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Design and comparative analysis of geared and gearless type 2 MW HTS wind power generators

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Abstract. This paper covers the design and characteristics of 2MW high temperature superconducting (HTS) wind generators according to geared and gearless types. The 2MW HTS generator is designed based on the electromagnetic analysis results obtained by 3D finite element method. The total length, volume and weight of the HTS wires of the designed 2MW HTS generator were compared. As a result, the HTS wire length of a geared HTS generator is about 95.2% less than that of a gearless HTS generator. Also, the weight of a geared HTS generator excluding the gearbox is 90.35% lighter than a gearless HTS generator. However, considering the mechanical reliability and weight of the gearbox used with the geared generator, as well as the structural simplicity of the gearless HTS wind generator, a gearless generator can be advantageous. The analysis results can be effectively used to design HTS wind generators with or without gearbox.

Keywords; Super conductor, wind turbine, geared and gearless, FEM

1. Introduction

Recently, wind power is considered one of the major renewable energy sources. Re searchers are working to increase the economics and electrical efficiency of wind gene rators by developing wind turbines with larger capacity, smaller size, and lighter weig ht. Superconducting wind power generators have been proposed because they are smal ler, lighter and more efficient than conventional generators [1], [2]. Various drivetrain s have been developed to effectively transfer energy from wind turbines to generators. The drive train affects the structure, mechanical reliability and efficiency of the gener

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ator. Therefore, a comprehensive study on the structure and electrical efficiency of a wind power generation system using a superconducting synchronous generator according to a gear box (geared or gearless) is required [3]. This paper deals with the design and characterization of 2 MW high temperature superconducting (HTS) wind generators according to geared and gearless types. The 2 MW HTS generator is designed based on the results of electromagnetic analysis obtained by 3D finite element method (FEM). The total length of HTS wires was compared to the weight of the designed 2 MW HTS generator.

2. Design of a 2 MW class HTS wind power generator

A. Detail design of a 2 MW class HTS wind turbine

The rated wind speed of the 2 MW class HTS wind turbine was chosen to be 11.2 m/s. The maximum power factor is 0.48 and the tip speed ratio is 8.1. The blade length and rotational speed of a 2 MW wind turbine are calculated by equations (1) and (2). Table 1 summarizes the design specifications of the 2 MW class HTS wind turbine.

$$R = \sqrt{\frac{2P}{C_p \rho \pi v^3}} \tag{1}$$

$$\lambda = \frac{R\omega}{v} \tag{2}$$

Table 1. Specification of the 2 MW class HTS wind turbine

Item	Value	Item	Value
Rated power(P)	2.1 MW	Rated rotation speed(ω)	2.26 rad/s
Rotor radius(R)	40.23 m	Rated wind velocity(v)	11.2 m/s
Tip-speed ratio(λ)	8.1	Max. power coef.(C_p)	0.48

B. Desgn of 2 MW gearless and geared type HTS generator

The structure of a 2 MW class HTS generator is shown in Figure 1. 2 MW class gearless HTS generator is composed of HTS coil and rotor body, cryostat, stator coil and stator body. The rotor body, the cryostat, is made of SUS304, which exhibits low temperature brittleness in a cryogenic environment. The stator body is made of M-27 24 Ga, which can change the magnetic path. Table 2 shows the material and mass density of each component of a 2 MW class HTS generator. The difference between gearless type and geared type is with and without gearbox. The gearbox gear ratio of the commercialized 2 MW geared wind generator is widely used as 75~135. In this paper, the gear

ratio of a geared wind generator is 1:84. To reduce the weight of the deceleration gen erator, the rated speed of the generator is designed to be 1800 rpm. Table 3 shows the specifications of 2 MW gearless and geared HTS generators.

