LINEAR GENERATOR PERFORMANCES DETERMINATION FOR WAVE HARVESTING SYSTEM

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DECLARATION

I declare that this thesis entitled "Linear generator performances determination for wave harvesting system" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature	:..
Name	: Saraswathy Rajandran
Date	:..

APPROVAL

I hereby declare that I have read this thesis and in my opinion this thesis is sufficient in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering (with Honours).

Signature :..

Supervisor Name : Dr. Yusmady Bin Mohamed Arifin

Date :..

DEDICATION

To my beloved family, friends and teachers

ABSTRACT

Wave energy is a classic example of renewable energy. The energy amount is measured by speed and height of wave, wavelength and water density. The stronger the waves, the more capable it is to produce power. Motion energy that is produced by the wave energy is used to do tasks such as generate electricity, powering plants and pumping of water into reservoirs. Wave energy does not emit hazardous gasses to the environment. This is why it is known as completely clean source. On the other hand, fossil fuels, oil, coal and natural gas contribute to pollution as they release dangerous gasses such as carbon dioxide, nitrous oxide, methane and ozone to the atmosphere. Linear generators in wave energy conversion depends on high force, low speed, irregular motion and cost. Their performance varies when they have some changes in applying those requirements. The purpose of this study is to develop a linear generator test rig and investigate the performance of the system by testing different linear generator configuration. An experimental setup was developed consists of DC motor, solenoid magnet, wave plotter and crankshaft shapes. The experiment is conducted using different crankshaft shapes. Plywood was cut in different shapes and named as A (semicircle), B (star), C (spur gear) and D (droplet). Wave plotter was used to determine the wave patterns of different shapes. Multimeter and speed controller were used to collect the current readings. Performance of the system is determined by the current produced by solenoid magnet due to crankshaft shapes. Shape B shows the highest current among the other but the reading starts to drop as the motor speed increases. Speed of motor inversely proportional to the current because as armature current increases, the flux produced also increases due to the series combination. So that, if armature current is reduced, flux is reduced which will increase speed of the motor.

ABSTRAK

Tenaga ombak adalah contoh klasik tenaga boleh diperbaharui. Jumlah tenaga diukur dengan kelajuan dan ketinggian ombak, panjang ombak dan ketumpatan air. Semakin kuat ombak, semakin berpotensi untuk menghasilkan tenaga. Tenaga gerakan yang dihasilkan oleh tenaga ombak digunakan untuk melakukan tugas-tugas seperti menjana tenaga elektrik, menjana loji janakuasa dan mengepam air menjadi takungan. Tenaga ombak tidak mengeluarkan gas berbahaya kepada alam sekitar. Maka ia dikenali sebagai sumber yang bersih sepenuhnya. Sebaliknya, bahan api fosil, minyak, arang batu dan gas asli menyumbang kepada pencemaran kerana mereka melepaskan gas berbahaya seperti karbon dioksida, nitrous oksida, metana dan ozon ke alam sekitar. Penjana gerakan lurus dalam penukaran tenaga ombak bergantung pada daya yang tinggi, kelajuan yang rendah, gerakan tidak tetap dan kos. Prestasinya berbeza apabila mereka mempunyai beberapa perubahan dalam melaksanakan keperluan tersebut. Tujuan kajian ini adalah untuk membangunkan peralatan ujikaji penjana gerakan lurus dan mengaji prestasi sistem dengan menguji konfigurasi penjana gerakan lurus yang berlainan. Peralatan ujikaji yang dibangunkan terdiri daripada motor DC, solenoid magnet, pelakar ombak dan bentuk engkol. Eksperimen ini dijalankan dengan menggunakan bentuk engkol berbeza. Papan lapis dipotong dalam bentuk yang berbeza dan dinamakan sebagai A (separuh bulatan), B (bintang), C (gear taji) dan D (bentuk titisan air). Pelakar gelombang digunakan untuk menentukan corak gelombang yang terhasil daripada bentuk yang berbeza. Multimeter dan pengawal kelajuan digunakan untuk mengumpul bacaan arus elektrik. Prestasi sistem ditentukan oleh arus elektrik yang dihasilkan oleh magnet solenoid disebabkan oleh bentuk engkol. Bentuk B menunjukkan arus tertinggi di antara yang lain tetapi bacaan mula menurun apabila kelajuan motor meningkat. Kelajuan motor berkadar songsang dengan arus elektrik kerana arus deras meningkat, aliran yang dihasilkan juga meningkat disebabkan gabungan siri. Jadi, jika arus angker dikurangkan, fluks dikurangkan seterusnya meningkatkan kelajuan motor.

