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Study of Generation of Electrical Energy from Ocean Waves

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Abstract: ***Electricity has become basic demand of humans. For the growing environmental awareness and increase in energy demand crisis, use of renewable sources has become popular. Renewable energy sources includes solar, wind, hydroelectric, ocean waves, etc. The use of ocean waves for generating power is promising because two-third part of the earth's surface is covered by ocean, which allows us a wide access across the globe. Large amount of kinetic energy is offered by ocean waves i.e. it is found to be 0.2% of untapped energy of ocean waves which would provide power sufficient to supply whole world. In India as we are heading towards using renewable energy sources to fuel human activities, the utilization of solar energy in generating electric energy is more as compared to other renewable energy sources. Basically, there are 2 types of ocean energies namely thermal energy due to sun's heat and mechanical energy from tides & waves. Ocean can be considered as heat engines as it converts thermal energy which is produced due to sun's heat into kinetic energy of waves & currents. In this project, we plan to study how electricity can be generated from ocean waves using a combination of offshore buoy and phase control. We purpose to implement and simulate the model in Simulink.***

1. Introduction

1.1 Overview

For the growing environmental awareness and increase in energy demand crisis, use of renewable sources has become popular. Renewable energy sources includes solar, wind, hydroelectric, ocean waves, etc. The use of ocean waves for generating power is promising because two-third part of the earth's surface is covered by ocean, which allows us a wide access across the globe. Large amount of kinetic energy is offered by ocean waves i.e. it is found to be 0.2% of untapped energy of ocean waves which would provide power sufficient to supply whole world. In this project, we are trying to present the study related to ocean waves, simulation in software, and also try a prototype testing of the wave power generation system.

1.2 Objective

1.2.1 Study of Ocean Waves and its Parameters

This section involves study related to basics of ocean waves and the parameters that would affect the ocean waves. The study involves following aspects:

1) About waves.
2) Causes of waves in ocean.
3) Steepness of wave.
4) Difference between tides and waves.
5) The parameters affecting the ocean waves.

On the basis of above study, we will understand the behavior of the ocean waves and can analyze and simulate various parameters to get the desired result.

1.2.2 Study of Different Softwares for Simulation

This section involves study related to various software on which simulation of various wave parameters can be done.

1) **Opera Software-** It contains a high frequency analysis module, which solves the full wave equation. This includes displacement currents for devices comparable in size to the wavelength at its operating frequency.
2) **Autodesk 3D Max-** It is a 3D modelling, animation and rendering software that allows simulation of waves with different parameters.
3) **MATLAB (SIMULINK)-** This solves the 2D wave equation on a square plate per unit finite differences method and plots an animation of the 2d movement.

   On the basis of above study, we will use **MATLAB (SIMULINK)** for analyzing and simulating ocean waves and energy.

1.2.3 Simulation of Generation of Electricity from Ocean Waves Using Suitable Software

Till date we have tried to simulate the ocean waves in MATLAB. As the waves are in 2D, it appears like a sinusoidal wave. The program comprises of ocean waves with a buoy and has parameters like the wavelength, amplitude, etc which affect or influence the ocean waves. We can change or vary the parameters so as to get the desired output.

2. Literature Review

2.1 Background Study

Ocean waves as a type of renewable energy has received considerable attention for producing electricity because of its competitiveness in comparison with other types of energy which are conventionally used for power generation. Ocean waves is a free source of energy and hence, is attractive in terms of the cost.

However, ocean wave is in nature intermittent and its energy has a large range of variations. Wave energy is the world's fastest growing energy source, expanding globally over the last decades.

In the last years MATLAB/Simulink has become the most used software for modelling and simulation of dynamic systems. MATLAB/Simulink provides a powerful graphical interface for building and verifying new mathematical models as well as new control strategies for the wave energy

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systems. Then, using a dSPACE prototype these new control strategies can be easily implemented and tested in a Harware-In-the-Loop structure This presents a new developed MATLAB/Simulink toolbox for wave energy systems. This toolbox ha been developed during the research project “”Simulation platform to model, optimize and design wave energy turbines”. MATLAB/Simulink has been used in this simulation platform as a general developer tool for other three tools, namely : Saber, DIgSILENT and HAWC.

2.2 Related Work

In the growing electricity supply industry and open access market for electricity worldwide, renewable sources are getting added into the grid system. This affects the grid power quality. To access the impact on the grid due to wave energy integration, the knowledge of electrical characteristics of wind turbine and associated control equipment is required.

The combination of a buoy and the overtopping system will be used for the generation of electricity. The buoy basically is a floating type device which uses the rise and fall of waves to drive the pumps and is responsible for conversion of wave energy into electrical energy. An overtopping system uses the pumped fluid to fill the reservoir at a level higher than the surrounding ocean. Thus the potential energy is stored in the reservoir tank.

The water stored from the reservoir tank is made to pass through delivery pipes to a rotate a turbine situated at a lower head.

The generator is the final component where the conversion of energy takes place. The generator shaft is coupled to the turbine whose rotation rotates the shaft which in turn produces the electricity in the generator.

