Power Generation Using the Bayous

Dr. Mahmud Hasan, University of Houston-Downtown

Strong and diverse teaching, research, industry, and service (department, college, university, and community level) experience in innovative safety environments. Worked in different multinational engineering companies: McDermott International, Inc., Genesis Oil and Gas (Technip USA Inc.), and Shahjibazar Gas Turbine Power Plant. A licensed Certified Safety Professional (CSP) and Professional Engineer (PE) from two states (Texas and Louisiana). Evidence of scholarship as demonstrated by national and/or international publications, and experience with ABET and SACS assessment.

Julio Enrique Aleman, University of Houston-Downtown

I'm a student at the University of Houston-Downtown who will be graduating this coming May of 2023. I will be receiving my bachelors degree in Control and Instrumentation of Engineering Technology. I am a current member of the International Society of Automation and hope to use my experience with it and the University to do good work in the future.

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Abstract

In today's world, scientists and engineers are always looking for different ways to generate electricity and power, especially within the last couple of decades when there has been an increase in interest in sustainability. To this in mind, this works tried to see what kind of power can be generated using the flow of Houston bayous' water as they provide constant flow of water in the city of Houston. Various types of generators needed for this purpose have been looked at. The power produced from the particular type of generator in the Houston bayous is unique idea. Results of these findings are interesting for future research on alternate and renewable energy sources while also changing certain measurements with the device to see what can be found on the best conditions. This work was submitted in partial fulfillment of the requirements for the a project in Modern Methods of Engineering Analysis course at the Engineering Technology (ET) department in the University of Houston – Downtown (UHD). Furthermore, to the best of the authors' knowledge, this is the first reported work where bayou water is used for power production which is an inexpensive way to produce power.

Keywords: Power, Bayou, Houston, Turbine, No head.

1. Introduction:

For most of the modern age, people have been getting most of the energy from coal, gas, and other types of fossil fuels. While people have used other forms of power generation, there has been a substantial movement to find and use other forms of power generation where wind turbines being the most well-known example. This work looks for alternate power generation that has led to look at what sources are available in Houston area that could be used. It is decided to go with the bayous of Houston as they are quite widespread and will have a constant flow of water. This type of electricity generation will be different than other more established forms of electricity generation techniques by using water flow. This will not be a large system like a hydroelectric power plant, but something closer to a personal power supply that does not interfere with the overall flow of the bayou. While something like this would likely not be able to power a city it may give people an emergency power supply in cases like the recent cold snap in 2021 that caused power outages across the city of Houston. This idea seemed interesting as every one of us needs to always think to use the environment to produce electricity as much as possible whereas looking for sustainable ways to do it.

This work ran across the literature of run of river hydropower [1]. It led to looking into other methods to produce electricity which is how this work found the micro generation idea of electricity production from the bayous. However, the literature did not seem to implement to the urban environment whereas this was being looked at with the Houston Bayous in this work. The biggest issue would be the amount of construction for diverting the water run to create the head need for this system to work. There would also need to be observed how big a head someone can generate between sections of the bayou. As the article states this method is meant for systems with fast-moving waters which the Houston bayou are not known for. These are the reasons why a method that would require little to no head and less construction was chosen with the tradeoff being less power generation. Another issue that can be resolved is connecting the system to the grid as most sections of the bayou are located close to the city and other urban areas which means there should be no issues connecting to the grid. One thing this article [1] addressed is importance of the consideration of the wildlife factors, this should be something that can further be investigated seeing how much wildlife travels the bayou, especially the concrete section vs the natural ones, and how to account for this. The fact that the runoff river system is much less disruptive to the environment than a dam is important and it would be prudent to see how this microgeneration affects the bayou.

2. Objectives:

The present study aimed to determine how much power can be generated using small-scale no-head electricity generation device by using water flow on Houston's bayous.

3. Literature Review

The concept of Hydroelectricity is not new. People have been using it for quite a while in the form of dams to control water flow to generate power. There needs to be a large body of water that needs to be blocked/hold to create the necessary head to rotate the blades on the turbines and create power. For this reason, dams are generally created in less urban areas when water flooding can be a potential problem. There used to be a hydroelectric plant in the outskirts of Houston called the Greens Bayou Power Plant. Figure-1 is showing that plant when it was functioning. This Plant used the method where water was pumped to plant and shot at high velocity in turbine that generated power. This plant eventually ceased operation in 1986 due to various causes. This shows that Houston did have the means to use the water for electricity.

