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Study on Electricity Generation by Water Wheel in Micro Hydro Power Plant

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Abstract

Hydropower can be used to supply domestic electricity in low cost to cover the increasing demand especially in remote areas. A small micro hydroelectric plant was designed in this study. Full plant design was made using "solid work' software consisting water wheel, wheel blade, frame, pulley. Water wheel was made with a belt and pulley arrangement and attached with a generator. Water was supplied at high discharge rate and was directed through the wheel. The vertical head created pressure on the bottom of the pipe. Pressurized water emerging from the end of the pipe introduced the force that drives the wheel. The turbine started rotating and drive the generated electricity. First of all, the water wheel and other parts were designed and location site was selected. A rectangular drainage canal was selected and water wheel was placed into the canal. When the flow of water started, with the force of water flow turned the wheel rotating and a DC current was generated. A bulb turned 'on' which was attached with the electric wire. Using multi-meter, produced voltage and current was measured. Finally found 3.01 Watt of electricity was generated from per 0.15 m^3/s discharge of the water from the wheel.

Keywords: *Micro-hydropower; hydroelectric; renewable Energy; hydro-electricity; power generation.*

1 Introduction

Hydro power is clean, nonpolluting and renewable source of energy. No harmful gases are emitted into the atmosphere to cause pollution, thereby making hydropower a clean energy source. By converting kinetic energy and potential energy of water into useful form, electricity can produce. No fuel means no fuel cost, no combustion, no generation of flue gases, and no pollution in the atmosphere. Only installation cost will need. Bangladesh is experiencing a difficult problem to deal with the power crisis because of its developing commerce and industries. Due to a lack of enough power generation capacity, the country cannot be fully powered by the national grid system as it currently exists. Although there is a low load demand in rural and isolated locations, the supply of electricity has been characterized by high transmission and distribution costs, transmission losses, and significantly subsidized prices. Despite the fact that power generation has not increased proportionally, the demand for electricity is rising quickly. Power demand and supply currently differ significantly. A shortage of about 2500 MW was estimated to meet off the local demand (Uddin and Tiplon, 2016). Islam et al. (2012) studied the scenario of hydropower generation in Bangladesh and its potential used. As a result, lack of a reliable electricity service has deterred foreign investment and held back economic growth. Bangladesh must choose alternative energy sources like fossil fuels and renewable energy sources to combat the severe power problem and rapid resource depletion. Only if the economic and environmental factors are taken into account can the roadmap to energy security and sustainability be realized. Hydro power is the most commonly used renewable energy since it makes up a significant 19% of the electricity produced worldwide (Raman et al. 2009). Hydro power plant can categorize according to the power range from 5-50 MW. But worldwide there is no consensus on the definition of hydropower. Some countries such as Portugal, Spain, Ireland, Greece and Belgium consider 10 MW as the upper limit of installed capacity. In the UK the small hydro power limit is generally 20 MW. India established a hydroelectric project with a capacity of up to 20 MW as a small hydropower project. According to the

