Abstract

For HTS conventional synchronous generator, the SC field windings or armature windings are rotating, which could complicate their industrial feasibility for the offshore wind generation. In order to overcome this drawback, a kind of HTS double-stator flux modulation generator (HTS-DSFMG) without rotating windings is proposed. This paper compares the electromagnetic performance of 10-MW HTS double-stator flux modulation generators with two different topologies, i.e., iron-cored stators with both field and armature coils and air-cored stator with filed windings and iron-cored stator with armature windings. In addition, the system comparison of HTS-DSFMG with conventional synchronous machine is conducted. The objective is to intensive study the advantages and disadvantages of HTS-DSFMG with different topologies, and to establish some design guidelines for HTS double-stator flux modulation generator without rotating windings.

Comparison of Electromagnetic Performance of 10-MW HTS Double-Stator Flux Modulation Generators With Different Topologies for Offshore Direct-Drive Wind Turbines

Yi Cheng¹, Yuanzhi Zhang¹, Ronghai Qu¹, Qian Wang¹

1. College of Electrical and Electronic Engineering, Huazhong University of Science and Technology

Topography introduction

Operating current of SC

Mass & Cost comparison

Magnetic loading

Operating current of SC coils for four model

Fig. 1. 2D model of DSFMG
Fig. 2. The structure of cryostat
Fig. 3. 3D exploded model of DSFMG
Fig. 4. Simulation model. M2 and M4 are conventional synchronous machine. The gray and white indicate the magnetic and non-magnetic material respectively.

Fig. 5. No-load flux density in the air-gap (close the armature.
Magnetic loading = B_{magnetic loading} \cdot \text{Pole ratio}. For DSFMG, pole ratio is 2.5 while the pole ratio of synchronous machine is 1.
For M1 and M3, Magnetic loading = 0.715 \times 2.5 = 1.79 T;
For M2 and M4, Magnetic loading = 1.6 \times 1 = 1.6 T.
Therefore, the four models almost have the same magnetic loading.

Fig. 6. Flux density distribution of M1 and M3 at the 1.8 T magnetic loading.

Fig. 7. Operating current of SC coils for four model
Fig. 8. No-load back EMF

Fig. 9. Mass comparison
Fig. 10. Cost comparison

Parameter

<table>
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<tr>
<th>M1</th>
<th>M2</th>
<th>M3</th>
<th>M4</th>
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<tr>
<td>Number of phase</td>
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<td>3</td>
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<tr>
<td>Output power [MW]</td>
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<tr>
<td>Efficiency</td>
<td>95%</td>
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<td>Rated revolution [rpm]</td>
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<td>Outer Stator diameter [m]</td>
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<td>Active stack length [m]</td>
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<td>SC operating current [A]</td>
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<td>150</td>
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Fig. 11. Symmetrical three-phase short circuit performance comparison

The short-circuit performance of DSFMG is better than conventional synchronous machine.

Conclusion

The active material cost of iron-cored rotor topologies is less 2 million dollar while the cost of air-cored rotor one may exceed 15 million dollar. Due to the high cost of SC nowadays, the iron-cored stator and rotor topology is preferable to commercialize. For DSFMG, Due to the stationary armature and field windings, no brush, slip ring and rotating excitation equipment are required, which can obviously improve the reliability of the topology. Besides, the short-circuit performance of DSFMG is better than conventional synchronous machine. Therefore, the iron-cored stator and rotor HTS double-stator flux modulation generator is a potential candidate for offshore wind direct drive generator in the future.