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A Novel Design of Water-Flow Based Electrical Generator as an Energy Harvesting Device

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Abstract—This paper is aimed to investigate, experimentally, new two designs of Energy Harvesting Device: Water-Flow Based Electrical Generator (WEG). This device directly converts the motion of water inside a permanent magnet tube to electricity. Its output power is affected by several parameters such as permanent-magnet tube diameter, its length, water velocity and the concentration of minerals in the water (fresh, sewage or sea water). The relationship and dependency of these parameters are examined experimentally to obtain a set of graphs which can determine the suitability and performance of the proposed model for different applications. Advantages of these new models are clean power resource, simple and non-expensive design. The output power of these generators can power or recharge cell phones, mobile computers, radio communication equipment, stairs lighting of residential towers, commercial street signs, inside sea signs, etc.

Keywords—Energy harvesting devices; Water-Flow Based Electrical Generator (WEG); Permanent magnet tube; Water velocity.

I. INTRODUCTION

Energy harvesting materials and systems have emerged as a prominent research area and continue to grow at rapid pace. A wide range of applications are targeted for the harvesters, including distributed wireless sensor nodes for structural health monitoring, embedded and implanted sensor nodes for medical applications, recharging the batteries of large systems, monitoring tire pressure in automobiles, powering unmanned vehicles, and running security systems in household conditions. Recent development includes the components and devices at micro–macro scales covering materials, electronics, and integration. Energy harvesting devices converting ambient energy into electrical energy have attracted much interest in both the military and commercial sectors. Some systems convert motion, such as that of ocean waves, moving of human body, etc. [1-3].

Water is one of the most abundant elements on Earth. It is the only item to exist in all three states of matter at once naturally, but what makes water truly unique are its "individual properties." These features include its high surface tension and cohesion, neutral PH, high electrical resistance, high specific heat, and capacity as the "universal solvent" [4]. There are several studies discussed the effects of several variables on properties of water itself. Banejad and Abdo Saleh examined the relationship between magnetic fields and flow rate in diamagnetic fluids, [5]. While the effect of the magnetic field intensities of zero Tesla, 0.05 Tesla, 0.075 Tesla, and 0.1 Tesla, on the water hardness were examined, [5]. The electromotive force generation with Hydrogen release by salt water flow under a transverse magnetic field was studied by Roberto De Luca, [6]. Michael Faraday found experimentally in 1831 that a time-varying magnetic field gives rise to an electric field which is known by "Faraday's law," [7]. The effect of concentration of minerals on water as a conducting material was studied by Ziedan et al. in [8].

This paper is aimed to investigate a novel two designs of energy harvesting device to generate electrical power from natural/forced flow of water inside a permanent magnetic tube, which called Water-Flow based Electrical Generator (WEG). This type of generators has no hydraulic turbine. It depends on Faraday's law. Two new models of WEG are designed and tested experimentally. The output power of WEG depends on water velocity, length, the diameter of the permanent magnetic tube, and concentration of minerals in the water. All these variables are studied carefully in experimental work.

II. METHODOLOGY

The electromotive force around a closed path C is equal to negative of the time rate of increase the magnetic flux enclosed by that close road [7], as shown in the following equation:

$$\oint_c E \, . dl = -\frac{d}{dt} DDT \int_s B \, . \, ds \tag{1}$$

Where E is the electric field strength in (V/m), and B is the magnetic flux density in Tesla (T). This can be represented by the first Maxwell equation as shown in (2):

$$\nabla \times E = -\frac{\partial B}{\partial t} \tag{2}$$

Permanent magnet tube produces a magnetic flux in radial directions cuts water in normal angle, Figure 1-5. Water has good electrical conducting properties depends on salt concentrations [4, 8]. Water velocity *v* was used to control time-varying in the magnetic field of a permanent magnet tube to generate electromotive force around a closed path through the magnetic tube. A non-magnetic grid placed at one terminal of the magnetic tube, the end side of permanent magnet tube in the first model only, Figure 2. This non-magnetic grid is used to transfer electricity from water to load circuit. Time-varying of the magnetic field will be controlled by water velocity *v* through a tube cross-sectional area *S* is expressed as shown in the following equation [9]:

$$Q = S \times v \quad (3)$$

Where; *Q* is flow rate or discharge in (m^3/sec), S is a cross-sectional area in (m^2), and *v* is water velocity in (m/s).