Department of Energy (DOE), large hydropower is defined as power facilities with a generation capacity of more than 30 MW (Borota et al. 2008). In hydroelectric power station, the kinetic energy developed due to gravity in falling water from higher to lower head is utilized to rotate a wheel to produce electricity. The potential energy stored in the water at upper water level will release as kinetic energy when it falls to the lower water level. This wheel rotates when the following water strikes the wheel blades. To achieve a head difference of water hydroelectric electric power station are generally constructed in hilly areas. In the way of the river in hilly areas, an artificial dam is constructed to create required water head. Ayesha et al. (2018) performed an analysis, evaluation and systematic representation of techniques of a low head micro hydropower system using a fixed water source and designed a water wheel for the system. Micro-hydropower facilities are those with generation capacities between 5 KW and 100 KW (Hossein and Raman, 2010). Hammed et al. (2018) designed a hydroelectric power generation unit using water wheel where full bridge rectifier was attached. Suryatna et al. (2021) designed a Prototype Model of Micro Hydro Power Plant (MHPP) for small water discharges (less than 10 Liters per Second), namely MHPP waterwheel and the Speed Converters from waterwheel to Dynamos, named "Converters" MHPP. With the right application of cutting-edge technology, water heads of 2 meters can be used to generate power effectively. Zaman and Khan (2012) designed a low head micro hydropower and theoretical output was calculated. Jasa et al. (2015) found triangular rather than straight or curved blades yielded the highest efficiency, but that the location characteristics strongly influence the optimum angle positions of the nozzle. Kaldellis J. K. (2007) evaluated the senerio of using hydropower energy for Greece which was quite power for small investment with subsidy. Due to the grid network's inefficient planning, there are energy issues in rural and hilly locations (Hossein and Raman, 2010; Borota M. 2008). Sitakunda, Richang, as well as Toibang of Chittagong, have the potential to establish micro-hydropower plant. Teesta barrage is the largest irrigation project in Bangladesh along with 19 potential sites for power generation. An overall percentage of electricity production from hydropower resources in Bangladesh from 1971 to 2018. Miskat et al. (2020) found a reasonable flow rate, 232 rivers of Bangladesh can be utilized small scale hydropower generation as well as ensuring energy security for remote people. The Hill tract of Bangladesh has enormous potential for hydro energy because of numerous small rivers and canals. Local Government Engineering Department (LGED) has been trying to employ hydro energy resources to meet the energy demand in hill tract areas. An undershot waterwheel performance study was done and found that undershot waterwheel was strongly influenced by the water discharge and the water level in the channel (Buku et al. 2021). For these outlying locations, micro-hydropower offers an affordable option. It offers a viable answer to energy issues in rural and hilly places where expanding the grid infrastructure is relatively unprofitable (Adhau et al. 2010).

2 Materials and methodology

2.1 Design consideration and components of the Micro Hydro Power Plant

The design consideration of the Micro Hydro Power Plant was simple. It was designed and fabricated in a way to perform a comfortably. The design consideration of the Micro Hydro Power Plant and section part of the machine is shown in figure 1.

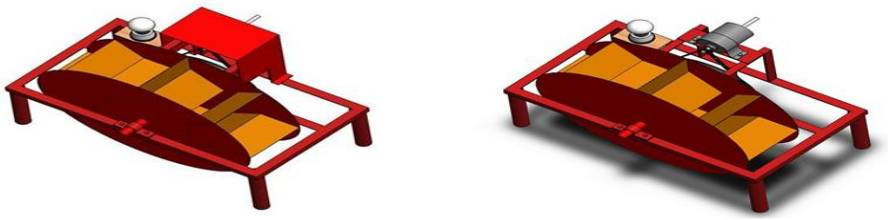
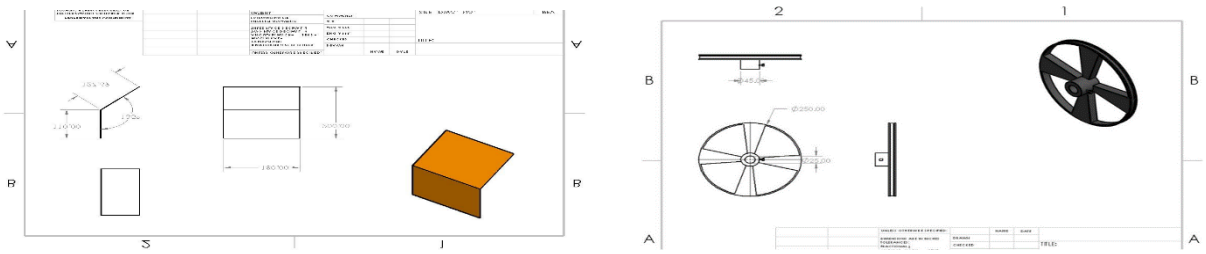


Figure 1. Design consideration of micro hydro power plant.



