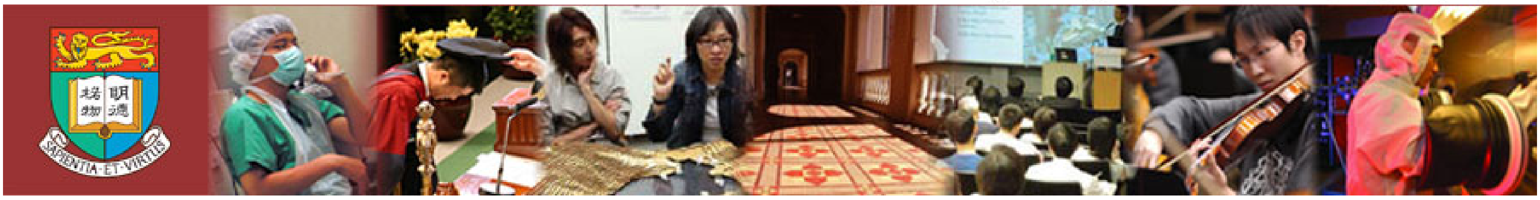

BP-09

A Low-Speed Linear Harmonic Generator for Grid-Tied and Stand-Alone Operation using Hybrid Excitation Topology.

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1. Introduction

Since intermediate mechanical conversion mechanisms for speed, torque and motion conversion can be entirely eliminated, the direct-drive wave power generation attracts more and more attention [1]. Among various proposed generators, the permanent-magnet (PM) vernier generator is considered as a viable solution for the wave energy harvesting. This generator can efficiently harness this low-speed and high-power energy source via a so-called vernier effect by utilizing the effective harmonic magnetic field [2]. However, since only PMs are engaged for field excitation and the harmonic magnetic field is adopted, it is incapable to provide a flexible voltage control and power factor improvement. Moreover, the voltage regulation is incredible high. The purpose of this paper is to design a linear harmonic generator for producing electricity in a wave farm. Except for the PM excitation, the proposed generator is equipped with a set of DC field winding for the hybrid excitation. With this merit, the proposed generator exhibits a satisfactory performance for voltage regulation and power factor improvement which is desirable for both grid-tied and stand-alone operation [3].

2. Proposed Linear Generator

Fig. 1 (a) shows the proposed low-speed linear harmonic generator using hybrid excitation topology. Due to the low-speed operation, PMs which usually adopt a large pair-pole number are surface-mounted on the mover. The stator adopts the split-pole configuration where one stator tooth is split into four auxiliary teeth. With the auxiliary teeth, the magnetic field can be modulated into an effective harmonic field. With interaction with magnetic field provided by PMs, the high thrust and low speed operation can be achieved. Since the pole-pair number of the PMs is large and little space is for accommodating the field winding, it is not practical to use one field coil for one PM segment as proposed in [4]. Therefore, a parallel hybrid excitation topology is adopted: its stator consists of a pair of the similar stator teeth which are coupled together by the stator yoke and the DC field winding is accommodated at the stator yoke between the stator pair. Correspondingly, the mover is also mounted with two groups of PMs with interleaved iron poles are mounted on the mover. PMs have the same magnetization direction in the same group and the opposite magnetization direction in the different group. There are mainly two flux paths in the proposed linear generator: one is the flux generated by PMs which passes PM pieces, rotor yoke, stator teeth and stator yoke as shown in Fig. 1(b) and one is the flux produced by DC field winding which passes iron poles, rotor yoke, stator teeth and stator yoke as shown in Fig. 1(b). Due to the parallel hybrid excitation topology, PMs are also immune for demagnetization to the faulty operation of DC field excitation.

3. Analysis

By using 3-D finite element method, the electromagnetic performances of the proposed linear generator can be assessed. Fig. 2(a) and 2(b) depicts air-gap flux density waveforms when the DC field winding performs flux strengthening and flux weakening operation. As shown in Fig. 2(a) and 2(b), it is obvious that for the flux strengthening operation, the iron poles are magnetized into the same polarity as that of its adjacent magnet which increases the flux linkage of the armature winding; for the flux weakening operation, the iron poles are magnetized into the opposite polarity which reduces the flux linkage in the armature winding. Fig. 2(c) and 2(d) shows the flux control capability for performing the voltage control and reducing the voltage regulation. As illustrates in Fig. 2(c), the induced voltage can be continuously adjusted by controlling the air-gap flux density. By the air-gap flux control, a range of 8 times voltage control in terms of amplitude can be realized. Consequently, the voltage regulation can be reduced due to the load fluctuation. As shown in Fig. 2(d), due to the flux strengthening, a reduced voltage regulation of 18% is resulted compared to a voltage regulation of 80% without flux control. This is especially desirable for grid-tied operation in the wave farm system which can enhance the power system stabilization. The detailed design, analysis, control and experimental verification will be presented in the full paper. This work was supported in part by a grant (Project No. MYRG067(Y1-L2)-FST13-CTW) from Research Council of the University of Macau, Macao Special Administrative Region and a grant (Project No. HKU710711E) from The University of Hong Kong, Hong Kong.

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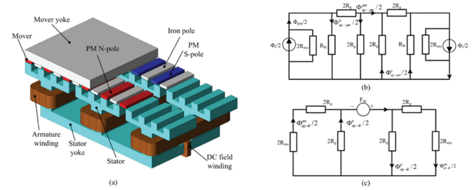

Fig. 1. Proposed linear generator. (a) Topology. (b) PM flux path. (c) DC field flux path.

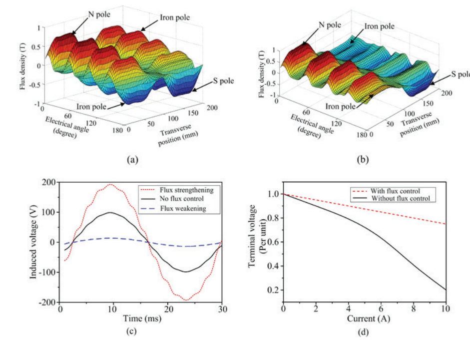

Fig.2 Proposed linear generator characteristics. (a) Air-gap flux density under flux strengthening. (b) Air-gap flux density under flux weakening. (c) Voltage control. (d) Voltage regulation improvement.