After the electricity is generated, the generator output terminals are then connected to battery terminals using flexible wires to store the electricity produced.

This mechanism is implemented in the MATLAB. A combination of various mathematical equations enables the implementation of the above mechanism.

3. MATLAB and SIMULINK

3.1 Introduction to MATLAB

MATLAB is a high- level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB product, you can solve technical computing problems faster than with traditional programming languages. Such as C, C++, FORTRAN.

MATLAB is in a wide range of applications, including signal and image processing, communications, control design, test and measurement, financial modeling and analysis, and computational biology. Add-on toolboxes (collection purpose MATLAB function, available separately) extend the MATLAB environment to solve particular classes of problem in these application areas. MATLAB provides a number of features for documenting and sharing your work. You can integrate your MATLAB code with other languages and applications, and distribute your MATLAB algorithms and applications.

Features include:
- High-level language for technical computing
- Developing environment for managing codes, files and data
- Interactive tools for iterative explorations, design, and problem solving
- Mathematical functions for linear algebra, statistics, Fourier analysis, filtering, optimization, and numerical integration
- 2-D and 3-D graphics functions for visualizing data

Tools for building custom graphical user interfaces
MATLAB is a high performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in a familiar mathematical notation.

Typical use includes:
- Math and computation
- Algorithm development
- Data acquisition
- Modelling, simulation, and prototyping
- Data analysis, explorations, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building.

3.2 SIMULINK

A simulation of a system is the operation of a model of the system. The model can be reconfigured and experimented with: usually, this is impossible, too expensive or impractical to do in the system it represents.

The operation of the model can be studied, and hence, properties concerning the behaviour of the actual system or its subsystem can be inferred. In its broadest sense, simulation is a tool to evaluate the performance of a system, existing or proposed, under different configurations of interest and over long periods of real time. Simulation is used before an existing system is altered or a new system built, to reduce the chances of failure to meet specifications, to eliminate unforeseen bottlenecks, to prevent under or over utilization of resources, and to optimize system performance.

Simulink is a platform for multi- domain simulation and Model-based design for dynamic system. It provides an interactive graphical environment and a customizable set of block libraries, and can be extended for specialized application.
- Simulink is graphical extension to MATLAB for modelling and simulation of system.
- In Simulink system are drown on screen as block diagram.

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- Many elements of block diagram are available such as transfer function, summing junction, etc. as virtual input and output devices such as function generator and oscilloscope.

4. System Description and Block Diagram

The system consists of two main components viz. Buoy and the Overtopping system. Further the buoy includes the Piston Pump arrangement and the overtopping system includes Reservoir tank, Turbine, Generator, and Battery.Figure given below shows the schematic diagram of the system.

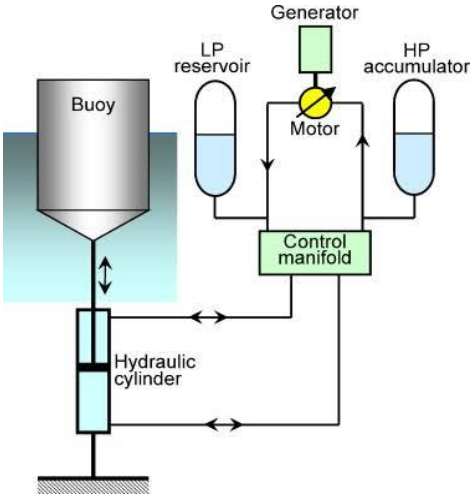

Figure 1: Schematic Diagram Of The System

4.1 BUOY

The buoy is a mechanical device that is responsible for the conversion of energy in ocean waves to electrical energy. It also undergoes motion as per the motion of the waves at a particular time. The device constitutes of a piston-cylinder arrangement, actuating mechanism, foundation and tether pipes. The device is anchored to the sea floor with a strong foundation. Various mechanisms are employed to generate electricity via turbines. The basic mechanism involved is the application of pumps supplying seawater under pressure to the overtopping system in order to drive the turbines.

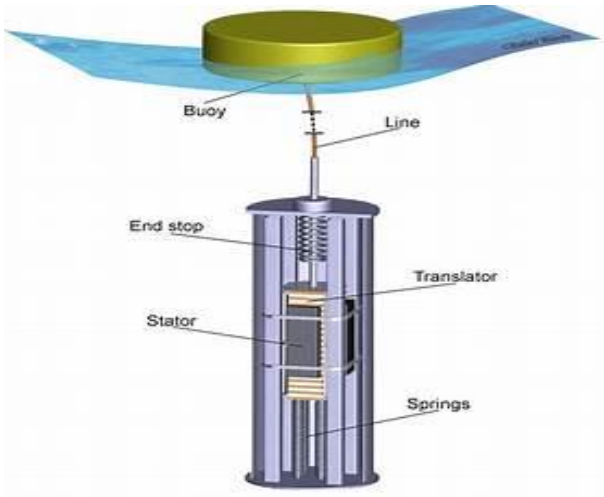

Figure 2: Schematic Diagram of a Buoy

4.1.1. Piston Pump arrangement

Piston pump is a piston cylinder arrangement is a part of buoyin which piston is arranged to reciprocate as its piston rod is actuated by a float when float moves up as a rising wave passes and it pulls the piston upward. When the float moves down it pushes the piston downward and partial vacuum generated at the end causes the inlet port to open and allow the fluid to flow in. The fluid is then pressurized again by the upward motion of piston which closes the inlet port and opens the outlet port simultaneously to pump the pressurized water. The piston pump mechanism pumps the pressurized water to an elevated overtopping system. The mechanism is made up of acrylic material. The pressurized water is delivered through flexible pipes to the reservoir of overtopping system.