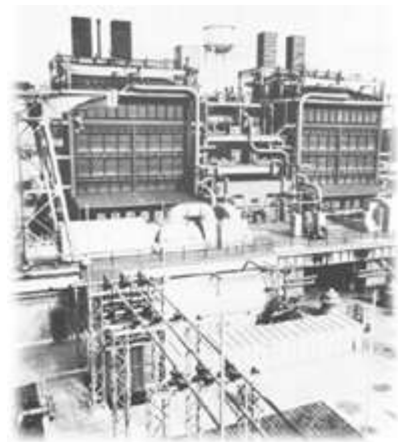

Figure-1: Greens Bayou Power Plant [2]

This work is not focused on these large-scale operations for hydroelectricity for several reasons. The first reason is the location. This study is looking at in the city itself or near the city, this means the massive structure cannot be built to create the head for a dam as this would cause large amounts of flooding. The second reason, the water flow of the bayou cannot be disturbed too much as it is used to get rid of water when the city gets large storms. Therefore something simple is needed that can be just drop into the water and start generating power.

There are quite a few commercial products that meet these requirements, a lot of which are used outdoors for people that want their source of power. Most of these products require no head to operate and, in many cases, can operate with low water flow speed that comes from rivers. The generator will not be seen that means a generator that would be submerged in the water. Figure-2 is showing one of those types of power generation devices.

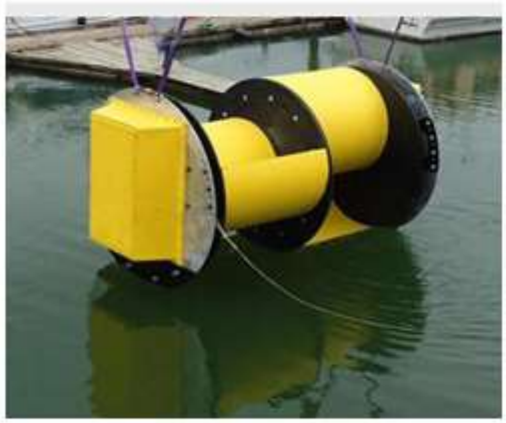

Figure-2: Small-scale water wheel [3]

4. Experimental Setup and Components:

To fulfil conditions as discussed in the previous section, a Jackrabbit submerged water turbine were decided to use. Figure-3 is showing the Jackrabbit turbine. This turbine is usually used to power scientific equipment in studies in remote areas by lowering it into water. It can function with very low velocities of water and only needs about 13 inches of water to function which should work with Houston's bayous.

Figure-3: Jackrabbit Turbine [4]

In addition, the area that the medium (water) passes through and was covered by the circular area accompanied by the blades of the turbine which have a diameter of 12.2 inches (about 0.31 m) [3]. When this blade diameter value put into the area equation of a circle resulted in an area value of 0.075 m^2.

5. Methodology:

To find the power generation, an equation for power was used. This equation was a bit different than the most water turbines where the head and discharge of the water are considered. This is a turbine that operates as little to no head. The equation becomes very similar to a wind turbine where air is used to generate electricity.

$$P = \frac{1}{2}(\eta_{turbine})(\rho_{water})(A)(v_{water})^3$$

In this equation, η is the efficiency of the turbine, ρ is the density of water, A is the area of blades rotation, v is the velocity of water flow.

To obtain all the components of this equation, it is first decided to get an efficiency value that would give a substantial result. However, based on the data that this turbine can produce 50W when the water is going at 5 mph or 2.23 meters per second, the efficiency value of this turbine is calculated.

$$\eta = \frac{2P}{(\rho_{water})(A)(v_{water})^3}$$

$$\eta = \frac{2(50W)}{\left(997\frac{Kg}{m^3}\right)(.075m^2)\left(2.23\frac{m}{s}\right)^3} = .12 = 12\%$$

The calculated actual efficiency is around 12%, however value of 30% for the calculations purposes were used which is pretty good for most high-end turbines. In reality the actual efficiency could be calculated.

Also, ρ is the density of water which was assigned the value of 997 kg/m^3. Area of rotation of the blades is calcucated previously. Table-1 shows different parameters for this turbine.

Table-1: Parameters of this Tubrine

Parameter	**Value**
Area (m^2)	0.075
Density (kg/m^3)	997
Efficiency	0.3

After finding the necessary information on the turbine that this study needed for the equation, the next step was finding the velocity that the bayous water travels at. There were various means that this study considered, the easiest being to buy a water velocity or flowmeter measurement device where data can be collected by flowing water through it and find the readings. The problem was that such devices were out of the price range, therefore this study needed to go with a more old fashion method.

