Design and Analysis of a Hybrid Field Modulated Linear Generator for wave energy conversion

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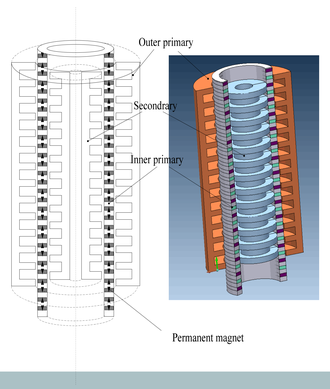
Introduction

The direct-drive wave energy converter (DD-WEC) system, using linear generator, are widely used for wave energy converter (WEC) . Linear generator is the main reach point of the DD-WEC. There are many linear generators have been investigated for DD-WEC. However, at the low direct-drive speed, how to increase the power density of the linear generator is the main objective of the researchers . Therefore, there are many linear generators have been investigated for DD-WEC. To solve the problem, a hybrid field modulated linear generator is proposed in this paper. Field modulated design can be increase the out put voltage and power density of the linear generator. The hybrid excited field coil can be used to adapt to the different wave situation and effectively improve the output performance of this kind of generators. Firstly, the proposed linear generator and operation principle are introduced. Secondly, the generator are designed and analyzed. The performance including cogging fore, output voltage and voltage regulation factor is obtained by using the transient FEM.

Conclusion

- Field Modulated effect can increase the output voltage successful
- Series magnetic circuit is useful to increase the output voltage and reduce the cogging force and harmonic component of voltage.
- Hybrid field excitation increase the output power and reduce the voltage regulation ratio of the proposed generator.
- All the results shows this kind of generator is well suit for wave energy conversion.

Operation principle



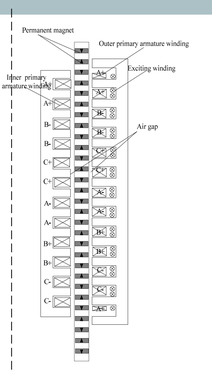
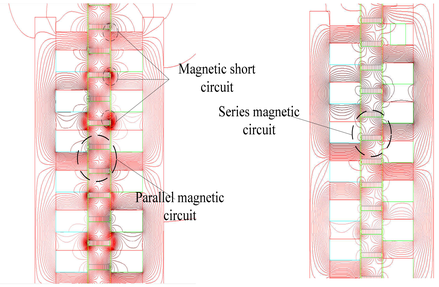


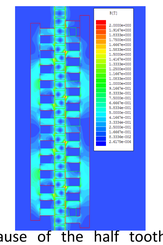
Figure shows the structure of the proposed hybrid field modulated linear generator. the proposed generator has two stators, the inner and outer primaries of the generator. The mover is the secondary of the generator and is connected with the heaving buoy. There is half tooth pitch shift between the teeth of inner and the outer primary. The axially magnetized permanent magnets are employed in the proposed generator to increase the flux linkage in the primary, to simplify magnetized method and to reduce cost. To obtain field modulated effect, the numbers of secondary pole pairs, the equal primary teach and primary armature field pole pairs should as follows

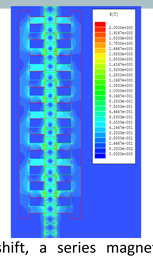
$$N_t = P_s + P_p \quad (1)$$

where P_s is secondary pole pairs number, P_p field pole pairs, N_t is equal primary teach number.

Series magnetic circuit

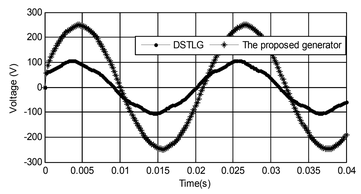




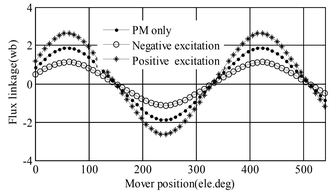


Because of the half tooth pitch shift, a series magnetic circuit between inner and outer primaries. To show the proposed generator, a typical double-sides field modulated tubular linear generator without half tooth pitch shift is compared with the proposed one。As shown in the by using half tooth pitch shift and end teeth optimized design, the magnetic circuit of the proposed is series magnetic circuit, and magnetic short circuit can be reduced significantly.

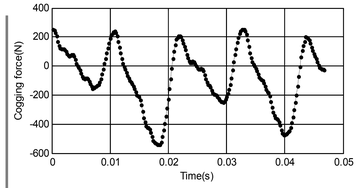
Performance analysis



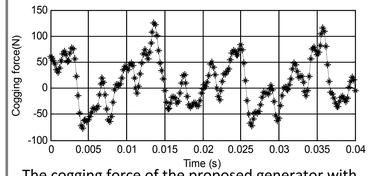
The proposed generator has higher output voltage and flux linkage. It is magnetic short circuit of the proposed generator is reduced. In addition, by using the design of half tooth pitch shift, the harmonic components can be compensated in inner and outer primary.



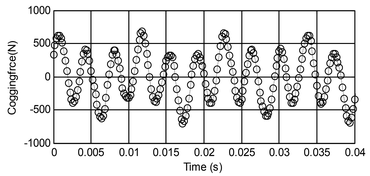
No-Load performance



The cogging force of the proposed generator without end teeth optimization



The cogging force of the proposed generator with end teeth optimization

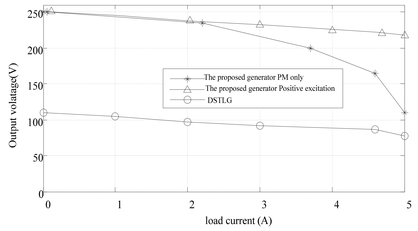


The cogging force of DSTLG.

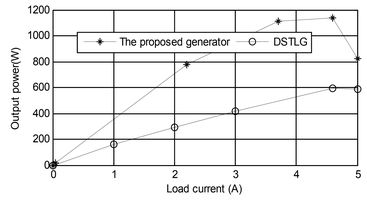
As we can see, the cogging force of the proposed generator much less than the cogging force of double-sides field modulated linear generator. The slot effect component is reduced for the compensation between inner and outer tooth shift, and the end cogging force component is reduced by using two end teeth of outer primary.

On-Load performance

The performances of the generator, with three-phase symmetrical resistance load, are determined by using a 2-D transient FEM on the speed of 0.6m/s. the output voltage and output power under different load current are obtained and shown



The output voltage



The output power

From the output voltage and power, it can be seen the proposed generator has higher output voltage and output power. The max output power of two generators is about 1100W and 600W, respectively. However, only PM excitation, the voltage regulation ratio of the proposed is slightly more than the voltage regulation ratio of the DSTLG. Under positive excitation, this problem can be resolved.

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