TIDAL ENERGY HARVESTING MODEL

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Keywords:

Arduino – ultrasonic sensor – Bluetooth module – servo motor - generator – turbine – sluice gates - barrage – gears - mobile application

Abstract

The energy crisis refers to the fear that the world's demands on the limited natural resources required to power modern society are shrinking as demand increases. Natural resources are in short supply. While they do occur naturally, replenishing the stockpiles can take hundreds of thousands of years. As a result, increased reliance on new sources of alternative energy, such as tidal energy, should help to resolve this quandary. This project, in fact, makes advantage of the potential energy of tides via a method known as tidal barrage. A tidal barrage is usually a dam constructed over a bay or estuary. Tidal barrages generate electricity using the same principles as hydroelectric dams, with the exception that tidal currents travel in both directions. Based on the project's efficiency in comparison to another initiative in the same field, the findings are quite promising. By replacing and modifying various materials' kinds, the total cost of the project was reduced. Tidal energy may have a negligible environmental impact when compared to other types of renewable energy sources. Also, there are only a few locations where this idea can be built on. Increasing the efficiency through gears, which reached 87.5 percent, and increasing the potential energy through increasing the surface area and height of the barrage all contribute to increasing the overall efficiency, and as a result, the final project is a large-scale project.

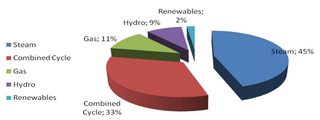
Introduction

One of Egypt's key goals for the 2030 vision is to focus attention on addressing climate change concerns and their negative consequences. Figure (1) shows that Egypt relies on fossil fuels for 89 percent of its energy, making Cairo the most polluting city in 2018. Egypt's target for 2035 is to increase the use of renewable energy sources to 42 percent in order to combat pollution. By increasing dependence on alternative energy sources while using current technology and communication networks in highly integrated projects.

This semester's capstone challenge is mostly focused on boosting the usage of alternative energy. Renewable energy (RE) generation reduces greenhouse gas emissions, provides energy access in remote areas, and diversifies fossil-fuel reliant energy supply, enhancing energy security. Energy harvesting through the use of wireless autonomous devices, such as those found in wearable electronics and wireless sensor networks. As a result, there is a greater need than ever before to develop research on this sort of energy.

Many sources of alternative energy are available today, but the challenge is to select one of these various types of alternative energies that can be applied on a large scale, as well as selecting a specific mechanism to be constructed and employed to solve this dilemma. Meanwhile, there is a specific type of these alternatives, which is tidal energy here in Egypt that is not completely exploited, so by utilizing this type of energy; it will be an additional source of energy. That shall contribute to solving this dilemma, the selected solution focus on this type of energy, the mechanism of the chosen solution in this case depends on the differences in water levels caused by tides. After examining several scientific studies and journals on the influence of tidal energy, it became clear that, in addition to being clean and renewable, tidal energy is also predictable and dependable, its equipment is long lasting, and it is effective at low speeds. In contrast, it has some drawbacks, including an adverse environmental impact on marine life, high building costs, a paucity of appropriate places, and inconsistency.

By analyzing the shortcomings and strengths of previous solutions, certain design requirements were established to assure the project's success, which are: low cost and high efficiency. Finally, taking into account all of these variables, the project concept was centered on utilizing an upgraded tidal energy mechanism for the first time in Egypt and integrating the project with current technology and communication networks to meet the necessary design criteria.



Figure(1): energy generation in Egypt

Materials

Hardware	Hardware	Software	power generation	measurement
				
				
				

Methods

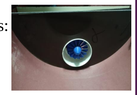
Pre – construction

1. The turbine was built at the fab lab using a 3D printer.
2. All of the electronic parts (Arduino and smart sensors)were purchased from an online store.
3. Software applications were installed to setup the smart sensors and create a mobile application that will track and monitor the data.
4. A plastic container, PVC tube, generator, and two wooden plates were purchased to create the main structure of the prototype.

Construction I

1. The prototype's construction proceeded through numerous stages, as follows:

a) Making two holes in the wooden plates with definite area according to the area of the PVC tube The turbine is inserted into the PVC tube.
b) Connecting the two wooden plates holes with the tube's ends.
c) Adding a small rod to the turbine to be like an axis that transfer the movement of the turbine through gears and rubber string to a generator which is vertical upward with the axis of the turbine.
d) Putting the previous system (barrage)in the middle of the container.

