P M TUBULAR LINEAR SYNCHRONOUS GENERATOR FOR WAVE ENERGY CONVERSION

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REZUMAT. Lucrarea de faţă prezintă un generator sincron cu magneţi permanenţi de tip tubular cu deplasare liniară pentru exploatarea energiei valurilor. Modelul propus este studiat prin realizarea unor simulări 3D cu ajutorul MEF. Rezultatele preliminare obţinute sunt analizate în contextul parametrilor de lucru impuşi de această aplicaţie.

Cuvinte cheie: generator sincron, magnet permanent, metoda elementului finit.

ABSTRACT. A permanent magnet tubular linear synchronous generator for wave energy conversion is presented in this paper. The proposed model is analysed by 3D FEM simulation and preliminary results are descussed taking into account the working conditions imposed by its application.

Keywords: finite element methods, permanent magnet, synchronous generatort.

1. INTRODUCTION

Finding alternative reneweable and environmental friendly energy sources was not such a challenge as making them profitable is. It is well known that one of the major problems in extracting renewable sources energy is the production costs that are significantly higher compared to the classic technologies based on fossil fuels. But the limited nature of these fuels and the pollution issue led the scientific research to improve performance of electromagnetic conversion systems and to adapt new technology to the renewable power sources such as wind or wave power, water-current power, bio-fuelled plants and conventional hydropower.[1]

Wave power is one of the renewable energy source with huge potential (world's oceans available energy is estimated to be between 200 and 5000 GW – comparable to hydro power potential) but insufficiently exploited, because of the extreme conditions that oceans have to offer (wave power devices are exposed to salt water, biological growth and sometimes very rough wave conditions).[2]

Even so, wave energy remains interesting for it has the highest energy density among all renewable energy sources and it is available allmost 90% of the time, much more than solar and wind power are.[3]

2. LINEAR SYNCHRONOUS GENERATORS IN WAVE ENERGY CONVERSION

Different principles are applied in wave energy conversion systems, most known using:

- oscillating water columns with air turbines that drive rotating generators,

- overtopping devices having hydro turbines that drive rotating generators,
- hinged contour devices that use hydraulic power take off systems,
- buoyant moored devices with linear generator systems.[4]

The concept took into consideration for this paper refers to a direct driven tubular permanent magnet synchronous generator with linear displacement, placed on the ocean floor, connected to a surface buoy (point absorber). Such electromagnetic conversion systems are characterized by high forces and low speed (about 1 m/s).[5]

Other particular aspects that must not be neglected refers to the irregular oscillating waves motion, which translates into variable induced voltage amplitude and frequency, and the solutions that can be adopted for power grid conection. [6]

3. PM TUBULAR LINEAR SYNCHRONOUS GENERATOR ARCHITECTURE

The proposed model is a permanent magnet linear synchronous generator with a tubular shape (Fig. 1). The spoked Ferrites magnets are placed in alternating polarity allong the inner fixed armature, while the external translating armature hosts the three-phase winding which is made of concentrated coils (Fig. 2).

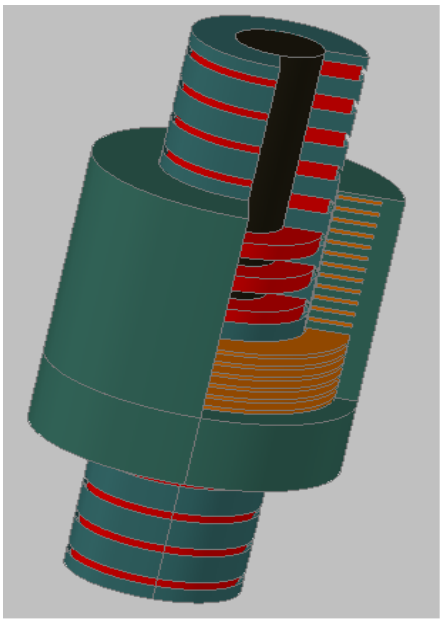

Fig. 1. Tubular linear permanent magnet synchronous generator.

