UNIVERSITI PUTRA MALAYSIA

DEVELOPMENT OF MULTI-TYPE INTERIOR PERMANENT MAGNET MOTOR

AMI NURUL NAZIFAH BINTI ABDULLAH

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DEVELOPMENT OF MULTI-TYPE INTERIOR PERMANENT MAGNET MOTOR

By

AMI NURUL NAZIFAH BINTI ABDULLAH

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia in Fulfillment of the Requirements for the Degree of Master of Science

MAY 2011

Dedication

TO MY BELOVED ~ HUSBAND MOHD KHAIRUL CHE KAMKAH, MY BELOVED PARENTS ~ MUHANIZAH MUSTAPHA, LATE FATHER CHE ABDULLAH CHE MAT AND MY FAMILY.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfillment of the requirements for the degree of Master of Science

DEVELOPMENT OF MULTI-TYPE INTERIOR PERMANENT MAGNET MOTOR

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MAY 2011

Chairman: Assoc. Prof. Norhisam Misron, PhD

Faculty: Engineering

A new three-phase Multi-type Interior Permanent Magnet Motor (MT-IPM) is proposed in this research. The type of motor is designed for high torque performance with diameter of 200mm and thickness of 30mm. The main advantage of this motor is to act as two types of motor as a Permanent Magnet Stepper Motor (PMST) and as a Permanent Magnet Brushless DC Motor (BLDC).

BLDC operates in bi-directional variable speed operation in full torque mode. In BLDC, the speed is simply controlled by DC supply voltage. However the BLDC motor requires essentially an input feedback from rotor position sensor unlike PMST that controls commutation sequences by using a frequency controller technique. PMST is usually run at high torque at low speed. Unfortunately, PMST is suitable only for large step angles applications as it is stepped by pulse frequency technique. Also missing or over stepping in the sequence of commutation occurs during the rotor rotation in a PMST for smaller step angles.

With this aim, the development of a three-phase multifunctional motor that act as brushless and stepper motor is proposed. This research also proposes new pitch arrangement of three-phase motor. The coils were arranged in a group according to their respective phases. Analyzing torque characteristic and motor performance of MT-IPM on various sizes of magnet and rotor are essential. The optimum model is derived and fabricated for various experimental testing to validate the performance of the proposed motor.

At the early stage, simulation analysis using finite element method (FEM) is performed to analyze the magnetic circuit on various sizes of rotor and magnet. The analysis parameters include the magnetic field flux, the cogging force and the developed torque. Further study on the research is then done to analyze the performance of the MT-IPM by using related mathematical model. The parameters considered are no load speed, no load current, stall torque and efficiency of the motor. Heat increment in coil is also taken into account during the observations. Overall analyses are done based on volume of magnet. Thus, the MT-IPM proposed is based on optimum result for testing in a laboratory environment.

As the result, optimized model are identified for the motors with volume of magnet between 2000mm^3 to 4000mm^3. The permanent magnet volume chosen for this MT-IPM is 3600mm^3 with the selected size of rotor as 50mm. Based on the measurement results, the optimum output torque with low cogging force of 6.5 Nm is achieved at phase current of 5A. Also the coil current when run as PMST motor is higher than BLDC motor.

Abstrak thesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

MEMBANGUNKAN MOTOR PELBAGAI-JENIS MAGNET KEKAL DALAMAN

Oleh

AMI NURUL NAZIFAH BINTI ABDULLAH

MEI 2011

Pengerusi: **Prof. Madya Norhisam Misron, PhD**

Fakulti: **Kejuruteraan**

Motor baru Tiga-Fasa Magnet Kekal Pelbagai Jenis (MT-IPM) telah dicadangkan dalam penyelidikan ini. Motor jenis ini direka untuk mendapatkan prestasi daya kilas yang tinggi dengan ukuran diameter 200mm dan ketebalan 30mm. Kelebihan utama motor ini adalah boleh berfungsi sebagai dua motor iaitu Motor Magnet Kekal Berlangkah (PMST) dan sebagai Motor Arus Terus Magnet Kekal Tanpa Berus (BLDC).

