Hydroelectric Technologies and Geographical Prospects in Louisiana

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ABSTRACT

Currently Louisiana has only one hydroelectric power plant called Sidney A. Murray Jr. Hydroelectric Station. The hydropower plant is capable of producing 192 Megawatts [1] which only makes up .8% [2] of the electricity generated in the state of Louisiana. This report addresses the feasibility of increasing the generation of electricity at the current hydroelectric station in Louisiana. It also compares the two types of hydroelectric power plants along with considering the possibility of increasing the electricity generation from low head technology currently used at the Sidney A. Murray Jr. power plant.

The study shows that the existing hydroelectric plant in Louisiana is extremely efficient and it is not economically beneficial to increase its efficiency at this time.

Keywords: louisiana, hydropower, efficiency, low head plant, sidney a. murray jr.

1 INTRODUCTION

As the world grows we struggle to meet our energy demands while trying to limit the greenhouse gas emissions. We must be responsible in exploring the most rational options for meeting the energy needs. Hydroelectric power is a responsible source for clean renewable energy. The inherent economic, technical, and environmental benefits of hydroelectric power make it an important contributor in meeting the upcoming energy demands in the world. The global economic success is driving the consumption of energy to increase at rates that will be greater than the overall energy supply. While we rely on natural fuels such as oil, natural gas, and coal to meet these needs now, they are negatively impacting the environment of tomorrow. The techniques used to mine the current resources underneath the earth are leaving long lasting scars on earth's landscape. Since fossil fuel and nuclear plants need fuel combustion to produce their power, they in turn are emitting air and thermal pollution into the environment. Hydropower does not rely on fuel combustion or other limited nonrenewable resources to produce its power. However hydroelectric power does have some limitations when it comes to producing power. Hydropower's main drawback is its environmental impact on the habitats of local fish, plants, and animal life caused from damming the rivers and streams. This drawback can be less severe and even possibility avoided when future planning on the location and environment are taken into consideration. Hydropower plants are reliable with low failure rates and operating cost while still not causing any air, land, or water pollution. Since hydropower is a renewable energy source it can be upgraded at the current dam site with little to no effect on the environment. It does not need to be relocated when it runs out of fossil fuels. Renewable energy like hydropower needs to be looked at closer as an answer to future energy demands. Currently hydropower provides one-fifth of the world's electricity [3].

Hydropower uses the earth's water cycle to produce electricity. The earth's water cycle starts with the sun heating the water on the earth's surface causing it to evaporate. The water vapor then condenses into clouds and falls back on the earth through precipitation. The water will flow through the rivers heading back into the oceans where it will evaporate and begin the cycle over again. Hydroelectric power uses the kinetic energy of moving water to make electricity. The water passes through a pipe or penstock which pushes against the turbine blades and turns a generator. The generator produces energy that can be delivered to people through long distance power lines.

The next section describes the two main different types of hydroelectric power plants along with their pros and cons, high head hydroelectric plant, low head hydroelectric plant, how to convert hydropower into energy, and the possibility of building one of these plants in Louisiana.

2 HYDROELECTRIC PLANTS

The efficiency of today's hydroelectric power plants is about 90% [4]. The energy created by hydroelectric power plants is done with no air or thermal pollutions being released into the atmosphere. Hydropower is an essential contributor in our national power grid due to its quick response to varying loads and disturbances. Combustible and nuclear processes cannot efficiently accommodate the rapid fluctuations in loads. These favorable traits make hydropower an attractive source for electric power.

Hydroelectric power converts one form of energy into another. It starts with the kinetic energy of moving water. The first conversion of energy is mechanical energy where the flowing water of the river turns the turbine's blades. The turbine is connected to a rotor which is also connected to a generator which converts the mechanical energy of the generator into electricity. The speed the turbine turns is controlled by a governor to maintain the standard electrical frequency of 60 HZ. This is done by a speed control sensor which senses a change in the speed of the turbine and allows the governor to adjust the water flow to the turbine. There are two main types of hydroelectric power plants, low head hydroelectric power plant and high head hydroelectric power plant.

2.1 Low Head Hydroelectric Power Plants

Low head hydroelectric power plants are located on rivers, streams, and canals and are referred to as a run-of-the-river plant. Portions of water from the fast flowing rivers and waterfalls are diverted to a pipe called a penstock that carries the water to the turbine. Another type of run-of-the-river plant is the water wheel which is usually on a floating platform. The water wheel acts like the turbine and uses the force of the moving river to turn the wheel which in turn turns the generator. This approach of harnessing the water's power is inexpensive, easy to implement, and has a low impact on the environmental habitat. The low impact on the environment is due to the fact that the fish and other aquatic wildlife can swim around or below the hydroelectric plant. Because the low head plants have little to no provision for water storage, the total river is used to produce electricity.