III. Experimental Set-Up

Water-Flow based Electrical Generator (WEG) was set-up in Electrical Power Laboratory, AlJouf University, Saudi Arabia. The set-up made it possible to measure the effect of varying water velocity *v,* length L, diameter D of the permanent magnetic tube, the concentration of water minerals with an output power of WEG units. There are two new models of WEG are presented in this paper.

A. *First new model of WEG*

Description of this type of WEG is shown in the following points:

- A tube of permanent magnet material of Cast Alnico magnet with 25, 50, 75 and 100 cm length L, inner diameter D of the tube is 2.5, and 5 cm, thickness of tube t is 0.5 cm, Figures 1, 2 and 3.
- Water flows through a permanent magnet tube with velocity *v* of 1, 2, 3 and 4 m/sec.
- None-magnetic cylindrical grid, Figures 2 and 3, is used to transfer electricity from water to load circuit.
- The electric pump is used to control water velocity *v,* Figure 3.
- Tank to store water, Figure 3.

B. *Second new model of WEG:*

In this type of WEG, a PVC tube of 1 m length is used. Copper wire of radii 0.5 mm is surrounded a PVC tube.

IV. Experimental Technique:

In the 1st model of WEG, water is flowing through a magnetic tube by certain velocity *v* controlled by an electric pump. None-magnetic cylindrical grid, Figures 2 and 3, is used to transfer electricity from water to load circuit. Induced emf is measured between non-magnetic cylinder and ground terminal by a digital voltmeter. Water velocity *v* is controlled by a valve placed close to the electric pump.

In the 2nd model of WEG, induced emf is measured between two copper wire terminals by a digital voltmeter, Figures 4 and 5.

Over the copper wire, a strong magnetic cylinder is placed. Induced emf is measured between copper wire terminals as shown in Figures 4 and 5.

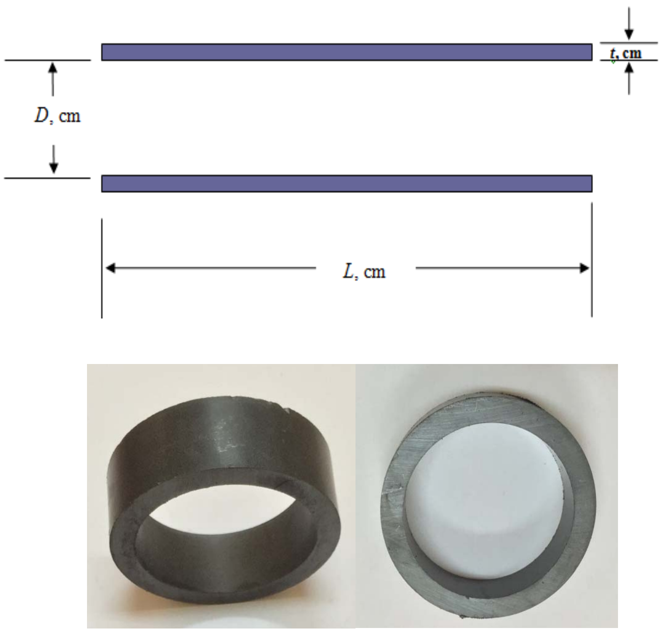

Fig. 1. Cylindrical permanent magnetic tube from Cast Alnico magnet.

V. Results and Discussion

Induced emf of the 1st model of WEG is increased by increasing water velocity *v* for same inner tube diameter and same tube length, Figure 6 - 7. Also, as inner permanent magnetic tube diameter increased the induced emf increased too, Figure 8 - 11. And it is increased with the increasing of the length of permanent magnetic tube for same water velocity *v* and same inner tube diameter, Figures 6 – 11.

Figure 12 shows the effect of concentration of minerals of water (fresh, sewage or sea water) on induced emf of 1st model WEG unit. Induced emf is increased by increasing of minerals in water due to increase water conductivity as reported in [8].

Induced emf of the 2nd model of WEG is affected by water velocity *v,* permanent magnetic tube diameter D, and length L as the 1st model except for the magnitude of induced emf is lower than in 1st model, Figure 13.