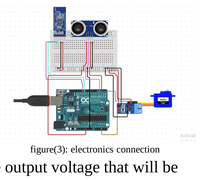


figure(2): construction of barrage

Construction II

The second part of the project is the communication system's construction and connection :

First, Connecting the programmed ultrasonic sensor with Arduino to detect and measure the water level (tide level) till it reaches a certain height then the sensor sends a signal to the Arduino which in turn translated to a command directed to the servo-motor to open the sluice gate that allows the passage of water. Also, connecting the voltage sensor to measure the output voltage that will be used to calculate the power. finally, Bluetooth module is connected to the Arduino and receives the sensor's output data and then directs it to a mobile application for analysis and processing.



figure(3): electronics connection

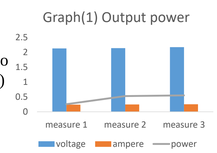
Testing

To achieve the design requirements (efficiency and cost), a test plan was created to determine the exact percent of efficiency of the selected solution as following:

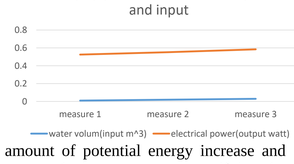
To simulate the real tides movement 00liters of water were added to one side of the splitted container to mimic the natural water level in the sea, then more water was added until the ultra - sonic sensor gives an alert (red light) which indicates that water level has reached the maximum height required and sends a signal to the Arduino. Next, the Arduino sends a command to the servo – motors which in turn open the sluice gates, enabling water to flow to the other side of the barrage spinning the turbine, then the output power passes through (voltage and current sensor) to monitor and calculate the output power. Finally, a mobile application connected with the Bluetooth module has received all data from the sensors and present it on graphs, then the project's efficiency is calculated by dividing average electrical power produced over the average amount of water passed through the turbine's tube.

Results:

To get an accurate results, the prototype testing was repeated 3 times with 3 measurements then calculating the average power to reduce errors in measurements as much as possible. As graph (1) shows, the prototype has produced an average power of 0.7 Watt.



To ensure that the project addresses the design requirements (efficiency and cost), the project efficiency was calculated by dividing the output(electric power) by the input(water mechanical energy). Graph (2) shows that the relation between the amount of water and generated power is a directly proportion relation means that as the amount of water increases the amount of potential energy increase and increasing the pressure on the turbine driving it more producing more power verifying the equation of the tidal energy $E=\frac{1}{2}APgh^2$. Graph(2) also indicates that the project has a total average efficiency of 87.5%.



Table(1) shows all data collected from the prototype testing, with an average power of 0.7 Watts

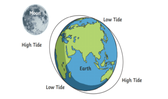
table(1)

Voltage	2.163	2.22	2.23
Ampere	0.292	0.318	0.332
Power	0.631	0.707	0.743

Analysis

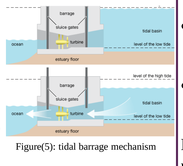
Given the environmental damage caused by nonrenewable energy sources, we must ensure that increasing reliance on renewable energy sources represents a significant step as a challenge that contributes to the resolution of many other problems such as pollution and climate change. This is especially important now that climate change has become a visible problem, causing global warming and the melting of ice at the poles. In light of this difficulty, Egypt has the opportunity to strengthen its reliance on renewable energy sources (tidal energy) that assist to reduce pollution and, as a result, will help to make progress in solving the great challenge of global warming. As the results shows, investigation in tidal energy harvesting is a promising investigation, inspite of its tiny environmental impact compared with other sources of renewable energy, it provides an effective solution that will be a strong addition to renewable energy sources in Egypt with the aid of contemporary technologies.

Tides are the rise and fall of sea levels produced by the combined influence of the Moon's and Sun's gravitational forces, as well as the rotation of the Earth. As the moon circles around the earth, its gravitational force pulls the sector of water facing it, creating high tide, while the sun's gravitational force pulls the water, generating another high tide. The low tide area is the gap between these two tides. So, because we have two high and two low tide areas, there are two tides every 24 hours.



figure(4): tides mechanism

A tidal barrage is a dam-like structure that captures the energy from volumes of water going in and out of a bay or river as a result of tidal pressures. Unlike a typical dam, which dams water on one side, a tidal barrage enables water to flow into a bay or river during high tide and releases it during low tide. This is accomplished by sensing the tidal flow and operating the sluice gates during critical tidal cycle periods. Turbines are installed at these sluices to capture the energy generated by the water as it flows in and out.

