ELECTRODYNAMIC LEVITATION EFFECT IN VERTICAL HTSC ALTERNATORS WITH AXIAL MAGNETIC FLUX

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Abstract. Vertical electrical alternators with axial magnetic flux and disc geometry of the rotor and the stator are characterized by the presence of electrodynamic force, which is acting perpendicular to the active zone elements. It depends mainly on the load angle value, magnetic flux density in the air-gap and armature current value. The presence of this force is to be accounted for during the alternator development and testing.

1. Introduction

Electrodynamic levitation in electrical alternators is based on the processes in the active zone and electromagnetic fields in the air gap. The idea of electrodynamic levitation in linear motors for trains was first discussed in [1, 2]. In [3] theoretical investigations were confirmed by experiments on a disc motor. Several years of our experimental investigation of HTSC vertical disc generators and motors shows the presence of this effect in electrical alternators with axial magnetic flux.

2. Bases of electrodynamic levitation effect

Cross-section of the disc alternator with two HTSC solenoidal armature windings positioned on both sides of the rotor with circular permanent magnets is presented in Fig. 1 and shows the levitation zone of the rotor. It represents two air-gaps between the rotor and two armatures. The 3-phase HTSC armature windings are settled on a cylindrical magnetic core of metallic glass tape. The rotor of the generator is fixed on a shaft, but presented below are general positions of its possible levitation in the air gap.

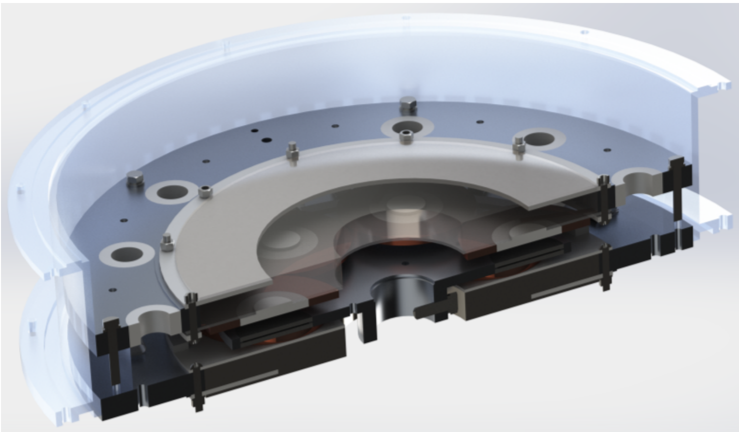

Fig.1. Presentation of the rotor levitation zone

The rotor electrodynamic levitation effect in disc alternators appears with the load angle δ. It equals zero in the no-load mode. The load angle δ depends on the armature synchronous reactance. Its maximum corresponds to $\delta = 90^0$, but from the point of view of stability synchronous alternators do not operate with the limiting load angle [4].

The density of electromagnetic forces influenced by electromagnetic fields of the alternator is determined as

$$\mathbf{f} = [\mathbf{jB}], \tag{1}$$

where j – vector of current density, B – vector of magnetic flux density.

The value of electromagnetic force Fem depends on the value and the rate of deformation of electromagnetic field in the air-gap. The latter is dependent on the load angle. The components of electromagnetic force, acting perpendicular to the air-gap F_{emx} and along it F_{emy} equal:

$$F_{emx} = iw\int_0^l B_{\delta y} dl \,, \tag{2}$$

$$F_{emy} = iw\int_0^l B_{\delta x} dl \,,$$

where i – armature winding current, w – number of turns in the armature winding, $B_{\delta x}$, $B_{\delta y}$ – components of the total magnetic flux density in the air-gap, l – armature winding coil length.

Components of magnetic flux density are determined as:

$$B_{\delta x} = B_{\delta} \sin\delta \,, \qquad (3)$$
$$B_{\delta y} = B_{\delta} \cos\delta \,.$$

where B_{δ} is the sum of the rotor and stator magnetic fields under load.

3. Results of magnetic field and levitation force modeling

To calculate the levitation force of the rotor, a full-scale model of synchronous electrical alternator (the ELCUT software) was performed, the parameters of the model blocks were set, accounting for the real properties of the materials used, such as high-coercive permanent magnets, HTSC, metallic glass, etc. The finite element mesh was optimized to reduce the error of the calculations. The element of the involute of the active zone with calculation results is presented in Fig.2.

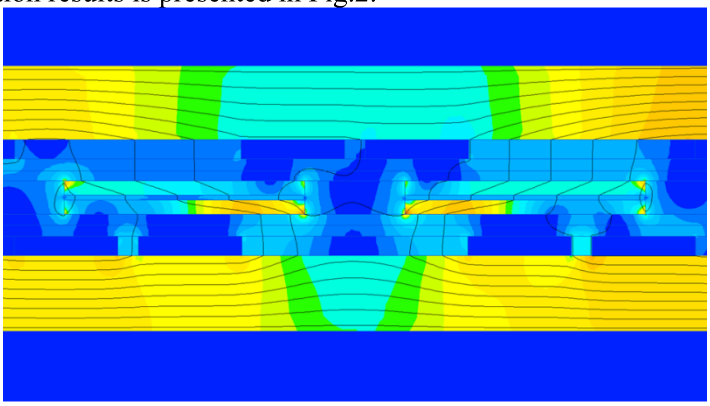

Fig.3. Magnetic field modeling of the levitation zone

Conclusions

- Electrodynamic levitation effect in electrical alternators with HTSC armature winding, high magnetomotive force of the armature and big load angle may cause problems during assembly and balancing processes. But it also opens way to an interesting version of electrical machine with a levitating rotor.

References

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