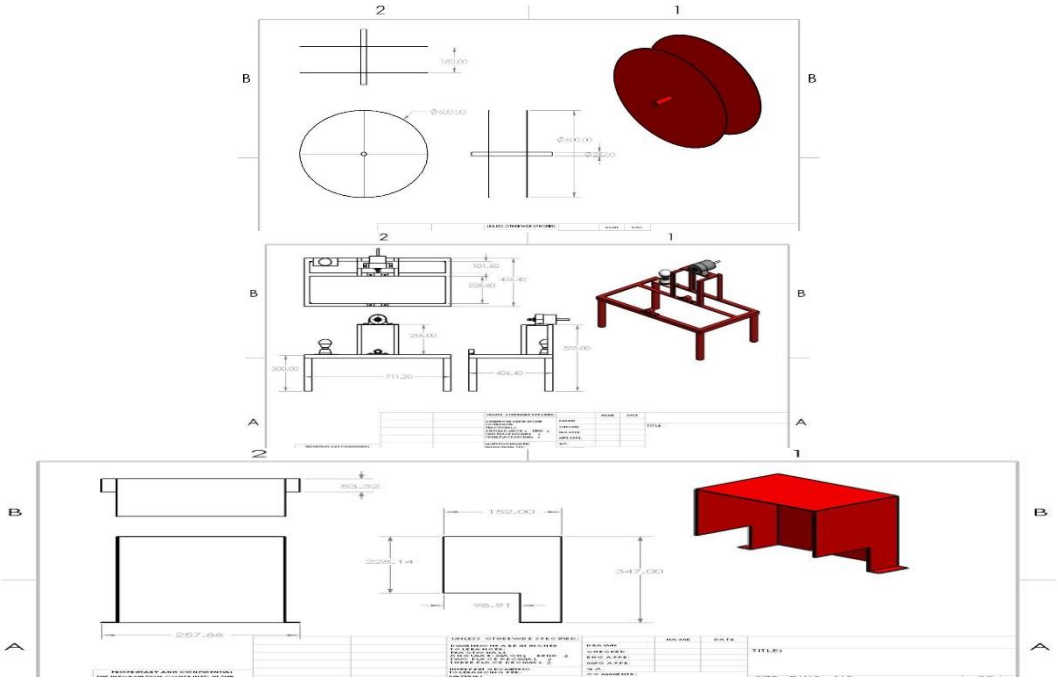


Figure 2. Design of wheel blade, pulley, water wheel. Frame and cover design for micro hydro power plant.

2.2 Working Principle of Micro Hydro Power Plant

The power plant from the water depends on the combination of head and flow height. Both must be available to generate electricity. Water will divert from the river to the pipe, where it will descend the hill and directed through the wheel. The vertical or head crop will create pressure on the bottom of the pipe. Pressurized water emerging from the end of the pipe will creates the force that drives the wheel. The turbine will rotate and drive the generator in which electricity will be generated. The water pressure or high drop will create by the difference in height between the water and wheel intake. The head can be expressed as distance, or as pressure. The net head will be the pressure that will available in the wheel during running water, which will always be smaller than the pressure when the flow of water will dead (head static) due to friction between the water and the pipe. The diameter of the pipe also affects the clean head. The discharge will be the amount of water available, and expressed as the volume of cubic meters per second (m^3/s), or liters per minute (l/s). The design flow will be the maximum flow in which the hydro system is designed.

2.3 Experimental Procedures

First of all, the water wheel and other parts were designed in solid works. Next, the location site at west side of Zia Hall in HSTU was selected. Then to perform the experiment, a rectangular drainage canal was selected. Then water wheel was placed into the canal. After that the flow of water started and with the force of water flow, the wheel started rotating due to the rotation of water wheel the DC Current was generated. With this generating current the Bulb started to enlighten. With the help of multi-meter, the produced Voltage and Current was measured. Finally, from the data production of the electrical power was calculated.

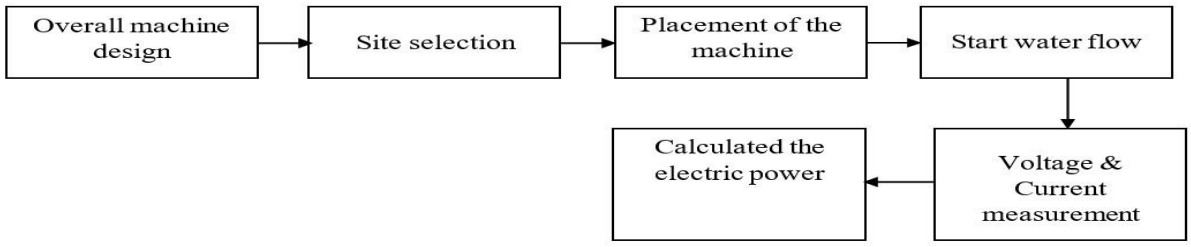


Figure 3. Flow chart for experimental procedures.