2.2 High Head Hydroelectric Power Plants

High head hydroelectric power plants use dams to create a "head", the height from which water flows. The water is forced to flow from a high level intake through the penstock which carries the water to the turbine located further downstream. The dam allows for the total use of the river to be used. Most high head plants also incorporate an upland storage lake that can be pumped into the lower reservoir during off peak times of the river. By using this pumped storage method the hydroelectric power plant can efficiently provide electricity when the demand is needed and store the rest when not. The down fall to blocking the river with a dam and controlling its flow is the impact on fish passages which render spawning areas for fish unusable. Section 115 subsections 2 and 3 of The Fisheries (Consolidation) Act 1959 require that fish have a free and uninterrupted migration path for all parts of the year. After providing an adequate path for fish and other wildlife, it must be approved by the Minister for Communications, Marine and Natural Resources which is stated in Act 1842, section 62/63. To further prevent mutilation of fish and wildlife from the turbine blades, screens and grates will be placed in front of the headrace and tailrace to prevent the upstream and downstream migrating fish from entering. Section 123 (a & b) of the 1959 Act stipulates that at the points of divergence to and from the return to the river, the channel shall have bar screens with gaps not greater than 2-inch fitted.

2.3 Transmission of Hydroelectric Power

Since hydroelectric power plants are often located in rural areas and the electricity needs to be transmitted over long distances to the city, a network of transmission lines and facilities are used. The electricity from the plant goes through transformers which raise the voltage to compensate for the long distance that needs to be traveled through the power line. Then, at local substations, the electricity is put through transformers again to reduce the voltage so it can be distributed to the power grid of the city. The electricity is then sent to transformers on poles or buried underground to further reduce the electricity to the proper voltage for our homes and businesses. Electricity is measured in kilowatt-hours and we are billed according to how much we use.

Hydroelectric power is just one of the many sources of electricity. Other sources of electricity include gas turbine, fossil fuels, nuclear, geothermal, and wind. All of these power plants can use the same transmission lines and stations to bring power to the city or power grid. This allows the source of the electricity to be interchangeable among many different power plants to meet the varying demands of the city.

2.4 Hydroelectric Energy Conversion

How much power a hydroelectric plant can make depends on two main factors: how far the water falls and the amount of water falling. The further the water has to fall, the more power it is capable of generating. What determines how far the water will fall is the size of the dam. The taller the dam is built the farther the water has to fall which means the more power the hydroelectric plant can produce. The power produced from falling water is directly proportional to the distance it falls or the height of the dam. The amount of water falling down through the turbine depends on the amount of water flowing down the river. Increased amount of water falling through the turbine will produce an increase in power. If two similar hydroelectric power plants are creating power, the hydroelectric power plant that is on a bigger river with more flowing water will produce more power. A river that has double the amount of water flowing as another river will be able to produce double the amount of power. The amount of power a hydroelectric power plant can produce is also directly proportional to the amount of river flow.

The number of kilowatts of power a hydroelectric power plant can produce can be derived using the following equation [5].

$$P = (H \bullet Q \bullet g \bullet \eta) \tag{1}$$

Where in Equation 1, $\boldsymbol{P}$ is power in kilowatts, $\boldsymbol{H}$ is the height of the dam in meters, $\boldsymbol{Q}$ is the flow of the river in cubic meters per second, $\boldsymbol{g}$ is the gravity which is 9.81 m^2/s and $\boldsymbol{\eta}$ is the plant efficiency defined as the ratio of the electrical output power to the hydraulic input power. Using

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the SI units we can derive the power in kilowatts using the following equation.

$$P = (H \bullet Q \bullet \eta) / 11.8 \quad (2)$$

Where in Equation 2, ***H*** is the height of the dam in feet and ***Q*** is the flow of the river in cubic feet per second. The term ***η*** for efficiency in Equation 1 and Equation 2 measures the effectiveness of the turbine and generator being able to convert the mechanical power of the falling water into electric energy. Most new hydroelectric plants have an efficiency of 90% where older, less maintained, hydroelectric plants might have an efficiency of 60% [6].