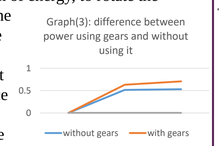


Figure(5): tidal barrage mechanism

The Model

Tidal power out put can be estimated using the equation $E=\frac{1}{2}APgh^2$ in which the main factors that affects the power generation progress is the area and height(volume of water).tides are predictable but are not constant as the mons movement around the earth in not in uniform circular path which affects the tide height and consequently affects output power.

to solve this challenge gears were added on the turbine and generator axis instead of connecting them directly which is the method that could be affected by the nonconstant tides range. The working idea of the gears is to transfer the kinetic energy between two terminal with a low torque input force into high output torque. the scientific base of this theory is that gears are not in the same size.by applying the law of conservation of energy, to rotate the biggest gear you need a high energy, when gears are connected the energy transmit from the large gear into the smallest one with the same ratio(with negligible friction energy waste) so when a high energy drives a small gear it is observed in the high torque output from the small gear and vice versa. Graph(3) shows the difference in output power when using gears, The ratio between these torques is called the gear ratio which is the number of teeth of the output gear to the number of teeth of the input gear. Suppose that the input gear teeth is30 teeth and the output gear is 105 the gear ratio is 105/30=3.5:1 which indicates that as the input gear completes one rotate it drive the output gear 3.5 rotates.



technology

Incorporating a communication system with a smart sensor network and developing a mobile application with a data base has improves the overall project's efficiency and accuracy. This is accomplished not only through the sensors and the application, but also by supporting the entire system with artificial intelligence (AI) programs.

scientific laws

The energy available from a barrage is dependent on the volume of water. The potential energy contained in a volume of water is $E=\frac{1}{2}APgh^2$ where h is the vertical tidal range, A is the horizontal area of the barrage basin, ρ is the density of water = 1025 kg per cubic meter (seawater varies between 1021 and 1030 kg per cubic meter) and g is the acceleration due to the Earth's gravity = 9.81 meters per second squared.in the real-life project A=22 km^2, h=2.3 meter.so, by substituting in the previous formula then: $\frac{1}{2} * 22 * 1025 * 9.8 * (2.3)^2$=584518.55 J

Then divide the energy by time to get power:584518.55/86400=6.7MW for one turbine, so by using 10 turbines the total power will reach 67.65MW.

The output power is calculated using this formula: P=IV, I is the electric current in ampere and V is the voltage. The SI unit for power is Watt.

Water flow rate is calculated by $F = \frac{V}{T}$ where F is the flow rate, V is the volume and T is the time.

The efficiency formula is $\frac{output}{input}$ output which is the electrical power, and the input is the amount of water.

Learning transfer

CH.3.01:relates to scientific methodology with the quantitative and qualitative analysis with explanation.

CH.3.02:relate to any project the uncertainty in measurement, accuracy and precision that relates to the errors in any work because there isn't any work absolute. There is difference between voltage sensor reading and voltameter reading(about ±0.35 to ±0.45 volt).

PH.3.04:relates to ground communication helped in understanding the mechanism of how data is sent from the Bluetooth module to the mobile application.

PH.3.05: relates understanding the difference between analog and digital data that helped in improve the accuracy of the results through using analog data transmission.

ST.3.01:concept the sample distribution and central limit theorem that convert the sample distribution into normal distribution by confirm 2 conditions n≥30 and 10%N >n where n is number of sample and N is the number of population.

Conclusions:

According to reviewing the collected data and analysis, exact conclusions have existed. The prototype price is 960L.E and the real-life project price is estimated to be 125000,000 L.E.

The tidal energy industry must develop a new generation of efficient, low cost and environmentally friendly apparatus for power extraction from free or ultra-low head water flow.

- The negative environmental impacts of tidal barrages are probably much smaller than those of other sources of electricity but are not well understood at this time. It is important to consider the influence of energy extraction while estimating the available energy from a potential tidal energy site.
- The future costs of other sources of electricity, and concern over their environmental impacts, will ultimately determine whether humankind extensively harnesses the gravitational power of the moon.
- Yet most of this tidal energy resource is under-utilized; however, if effectively captured using suitably engineered systems, it could be capable of making a major contribution to our future energy needs.

It is proved that the amount of power generated is strongly related to the size of the tidal range. The output varies with the square of the tidal range. Next, the output power is directly related to the area of the impoundment structure that indicates the amount of water passing through the turbine during each generated phase. This model and new renewable energy (Tidal energy) must be used specially for the remote locations that after an opportunity to build small tidal generators (1-10 MW). The optimal solution is important to design the tidal station depending on the critical values of parameters to generate the optimal electrical energy. This is a preferable, friendly, environment clean and healthy renewable energy source.

Recommendations:

There is no project that is completely perfect or done, and because science is cumulative, there are several recommendations that should be noted for future research on this study: Places with a minimum tidal level of 3 meter are strongly suggested for maximum performance and efficiency. Extending study into the project's targeted region for development in minimize the environmental impact on marine life. Finally, increase reliance on modern technology such as AI and machine learning to more accurately predict tides and enhance overall system control, particularly control of the flow of water from the two sides of the barrage.

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