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DESIGN AND CONSTRUCTION OF A TIDAL TO ELECTRICAL ENERGY CONVERTER (WITH MATLAB SIMULINK)

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Abstract

Like many riverine communities in Africa, sea travel is one of the important means of transportation. The kalabari community in Rivers State, Nigeria is one of such communities. It is bounded to the south by the Atlantic Ocean with an approximate population of 5.8 million. The Tidal wave converter, a floating electromechanical System is a proposed solution to this problem. The device coverts wave energy into electrical energy through the use of a crankshaft and piston mechanism and a permanent magnet direct current (dc) generator. The generated Voltage is used to charge a 6 volts dc battery. The output from the charging circuit powers the revolving light system, the interfacing circuit and light emitting diode (LED) display unit. In operation the search lights cover a span of 180 degrees while the sensing circuit monitors the sea level. The top row of display indicates the topology of the water body. In this case it displays the word "SHALLOW". The second row displays the increase in sea level from a reference point. This project hence effectively reduces sea related accidents by providing adequate illumination and also provides navigational guidance for sea users at any time of the day.

Keywords:
Tidal energy, Electrical energy, Permanent Magnet (PM), Direct Current (DC), Light Emitting Diode (LED), Piston, Overhead Crankshaft, Connecting rod, Gear Train Gear Ratio.

1 Introduction

The tidal to electrical converter as the name implies a device which converts tidal energy (wave energy) to electrical energy. The major components of this device are the piston, connecting rod, overhead crankshaft, ball bearings, gears light sources, ultrasonic sensors and permanent magnet direct current (dc) motors. For the device to effectively function, it has to float on water. This is in line with the principle of buoyancy which state that" the buoyant force of an object is equivalent to the mass of water displaced by the object". The basic operation of this device is such that the partially submerged piston linked to the overhead crankshaft with a connecting rod is set in motion by incoming wave turbulence. This causes the crankshaft to rotate about a fixed axis through the single row deep groove ball bearing. The piston is displaced linearly, in a vertical hollow pipe were it moves from the top dead center (TDC) to the bottom dead center (BDC). The shaft through the ball bearings connects drive pulleys to the crankshaft. Hence as the crankshaft rotates the pulleys rotates. Torque is transfered from the drive pulley to the driven pulley using a drive belt. This provides the required external

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torque to crank the 9 volts permanent magnet dc generators which in turn generates the required voltage for the charging circuit.

1.1 PROBLEM STATEMENT

In the southern part of Nigeria and other countries in Africa along the coast of the Atlantic, night travel on water ways has always been a nightmare for users due to the alarming rate of sea related accidents and crime in the area.

Figure 1: Boat mishap [3]

Also, security agents and coastal guards in the area have related the frequent occurrences of the incidents to unavailability of navigational signs and poor visibility in the area at night.

1.2 AIM

The main purpose or intention of this project is to provide an environmentally friendly device which provides adequate visibility and navigational guidance for sea users at night using renewable energy from the sea.

1.3 OBJECTIVE

At the end of this project, the device should be able to successfully convert wave energy into electrical energy through the crank – piston mechanism and the 9 volts permanent magnet direct current motor. The light system should turn at 180 degrees sweep in reverse directions. The LED display unit should indicate the water topology by displaying the word "SHALLOW" and also and also a figure "1 m" showing the increase in sea level from a reference point using an ultrasonic sensor.

2.0 The Block Diagram

The design and construction of the tidal to electrical converter was based on the flow from the block diagram. In this, each block represents the particular hardware used for the construction as shown in the Figure 2.