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LIST OF ABBREVIATIONS

WEC	Wave Energy converters
LPMG	Linear Permanent Magnet Generator
TENG	Triboelectric Nanogenerator
AWS	Archimedes Wave Swing
DC	Direct Current
PVC	Polyvinyl Chloride
AC	Alternating Current
LED	Light-Emitting Method
PTO	Power Take Off Method

CHAPTER 1

INTRODUCTION

1.1 Background

1.1.1 Wave energy

Wave energy is a classic example of renewable energy. When wind blows over the sea surface, it conveys the energy to the waves. The energy amount is measured by speed and height of wave, wavelength and water density. The stronger the waves, the more capable it is to produce power. Motion energy that is produced by the wave energy is used to do tasks such as generate electricity, powering plants and pumping of water into reservoirs.

Wave energy is highly predictable. They are available 24/7 and harbor more energy compared to wind energy and solar energy. Wind energy and solar energy cannot be predictable. Wind speed slows down unexpectedly might affects electricity while solar energy depends on sun, which cloud coverage and night hours can reduce sun exposure leading to less efficiency. Moreover, wave energy is an endless resource. Humans will continue consuming it to the very end.

Wave energy does not emit dangerous gasses to the atmosphere. This is why it is known as completely clean source. On the other hand, fossil fuels, oil, coal and natural gas contribute to pollution as they release dangerous gasses such as carbon dioxide, nitrous oxide, methane and ozone to the atmosphere.

1.1.2 Wave Energy Converters

Wave Energy Converters (WECs) change wave power into electricity. The WECs can be categorized into three types based on their size and direction of elongation. They are attenuators, point absorbers and terminators. Attenuators lie in parallel to the wave and they essentially they ride the waves. Figure 1.1 shows Pelamis wave farm, which is developed by Ocean Power Delivery is an example of attenuators WECs.

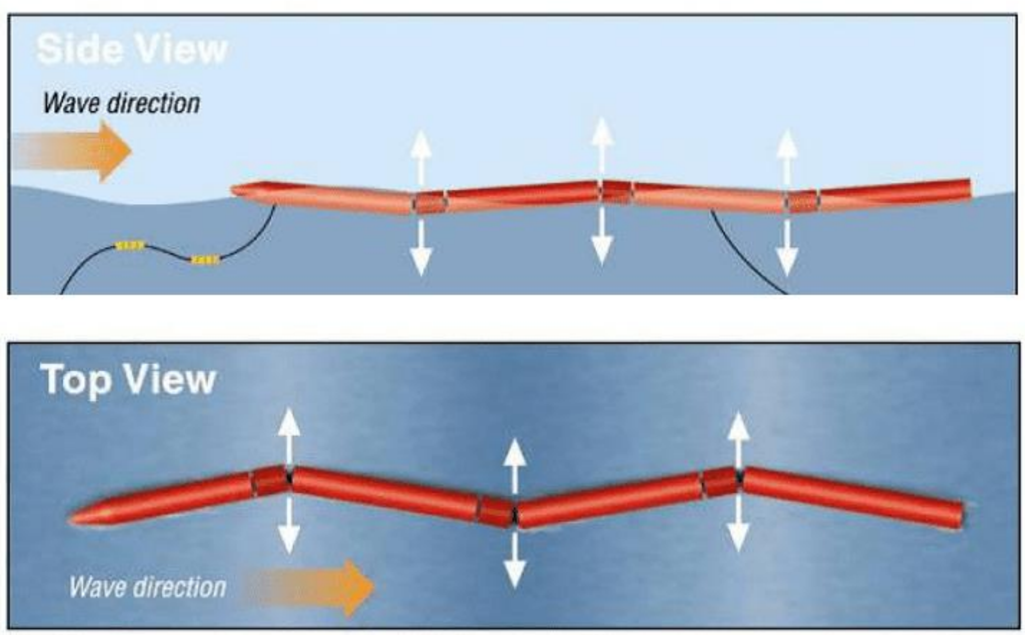

Figure 1.1 Pelamis wave farm (https://alchetron.com/Pelamis-Wave-Energy-Converter)

Point absorbers are buoy-type WECs that harvest wave energy from all directions due to their size which is smaller than wavelength. They are placed offshore at or near the ocean surface. They have floaters on movable arms as shown in Figure 1.2. The motion energy from the arms captured in common hydraulic line and transmitted into electric current.