BLDC beroperasi dalam keadaan kelajuan dua-arah boleh ubah iaitu dalam keadaan daya kilas penuh. Bagaimanapun, BLDC pada asasnya memerlukan maklum balas input dari alat pengesan posisi rotor yang mana tidak seperti PMST yang mana mengawal jujukan-jujukan penukaran dengan menggunakan teknik kawalan frekuensi. PMST biasanya beroperasi pada daya kilas tinggi dan pada kelajuan perlahan. Malangnya, PMST hanya bersesuaian untuk aplikasi sudut langkah besar memandangkan ianya berlangkah dengan teknik denyutan frekuensi. Malah, untuk sudut-sudut langkah yang lebih kecil, PMST akan kehilangan atau terlebih langkah dalam jujujan penukaran semasa rotor PMST berputar.

Dengan tujuan ini, pembangunan satu motor tiga-fasa pelbagai fungsi yang dapat berfungsi sebagai motor pelangkah dan motor tanpa berus adalah dicadangkan. Penyelidikan ini juga mencadangkan susunan jarak larasan baru bagi motor tiga fasa. Kumparan pada motor telah diatur dalam secara berkumpulan mengikut fasa masing-masing. Menganalisis ciri-ciri daya kilas dan prestasi MT-IPM pada berbagai saiz magnet dan rotor adalah sangat penting. Model optimum diterbitkan dan dihasilkan untuk pelbagai ujian eksperimen bagi mengesahkan prestasi motor yang dicadangkan.

Pada peringkat awal, simulasi analisis menggunakan kaedah unsur terhingga (FEM) dilakukan untuk menganalisis litar magnet pada pelbagai saiz rotor dan magnet. Parameter analisis adalah meliputi fluks medan magnet, daya 'cogging' dan daya kilas yang telah dibangunkan. Kajian yang lebih lanjut tentang kajian ini kemudian dilakukan untuk menganalisis prestasi MT-IPM dengan menggunakan kaedah mathematik yang berkaitan. Parameter ini adalah kelajuan tanpa beban, arus tanpa beban, daya kilas terhenti dan kecekapan motor. Pemerhatian terhadap peningkatan haba dalam gegelung juga diambil kira dalam analisis matematik. Keseluruhan analisis dinilai berdasarkan isipadu magnet. Kemudian, MT-IPM yang dicadangkan berdasarkan keputusan optimum tersebut akan diuji dalam persekitaran makmal.

Sebagai keputusannya, model yang optimum dikenalpasti sebagai motor yang mempunyai isipadu magnet antara 2000mm^3 untuk 4000mm^3. Isipadu magnet kekal yang dipilih untuk MT-IPM ini adalah 3600mm^3 dengan saiz rotor yang dipilih adalah 50mm. Berdasarkan keputusan ekperimen, hasil daya kilas optimum dengan daya 'cogging' rendah iaitu 6.5 Nm dicapai pada arus fasa 5A. Arus pada belitan atau

gegelung berfungsi sebagai Motor Magnet Kekal Berlangkah (PMST) adalah lebih tinggi dari Motor Arus Terus Magnet Kekal Tanpa Berus (BLDC).

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I certify that a Thesis Examination Committee has met on May, 23 2011 to conduct the final examination of Ami Nurul Nazifah binti Abdullah on her thesis entitled "Development of Multi-type Interior Permanent Magnet Motor (MT-IPM)" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 march 1998. The committee recommends that the student be awarded the degree of Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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DECLARATION

I declare that the thesis is my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously and is not concurrently, submitted for any other degree at Universiti Putra Malaysia or other institutions.

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AMI NURUL NAZIFAH BINTI ABDULLAH

Date: 23 May 2011

TABLE OF CONTENTS