2.4 Required Materials

Table 1. Required materials

Name	Specifications
Water Wheel	Wheel diameter 60 cm, wheel width 18 cm, Angle of blade 45^0.
DC Motor	12-Volt DC Motor.
Pulleys	Larger pulley diameter 25 cm, smaller pulley diameter 1.3 cm.
Power Transmission Belt	Belt length 48 cm
DC Bulb	Power 3-Watt, Weight 41 gm, long life up to 3,0000 Hours.
Bearing	Bearing diameter 5 cm.

3 Results and discussion

3.1 Power Calculations

The potential power can be calculated as: Power of the wheel, P= η×w×Q×H Kw (1)

Were,
Q= Flow rate (is in a cubic meter per seconds)
H= Water head (in meters) and
W= 9.81 ms^{-2}
Again,

The discharge of the wheel, Q= A×V= b×d×V (2)

Were,
A= Area of the wheel
d= Diameter of the wheel (in meter)
b= Width of the wheel
According to Float Method Water Velocity is achieved by, $V = \frac{S}{t}$ (3)
Were,
V= Water velocity
d= Distance of float travelled by the water
t= Time taken by the float

3.2 Field Experiments

Here the parameters were, Head of water = 17 cm, Diameter of the wheel = 60 cm.
For velocity of Wheel, Diameter of the wheel = 60 cm, Radius of the wheel = 30 cm = 0.3 m.

Circumference of the wheel = 2πr = 2×3.1416×0.3 = 1.9 m. (4)

Velocity obtained of the Wheel, $V = \frac{S}{t} = \frac{1.9x45}{60}$ = 1.4 m/s were, Rotation of the wheel= 45 rpm. (5)

Again, Discharge of the wheel, Q = AxV = b×d×V = .18× .60 × 1.4 = 0.15 m^3/s. (6)

Power of the wheel, P = η×g×Q×HKW = 0.6×9.81× 0.15× 0.17 = 0.15 kW = 150 Watt. (7)

3.3 Calculation for pulleys:

For larger pulley diameter = 25 cm
For smaller pulley diameter = 1.3 cm
For 1 revolution of larger pulley, smaller pulley revolves 11 Nos
For 45 revolution of larger pulley smaller pulley revolvers 11x45= 495 Nos
From practical work in the field using multi-meter
Here we got: Current, I = 0.86 Ampere, Voltage, V = 3.5 Volt, Power, P = VI = 3.5x.86 = 3.01 Watt

3.4 Cost estimation

The cost estimation along with the part in words: Seven Thousand Six Hundred Eighty Taka Only.

Table 2. Cost estimation.

SL NO	Name of the Implements	Amount	Cost
01	12-volt Dc Motor	450 ×1	450/-
02	Belt	100×1	100/-
03	Pulley	750	750/-
04	Led Bulb	165×1	165/-
05	Bulb Socket	45×1	45/-
06	Water Wheel	2000×1	2000/-
07	Bearing	75×2	150/-
08	Wire	20×1	20/-
09	Metal cost	-	1800/-
10	Labor Cost	-	1500/-
11	Transport	-	450/-
12	Others	-	250/-
		Total	**7680/-**

4 Conclusion

Micro-hydro power plant is an important part of world's electricity supply. Specially in remote areas it is providing reliable and economic source of electricity. In this study, designed water wheel was placed in a rectangular drainage canal. Though water was started flowing in the canal, rotating wheel generated a DC current and attached bulb was turned on. With the help of multi-meter, produced voltage and current was measured. A 0.15 m^3/s of flowing water generated 3.01 watt of electricity with existing micro hydropower plant. Sometimes electricity generated was dropping due to discontinuous flowing speed and volume. As no fossil fuel was required in this hydro power plant, it can help to produce small amount of electricity and save other source of energy. More research and collaboration is necessary to used it for industrial purposes. The generation of electricity in Bangladesh is still incredibly dependent on fossil fuels. But the nation's resources are finite and will probably run out shortly. Furthermore, burning fossil fuels has a very bad impact on the ecosystem. The globe is more concerned than ever about a variety of energy resource depletion as well as environmental deterioration brought on by the current pattern of fossil fuel consumption. We are considerably more concerned because we are a large country with limited energy resources. An incentive to develop a micro-hydro plant for local use can be created by carefully weighing the characteristics to be used while examining possible sites. Due diligence in creating decentralized small-scale water power or micro-hydro schemes can demonstrate their viability as an eco-friendly form of power generation, and with the availability of international funds for green energy, governments may be greatly encouraged to consider this alternative.

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