A Design and Analysis of Artificial Vortex (ArVo) based Stand-Alone Microgrid on Universities of Bangladesh

ABSTRACT

The administration of universities of Bangladesh faces financial drawbacks every year due to subsidies in the field of electrical power cost. The reason behind this is, students, consume more electric power than they pay for. To solve this problem a modern hydroelectric technology can be implemented. This new technology is called Artificial Vortex (ArVo). This method of power generation utilizes the natural tendency of whirlpool formation of fluids by defining a new flow path thereby causing a turbulent circular movement of fluid layers. Every day students and teachers use a huge volume of water. This water is excluded from the university premises by the wastewater paths. This wastewater flow can be utilized to generate electricity. In Artificial Vortex, a curved wall is designed in the water path to concentrate the water flow and generate rotational energy. This rotational energy is implemented on a vertical axis turbine. This turbine is rotated by the water flow impact and produce clean electricity through an alternator. The cost of electricity has been simulated by HOMER Pro software.

Keywords: *drawbacks, subsidies, Artificial Vortex (ArVo), wastewater flow, kinetic energy, ArVo tank, rotational energy.*

1. INTRODUCTION

Bangladesh is a developing country. There are 53 Public universities in Bangladesh. There are also 103 Private universities and lots of affiliated Colleges [3]. Among these institutions, 90 percent of them have student hostels. These students use electricity for their daily study and living. The amount of usage of electricity is often higher than they pay for. This results in financial drawbacks for the administration. To overcome this problem, a small microgrid can be imposed on the campus premises that will generate electricity from a renewable resource. The typical renewable resource includes solar panels, wind turbines, biomass, etc. but, in this paper, an emerging renewable technique is discussed and designed called Artificial Vortex (ArVo). Recently a modern hydroelectric technology is emerging worldwide, called turbulent energy [2]. This technique uses the Artificial Vortex (ArVo) technique to generate electric power from flowing water [1]. The faculty and the students of universities use a huge ~~amount of water each day.~~ This huge volume of water is passed through the wastewater pipes. This flow of water can be used to generate electricity using the ArVo technique. If this ArVo generation is implemented from 8:00 am in the morning to 2:00 pm in the noon, a university will be able to generate its own energy and reduce the electric bills it has to pay each year.

In this paper, Homer Pro [13] has been used for finding the best electric system for Mymensingh Engineering College with low NPC (net present cost) and low COE (cost of energy). Homer is the most frequently used software by student researchers worldwide [7].

2. LITERATURE REVIEW

Artificial Vortex was first introduced in 2013 on IEEE Global Humanitarian Technology Conference: South Asia Satellite (GHTC-SAS). It was a paper by Aravind Venukumar [1]. He proposed a system by which straight line waterflow can be manipulated by smartly designing the water path. Since then, projects have been taken in hand by a group on engineers to implement this idea. The project headquarters is in Belgium and called “Turbulent’. Turbulent project has already placed artificial vortex technology in several countries, such as, 5kW generation Portugal, 5kW in France, 5 kW and 15 kW in Chile, 5.5 kW in Estonia, 13 kW in Indonesia, 15 kW in Suriname and 100 kW in Taiwan [2]. The plant in Taiwan is planned to extend for 500 kW more generation capacity [2]. Ismaeel et al. released a review and comparison on the artificial vortex strategy to power generation in 2017, focusing on the desert and rural regions [14]. In 2018, Khan et el. presented micro hydropower units for standalone power generation. It was a gravitational water vortex power plant running in a specified basin and turbine blade configurations [15]. Ullah et al. completed a performance investigation of a multi-stage gravity water vortex turbine in 2019 and discovered that vortex distortion has a negative impact on the rotational speed of the blade [16]. In 2022, Kora et al. created a gravitational water vortex turbine that can aerate water and gather energy as it is moving through a waterway. It is ideal for low to ultralow head and medium to low flow [17]. This genius process of utilizing the simple waterflow to generate electricity is getting popularity worldwide, thus, in this paper, we have decided to design a plant using this technology in Bangladesh.

