A Novel Coreless Contra-Rotating Axial-Flux Machine for Wind Power Applications

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***Abstract*—This paper presents a novel coreless bidirectional axial-flux-modulation machine for direct-drive contra-rotating wind power generation. Different with the conventional axial flux wind generators, in the proposed machine, dual rotors rotate in the opposite directions and all permanent magnets (PM) with the same polarity are alternatively located with salient poles in rotors. With the bidirectional flux modulation effect, a high-speed rotating magnetic flux harmonic is produced in the air gap and interacts with the coreless windings to produce electricity. With this design, the induced frequency is enhanced and machine volume can be reduced. In addition, the coreless structure can reduce the iron loss. The electromagnetic performance of the proposed machine is analyzed by finite element method (FEM).**

***Index Terms*—contra-rotating, flux modulation, coreless, FEM**

I. Introduction

With the increasing concerns on energy and environment problems, how to efficiently absorb the wind energy has drawn more attention. Compared to the single rotor generators, contra-rotating wind power generators have an improved wind energy conversion efficiency.

In this paper, a novel coreless contra-rotating axial-flux machine (CCAM) is proposed. Based on the bidirectional flux modulation effect generated by two contra-rotating rotors, the design of armature windings can be simplified with fewer poles compared to the conventional direct-drive permanent magnet (PM) generator. In addition, with the coreless structure adopted, the iron loss is reduced. By integrating the merits of two popular concepts- flux modulation and coreless axial-flux machine, the proposed machine is very suitable for a direct-drive contra-rotating wind power generation.

II. Structure and Operating Principle

As shown in Fig.1, the proposed machine has a very compact structure which consists of two contra-rotating rotors and one set of armature windings. PMs and modulation steels are alternatively arranged on each rotor. One piece of PM and its adjacent modulation steel constitute one pole pair. There are 23 pole pairs on the left rotor and 21 pole pairs on the right rotor. The armature winding has 2 pole pairs. To reduce the iron losses, coreless armature windings are adopted and integrated into a printed circuit board to increase the air gap flux density.

With two contra-rotating rotors, there are two sets of modulation combinations in the proposed machine at the same time. Based on the bidirectional modulation theory, the relationship between the winding frequency and rotor speed could be written as:

$$f_1 = \frac{n_1 p_1 - n_2 p_2}{60} \quad (1)$$

where p_1 and p_2 are the number of pole pairs of the left rotor and right rotor, respectively. And n_1 are n_2 the rotational speed of the left rotor and right rotor, respectively. With two rotors rotating in opposite directions in the proposed machine, the winding frequency and voltage is enhanced, and also the wind energy conversion efficiency is improved.

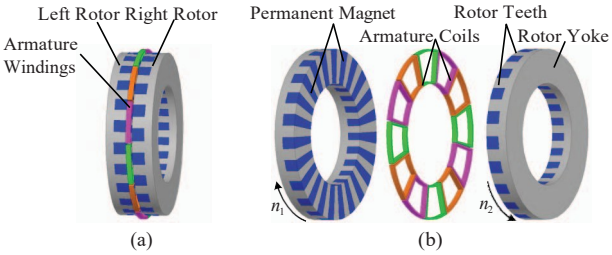

Fig.1. Structure of the proposed CCAM. (a) 3D View. (b) Exploded view.

III. Performance Analysis

Finite-element method (FEM) is engaged to analyze the electromagnetic performance of the proposed machine. Three different working conditions are studied. As shown in Fig.2 (a) when the left rotor rotates at 110 rpm and right rotor keeps still, the winding frequency and voltage is 42 Hz and 72 V, respectively. Similarly, Fig.2 (b) shows that when the left rotor keeps still and right rotor rotates at 90 rpm, the winding frequency and voltage is 30 Hz and 60 V, respectively. However, as shown in Fig.2 (c), when these two rotors contra-rotate at the same time, the winding frequency and voltage increase significantly to 73 Hz and 130 V, respectively, thus proving the validity of the theoretical analysis.

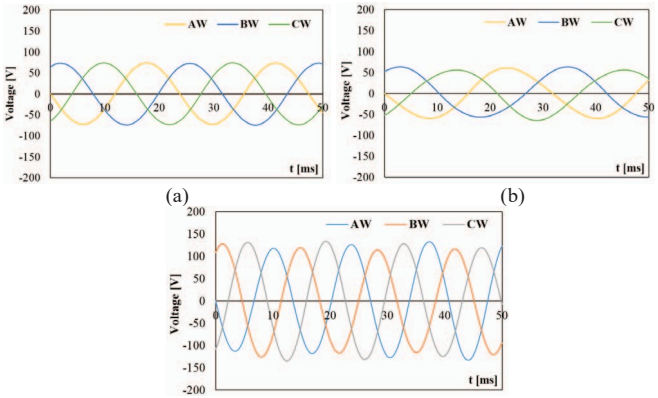

Fig.2. Induced EMF waveforms. (a) With left rotor at 110 rpm, right rotor 0rpm (b) With left rotor at 0 rpm, right rotor 90 rpm (c) With left rotor at 110 rpm, right rotor 90 rpm.

REFERENCES

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