A Vertically Oriented Linear Faraday Electrical Generator Used as Point Absorbing Wave Energy Converters to Transform Ocean Surface Wave Kinetic Energy into Electrical Power

Technology Description

Applicable to the FOA topic area of MHK innovative structures, the proposed technology relates to a novel type linear electric generator (LEG) and its incorporation within a structurally simple wave energy converter (WEC).

Much of the 2 Terawatts[1] of extractable ocean wave energy is within US water resources and given its high power density, is held to be the most concentrated, consistent, and potentially cheapest renewable energy source, capable of supplying 1,170 TWH per year or half the US annual electricity demand.[2]

This potential has not been realized because of difficulties in power take off (PTO) system components used in earlier wave energy converter (WEC) technologies including the prime mover to where the absorbed wave kinetic energy is transferred, the electric generator that converts the kinetic energy into electrical power, the power collection circuitry (PCC) collecting power from the armature coils, and the cable that removing electrical power from the WEC. Prior wave energy harvesting technology had serious problems of low conversion efficiencies, large numbers of moving parts with complicated mechanical power trains, hydraulic fluids with risk of leakage into the environment, huge capital costs, unwanted environmental effects, and reliability issues in harsh marine environments. Furthermore, prior wave energy harvesting technology used single or several large widely spaced units resulting in most of the propagating wavefront not intersecting a device causing significantly reduced efficiency.

This project will verify the operational feasibility of a proposed WEC comprised of a radically different vibrational Faraday LEG composed of a patented arrangement of vertically oscillating compressed repulsive magnetic fields radiating out perpendicular to and along its entire vertical axis enveloping specially designed coils, a magnetic field focusing system to prevent flux leakage, and an electromagnetic breaking system for protection against large waves, all resulting in improved efficiency, only one moving sliding structure for improved survivability, a low ecological impact, and no hydraulic fluids, bearings, or rotary motion structures. The omnidirectional wave energy absorbing component is both the prime moving body and the rotor of the LEG itself and thus part of the power take off (PTO) mechanism along with the stator, power collection circuitry (PCC), and power output cable thereby leading to direct conversion of wave kinetic energy into electrical power without intervening mechanical structures. A low mass floatation collar absorbs and transfers wave kinetic energy directly to the prime mover LEG rotor mass spring system which oscillates the specially configured magnetic fields across the coils to produce the power conversion. The PCC is a simple hierarchal modular system that collects, rectifies, and filters AC power from unlimited numbers of armature coils in single or multiple WEC's to produce a single large AC or DC output; electric power is transmitted to shore by electric cables or converted to stored chemical energy for use as needed on demand.

The buoy shaped WEC uses low cost standard components that can be easily overrated to enhance survivability and reduce failure rates in harsh marine environments. The device is designed for mass production, and is simple to transport, install, service and replace. Multiple patents encompass the key components of this WEC and its contained LEG.[3] The pre-prototype LEG structure has produced considerable power (up to 60 W) while floating in a water environment.

The WEC is deployed as single large units or in widely spaced large units as was the case of prior technologies. However, as a result of its ability to be downscaled in size and manufactured as a mass produced item because of its structural simplicity, unlimited numbers of small units can be densely packed into an array whose geometry and size are optimized to harvest wave energy from arbitrary shaped or sized ocean surface areas. Such arrays will allow for a significantly increased portion of the wave front to be captured by two mechanisms. First, the distance between WEC's through which wavefronts propagate without intersecting a WEC is markedly reduced. Second, as ocean waves propagate and ripple through the array, their amplitude decreases as their kinetic energy is changed into electrical energy by each successive WEC they encounter. WEC's are attached to bulkheads, sea walls, piers, to each other in arrays, anchored to the seabed, or freely floating. The various configurations of using closely adjacent WEC's in groups or arrays have been patented.[3]

To prove project feasibility, five hypotheses must be validated:

1. The WEC can produce a sustained 100 to 1000 W in harsh marine environments, with testing first in the lab, then in a controlled wave tank, and finally in the field.
2. Power generation is improved by at least 25% and optimally up to 200% by this LEG WEC versus structures using older conventional magnetic field technology for a given weight and size. This will be determined through magnetic field computer simulations and measurements of the new compressive repulsive focused magnetic technology versus the prior technology used in older LEG's.
3. WEC electrical output is maximized by optimally configuring the PCC, of which many different arrangements are possible.
4. The WEC can survive in a harsh marine environment.
5. The technology has few unwanted environmental effects.

Verifying these hypotheses will validate this technology as significant, reliable, and transformative capable of harvesting large amounts of electricity from ocean wave energy. The WEC in single or array format is applicable to any sized or shaped body of water that can sustain propagating water waves. Optimally scaling up LEG magnet coil structure size, WEC number per array, as well as array shape, density, and geometric size for a given location to achieve maximal power output, conversion efficiency, and reliability, can make grid applications realistic. This ocean wave energy conversion system can transform US energy production by reducing energy costs, carbon emissions, and hydrocarbon imports with new job creation from mass manufacture of the WEC, a potentially truly beneficial and disruptive technology.