3. ARVO GENERATION

In hydroelectric power system, a dam wall is made to store the water on a certain height. When the water is released, the flow of the water from that height is used to rotate a huge turbine. Water has to be in motion to generate electricity. When water flow turns the turbine blades, the form is changed into mechanical energy [1]. This mechanical energy rotates an alternator and generates electricity.

Water under motion is trapped in a dynamic way in the vortex technology. This increases the amount of kinetic energy inside and boosts the power inside a vortex. This ArVo technology is a great way to produce more energy from a simple flow motion. In a vortex a large quantity of water is in motion which enables the fluid to impart more power into the turbine blades compared to utilizing the original flow rate. In other words, the weigh of water flow rate is largely increased inside the ArVo tank by accumulating lower power inflows [1]. In this system the water flow is concentrated by the curved wall and given an artificial rotational way of movement. This rotational movement is then implemented on the blades of the turbine. The turbine spin by the rotational force.

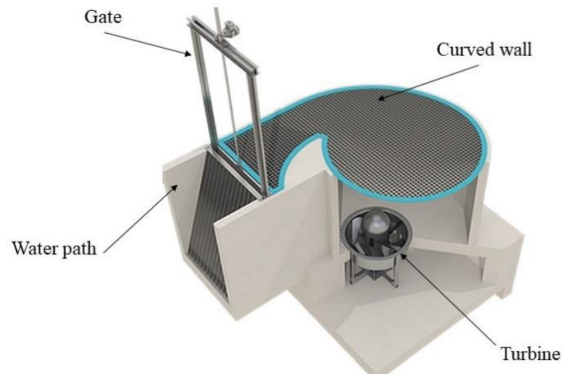

Fig. 1. Basic ArVo Power Plant [2]

In the Fig. 1 above, a basic ArVo plant is shown. The water path is shown where water comes in a straight line. The gate can store the water to a certain height. After the required height is acquired, the gate is opened and the curved wall rotates the water flow. The rotating water impacts the turbine blades and rotates the turbine.

The equation for the power generation in an ArVo power plant is,

$$Total\ Power = \rho A v \left\{ \frac{1}{2} v + gh \right\} \qquad (1)$$

Where the area of the cross-section of the inlet of diameter D,

$$A = \frac{\pi}{4} D^2 \qquad (2)$$

4. LOAD ESTIMATION

During the time period of 8:00 am to 2:00 pm classes will definitely need a power supply. So, if we estimate the electric power supply needed in a department during this time period, we will be able to estimate the required load for that time.

These departments have some heavy load machines [6]. These machines will not get the supply from the proposed micro-grid. The power will be supplied only in the ceiling fans and lights of the department and from 8:00 am to 2:00 pm. Supply will not be required during the off days and during government holidays.

The estimation of the load is given in the Table 1 below,

TABLE 1. LOAD ESTIMATION

Type of Load	Load of a Component (W)	Number of Components	Total Load (kW)
Ceiling Fan	55.0	30	1.650
Light	35.0	10	0.350

Total Load	2.000

In the table above, we have estimated the load for a department. The load for a ceiling fan is 55.0 W and for a light is 35.0 W. The total load for both components is 2.00 kW.

This estimation on the table is for only one department. This load is also variable to seasonal time. During winter ceiling fans are almost unused, and lights are rarely used due to sufficient lighting. Load also varies during class times as all batches do not have classes at the same time.

For example, generally, a batch has the highest 5 classes a day, which means supply is needed only four hours, but, other batches might not have more than 3 classes a day, which means supply will be required for only 3 hours. This paper will discuss the sufficient way and time to deliver power to these loads by simulation in Homer Pro.