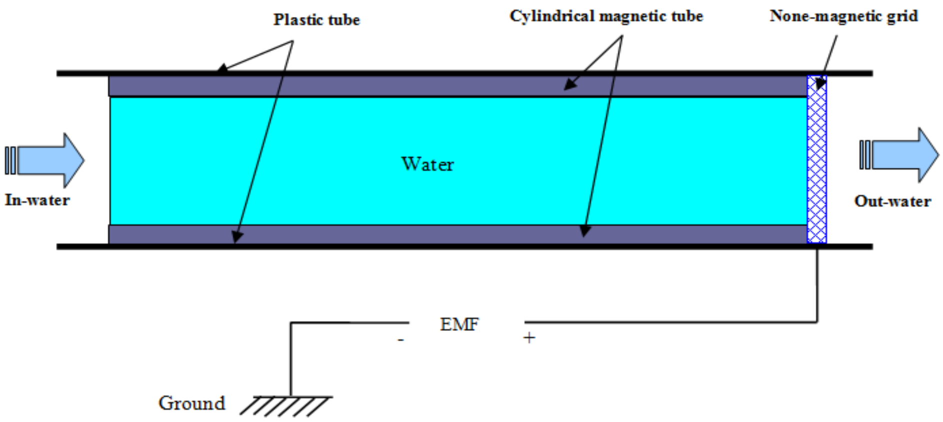

Fig. 2. Schematic diagram of the 1st model of Water-Flow based Electrical Generator (WEG) Unit.

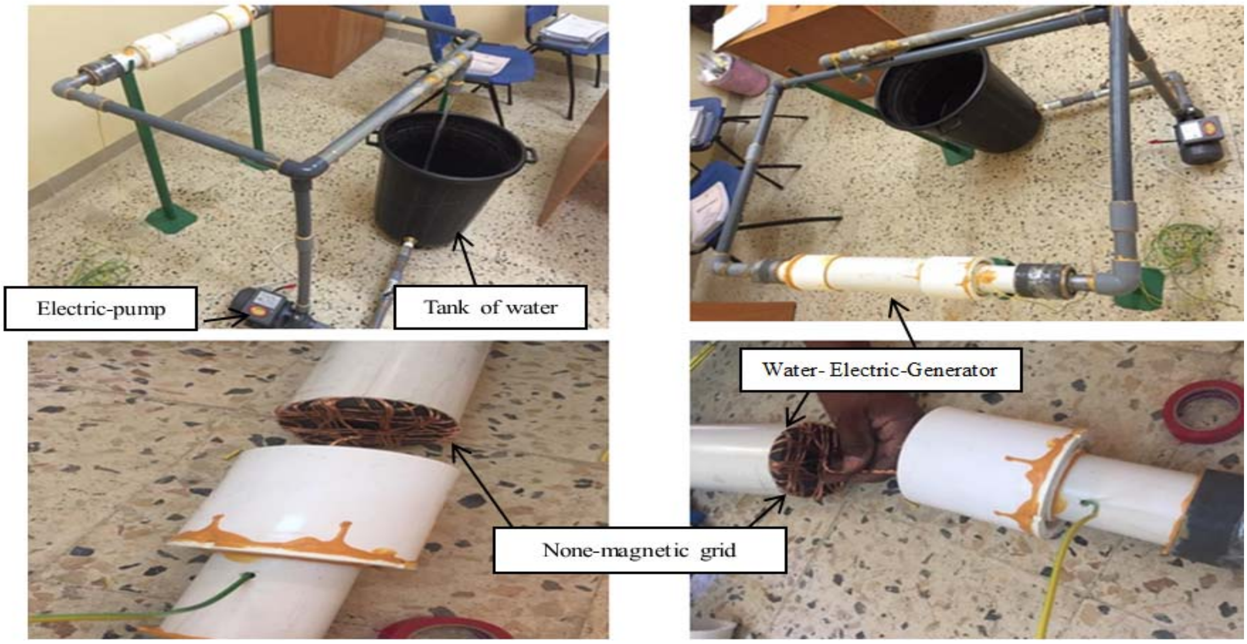

Fig. 3. Prototype model of the 1st model of WEG Unit (AlJouf University).