The work on finding velocity started by going to the local bayou, in this case, the bayou located at Pinemont Dr and TC Jester Blvd in the north-west side of Houston where bayou water flows constatly uninterrupted. Once there, about 10 m marking of a spot is placed. Then a buoyant object (in this case a block of wood) was dropped on the water several meters before the starting point. Once the block reached the starting point, a timer/stop watch was started that would continue until the block reaches the endpoint. Then divided 10m by the time and this would be the velocity in meters per second. Then repeated this process another 3 times and average out the velocity. This process was repeated another 3 times at various times throughout the work period. This process does have some shortcomings. The main being that the velocity at the surface does not accurately represent the velocity that will be hitting the blades of the turbine as the lower in the water from the water surface the slower the velocity is. At nearly a foot down the water would likely only be getting about 66% of the velocity at the surface. Due to getting higher value for this turbine, it is decided to use the surface velocity in the calculations. The velocity was found through a series of physical measurements that were done over 4 days which is included in Table 1. After few initial velocity data of the bayous, it was found that the velocity was quite slow. Therefore the kind of power that could be potentially found if water traveled at its fastest that needs to be observed.

This study looked at the United States Geological Survey (USGS) information that includes water velocities and monitors the bayou. This study looked at this USGS data to find the maximum velocity. Using Figure-4 it is found that the highest velocity that the bayou reaches is around 12 ft per second which comes out to about 3.65 m per second. This will be used to find the maximum amount of power that can be generated from this type of turbine.

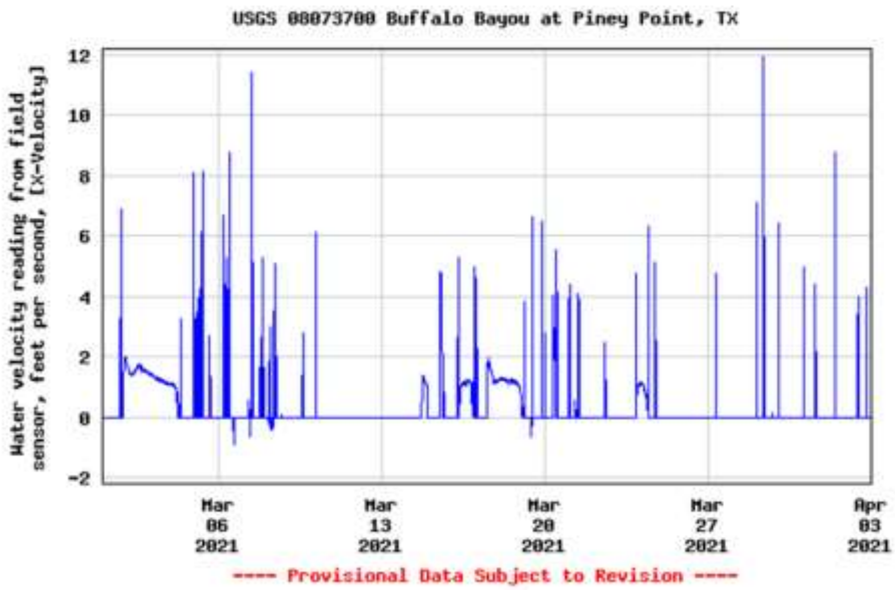

Figure-4: Water Velocity Readings in USGS [5]

6. Results and Discussions:

Once all the components are confirmed, it is decided to chose averaging out the 4 days data. Table-2 contains velocity of water flow data that was used in this study. These pieces were then put into the power equation to get the total wattage that can be produced. Then multiplied the amount by 24 to find the watt-hours for one day and then multiplied that amount by 365 to see how much power could be produced in a year. This calculation was repeated for the maximum velocity to find the absolute maximum amount of power that could potentially be obtained if that velocity continued for a year.

Table-2: Bayou Water Velocity (m/s) Data

<table>
<tr><th>Sample</th><th>1</th><th>2</th><th>3</th><th>4</th><th>5</th><th>Average</th><th>Average</th><th>Max</th></tr>
<tr><td>Day-1</td><td>0.62</td><td>0.75</td><td>0.63</td><td>0.59</td><td>0.65</td><td>0.648</td><td rowspan="4">0.696</td><td rowspan="4">3.65</td></tr>
<tr><td>Day-2</td><td>0.64</td><td>0.61</td><td>0.55</td><td>0.76</td><td>0.64</td><td>0.64</td></tr>
<tr><td>Day-3</td><td>0.55</td><td>0.62</td><td>0.63</td><td>0.6</td><td>0.6</td><td>0.6</td></tr>
<tr><td>Day-4</td><td>0.79</td><td>0.97</td><td>0.89</td><td>0.93</td><td>0.9</td><td>0.896</td></tr>
</table>

Once these values were found and calculation for the wattage per hour is conducted, then multiplied this value by 24 to get the watt-hours per day. Then multiplied the new value again by

365 to obtain the watt-hours produced in a year. Table-3 shows power generated data in different duration of time.

