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Analysis of Linear Permanent Magnet Generator for Tidal energy applications

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ABSTRACT: Renewable energy is reliable and plentiful and will potentially be very cheap once technology and infrastructure improve. It includes solar, wind, geothermal, hydropower and tidal energy, plus biofuels that are grown and harvested without fossil fuels. Efficient design of Generator in the renewable power plants plays an important role in deciding the overall efficiency of the plant. Direct drive permanent magnet generators are ever more capturing the global interest in Tidal energy applications, especially in high tidal wave region. The prior knowledge of electromagnetic field patterns inside the generator helps the designer to build an efficient, reliable and long lasting generator. Many commercial software packages are available in the market to assist the design engineers in this respect. Effort is being made to design the modified Linear Permanent Magnet Generator with the help of Ansoft Maxwell software package. Electrical and Magnetic characteristics will be obtained to realize the performance of Generator in holistic manner.

Keywords: Linear Permanent Magnet (LPM) Generator, Finite Element Method (FEM).

I. INTRODUCTION

For our generation, exploration in Renewable Energy is of great help as other conventional resources have problem either for obtaining the raw material or environmental effects. In this paper, emphasis is given on the wave energy application as it is still in its budding stage and a lot can be done to exploit this. Since wave energy is available in adequate and it is included in renewable energy, various research work is being done in the field of Wave energy conversion [1]. Turbine type and Buoy type are some of the prominent types used in Wave energy conversion. In turbine type, rotor rotates in circular motion based on the kinetic energy of the waves and magnets of circular shape are installed on the rotor. In Buoy type, a floating device is installed which is connected to the rotor and the magnets are of linear shape and the movement of buoy can be translator either above or below the sea surface.

In last decade, an exponential growth is witnessed especially with advancement in Linear Permanent Magnet Generators. There are types of LPM generators depending on the shapes of the rotor which moves in translation motion. Most common of them is Tubular LPM and another one is Flat LPM rotor [2].

Flat-type Linear Permanent Magnet rotor is preferred over the Tube-type Linear Permanent Magnet rotor [3]. In general a LPM generators consists of-Rotor-permanent magnets suspended with buoy.

Stator- mounted on seabed, contains copper wires in output will be generated. Buoy- floats on sea surface causing translation motion of rotor with the movement of waves.

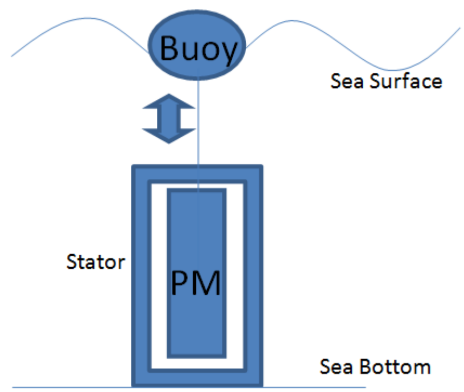


Fig. 1. LPM generator with Buoy installed.

The movement of the waves causes the up and down movement of the buoy which in turn makes the rotor to move on which the Permanent Magnets are mounted. The stator is fixed at its position and thus the flux linkage to the stator conductors is changing with the movement of buoy. This induces emf in the coils of stator and this induced energy can be linked to the grid via underground cables [4-5].

The flat-type double sided PML generator's operation is same as that of the tubular type generator. It can be used for the exploitation of wave energy.

II. MODELING OF FLAT TYPE LPM GENERATOR

The basic design of Flat-type LPM generator consists of Magnet of alternate polarity are embedded on the shaft of rotor and coils are kept in the slots provided on the stator. The rotor moves in translation motion in the positive Z direction. The coils of stator are not of tubular shape instead they are of Quasi-flat type and are not totally covered by stator core.

For this Maxwell Ansoft v15 software is used to solve all magnetostatic problems. Maxwell is a computer operated interactive software that uses finite element analysis to solve 3D magnetostatic problem. It allows us to draw 1D, 2D and 3D models.

Dimensions of LPM generator	
Dimensions	***value***
Magnet length	64.8 mm
Stator length	144 mm
Stator width	252 mm
Slot width	16 mm
Magnet width	9 mm
Air gap	2 mm
Tooth width	8 mm
Pole pitch	72 mm
Stator yoke	16 mm

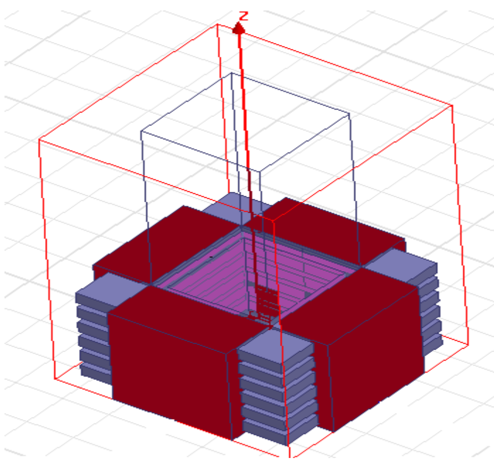


Fig. 2. Model of the Quasi-Flat LPM generator.