5. WATER FLOW ESTIMATION AND DESIGN OF MICROGRID

We need to confirm that the total volume of water used each day by students and staff of a university is sufficient for a continuous generation. In this paper, for simulation, we have taken Bangladesh Agricultural University for water flow calculation. Students and staff use a total amount of 200,500 m^3 of water per day. This water can be stored by making a 2-meter-high dam. During the time of generation, the gate of the dam can be opened and water can be passed through the turbulent blades. In Donihue, Chile a 1.8 m^3/s water flow turbulent ArVo tank produces 15kW of energy [4]. The output power for a certain water flow speed is provided in the given Table 2 below.

TABLE 2.. GENERATION FOR WATER SPEED

Water Speed m^3/s	Power Output kW
1.00	11
1.20	12
1.40	13
1.60	14
1.80	15
2.00	16
2.20	17
2.40	18
2.60	19
2.80	20
3.00	21
3.50	23.5
4.00	25

In the table above the generation estimation according to turbulent technology [2] is provided. For a water flow of 1 m^3/s the generation is 11 kW and it increases to 25kW for 25 m^3/s of water flow.

The ArVo plant is an AC power supplier. A generator is added to the design for the continuation of supply if a water shortage occurs. This generator will supply power if the ArVo plant is under maintenance. The AC bus bar is connected to the department's 220V bus bar. It is a stand-alone grid, so it will not be connected with the main grid of the substation. The design of the microgrid is shown in Fig. 2.

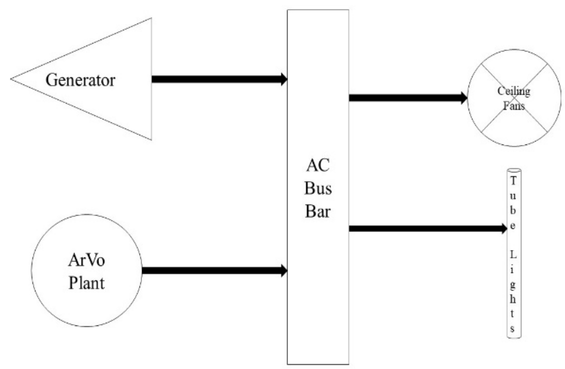

Fig. 2. The simple design of the microgrid

6. COST OF THE COMPONENTS

The components for the microgrid are one MT Generator, one ArVo plant. They are briefly discussed below.

6.1 Microturbine (MT) Generator

LNG is used as fuel in the MT generator. Bangladesh has started importing LNG in 2018 [9], and the price is as low as 33 BDT per cubic meter. Including the transportation and other costs, the LNG price becomes 35 BDT [9]. A 10 kW MT generator is considered in the system.

TABLE 3. Parameters Considered for Microturbine Generator

Parameter	Unit	Value
Capital Cost	USD	2500
Replacement Cost	USD	1500
O & M Cost / Year	USD	0.300
Operational Lifetime	Hours	15000
Fuel Price	USD/m^3	0.00042

The above Table 3 shows the parameters of the Microturbine Generator. Capital cost of the generator is 2500 USD and the operation and maintenance cost per year is 0.300 USD.

6.2 ArVo Plant

Artificial Vortex (ArVo) plant or an ArVo tank is made via some civil and some electrical works. The preparation of an ArVo tank costs nearly about 500 USD for 15kW generation capability [4].

The initial cost is larger than the replacement cost. Because the civil work that is required is a one-time expenditure. As the civil work is not required to repeat, the replacement cost becomes 100 USD.

TABLE 4. Parameters Considered for ArVo Plant

Parameter	Unit	Value
Capital Cost	USD	500
Replacement Cost	USD	100
O & M Cost / Year	USD	0.50

The above Table 4 shows the parameters considered for the ArVo plant. Capital cost is 500 USD and operation and maintenance cost is 0.50 USD per year.

7. SIMULATION AND RESULT

Homer Pro software is used for simulating the process and estimate the cost of energy (COE).