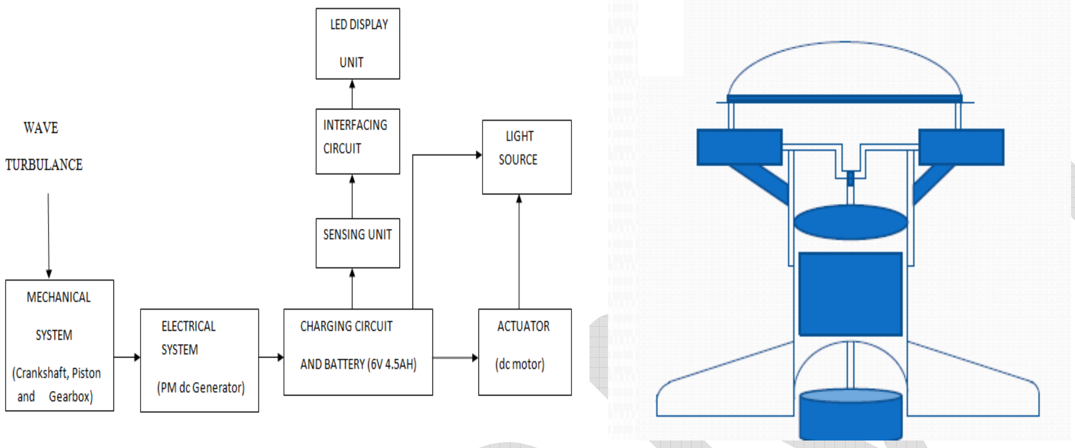

Figure 2: Block Diagram and schematic design

2.1 MATLAB SIMULINK MODEL

The mechanical design was done with Matlab Simulink as shown in the Figure 3.

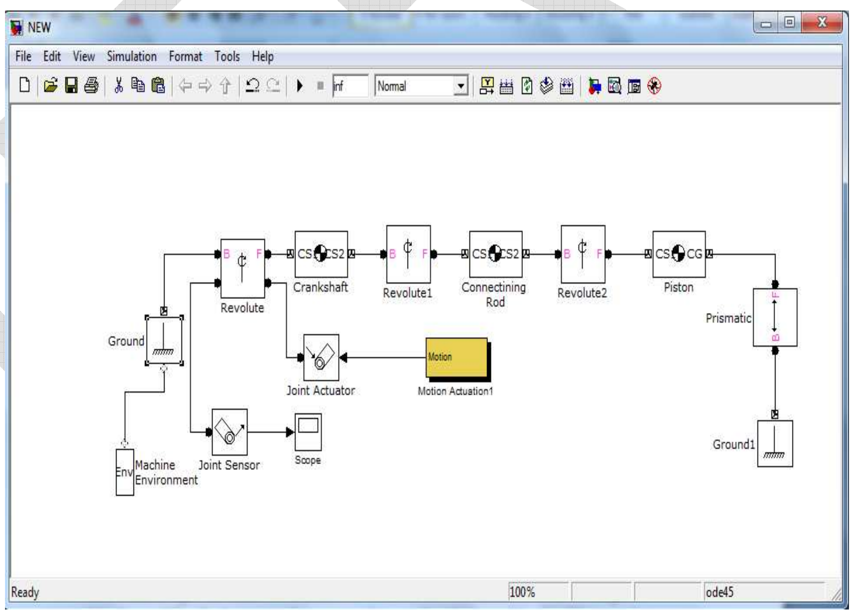

Figure 3: Matlab Simulink Mechanical Block

The mechanical construction of the tidal to electrical converter can be divided into its outer framework and link mechanism which include the piston, connecting rod and overhead crankshaft. Also included in the mechanical system are the rotating bodies, the pulley systems. The outer framework material used is plastic due to its non reacting property with the surrounding environment (i.e. water) and its low weight per unit area. The outer frame can be divided into to two main areas:

- The vertical hollow tube
- The floating base extension

A vertically positioned hollow tube is used with inner diameter 175mm and height 305mm. Opening were created on the curved surface of the vertical hollow tube. At the top, a rectangular shaped opening was made for the LED display unit, while at the bottom just below this opening is another opening that is curved in shape. This opening is necessary as to guide waves into the hollow tube. Surrounding the vertical hollow pipe are three vertical support square pipes. These pipes are positioned at exact 60 degrees apart forming an equilateral triangle around the hollow tube. The vertical pipes also used as rigid supports for the overhead panel base. Each of the pipes has a length of 610 mm. The base extension also made of plastic material and is semi- circular in shape. This shape is chosen so as to allow a broad area over the water surface as this aid floatation. To reinforce the base support, a rigid truss pattern made of plastic was used. The truss design follows the side of the hollow tube in a sloping manner, down to the base extension. They are placed at exactly 45 degrees interval to the center of the vertical hollow tube. Attaching the base extension to the vertical hollow tube, araldyte solution was used to establish a strong and lasting bond. The Figure 4 shows a pictorial view of the finished outer framework construction.