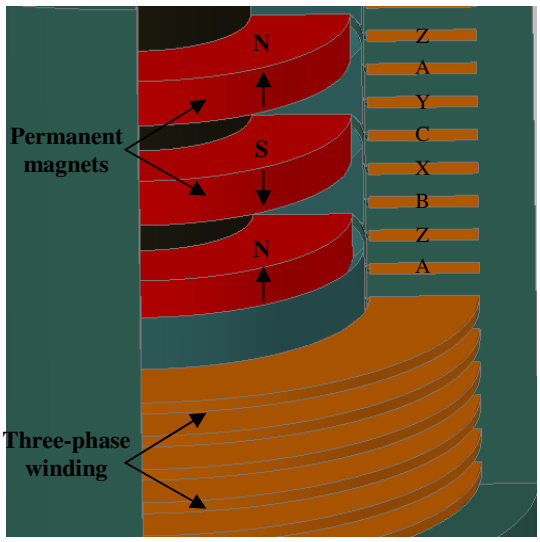

Fig. 2. Constructive detail.

Main geometrical dimensions are presented into Table 1.

Table 1. **Main geometrical dimensions of the machine.**

Componente	Dimension
Axial length of the fixed armature	1440 mm
Inner diameter of the fixed armature	200 mm
Outer diameter of the fixed armature	396 mm
Fixed armature teeth height	98 mm
Fixed armature teeth width	50 mm
Poles number	16/8
Permanent magnet inner diameter	200 mm
Permanent magnet outer diameter	376 mm
Permanent magnet thickness	40 mm
Axial length of the translating armature	770 mm
Inner diameter of the translating armature	400 mm
Outer diameter of the translating armature	700 mm
Translating armature teeth height	100 mm
Translating armature teeth width	20 mm
Translating yoke thickness	50 mm
Number of slots	24
Number of slots/pole/phase	1
Air gap thickness	2 mm

For this design it would have been easear if the external armature which hosts the three-phase winding was fixed and the inner permanent magnet component mobile. However this would have lead to an increased dimension (almost double) of the housing that would protect the machine from the environmental condition (sea water).

3. SIMULATION RESULTS

For the proposed permanent magnet tubular linear synchronous generator study a 3D FEM based simulation has been performed. In order to reduce the computation time all three planes of symmetry (YZ – ZX – XY) were used. Consequently, only 1/8 of the machine has been modeled.

After building the geometry of the machine (Fig. 3), assigning the material properties and generating the mesh, the equivalent electric circuit has been coupled. The solving scenario consists in a transient magnetic simulation for a translating motion of 0.5 m/s.

Fig. 4 shows the magnetic induction color shade and the magnetic field orientation harrows for one of the computation time step.

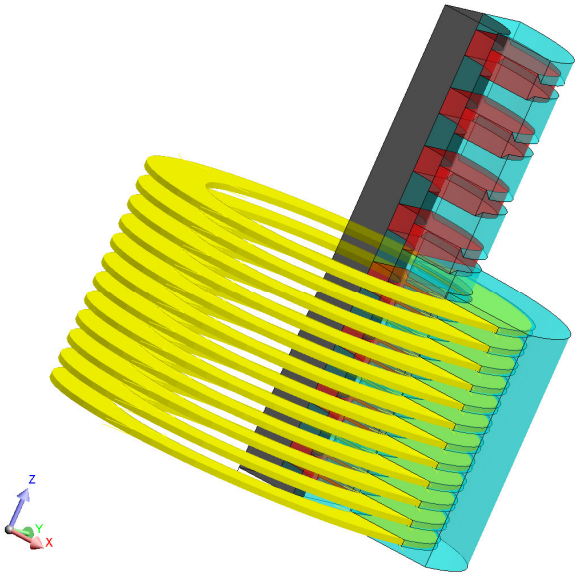

Fig. 3. 3D model of the machine.