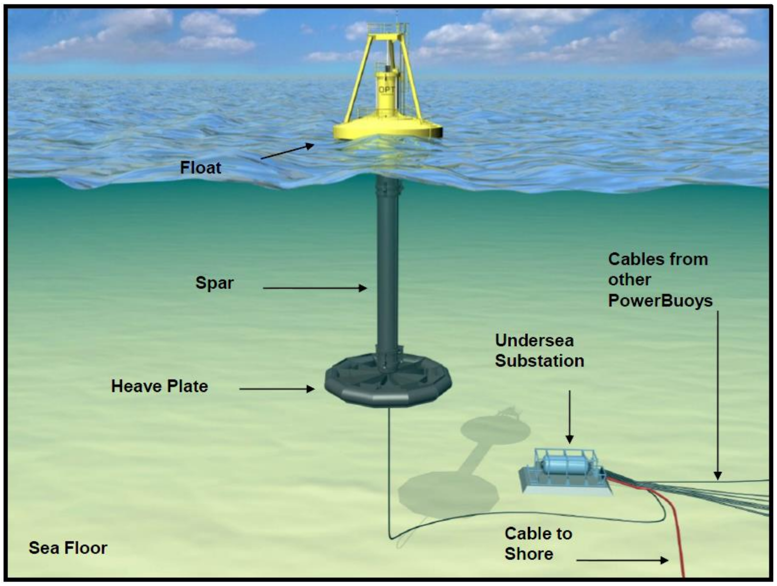

Figure 1.2 Point absorber (https://kaankoca.wordpress.com/tag/point-absorbers/)

Figure 1.3 shows terminator device that have their principal axis parallel to the wave front and physically intercept waves. The terminators are same as attenuators but they are perpendicular to the wave propagation direction. Salter's Duck, developed at the University of Edinburgh is terminator type of WEC.

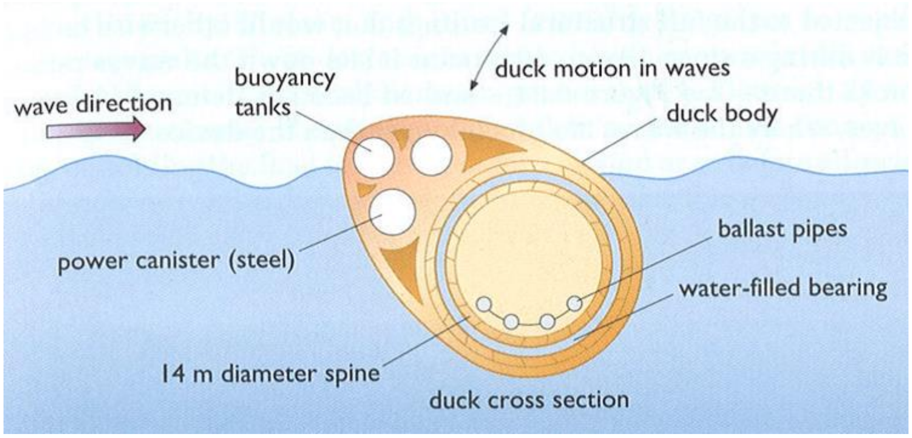

Figure 1.3 : Terminator type WEC (https://wave-energies.weebly.com/types-of-wec.html)

1.1.3 Linear Generator

Linear generator works on the principle of electromagnetic induction similar to any other generators. But it is differs from other generators because it works on linear motion while other generators work on rotatory motion. Linear motion is motion in straight line when magnet moves in to electromagnetic coil. This changes the magnetic flux passing through the coil and induces the flow of electric current which can be used to work. Linear generator is used to convert back forth motion directly to electrical energy. There are various conventional generator types that can be used in wave energy conversion, such as linear induction machines, linear synchronous machines with electrical excitation, linear switched reluctance machines and linear permanent-magnet synchronous machines.

1.2 Problem statement

Wave energy is the lowest cost renewable energy sources by its high power density. Compared to solar and wind energy, wave energy is more predictable by offering better possibility of being dispatched to an electrical grid system. The conversion of wave energy to electricity is the most harmless way to generate energy, hence it does not give any waste or destroy the environment. Wave energy foreseen to be the best solution for the electrical power supply in upcoming years as it provides clean energy production and incorporated along with green technology available as well as supportive sustainability conceptual of living. Linear generators in wave energy conversion depends on high force, low speed, irregular motion and cost. Their performance varies when they have some changes in applying those requirements. The main purpose of this project is to develop wave generator which is simple and less expensive. Besides that, the wave generator should be environmental friendly and not releasing dangerous gases.