Table-3: Power Generated from this Turbine

Time	Hourly	Daily (24xHour)	Yearly (365xDaily)
Average (Wh)	3.7	90	32673
Maximum (Wh)	534	12827	4681982
Maximum (kWh)	0.5	12.8	4681.9

Data indicated that the results were not great. For an hour the average velocity from the measurements produced was 3.7 Wh and extension for the year resulted in 32673 Watt-hours for a year or 32.7 kWh for a year which while not a small amount is not enough to be especially useful for anything other than charging some small items. Comparing this value to the annual power consumption of a household, which according to the United States Energy Information Administration (EIA) is around 10,649 kWh in a year [6], these methods of energy production cannot meet the needs of a whole household.

When looked at the power of the best-case scenario, it seemed a little improvement. With the maximum velocity, this arrangement generates 534 Wh in an hour and 468 kWh in a year which is a substantial increase from the average that was obtained. This is still only about half of what a household uses in a year. The caveat is that if water had the fastest velocity for a year then better efficiency could be obtained. In reality, this numbers likely gets closer to the average value.

To accomplish this goal, the equation for power which is based on a little to no headwater for the generator, the accurate velocity of the bayous of Houston, and information on the type of water generator will be needed. This work obtained some physical measurements of the bayou in the local area as well as some information from the USGS website, and used this information along with a power equation to find the wattage produced and scaled this up to the amount generated in a year. From findings and changing certain measurements to see what could be found on the best conditions, it was a surprise to see that only a small amount of power was generated even when going with the case where the fastest velocity is applied in a year. It looks like it will not be able to power homes for a long hour using this method, but it may provide a decent emergency power supply for instant power for a short period of time. This type of power generation under these conditions is a far way away from being efficiently viable for bigger industries.

Other generators also can be looked at and see if any other models are similar to the Jackrabbit turbine. There are more modern versions that have a higher efficiency than the Jackrabbit one or if there is other underwater designs that work better and produce more power need to look at. Other types of waterwheels or other types of generators that rest on the surface of the water need to look at.

Measurement of water velocity on days that have heavy rainfall can be investigated. This study took most of the readings on days where the readings could get down to the ground level of the bayou and never really was able to do a comparison with good readings on when the water flow of the bayous change when dealing with a greater water volume. This study gave a better depiction of the potential speeds that the bayou water travels.

Future study can be conducted to see the diversity of the areas covered, this study only took reading at one specific area. Future study can also be conducted to see if the bayous at other areas yield similar results or if there are areas that have a higher average velocity. Future study could investigate if there are optimum areas to set up turbines to get the maximum power generated.

The findings from this study are for a single turbine and the results were a little disappointing. However, future study can be conducted to know what kind of numbers could be achieved if a larger number of turbines around the city were considered. The main thought on this is that the design and math of the turbines are very similar to those of air turbines. Therefore, a system could be set up like a wind farm where the study can find the distance that each turbine needs to be spaced to keep the flow of the bayou water steady and not bring it to a halt. From that finding, a general idea of how much velocity is lost and how much power is generated when there have been a lot of numbers (e.g. 100) of turbines around the city.

While the findings were a little small, this study does earnestly believe anyone can use the bayou for energy production without blocking it up. The methods need to be expanded and refined. May be in the future with further study may lead to have the bayou doing more than just getting rid of the floodwaters.

7. Conclusion:

From the findings, it is concluded that this method of power generation is not necessarily ready to be used to power a city. The power produced by a single unit is not enough to be practically useful. The cost and maintaining the equipment would likely take quite a while to consider reaching to break-even point from power generation aspect. Even with optimum conditions the power produced was not enough to power a single household. That does not mean this could not be used as an emergency power supply in the case that standard power production from national grid fails that was seen the kind of damage that caused recently with the recent cold snap in 2021 that caused massive failures in the power grid. Although, the power produced by this method would not fully fulfill the need of people, however there is much that can be expanded on this method.

This work was performed in partial fulfillment of the requirements of the project in the Modern Methods of Engineering Analysis course at the Engineering Technology (ET) department in the University of Houston – Downtown (UHD). The work was completed in a semester's time. By completing this work, the student demonstrated proficiency in a number of technologies and methods including: turbine and generator design, instrumentation, modeling, and power systems implementation. Furthermore, to the best of the authors' knowledge, this is the first reported work where low cost power production is conduction using Bayou water. This type of work solidifies the alternate and renewable energy background for Engineering Technology students.

8. Acknowledgments:

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