Figure 4: Outer framework design and finished mechanical design

The Tidal energy converter is kept in a floating state by designing a curved extension made of cork or plastic attached to the side walls of the hollow cylindrical tube. It is tethered with chains to piles at the bottom of a river or creek. The device is positioned facing the waves hence the side walls also aid in guiding the waves into the opening. Piles are driven into the ocean bottom and by use of chains the device is prevented from vertical

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and horizontal movements. The wave action raises the partially buoyant piston that drives the overhead crankshaft by half turn. The preceding wave drops the piston completing the balance half turn. One revolution is obtained for every wave. Using a pulley system and dc generator the current is produced continuously.

2.2.1 Mechanical Design Considerations

Design Considerations	Influence
Weather conditions	Natural sources like ocean currents, moon, earth rotation, wind, sun and tides has a substantial influence on sea wave devices. Also the intensity of the sun has a huge influence on the performance of the solar panel.
Buoyancy of Piston	The buoyancy of the piston has a huge effect on the piston displacement. The piston is made of cork material, with a hollow inner compartment filled with fine grains of sand up to half the volume of the inner section. The top opening is properly sealed to avoid water penetration.
Piling conditions	To avoid vertical and horizontal movements of the floating device, it is anchored to piles driven into the ocean floor. To avoid rusting of the chain material, it is coated with enamel and then oil paint.
Weight and Balancing	Weight was a very important feature considered during the design of this device. All components was uniformly distributed across the structure to provide adequate balance. Also more stability there is a curved extension of cork behind the structure to aid floatation and avoid the device tilting forward.
Lightening Conditions	To increase the luminosity of the light intensity so that it covers more distance, high reflective materials are used

Figure 5: Showing initial conditions during construction

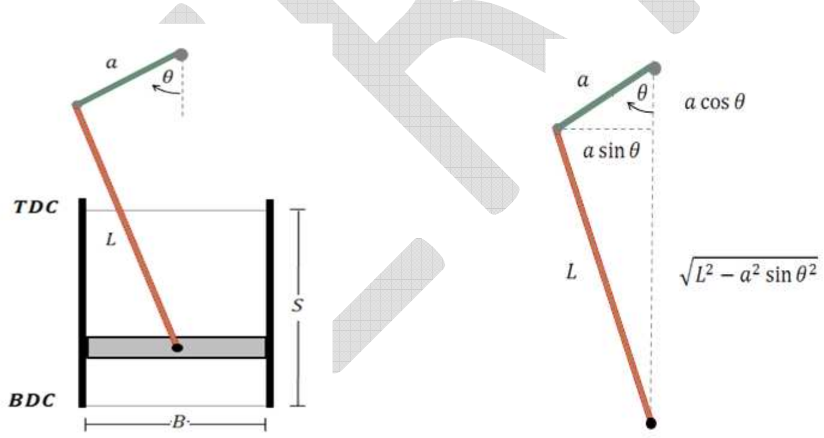

Figure 6: Showing Crank shaft and connecting rod mechanism and trigonometric analysis

Where:

TDC and BDC = top dead center and bottom dead center
B = bore (i.e., diameter of the cylinder)
L = length of the connecting rod

S = stroke length
a = crank radius
θ = crank angle

2.1.2 Calculations for construction:

At crank radius of 0 degrees (TDC), the piston is at its highest.

