HU-04

Development of a new brushless doubly-fed doubly-salient machine for wind power generation.

Y. Fan[1] and K. Chau[1]
1. The University of Hong Kong, Hong Kong, China

INTRODUCTION

With ever increasing concerns on energy crisis and environmental protection, the development of renewable energy resources has taken on an accelerated pace. Wind power is one of the most viable renewable energy resources, and its core element is the electric machine – the generator.

Conventional generators, such as the synchronous and induction ones, are mainly designed for constant-speed turbine operation so that they are inefficient or even ill-suited for variable-speed wind turbine operation. In[1], the doubly-salient permanent magnet (DSPM) machine, incorporating the structure of a switched reluctance (SR) machine and the use of PM material, was proposed for wind power generation. Although this DSPM generator offers the advantages of high power density and high robustness, it suffers from the drawbacks of high PM cost and uncontrollable flux. In[2], with the replacement of PMs in the DSPM motor by a DC field winding, the brushless-doubly-fed doubly-salient (BDFDS) motor was proposed for electric vehicles (EVs). It can offer the definite advantage of wide constant-power speed range for EV cruising. The purpose of this paper is to further extend this idea to wind power generation, namely development of BDFDS wind power generators.

METHOD

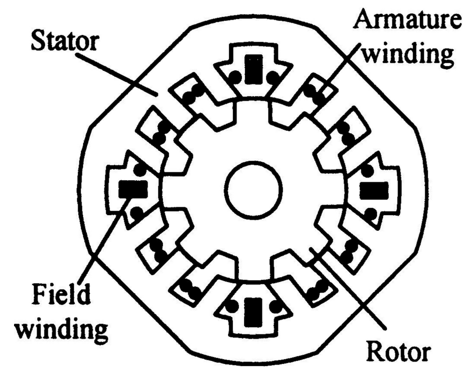
In this paper, a 3-phase BDFDS machine is specially designed for wind power application as shown in Fig. 1. It adopts the same structure as a SR machine, There are no windings or PMs on the rotor, whereas there are a poly phase armature winding and a DC field winding on the stator. The key is to optimize the combination of stator and rotor pole numbers, the coordination of stator armature and dc field windings, and the machine dimensions by using finite element analysis (FEA), Fig.2 shows the magnetic field distributions. Moreover, the machine static characteristics can be obtained. Furthermore, the newly designed 12/8-pole BDFDS machine is controlled in such a way that the output voltage can be maintained constant throughout the whole wind speed range. The key is to online tune the dc field winding current using self-tuning control so that the conversion efficiency is automatically optimized.

RESULTS

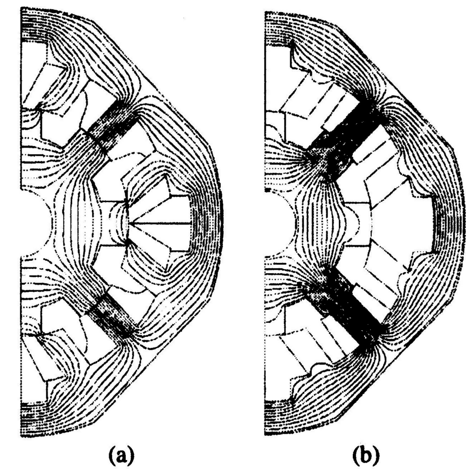
A 750-W prototype has been designed and built for experimentation. The simulated and measured no-load EMF waveforms at the rated speed are shown in Fig. 3, as expected, the agreement is very good. Also, the measured output voltage is very constant with insignificant ripples, verifying the FEA results. Furthermore, the machine efficiency characteristic at various field currents is measured as shown in Fig. 4. It confirms that the efficiency can be optimized by fine tuning the field current.

[1] K.T. Chau, Y. Fan and M. Cheng, "A novel three-phase doubly salient permanent magnet machine for wind power generation," IEEE Industry Applications Society Annual Meeting, 2004, pp. 366-372.

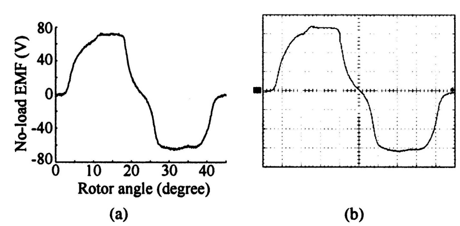
[2] K.T. Chau, M. Cheng and C.C. Chan, "Nonlinear magnetic circuit analysis for a novel stator-doubly-fed doubly-salient machine," IEEE Transactions on Magnetics, Vol. 38, No. 5, 2002, pp. 2382-2384.



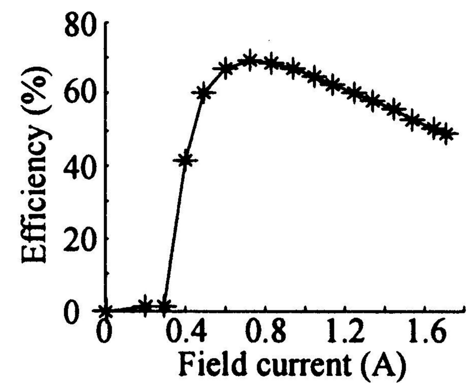
Proposed 3-phase 12/8-pole BDFDS machine



Magnetic field distributions. (a) Field current only. (b) Armature current only.



No-load EMF waveforms. (a) Simulated. (b) Measured (20 V/div, 500 us/div).



Measured efficiency characteristic at various field currents.