Equation 3 measures electric energy produced by a hydroelectric plant in a year.

$$AEE = \int_{t=0}^{8760} P\,dt \quad (3)$$

The Annual Electric Energy (*AEE*) is given in the units of kilowatt-hours, where we have assumed 8,760 hours in one year. The average residential energy that is consumed in the South region of U.S. is about 15,000 kilowatt-hours per household per year [3]. This data and Equation 3 may be used to determine the number of households that can be served by a hydroelectric power plant in a year. We estimate presently more than 47,500 households are served by the Sidney A. Murray Jr. hydroelectric plant when it operates at the average river flow of about 100,000 *cfs*. We devote Section 3 to address using Sidney A. Murray Jr. plant to serve beyond the existing residents.

3 EFFICIENCY CONSIDERATION OF SIDNEY A. MURRAY JR. PLANT

The only low-head hydroelectric plant was built near a small town along the Mississippi River called Vidalia. The idea for the plant came along during the 1970's when the residents became concerned about rising energy costs. The mayor, Sidney A. Murray, Jr., decided to start a feasibility study to see if the Mississippi River was a viable means of generating electric power for the town. In 1977, Sidney decided to utilize the Mississippi River by developing the low-head hydroelectric plant about 40 miles south of Vidalia, Louisiana. This was a good location due to the Mississippi, the Red, and the Atchafalaya Rivers running almost parallel to each other in a north-south direction. The distance between them is approximately 5km. The estimated head drop varies between 2.5m-6m. The hydroelectric plants construction began in 1985 and was finished in July of 1990. The hydroelectric plant was named Sidney A. Murray Jr. after its mayor's vision of clean energy. The Sidney hydroelectric plant utilizes the difference in the head pressures between the Atchafalaya and Mississippi Rivers. While there are many ideas to achieve the goal of increasing the generation of hydroelectric power in Louisiana, there are two promising ideas. The first one is to conduct a feasibility study for development of a new hydroelectric power plant at a new site in Louisiana. The second is to increase the efficiency of the existing Sidney A. Murray Jr. hydroelectric power plant. In conjunction with the second idea, one may look into improving the height differential (*H*) between the headwater and tail water of the plant. With the existing type of turbines (bulb turbines) used at Sidney A. Murray Jr. plant, it would require the riverbed dredging and the reinstallation of the existing turbines at a new, deeper level, to increase the height differential. However, the existing rainfall and the rated head for the turbines have to be considered to verify if the method is feasible and if the existing capacity of the turbines can handle the increased differential [7, 8]. Based on our study reported in this paper, the Sidney A. Murray Jr. hydroelectric power plant is 90% efficient and there is no viable solution for increasing its efficiency beyond existing generation.

The Sidney A. Murray Jr. hydroelectric plant is equipped with eight bulb turbines which can discharge up to 170,000 *cfs* and produce 192MW of power with an operating head varying from 8 to 25 feet. Due to the Old River Control Complex, the amount of water flow from the Mississippi and Red to the Atchafalaya Rivers through the hydroelectric power plant is limited to approximately 30% of the combined flow from the Mississippi and Red River [9]. The Corps monitors and adjusts the daily percentage of flow allocated to the hydroelectric power plant according to the conditions on the Mississippi, Red, and Atchafalaya Rivers. The Sidney A. Murray Jr. hydroelectric plant is the largest low head run-of-the-river hydro plant in the world [1] and operates at an outstanding rate of 90% efficiency. Although the plant efficiency can be increased beyond the present ***η*** = 0.9, the increased electrical output power needs to be transmitted to the transmission grid for distribution. At the present time the transmission system infrastructure in place needs to be upgraded before the plant efficiency is increased for production of higher electrical output. Our preliminary cost-benefit analysis, that shall be confirmed and reported in our future publications, indicates that the ***cost*** of increasing the efficiency and successfully transmitting it to the users in Louisiana starts to outweigh the ***benefit*** gained by increasing Sidney A. Murray Jr. plant efficiency beyond ***η*** = 0.9. Furthermore, we shall report the cost-benefit ratio of Sidney A. Murray Jr. plant with benefits obtained from installing new hydroelectric plants in Louisiana in future publications. It is only the right combination of hydroelectric generation and transmission infrastructure that could make installation of new hydroelectric generation in Louisiana a viable solution for increasing an environment-friendly source of energy.

4 CONCLUSION AND FUTURE WORKS

This study helped to determine that the Sidney A. Murray Jr. hydroelectric power plant is efficient and that it would not be cost-effective to increase its efficiency at this time. For future works we will have to look for other means to increase the hydropower generation in Louisiana. In addition, a study that considers the transmission network in conjunction with the desired increase in the hydroelectric generation should be preformed to address the effect of increased generation on the existing power grid. The mathematical models that represent a hydropower plant such as that presented in [10, 11] should be considered in new studies. The optimal scheduling such as [12] to control the head and tail water levels should also be considered in the study.

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BIOGRAPHIES

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