A Novel Double-Rotor Parallel Hybrid-Excitation Machine for Electric Vehicle Propulsion

Xing Zhao, Shuangxia Niu

The Hong Kong Polytechnic University, Department of Electrical Engineering, Kowloon, Hong Kong
Email: xing.hi.zhao@polyu.edu.hk, eesxniu@polyu.edu.hk

***Abstract*—A novel double-rotor parallel hybrid excitation machine with improved field adjustment capability is proposed in this paper. The key is to embed a stator electrical-excitation machine (SEEM) into the internal space of permanent magnet synchronous machine (PMSM) and the problem of magnetic field adjustment for conventional PMSM is effectively solved. This design integrates the merits of PMSM and SEEM, and provides high power density and a wide constant power speed range, thus making the proposed machine especially suitable for electric vehicle propulsion. In this paper, the selection, combination and design consideration for effective integration are investigated and verified by finite-element analysis.**

***Index Terms*—Magnetic field adjustment, parallel hybrid excitation, double-rotor, PMSM, SEEM**

I. Introduction

Due to its good field adjustment ability, hybrid excitation machine (HEM) is a competitive alternative for electric vehicle applications [1]. As an important branch of HEMs, parallel HEMs, has attracted much attention because there is less risk of demagnetization in the flux weakening caused by reverse field current.

This paper presents a novel double-rotor parallel hybrid excitation machine, namely DR-PHEM, which integrates the merits of two popular concepts- permanent magnet synchronous machine (PMSM) and stator electrically excited machine (SEEM), hence providing a new solution to magnetic field adjustment for conventional PMSM.

II. Selection and Integration Criterion

In recent years, the development of SEEM has become more and more attractive, including doubly salient machine (DSM), variable flux reluctance machine (VFRM), flux-switching machine (FSM) and so on. To reduce the flux linkage harmonics and iron loss, SEEM with sinusoidal flux linkage is relatively a better choice to be integrated with PMSM than that with single polarity biased flux linkage.

The proposed DR-PHEM can be regarded as an integration of an outer-rotor PMSM and an inner-rotor VFRM as shown in Fig.1. Two machines share a common stator yoke, and the outer rotor on which permanent magnets are arranged is mechanically connected with the inner salient pole rotor by an end disc to form an integral rotor, thus realizing the torque boosting effect and power composition. The winding coils of these two machines are cascaded together, which means two machines share one set of armature windings. The field windings are naturally wounded on the stator teeth of the inner VFRM without any use of brush or slip ring. With permanent magnets and field windings placed on the outer and inner side of stator yoke, respectively, the magnetic circuit of two machines is independent and parallel.

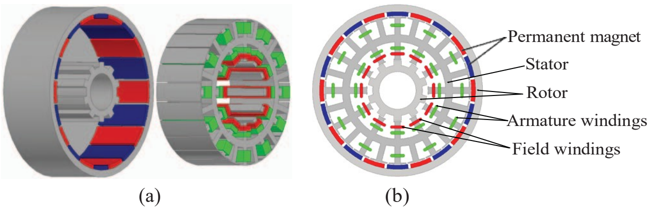

Fig.1. Structure of the proposed DR-PHEM. (a) Exploded view.(b) Front view

TABLE I
MOTOR PARAMETERS

Parameter	PMSM	VFRM
Stator pole number	24	12
Rotor Pole-pairs/Pole number	10	10
Air-gap length	0.6mm	0.5mm
Turn number of armature winding	30	40
Turn number of field winding	-	40
Outer rotor outer diameter	120mm	-
Inner rotor outer diameter	-	44mm
Stack length	40mm	40mm

To realize the effective electromagnetic integration for the proposed DR-PHEM, the flux linkage of outside and inner winding must keep synchronous in frequency to cascade two set of armature windings, thus the number of poles in the inner rotor must be equal to that of pole pairs in the outer PMs. Besides, the dimension of inner stator slot and outer stator slot should be discussed based on the tradeoff between field adjustment capability and output power density.

III. Performance Analysis

With the same dimensions in Table I, the performance of the proposed DR-PHEM is analyzed by using finite element method. As shown in Fig.2, it can be seen that the back EMF of the machine can be easily strengthened or weakened via a positive or negative field current, hence proving the validity of the theoretical analysis.

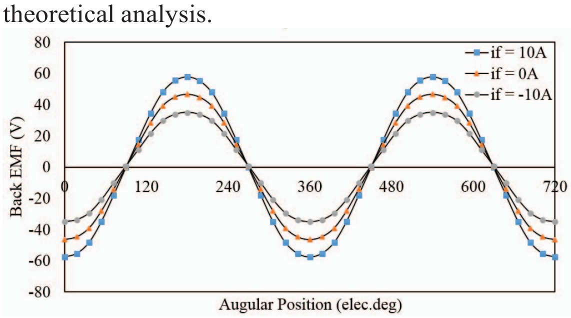

Fig.2. Back EMF of the proposed DR-PHEM with different field current.

References

[1] Y. Amara, L. Vido and M. Gabsi, *"Hybrid excitation synchronous machines: Energy-efficient solution for vehicles propulsion,"* IEEE Trans.Veh. Technol., vol. 58, no. 5, pp. 2137–2149, Jun. 2009.