rendah (LPM) yang digunakan bagi pengudaraan dalaman bangunan. Motor yang dicadangkan terdiri daripada sistem elektromekanikal (penggerak), spring, gerakan penukar, pengawal kedudukan dan sensor jarak. LPM adalah berdasarkan prinsip integrasi mekanisme penggerak solenoid yang menghasilkan gerakan linear dan akan ditukar kepada pergerakan putaran dengan menggunakan gerakan penukar. Gerakan penukar terdiri daripada magnet stator berayun dan susunan magnet kekal. Penghantaran kuasa akan dikawal dengan menggunakan pendekatan kawalan kedudukan. Dengan prototaip ini, pengedaran atau pergerakan udara untuk pengudaraan dalaman bangunan adalah sesuai untuk penduduk luar bandar. Ini dapat dicapai dengan menggunakan satu sumber kuasa yang terhad bagi tempoh yang panjang. Kajian ini bermula dengan mengkaji sistem elektromekanikal (penggerak/motor) dan susunan magnet kekal. Simulasi sistem elektromekanikal telah dijalankan melalui model yang dibangunkan dalam persekitaran Matlab/Simulink. Uji kaji bagi prototaip telah dijalankan untuk membuat perbandingan di antara keputusan-keputusan simulasi. Prototaip yang dibangunkan telah diuji dengan menggunakan bilah bersaiz biasa yang sering digunakan dalam pengudaraan. Ia mampu untuk menghasilkan kelajuan putaran sebanyak 350 rpm pada kuasa 4.4 W, yang seharusnya mencukupi bagi pengudaraan dalaman bangunan dan juga penyejukkan rumah-rumah dan bangunan.

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LIST OF SYMBOLS

P	-	Power Consumption
I	-	Current flowing through the coil and load resistor
V	-	Voltage across the coil
L	-	Inductance of the coil
N	-	Number of turns of wire in the coil
R	-	Resistance of the coil
M	-	Mass of the movable coil
K_s	-	Coefficient of the spring rigidity
x	-	Linear displacement of the coil
F_e	-	Force produce by electromagnet
d_o	-	Outer diameter of the coil
d_i	-	Inner diameter of the coil
h	-	Height of the coil
B	-	Magnetic flux density
S_m	-	Magnetic field strength
G_a	-	Air gap
A_m	-	Area of magnet
C_d	-	Coefficient of magnetic motive force
l_m	-	Coil mean length per single turn
g_c	-	Core thickness
C_h	-	Coil holder thickness
w	-	Coil layer thickness
S_o	-	Space occupation rate of coil
d_{ic}	-	Diameter of insulated coil
T_c	-	Coil temperature

λ	-	Heat dissipation coefficient
γ	-	Coil shape
μ_o	-	Magnetic permeability of air
ρ	-	Resistivity of the coil wire material
Q	-	Duty ratio
ω	-	Angular velocity
$\propto$	-	Angular acceleration

CHAPTER 1

INTRODUCTION

1.1 Overview

This chapter gives an introduction to a low power actuator/motors, describes the objectives and problem declaration of the research and the scope of work.

1.2 Introduction

Globally, the level of energy consumption has tinted the needs to develop and implement novel methods of energy preserving. Designs of actuators/motors are done according to their application. Achieving good low power consumption, the characteristics and the circumscriptions of the actuator should be kenned in the regulator design method. There are several mechanisms in general for controlling actuators for the purpose of decreasing power losses, heating and power consumption in systems, Actuators like moving coil electromagnetic, piezoelectric, electrostatic and pneumatic actuators have been used for many years.

The studies of actuator/motor characteristics are generally based on both theoretical and experimental study to control the rate of power consumption and losses. The objective of the study is to model the actuator for the purpose of saving energy. K. Won-Jong and S. Ali [1] has developed a novel low-power linear actuator. According to authors, the proposed system shows power consumption can be decreased significantly by making use of local excitation approach and a maximum power consumption of 95W was realized. Actuator power characteristics are presented for two tangible examples of control technique of energy consumption. This control method was proposed by Chandrasekaran and Lindner [2]. Analysis of the energy flow and consumption were presented. Other example consists of utilizing a conservative positive position controller that feeds back to the actuator current. Other methods used to control the rate of power consumption were reviewed [3] [4].

In this study, a moving coil actuator is modeled in Matlab/simulink. Position control approach is implemented to control the rate of power consumption of the system. Following this introduction, the report is organized into five chapters. The first part of this report presents literature review on actuators/motors. Next, the identification method and constitutive equation for power consumption of moving coil actuator and performance of the system as a low power (energy saving) motor. Finally, all results are summarized and discussed in the last chapter.

1.3 Objective

The objectives of this thesis include modeling and simulation, the prototyping, and the performance characterization (power consumption) of the proposed motor. They are described in detail as follows:

(i) To model and simulate electromechanical system in Matlab/Simulink.

(ii) To develop and build electromechanical system (actuator) that is able to provide linear actuation force for available conversion to rotational motion, by using a motion translator.

(iii) To test different configuration of motion translator which consists of oscillating magnet (stator) and magnet array (rotor).

