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A developed system design for blue energy generation

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Abstract. Sustainability is an important factor in energy generation. Sea or ocean waves can be used as a sustainable source of energy generation. A technique of using buoyant floats submerged in water to drive a magnetic generator for energy conversion can be applied and studied. In the current article, a developed system design is presented for harvesting wave energy (blue energy). The wave power and generator power are calculated based on the studied model. The presented design enhances the concept of wave energy harvesting, as a renewable energy source, and shows the possibility of applying it. Applying wave energy harvesting should get more attention as a sustainable and clean source of power electricity.

Introduction

Sea or ocean wave energy, which is an abundant and untapped source of energy, can be used to reduce the use of fossil fuels. Wave energy, which can be called "blue energy", is a clean renewable source of energy and supports sustainability. This method reduces greenhouse gas emissions and protects marine ecosystems, unlike traditional power generation. Innovation in wave energy technology boosts energy security. Waves can help coastal regions become more energy self-sufficient and less vulnerable to energy supply disruptions. Exploring and refining a linear wave energy generator advances wave energy conversion technology, potentially paving the way for future developments and commercial applications [1,2]. Electricity generation in remote or island regions often relies on imported fossil fuels. In such areas wave energy generators provide a more sustainable and independent energy source than expensive and environmentally harmful fuel imports [3]. These generators use ocean waves to provide clean renewable energy that supports the global transition to a carbon-neutral future [4]. The generator design, materials and operation, which is driven by the need for reliable and efficient wave energy converters, was discussed in [5,6]. The environmental assessments were examined to ensure sustainable ocean resource use. It helps evaluate existing technologies, identify gaps and guide this project toward a more efficient and sustainable wave energy generator [6].

A comprehensive literature review of wave energy was presented in [7] to discuss the concept development since the 1970s, highlighting its growing global importance and promise. It thoroughly examines sea wave energy understanding and use. The paper focused on wave energy resource characterization and the theoretical foundations for wave energy absorption and control hydrodynamics. The review emphasizes the complexity of wave dynamics and the theoretical frameworks needed to extract energy from ocean waves.

Wave energy using linear generator system was presented and discussed in [8,9]. Wave energy conversion and the variety of generator systems were discussed. This variety highlights the different ways to design wave energy-efficient systems. The authors discussed modern linear generator systems, including the Archimedes Wave Swing (AWS) and Uppsala systems. These systems demonstrate linear wave energy conversion technology's progress. The authors also

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suggested investigating air-cored machines for integrated electrical-mechanical-structural designs suggesting a holistic generator development approach. The search for cost-effective solutions suggests exploring generator constructions that may be cheaper. This includes cylindrical generators and concentrated coil generators.

Wave energy conversion using linear generators was examined in [10]. The differences between rotary and linear generators application were discussed. The fact that linear generators convert wave energy efficiently is important in energy generation. Linear generators can adjust wave speeds unlike rotary generators. Flexible motion matches wave variations resulting in different voltages, currents and phase sequences. The peak to average power ratio increases due to this variability improving efficiency. The ocean wave energy fundamental calculations were presented in [11]. The ongoing research on wave energy at Oregon State University was sumarasied.

Despite the benefits of the wave energy technique, its applicability is still challenging. The device durability in harsh marine environments, cost-effectiveness, energy production and grid integration complexity still require more investigations. The previous works involved immersing the generator in the water. In the current work a new system design is developed for power generation using the wave energy. The presented system is designed to be attached to a structure above the water on the coastal wave breaker. The design concept is presented and discussed in terms of manufacturability, productivity and applicability.

System Design

In the current work a system design is developed for generating power using the wave energy. The system consists of a magnetic shaft and electric coil directly connected to a float movement. As the magnetic shaft moves inside the coil, an electrical current is generated. Electromagnetic induction generates electricity from the float's wave induced kinetic energy. Linear motion of the magnetic shaft inside the coil changes the magnetic field generating an electric current. The heart of the wave energy generator system is converting mechanical motion into electrical energy.

Fig. 1 shows the developed system model and Fig.2 shows the coil and armature used in the system. The designed model is provided by a platform to be attached to a structure above the water on the coastal wave breaker. This will provide the feasibility to locate number of the generator units for more energy generation.

The design meets practical deployment size and spatial constraints. A small footprint and streamlined design allow for efficient integration into existing marine infrastructures maximizing system effectiveness without taking up too much space.

Sustainability guides material selection and operational strategies, aiming to minimize the environmental footprint. Using eco-friendly materials and energy-efficient components creates a renewable energy and environmental preservation system. The system minimizes marine ecosystem damage. The system's deployment and operation are designed to minimize noise pollution and aquatic life disturbances to preserve marine environments. Beyond technology, by considering social impacts, the generator design concept encourages community for sustainable energy initiatives.

Efficiency and affordability are balanced by cost effectiveness. To encourage adoption, strategies optimize system efficiency while lowering manufacturing and operational costs. The system design prioritizes readily available components and construction methods for large-scale manufacturing, streamlining production for efficient and cost-effective deployment. The system's strict safety protocols and design features reduce risks for maintenance personnel and the marine environment.

