Research of a Novel Multidisk Axial Flux Compensated Pulsed Alternator

Xin Liang, Caoying Ye, Jiangtao Yang, Wei Xu, Fei Xiong, Wenhao Li, Yu Xiang

State Key Laboratory of Advanced Electromagnetic Engineering and Technology (AEEET), School of Electrical and Electronic Engineering (SEE), Huazhong University of Science and Technology (HUST), Wuhan, 430074, China

Introduction

The design purpose of multidisk axial flux compensated pulsated alternator (MACPA) mainly focus on reducing the subtransient reactance while discharging, which contributes to increasing discharging power. In detail, the compensated shield made in aluminum alloy helps decoupling the mutual-inductance among windings in different disks. By connecting the windings with little mutual-inductance in parallel, the purpose is achieved. In this paper, an equivalent electric circuit model is established to analyse the protective effect of compensated shield to PM and its electric-magnetic shield effect. In an analytical method, the effect of decreasing reactance by connecting windings in parallel is proved. A 0.8MW MACPA in Finite Element Method (FEM) is built and simulated.

Objectives

- Establish an equivalent electric circuit model to analyse the protective effect of compensated shield to PM and its electric-magnetic shield effect.
- Prove the effect of decreasing reactance by connecting windings in parallel is proved. In an analytical method.
- Establish models of single-disk and multidisk axial flux CPA in Finite Element Method (FEM), and compare the performance of them.

Effect of compensated shield

The equivalent electrical circuit model of single winding and single compensated shield is introduced as Fig.1. In the circuit model, L1 and L2 represent the inductance of one phase winding and compensated shield respectively. And B represents the mutual inductance between them. To simulate a common condition in CPA while discharging, current i(t) is half-sinusoidal pulse.

Analytical expressions

In Fig.1, it shows the effect on flux density behind compensated shield. The wave of flux density in the condition with the shield consist of a sinusoidal component and an exponential component, which is proved by analytical equations. The differences of flux density compensated shield will be divided into two effects. The one is that it decreases the slope of flux density, and the other is that it decreases the flux density magnitude. So from equation (5), it can be seen that lower conductance in compensated shield and higher current frequency leads to less demagnetization to PM, while M and L is decided by the shape of the shield which is usually cannot be changed.

Equivalent model

To analyse the effect of compensated shield on decreasing mutual inductance between two armature windings, an equivalent electrical circuit model of two windings and one shield sandwiched between them is established, as Fig.6 shows. Symbol Li, L1 and L2 represent the inductances of winding A, winding B and the compensated shield between windings respectively. Symbol M denotes the mutual inductance among them.

Analytical expressions

The coupling coefficient of the mutual inductions is introduced, as equations (11) shows. So the equivalent mutual inductance can be simplified as equation (12). The coupling coefficient k is decided by armature windings A and B while the parameter k2 varies with compensated shield.

Conclusion

- The wave of flux density in the condition with the shield consist of a sinusoidal component and an exponential component. The compensated shield decreases the slope and magnitude of flux density in permanent magnet (PM).
- The flux magnitude in PM is reduced to compensate shielded displacement and discharge current frequency.
- The existence of compensated shield helps decreasing the mutual inductance between the two windings next to the shield, and what extent mutual inductance can be decreased is decided by the value of k1 and k2, where k1 and k2 is coupling coefficient of the mutual inductions.
- The mean value of discharge current with load is 8.45kA, the peak power is 0.66MW, the width of pulse is 2.7ms and the energy released is 1.04kJ, where the resistance and inductance of load discharged to is 5Ω, 1μH respectively.

Results

The structure of MACPA is shown in Fig.1 which mainly consists of four stators and five rotors. The stators, sandwiched between rotors, are made of epoxy resin with armature winding in it. In each stator, the armature winding has 2 layers with 2 phase windings in each layer. The phase windings, in the same electrical angle in different stators are connected in parallel. As for rotors, they consist of PM, aluminum alloy frame and compensated shield. The compensated shield is also made in aluminum alloy which is used to compensate armature winding while discharging. The PMs, used for establishing air-gap field, are magnetized in the direction of shaft. The magnetization directions of PMs next to each other in the same rotor are in opposite.

Analytical expressions

Table I: Parameters and Performance of MACPA

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Single-disk machine</th>
<th>Multi-disk machine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Outer diameter of PM</td>
<td>115mm</td>
<td>230mm</td>
</tr>
<tr>
<td>Number of phases</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Inner diameter of PM</td>
<td>115mm</td>
<td>230mm</td>
</tr>
<tr>
<td>Rotor speed</td>
<td>1050rpm</td>
<td>750rpm</td>
</tr>
<tr>
<td>Amplitude of flux density</td>
<td>0.9T</td>
<td>0.6T</td>
</tr>
<tr>
<td>Peak current of discharge current</td>
<td>11.5kA</td>
<td>11.5kA</td>
</tr>
<tr>
<td>Peak power of discharge current</td>
<td>0.66MW</td>
<td>0.66MW</td>
</tr>
<tr>
<td>Energy released in one discharge</td>
<td>1.04kJ</td>
<td>1.04kJ</td>
</tr>
<tr>
<td>Width of pulse</td>
<td>2.7ms</td>
<td>2.7ms</td>
</tr>
</tbody>
</table>

The inner subtransient reactance is 29Ω and 10Ω for single-disk machine and multi-disk machine respectively. In addition, the volume of single-disk machine is 2.3 times larger than the single-disk one, while the short discharging current is 3 time larger.

The detail parameters and performance of MACPA are listed in Table I. The discharging current on load is shown in Fig.10, from which it can be seen that the mean value of current is 8.45kA, the peak power is 0.66MW, the width of pulse is 2.7ms and the energy released is 1.04kJ.

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