1.3 Objectives

The objective of this project are as follows:

1. To develop a test rig for wave harvesting system
2. To compare performance of different linear generator configuration

1.4 Scope of the project

The scopes of this project are :

1. Using different crankshaft shapes to simulate different wave pattern.
2. Produce electricity through linear generator

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The purpose of literature review is to provide knowledge on topic and place own research within the context of existing literature making a case for why further study is needed. This chapter review previous researches on wave energy conversion, linear generators, types of generators and Archimedes Wave Swing (AWS).

2.2 Wave energy conversion

Waves as a source of renewable energy offers several benefits than other methods of energy generation. First and foremost, sea waves has the highest energy density than other renewable energy sources. Waves are produced by winds then generated by solar energy. Solar energy intensity of typically 0.1– 0.3kW/m^2 horizontal surface is converted to an average power flow intensity of 2–3kW/m^2 of a vertical plane perpendicular to the direction of wave propagation just below the water surface. Besides that, limited negative environmental impact in use. Thorpe details the potential impact and presents an estimation of the life cycle emissions of a typical near shore device. In general, offshore devices have the lowest potential impact. Natural seasonal variability of wave energy, which follows the electricity demand in temperate climates. Waves can travel large distances with little energy loss. Lastly, wave power devices can power up to 90% of the time, compared to 20–30% for wind and solar power devices. (Drew et al., 2009)

Wave energy conversion systems are categorized in different ways (Polinder et al., 2007). One possible way of classification is according to the operating principle with their power take off systems. Four important types are the following :

(i) Oscillating water columns (OWC) have air turbines that drive rotating generators.

(ii) Overtopping devices such as the Wave Dragon that have hydro turbines that rotating generators.

(iii) Hinged contour devices such as Pelamis use hydraulic power take off systems.

(iv) Buoyant moored devices such as the Archimedes Wave Swing (AWS) with (2-7 configuration)

2.2.1 Power Take Off Method

The power take off (PTO) system converts the captured mechanical energy into electrical energy. In both wave and tidal systems a mechanical interface can be employed to convert the slow rotational speed or reciprocating motion into high speed rotational motion for connection to a conventional rotary electrical generator. Direct drive is also an option, but is not typical in currently developed marine devices. The energy conversion mechanisms within a wave energy converter can be divided into 3 areas: device, PTO and electrical generation system (including generator and power converter), all of which have losses associated with them (Polider et al., 2007

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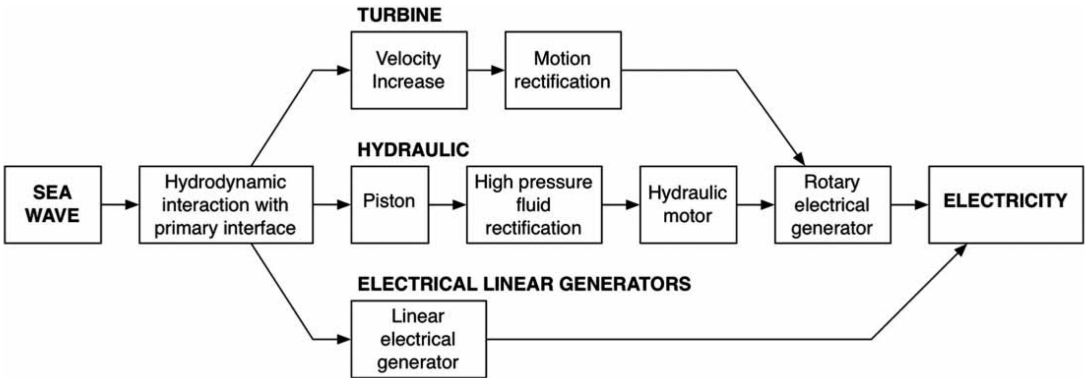

Figure 2.1 : Power take of method mechanisms (Polinder et al., 2007)

2.3 Linear generator

Linear generators are rarely used. Rotation motion mostly used to convert mechanical energy to electrical energy. Rotating generators used in conventional power stations, in hydro power stations, in wind turbines, and in vehicles. Linear motors or actuators are used in transportation system, robotic systems and positioning stages. Mostly, these systems have a low power level. However, there are a few applications with power levels comparable to the power levels of wave energy converters, such as maglev trains, aircraft launching systems for future aircraft carriers and roller coasters driven by a linear machine.