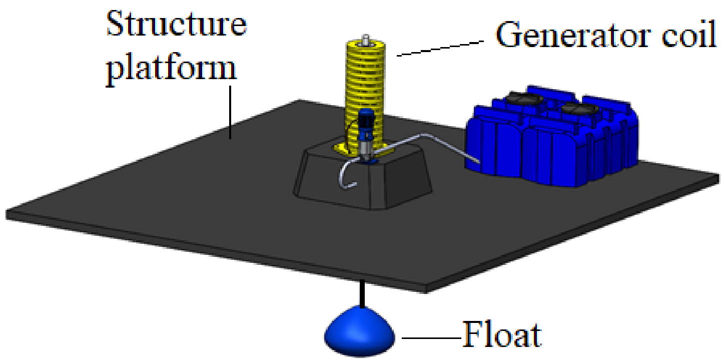
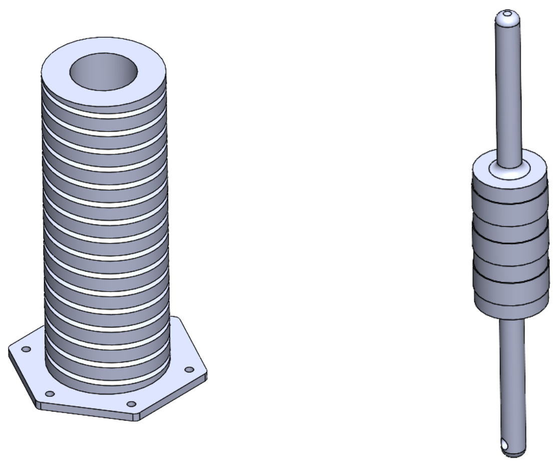


***Figure 1** the developed generator system design*



a b

***Figure 2** the generator parts, a. the generator coil, b. the magnetic armature*

Theoretical Calculations

The wave motion can be caracterized by the wave length or the time period (T_{wave}), and the wave height or the wave amplitude (H_{wave}). The input power to the generator is P_{wave} , which is the wave power per one meter of the wave length, can be calculated as follows [11,12,13].

$$P_{wave} = \frac{(\rho \times g^2 \times H_{wave}{}^2 \times T_{wave})}{32\,\pi} \tag{1}$$

$$= 7662\ W/m$$

Where,

The water density, $\rho = 1000\ kg/m^3$

The gravity constant, $g = 9.81\ m/s^2$

The wave amplitude, $H_{wave} = 1\ m$

The wave time period, $T_{wave} = 8\ s$

The power output of the linear $generator$ ($Pgenerator$) can be calculated as follow.

$$P_{generator} = \eta \times P_{wave}$$

$$= 0.85 \times 7662 = 6512.8\ W/m$$

Where,

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$The\ efficiency\ of\ the\ generator, \eta = 0.85$

These calculations reveal wave power, linear generator output and system energy conversion efficiency.

Discussion

The system is designed to provide the feasibility to be located and attached to the wave breakers. A number of the generator units can be used for power generation and at the same time attaching the units to the wave breaker structure will give more strength to the units and will make the maintenance easier.

The buoyant float should be made of a sturdy material for hostile sea settings. Material weight, corrosion and wave resistance matter. The linear generator component selection is crucial to the subsystem. Effective electromagnetic induction is achieved by the magnetic shaft, coil and materials. Optimizing wave motion to electricity conversion demands high quality materials and precision engineering. Primary capture systems should use oscillating water columns or point absorbers to efficiently catch wave energy. In diverse wave situations, subsystem components must maximize energy absorption. Frame, bearings and anchoring systems are crucial converter components. For converter structural integrity and lifetime, durability, stability and seawater resistance are used. Controlling and converting electricity requires inverters, transformers and control units. Critical components must work well under different electrical loads and environments. These components should be chosen for performance, durability, pricing and system compatibility. The goal is an integrated system that efficiently converts wave energy into electrical power in marine conditions while being reliable and durable. Designers must choose components that enhance efficiency, safety and sustainability. To ensure alignment and functionality, the system model parts have to be fabricated, assembeled and tested.

Conclusions

The wave energy converter is caracterized by the aspects of innovation, perseverance and sustainablity. This current work advances renewable energy and shows a shared commitment to energy issues. This work demonstrates how engineering and real-world application can use the sustainable wave energy (blue energy) for power electricity generation. A developed design is presented to use the wave energy and promote the growth of renewable energy dependency. In an age of clean energy and environmental concerns energy generation can be more sustainable. It symbolizes the commitment to fighting climate change, conserving resources and boosting economic resilience through technology. To reduce design complexity, a linear generator is applied in the project to avoid the use of extra mechnism for converting the linear motion to a rotary motion to adapt the rotary geneartor. Developing wave energy harvesting techniques and improving the efficiency should get more attention as a sustainable and clean source of power electricity.

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