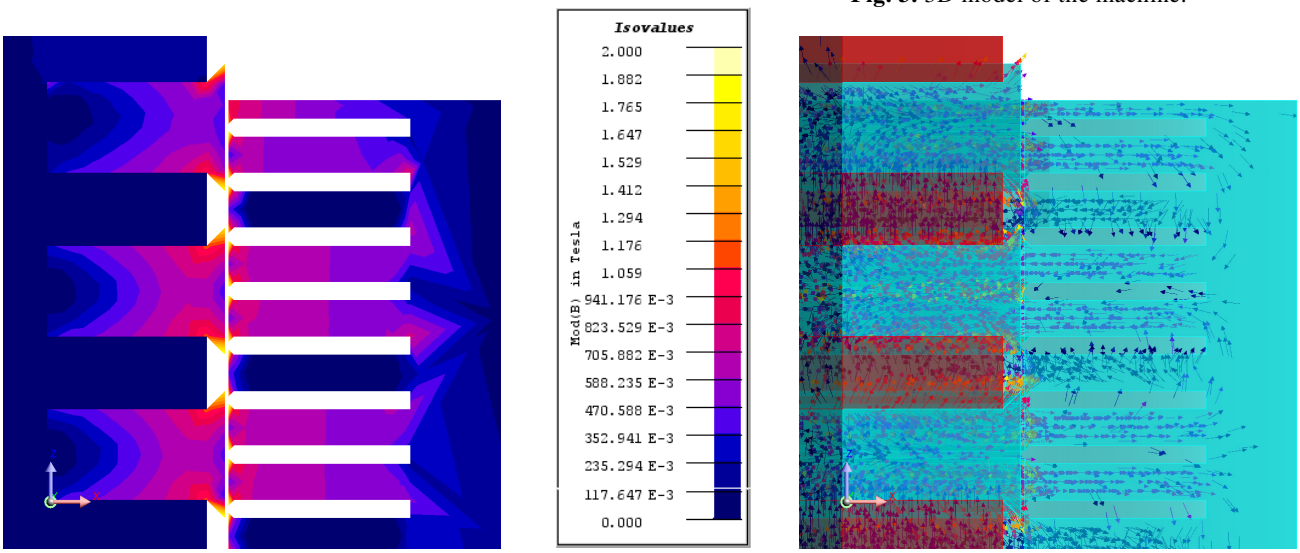

Fig. 4. Magnetic color shade and harrows.

The induced three-phase line voltage is presented in Fig. 5. Some unsymmetries between phases can be spoted. A plausible cause of that may be the end effect of the magnetic circuit. It can be also noticed that the voltage wave forms differ of the ideal sinusoidal shape, but this is not a real proble while the produced voltage will be rectified, filtered and then converted (AC/DC – DC/AC) in order to connect the generator to the power grid. However, a later optimization will be still necessary.

As concerning the generator power a modular construction can be applied in order to adjust the working parameters to those imposed by the force and height of the oceans waves in order to achive the best efficiency.

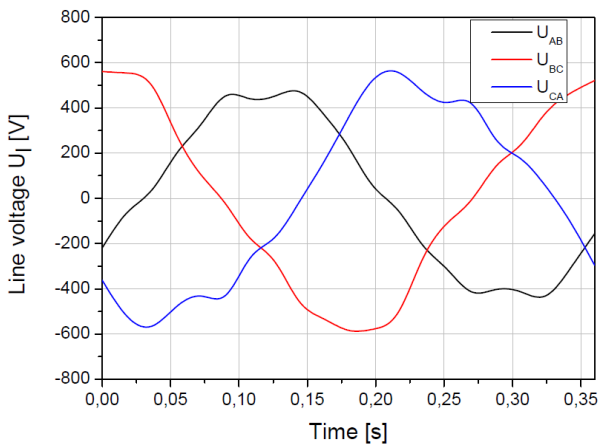

Fig. 5. Three phase line voltage system.

4. CONCLUSION

A tubular linear permanent magnet synchronous generator can successefully be used for wave energy convertors.

The non-sinusoidal induced voltage wave form is not such a big problem as the continuously varying speed which lead to variable frequency and amplitude.

The waves energy linear convertors implies a limited efficiency compaired to rotating generators but eliminates the gearboxe that convert the low-speed of linear motion into rotating motion of a higher speed.

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