When these linear systems have to break, the machine is also operated in generator mode. However, in this case the objective is not to convert energy from a mechanical from to an electrical form in an efficient way, the objective is just to slow down the motion or to position the moving part. Linear generators in wave energy converters are characterized by a high force (depending on the size of the wave energy converter) and a low speed. The main other application of generators with a high force and a low speed is in direct-drive wind turbines. There are many correlations between the problems in direct-drive wave energy conversion and direct-drive wind energy conversion. However, the irregular motion in wave energy conversion makes direct-drive wave energy conversion more difficult than direct-drive wind energy conversion.

Generators are based on the principle of inducing electrical tension on the wire that moves in a magnetic field with the action of a mechanical force. Generators consist of two main parts stator and rotor. The moving part is called as rotor while fixed part is called as stator. There is an air gap between stator and rotor, because the rotor can be moved. (Sahin and Ozdinc, 2015)

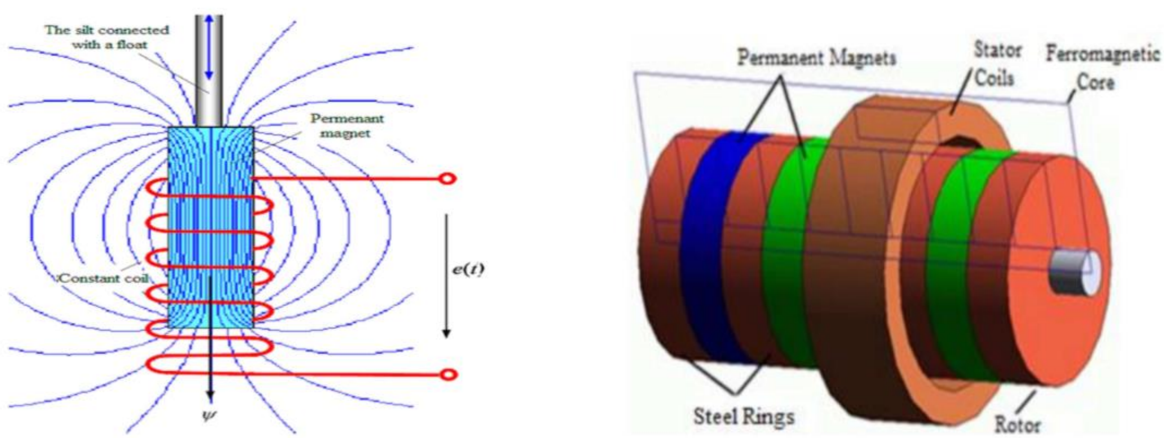

Figure 2.2 : Linear generator schemes that having a permanent magnet rotor (Sahin and Ozdinc, 2015)

The moving part of the linear generator in which the rotor consists of four fixed ring magnet is in the designed system. The magnets which are used for rotors, are Neodymium-Iron magnets, is the value of each 3000 Tesla. Non-magnetic permeability steel rings are placed between the permanent magnet and their poles are placed as N-S and S-N as shown in Figure 2.3.

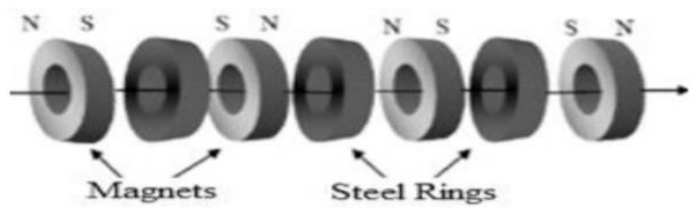

Figure 2.3 : The placing of the magnets according to the poles

(Sahin and Ozdinc, 2015)

Sahin and Ozdinc (2015) reviewed that to design efficient linear generator, the length of the rotor should be equal to the length of the winding field in the stator. Therefore, this area is the maximum variation of magnetic flux. A mechanism is required which reduces friction losses between rotor and stator with a minimum air gap. The mechanism has to be fixed to the rotor to move only vertical direction with wave motion. The bigger conductor cross section reduces the power losses. It is noted that the obtained voltage value can be increased with the addition of power electronic circuits and more smooth direct current voltage can be obtained.

2.3.1 Characteristic of linear generator

The requirements for linear generators applied in wave energy conversion systems are high peak force, low speed, irregular motion and low cost. Other characteristics of linear generator systems in wave energy conversion systems are the following: (Polider et al., 2007)