7.1 Simulation

For the simulation, we have selected the location of Bangladesh Agricultural University in Homer map search. We have downloaded the resources from NASA satellite using this software [8] [9]. We have provided the title and names of the authors and abstract on the description box [11].

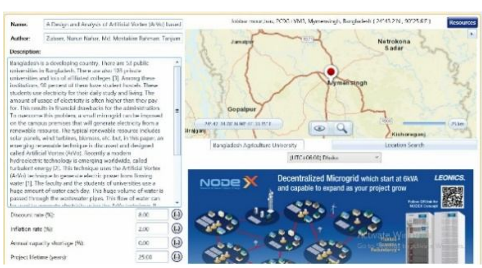

Fig. 3. Place selection for the microgrid

We added the electrical load from the load component. We have defined the required yearly load by inputting the kW required from 8:00 am to 2:00 pm. The seasonal load profile for ceiling fans is given in Fig. 4. The seasonal load profile for tube lights is given in Fig. 5.

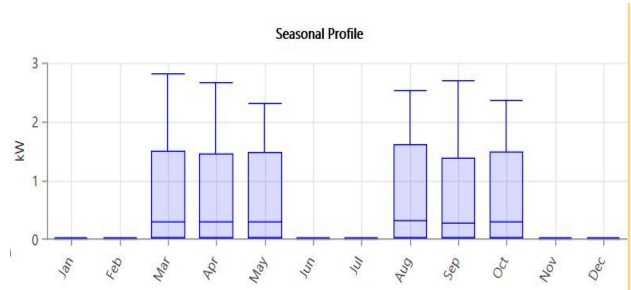

Fig. 4. Seasonal load profile for ceiling fans

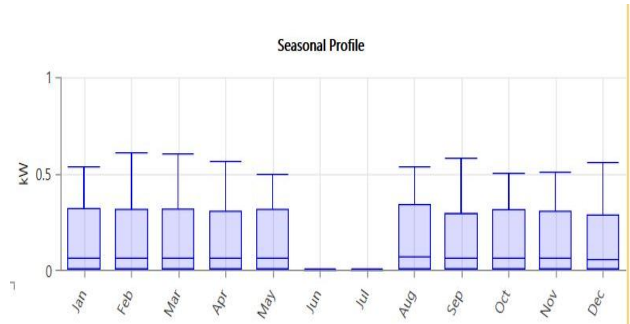

Fig. 5. Seasonal load profile for tube lights

We have added an MT generator and the ArVo plant using components from the software. The schematic diagram of the microgrid is shown in Fig 6.

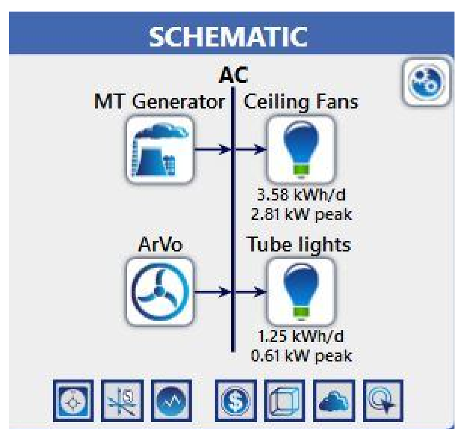

Fig. 6. Schematic diagram of the microgrid

We had to define the monthly water speed for the ArVo plant. The monthly water speed is shown in Fig. 7.

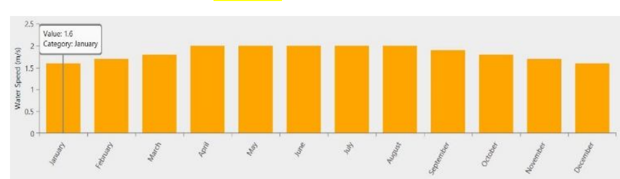

Fig. 7. Monthly water speed graph

After providing the costs for the MT generator and ArVo plant we have calculated the process [10].

7.2 Results

Homer pro provides us with the best possible way to supply the required energy for the lowest cost [12]. The results of the simulation are provided in Fig. 8.