These magnetostatic problems are described by following Maxwell differential equations.

Ampere's law: $\Delta \times H = J$

Gauss law: $\Delta \cdot B = 0$

Where, J - Current density

H- Field intensity

B- Magnetic flux density

III. FINITE ELEMENT ANALYSIS

The finite element method (FEM) currently represents the state-of-the-art in the numerical magnetic field computation relating to electrical machines. The converter models are generally composed of relatively simple electrical circuits and a control system with varying complexity. It allows solving equation used for magnetostatic problems with non-linear B-H relationships.

Using Ansoft Maxwell platform, study of the transient behavior of the model is done. Thus, giving the intensity of the magnetic field of the whole model based on the parameters of magnets, coils and stator materials. The linear generator consists of 4 identical parts joined by the common winding.

In the model, the secondary part (rotor) consists of permanent magnets are made up of Neodymium Iron (NdFe35). There are many magnets which can also be used at permanent magnets and one of them is NdFeB magnets are also gaining popularity these days [6]. In the primary part (stator) core is of Iron and the coils are of copper.

Linear generator will operate under the variable speed, which depends on sea wave parameters such as length of the wave and its height. It means that generator needs to be analyzed in dynamic conditions.

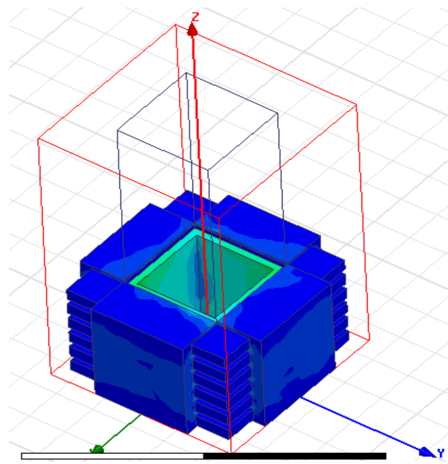


Fig. 3. Distribution of B at t=0.01 sec.

The lighter color means more magnetic field density (B). The more is the distance from rotor darker will be the shade. This figure gives the information about the distribution of magnetic field density. The distribution gives the information about the core material to be used so that there is less magnetic loss thus causing lesser overall losses. The rotor is oscillating on the Z-axis but at linear speed.

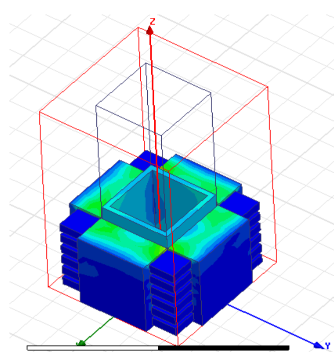
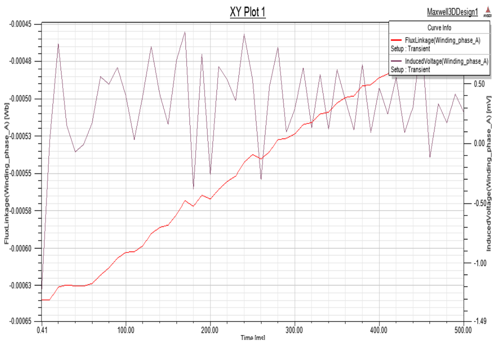


Fig. 4. Distribution of B at t=0.5 sec.

According to Faraday's law of Electromagnetic induction there should be emf generated proportional to the rate of change of magnetic flux. Therefore, flux linkage and induced emf in the coil of stator is shown in figure. Here, the flux linkage and induced emf in the coil is shown of only 1 particular coil which is the topmost copper coil.



Mentioned plot is of only quarter cycle (i.e. 0.5 sec) of the full waveform (2 sec). Here, X-axis is time while red line gives the flux linkage with the coil and black line grey line represents the induced voltage in the coil. Magnitude is not that much high as output shown is related to one coil. But, results of the machine can be further improved by adding more magnetic poles and sinusoidal movement of the linear PM rotor. Dimensions are taken as mentioned.

IV. CONCLUSION

The performance of linear quasi-flat type generator driven by sea wave energy has been studied. The linear generator with quasi-flat linear machine structure is designed using the magnetic circuit. But there are further scopes of study by simulating the model at more practical conditions.

As mentioned this field is still under research a lot can be achieved. For better results the structure of the rotor can be altered to give better voltage and flux linkage. The material can also be updated, as with advancement in the magnets it opens further scope in the amount of voltage generated for the same size.

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