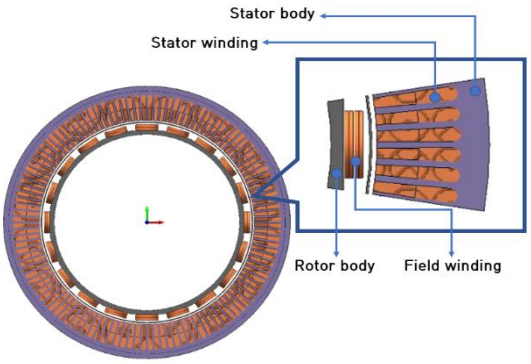

Fig. 1 Configuration of the 2 MW HTS generator

Table 2. The material and mass density of each component of the 2 MW class HTS generator

Part	**Material**	**Density(kg/m^3)**
Rotor body	SUS304	8,190
Rotor wire	YBCO	7,877
Cryostat	SUS304	8,190
Stator wire	Copper	8,940
Stator body	M-27 24 Ga	7,650

Table 3. Specification of the 2 MW gearless type HTS generator and geared type HTS generator

Specifications	**Gearless type**	**Geared type**
Rated output power	2.1 MW	2.1 MW
Rated line-to-line voltage	3,300 V	3,300 V
Rated armature current	367 A	367 A
Rated rotation speed(rpm)	21.53	1800
Rated torque	0.93 MN·m	9.94 N·m
Operating temperature	30 K	30 K
Number of rotor poles	20 ea	4 ea

3. Comparative analysis of FEM results of the 2 MW class HTS wind power generator

The magnetic field analysis of the 2 MW gearless and geared type HTS generator ar e shown in Fig 2 and 3. Table 4 shows the results of comparison between the weights of the HTS coil and the rotor body, the cryostat, the stator coil and the stator body, and the HTS wire length of the gearless and geared types.

Table. 4 Weight and HTS wire length of the 2 MW gearless and geared type HTS generator

Part	Gearless type	Geared type
HTS coil	1.34 ton	0.06 ton
Rotor body	2.94 ton	0.12 ton
Cryostat	0.99 ton	0.05 ton
Stator coil	8.57 ton	0.85 ton
Stator body	11.04 ton	1.32 ton
Total weight	24.88 ton	2.4 ton
HTS wire length	53.65 km	2.6 km

The total weight of the gearless HTS generator is 24.88 tons, and the weight of the s tator coil and body make up 79% of the total weight. The total weight of a geared HTS generator is about 9.65% compared to the weight of a gearless HTS generator. In addi tion, the HTS wire length of a geared HTS generator is 2.6 km, which consumes about 95.2% less than a gearless HTS generator.

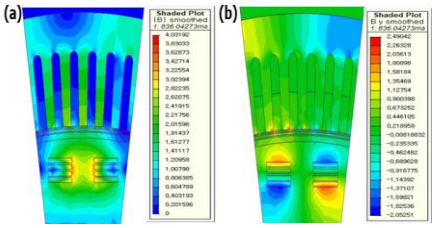

Fig. 2 (a) Maximum and (b) perpendicular magnetic fields of the gearless HTS generator

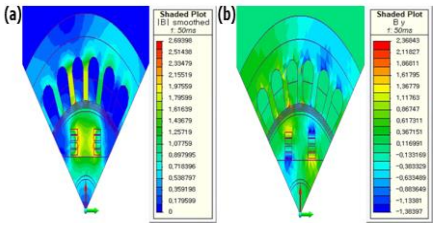

Fig.3 (a) Maximum and (b) perpendicular magnetic fields of the geared HTS generator

4. Conclusion

In this paper, a 2 MW class HTS generator for wind power generation was designed in consideration of two driving methods. Considering only the HTS generator, the geared HTS generator has a smaller weight and consists of HTS wire, which makes it look more attractive than a gearless HTS generator. However, considering the mechanical reliability and weight of the gearbox used with the geared generator, as well as the structural simplicity of the gearless HTS wind generator, a gearless generator can be advantageous. These results will help you choose an appropriate drive method when designing a 2 MW class HTS wind generator, taking into account the weight and total length of the HTS wire.

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