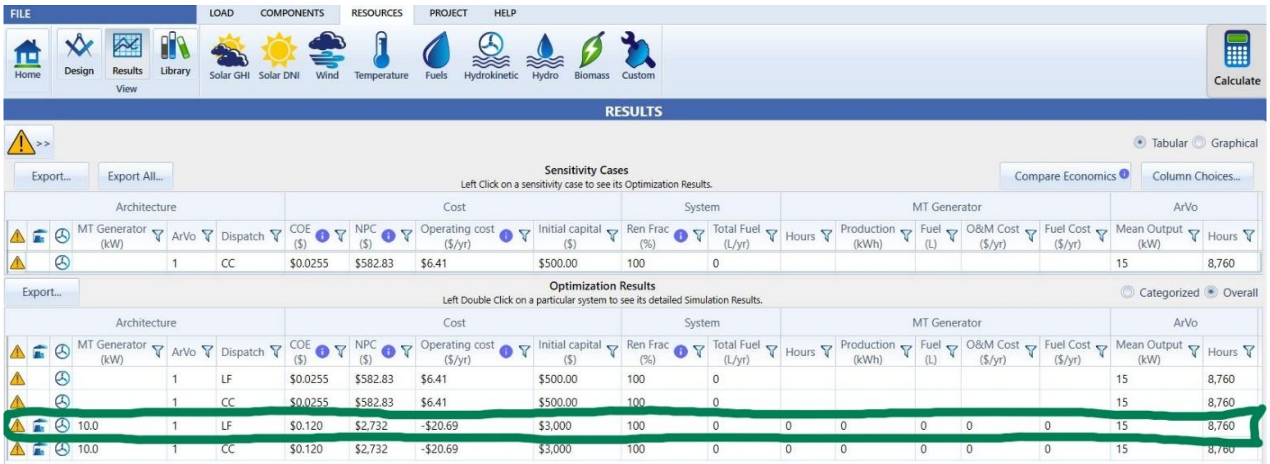

Fig. 8. Result of the simulation of stand-alone microgrid

We shall that case 3, where both MT generator and ArVo shall be used in power generation. From the result, it is quite clear that the COE is 0.120 USD which is 9.96 BDT. We have included the individual results of the simulation in the figures 9, 10 and 11 below.

Fig.9. Cost summary of the stand-alone microgrid

Fig.10. Monthly average electrical production

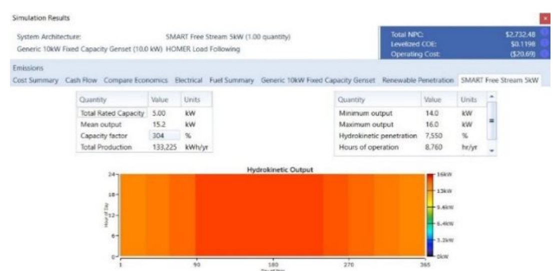

Fig.11. Hydrokinetic output of ArVo from HOMER

As we can see from the results the proposed microgrid has a great possibility to generate electricity with a very low COE.

8. CONCLUSION

Hybrid microgrids are very important for educational institutions. The proposed microgrid generates electricity from the wastewaters that students and faculties of the campus use. It is a very cheap way to produce electricity. The COE is only 9.96 BDT. If this proposed method is implemented in the universities of Bangladesh, they can generate their own electricity for their departments. This will also pave the way for the students to learn and inspire for green energy generation.

FUTURE WORK

Artificial vortex (ArVo) has paved a new pathway towards a possibility of modern electricity generation. As Bangladesh is a land of more than 310 Rivers, Artificial vortex (ArVo) has the potential to electrify many places including riverside and rural areas. The important rivers, like the Padma and the Meghna, have many turning points where the water current is high enough to set up Artificial vortex (ArVo) and generate sufficient electricity which can further be added to the national grid, supporting our national electrification system.

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