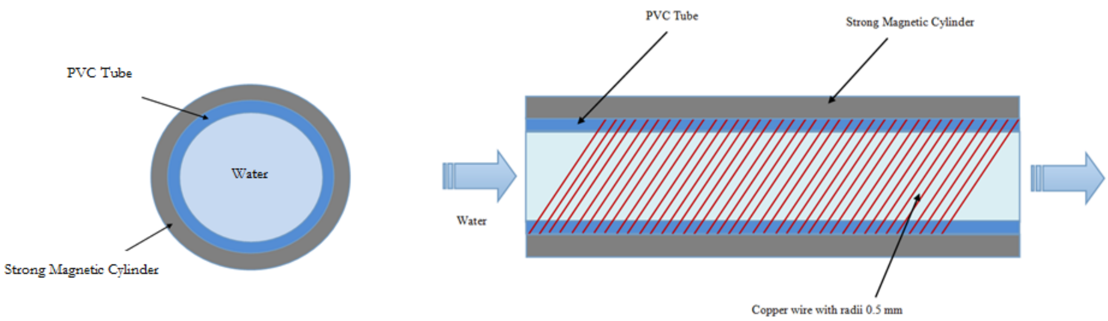

Fig. 4. Schematic diagram of the 2nd new design of WEG unit.

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Fig. 5. Prototype model of the 2nd model of WEG Unit (AlJouf University).

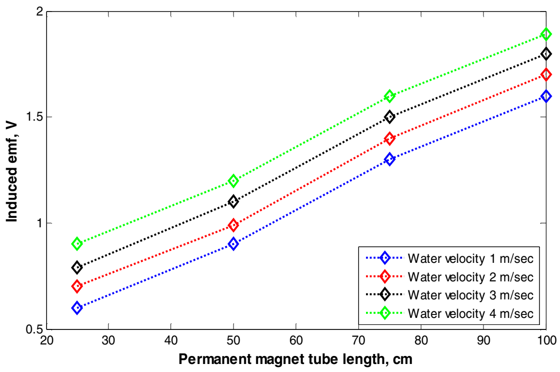

Fig. 6. Effect of varying tube length with different water velocity, v on induced emf of 1st model WEG unit. (Inner tube diameter, D = 2.5 cm)

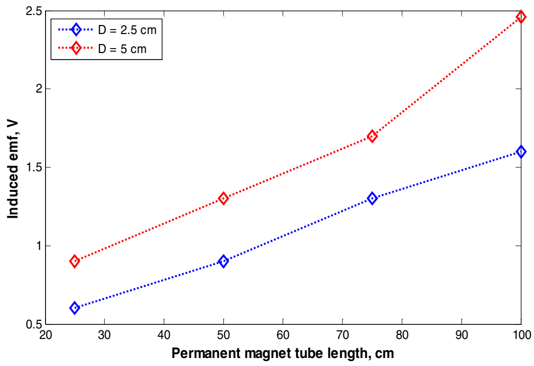

Fig. 8. Effect of varying inner tube diameter D on induced emf of 1st model WEG unit, (Water velocity, v = 1 m/sec).

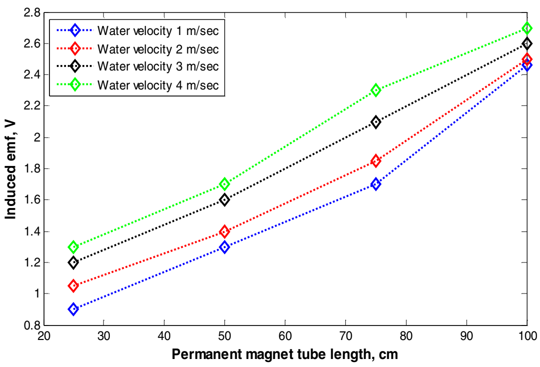

Fig. 7. Effect of varying tube length with different water velocity, v on induced emf of 1st model WEG unit, (Inner tube diameter, D = 5 cm).

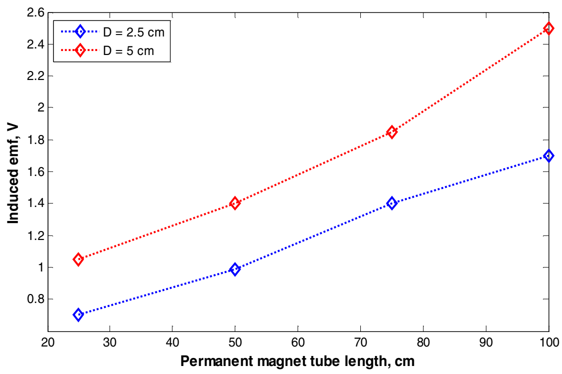

Fig. 9. Effect of varying inner tube diameter D on induced emf of 1st model WEG unit, (Water velocity, v = 2 m/sec).