4.2 Overtopping system

The overtopping system uses the wave to fill the reservoir which is at a higher level than surrounding ocean. Due to the water stored at a height there is potential energy flux available in the stored water which is then used to run a turbine having a low head. The system consists of a reservoir, a turbine, a generator coupled with the turbine shaft and connecting pipes. In this project, the design of an overtopping system has been improved in the way that the seawater which is pumped from the buoy is stored in the reservoir onshore and not within the seabed itself. Also, the turbine and generator assembly is situated near the reservoir so that the water from the turbine exit can be reused for other purpose like desalination of seawater.

4.2.2. Reservoir tank

The reservoir tank is a part of the overtopping system whose function is to store the pumped water from the piston pump mechanism. It serves to create the potential energy from the stored water. The water is then made to rotate a turbine which is coupled to the generator shaft and finally generate electricity.

4.2.3. Turbine

The water stored from reservoir tank is made to pass through delivery pipes to rotate a turbine. The turbine rotates the generator shaft which in turn generates electricity.

4.2.4. Generator

The generator or the motor is the final component where the conversion ofenergy takes place into electricity. The generator shaft is coupled to the turbine whose rotation rotates the shaft which in turn produces the electricity in generator. The generator output terminalsare then connected to battery terminals using flexible wires to store the electricity produced.

4.2.5. Battery

After the electricity is generated from generator it is stored in a battery.

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5. Block Diagram

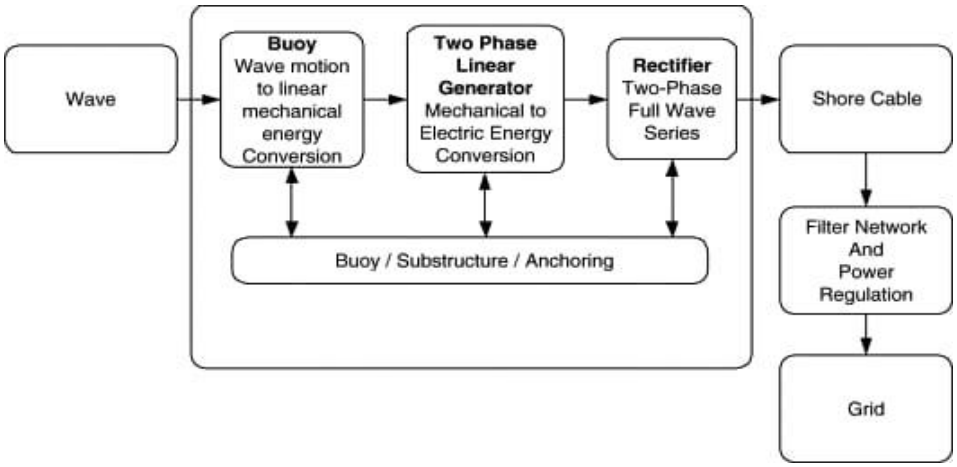

Figure 3: Block Diagram of the System

6. Summary and Conclusion

6.1 Summary

Wave energy is a promising renewable energy resource because of its high energy density. No one has yet found a way to extract this energy efficiently enough, even though many researches have taken place. To achieve this, the development of point absorbing Wave Energy Converter came into existence. This Wave Energy Converter uses a buoy, a special type of Power Take Off (PTO) and a control strategy. (Phase Control). For optimization of power output, Phase Control is used which optimizes the velocity of the buoy by making the buoy move in phase with the incident wave. The model of the buoy and PTO are merged to get a complete model of the Wave Energy Converter. The reason for developing the model is to provide a tool, which can be used for the WEC development. We want to evaluate the effect of Phase Control on the buoy motion and the WEC power output. The implementation is done in the graphical simulation program Simulink, where different blocks represent different parts of the model. The model is controlled by a graphical user interface that sets parameters and shows the simulation results. In conclusion, the WEC holds great promise for generation of electrical energy.

6.2 Conclusion

Ocean wave energy system is to be designed and modelled for a grid-independent user with appropriate power flow controllers. The available power from the renewable energy sources is highly dependent on environmental conditions such as wave speed. This is studied and simulated according to the variation in environmental conditions for optimized output. With the arrangement consisting of a buoy, PTO and control strategy (Phase Control), we can extract the ocean wave energy for electricity generation.

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