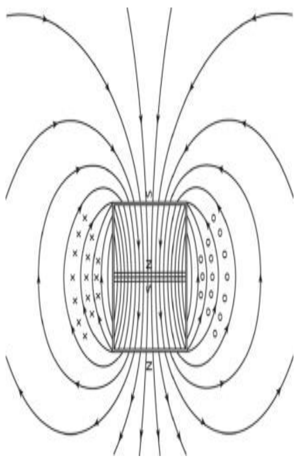
Considerable private funding on the part of Prime Investigator himself has so far led to milestones including obtaining multiple patents, working out the theory of operation of the technology, production of laboratory circuit PCC prototypes, constructing a LEG pre-prototype that has been in the water, construction of small concept WEC prototypes operating in the laboratory, and initiating a small joint project with an academic university engineering team to do a finite element analysis computer simulation and vibrational analysis of the linear electric generator. Additional funding is required to complete the development of 2 quarter scale prototypes allowing for power production from two units in parallel, a full operational prototype, wave tank testing, field testing, contractual costs associated with device machining and assembly, vibration analysis testing, electrical component testing, power output and efficiency determinations, device transport costs, and failure testing and risk management analysis. EERE funding will allow the technology, now at a TR-4 level, to proceed to a TR-7 level allowing the above stated research goals to be achieved with the necessary OEM and academic input in order to get this project to the pre-commercial stage.

With respect to failure testing analysis and risk management, particular areas of concern that will be addressed will include among other items: rotor moving magnet assembly failure via corrosion and mechanical stress, cable and spring endurance, armature coil integrity, WEC water tightness and corrosion resistance, mooring integrity, power collection circuitry rating and integrity, time before failure testing, loss of device prevention, severe weather operation performance and possible consequences of device destruction, expected versus actual power conversion efficiency and output, integrity of the one water seal in the device, operational safety during device repair and operation, environmental impact, electrical leakage and faults, electrical current escape into surrounding water, and transport to and from site of operation during installation and maintenance. Furthermore, since the technology is designed for two or more WEC's and their LEG's to work in parallel absorbing power from the oncoming wave front, the interaction between two closely adjacent WEC's need to be analyzed with respect to all of these listed risk management parameters. It is anticipated that the Project Team will rely heavily on the OEM and university academic components of the team and its personnel to accomplish these metrics and any engineering modifications or improvements that might be necessarily designed and will represent an important use of the funds derived from this funding proposal.

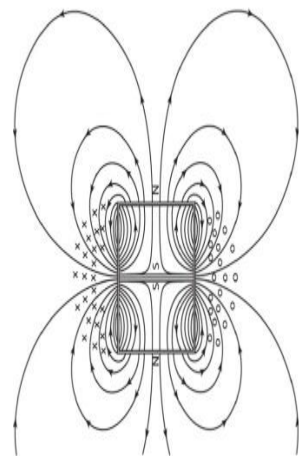
Footnotes:

1. World Energy Council
2. Electric Power Research Institute
3. US Patents # 86295572, # 8946919, # 8946920, # 8952560, additional patents pending

Addendum

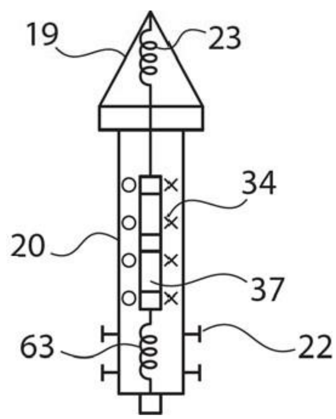


Conventional NSNS Attractive
Magnetic Field



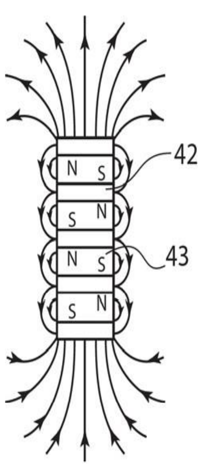
Compressive NSSN Repulsive
Magnetic Field

19-Float, 20-Shell, 22-Stabilizer, 23 Spring

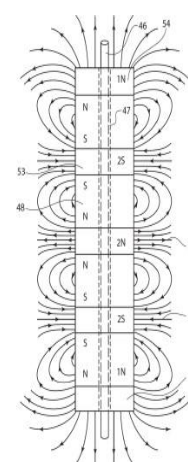


34-Coils, 37-Magnets, 63-Spring

Schematic of LEG inside WEC



Conventional Stacked NSNSNSNS
Attractive Magnetic Field



Novel Stacked Compressive
NSSNNSSN Magnetic Field