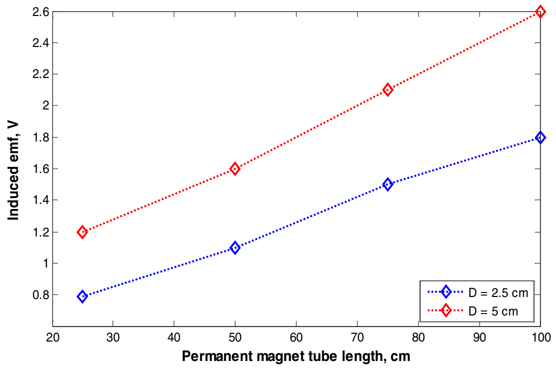

Fig. 10. Effect of varying inner tube diameter D on induced emf of 1st model WEG unit, (Water velocity, v = 3 m/sec).

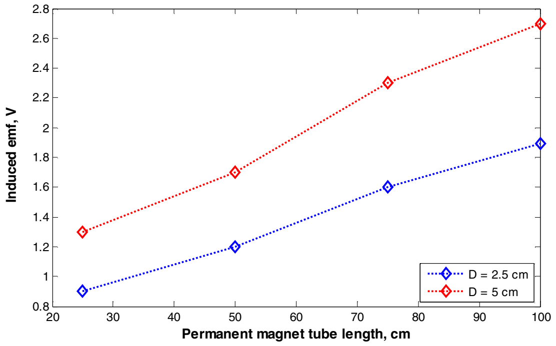

Fig. 11. Effect of varying inner tube diameter D on induced emf of 1st model WEG unit, (Water velocity, v = 4 m/sec).

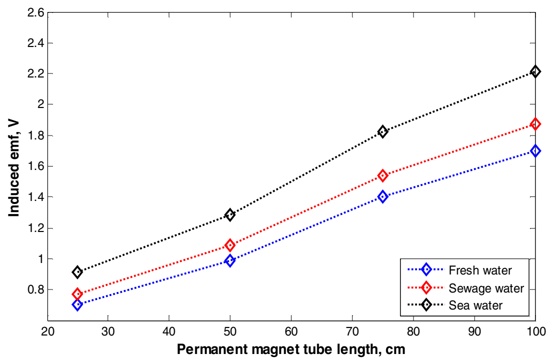

Fig. 12. Effect of concentration of minerals of water (fresh, sewage or sea water) on induced emf of 1st model WEG unit. (Inner tube diameter, D = 5 cm and Water velocity, v = 2 m/sec).

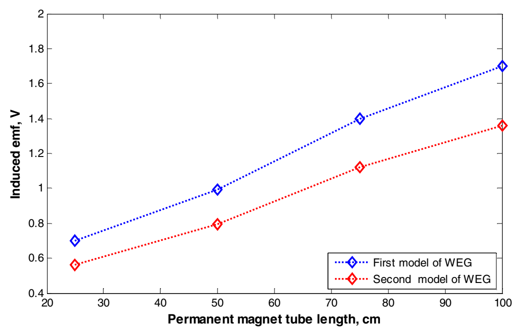

Fig. 13. Induced emf from 1st and 2nd models of WEG, (Inner tube diameter, D = 5 cm and Water velocity, v = 2 m/sec).

VI. Conclusion

Novel two models of Water-Electrical-Generator (WEG) as an Energy Harvesting Device are designed and tested experimentally. WEG depends on natural water flow through a permanent magnet tube. The first model is more power efficient than the second one. WEG models are used to generate electrical power; its rate depends on the dimensions of the system; length, diameter, and thickness of permanent magnet tube flow velocity of water inside this tube, the concentration of minerals in the water (fresh, sewage or sea water). This electrical power is a clean and not expensive power. The amount of generated electrical power can be controlled by several parameters such as water flow rate, magnetic tube length and inner magnetic tube diameter. This electrical power can be used in several personal applications such as Stairs lighting between floors depend on the natural flow of water from water tanks to supply apartments. Commercial street signs can be energized depend on water flow of fresh water or sewage. By using rechargeable batteries, the electrical power generated during water flow may be stored and be used through any moving application, cell phones, mobile computers, radio communication equipment, inside sea signs, etc.

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