Crank Radius (a) = 65mm

Length of connecting rod (L) = 200mm

Note: The length of the connecting rod must be within the range of 140mm to 200mm

Bore= 180mm

Using trigonometry for analysis,

The height of the piston relative to the crank origin at the bottom dead center (BDC) position is given by

$$a + L \quad (1)$$

The Stroke (s), the distance between the top dead center (TDC) and the bottom dead center (BDC) is given by the formula,

$$S = \sqrt{(L\char94(2\,) - a\char94 2\sin(\theta)\char94 2)} - a\cos\theta \quad (2)$$

S= $\sqrt{((200)\char94 2-(65)\char94 2\sin(360)\char94 2)} - 65\cos 360$

=$\sqrt{39935}$

S= 199.8mm

This value for the stroke includes height of the piston. Hence the distance covered by the piston with respect to the base of the piston is given as,

$$S_p = S - Height\ of\ piston \quad (3)$$

Where, $S_P = Distance\ between\ the\ top\ dead\ center\ (TDC) and\ bottom\ dead$

and bottom taking consideration of the bottom of the piston

Height of piston= 68mm

Hence, S_p= 199.8mm$-68mm$

$S_p \ = 131.3mm$

Note: This agrees with the safety measure in designing crankshaft mechanisms that the stroke is equal to twice the crank radius.

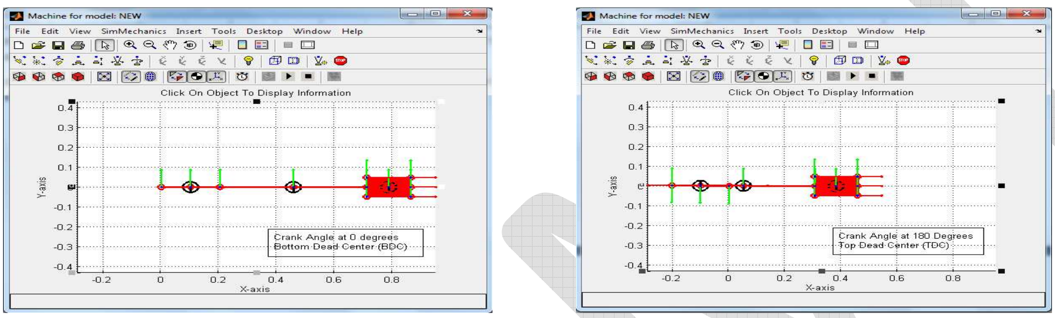

Figure 7: Design showing mechanism at TDC and BDC

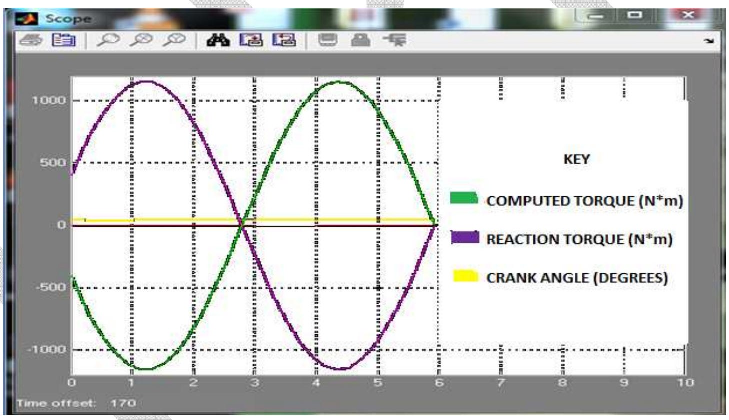

Figure 8: Crankshaft Output Waveform

3.0 Electronic Design

The electronic circuit comes in three parts, the charging circuit, the relay and the ultrasonic sound circuit. The charging circuit is placed between the 9 volts dc motor and the 6volts rechargeable battery. The input voltage for the charging circuit is obtained from the cranking of the 9 volts dc motor. The relay circuit is used to switch the polarity of the onboard direct current motor such that it rotates the overhead search lights in a clockwise and anticlockwise motion making a sweep of 180 degrees. The ultrasonic sensor is subdivided into two parts, the transmitter and the receiver. It transmits and receives at 40 KHz. It is used to measure the increase of sea level from a reference point by taking into account the speed of sound in air. The electronic circuit for the project is shown below.