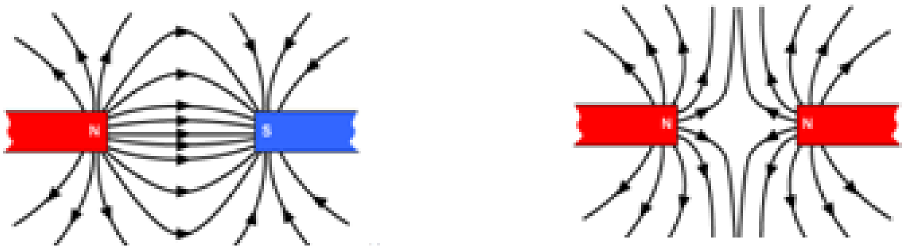
(iv) Hardware implementation of a low power motor (LPM) for indoor ventilation.

(v) To test the performance of the developed system power consumption and verify the results of the simulation with the experiment.

1.4 Problem statement

Conventional motor for indoor ventilation uses high input power source for its operation. The low power conventional motors are design in small sizes and will not be suitable for large fan (blade) for indoor ventilation. During raining season in many tropical countries such as Nigeria, there is high rate of malaria infection caused by mosquito, mostly in the rural area, and these parasites are active at night and may harm humans if the windows of homes are left open for ventilation. Therefore, simply providing the low power motor ventilation system that can constantly produce movement or circulation of air in a building even when the windows are closed can prevent this. In addition, drying of cloths or some agricultural products that require circulation of air is also difficult during the rainy season. This prototype LPM will be suitable for rural area considering the fact that most of the rural communities are not connected to the grid. A typical solar PV module of about 20-40W would be sufficient to power such system. For night operations batteries charged from the solar PV module can power the motor ventilating system. Such system would also provide comfort to occupants of simple homes in rural areas without electricity supply.

Therefore, by working out a design configuration of permanent magnet which operates by the relative movement of the magnetic pole of electromagnet and permanent magnets, which can either be repulsion or attraction. Lines of flux are main feature to characterize magnetic fields of permanent magnets. They avail us to visualize the magnetic field of any magnet. The more magnetic field strength, the more preponderant the number of lines of flux which are drawn to represent the magnetic field. The lines of flux are drawn with a direction of kineticism from N-pole to S-pole as illustrate in Figure 1.1a. The appearance of flux [5] describes the magnetic field, which are usually in concentric circles around the magnet.



a. Magnetic field attraction   b. magnetic field repulsion

Figure 1.1 Magnetic fields of permanent magnet

Using the principle of magnetic fields Figure 1.1, a new electromagnetic actuator is developed to transform electrical signals into controllable motion. Attractive and repulsive forces are generated adjacent to the conductor (coil) and are proportional to the current flow. The principle of operation is based on force interaction in a magnetic field. An iron core holding two opposite permanent magnet of the same pole inward and a coil at the middle demonstrate magnetic field principles. When the coil is energized, it becomes an electromagnet with N and S pole. Attraction and repulsion occurs at both sides forcing the coil to move due to the field interaction between the permanent magnet and electromagnet. When the coil is de-energized, the spring pulls it back. Using a motion translator, this action converts the linear motion to rotational motion.

1.5 Scope of work

With the aim to achieve the objectives of the research, the following scopes will be covered:

(i) Literature review on electromechanical systems (actuators/motors) and permanent magnet array. Their advantages and shortcomings.

(ii) Study on magnetic fields of a permanent magnet.

(iii) Propose a low power motor for indoor ventilation. A new method based on the relative movement of the magnetic pole of the rotor magnet with respect to that of the stator magnet is proposed. Theory and development procedure of the proposed machine are presented. The prospective and feasibility of the proposed machine is studied.

(iv) Analysis of the motor's characteristic behavior as a low power system according to computer simulation and experimental results. To verify the power consumption performance of the LPM, MATLAB/SIMULINK is utilized to model and simulate the electromechanical system (actuator). Mathematical model were presented to analyze the performance of the motor.

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(v) Develop and build a low power motor for indoor ventilation. To validate the feasibility of the proposed motor, which uses the principle of magnetic field of a permanent magnet, hardware prototype is constructed. The tasks include selecting the appropriate permanent magnets, proper orientation and configuration of the magnet stator and rotor, design of electromechanical system.

(vi) Verification of the proposed LPM effectiveness and performance through hardware implementation.

1.6 Thesis contributions

This research will contribute significantly to the development of a low power motor using actuator and permanent magnet array for indoor ventilation.

The significant contributions of this thesis are listed as follows:

- A new prototype linear electromechanical system using magnets and moving coil were developed. It provides a revolutionary new concept concerning the utilization of magnetic field principle.
- A new approach to control the rate of power consumption and a new method of conversion (motion translator) of linear motion to rotational motion with the help of inductive proximity sensor were presented.
- The proposed LPM will contribute significantly by using a large sizeable fan (blade) for indoor ventilation. Also, the motor is eco-friendly and easy to maintain.

1.7 Thesis Report Overview

This thesis is organized into five chapters. Their contents are outlined as follows:

(i) Chapter 2 presents a theoretical background and literature review of electromechanical systems (actuators/motors) and magnet array. Different types of design, their power consumption, capabilities and shortcoming are also presented.

(ii) Hardware development and implementation are presented in chapter 3. The descriptions of the proposed low power motor are discussed and a detail description of the electromechanical unit of the system, modeling and simulation of the electromechanical system and investigation of permanent magnet array configuration is presented. Verification and validation of the low powered motor for indoor ventilation based on the performance of the proposed LPM is discussed and presented.

(iv) The simulation and experimental results are presented and discussed in chapter 4. For the simulation part, the system is model in Matlab/Simulink environment. Experimental results are presented to show the performance of the machine as a low power system.

(v) Chapter 5 concludes the works undertaken and highlights the contributions of this research. Several suggestions are provided as possible directions for future work.

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