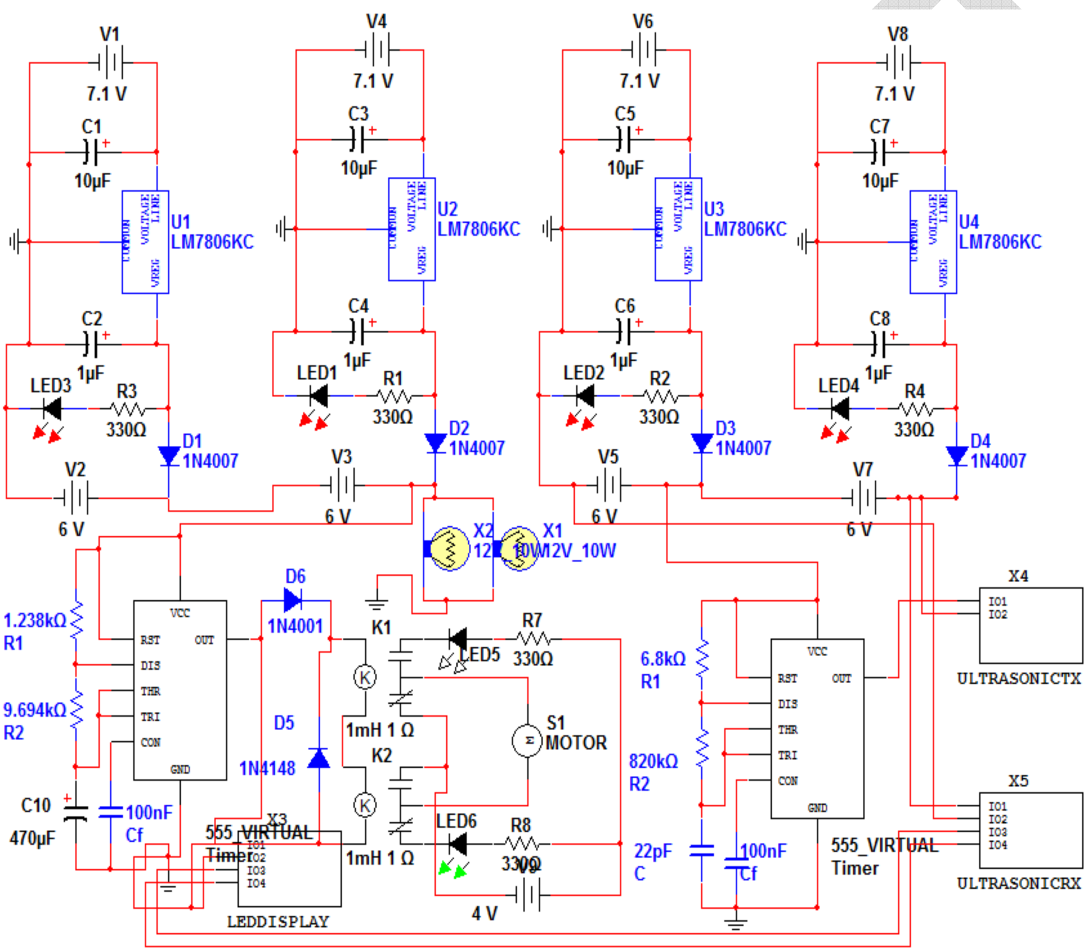

Figure 9: Showing Complete Circuit

4.0 CONCLUSION

The tidal to electrical energy converter met its objectives after construction. The input waves were provided by the torque from an alternating current (ac) motor attached to a bath trough. It was able to provide the sinusoidal (wave like) motion for the piston. The piston moved linearly in the vertical tube causing the crankshaft to rotate in a circular motion. Voltage of 7 volts was produced from the direct current generator; this charged the 6 volts battery. The overhead search lights are switched on and revolve at about 180 degrees sweep in reverse directions. The light at the back of the device goes 'high'. The first row of LED display flashes "high" and "low", spelling the word "SHALLOW". The second row of LED's on the display is switched "high" displaying "1" and "2" when the ultrasonic receiver sensor receives the echo from the transmitter sensor and goes "low" when the receiver does not receive any echo. Conversely more research can and should be done on tidal to electrical energy converters for use domestically and as a support for the national grid.

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