A Novel Approach of Electrification of the High Rise Buildings at Dhaka City during Load Shedding Hours

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Abstract- The scope of this paper concentrates on an approach to provide additional power supply by the implementation of the integration of wind turbine and Pico hydro turbine installed at the roof of high rise building. The Pico hydro turbine is installed over the storage tank where the tank is filled with water by the high capacity pump which is installed at the ground floor of the building. In the storage tank of high rise building water is thrown by the pump with a very high velocity which pushes the turbine to make it spin. The spinning of the turbine is turned into electricity by means of a generator and immense amount of wasted kinetic energy of the water is recovered thrown by the pump. The electrical energy created is usually stored in a battery which can then power electrical objects in house, such as appliances and lights. When the storage tank will be filled by water no more power can be extracted from the Pico hydro turbine. A wind turbine could also be installed at the roof of the high rise building with the purpose of acquiring additional power supply as the wind velocity is generally higher at the roof of the building. The electrical power, obtained from both the generators one coupled with the Pico hydro turbine impeller and another with the wind turbine blade can be utilized in houses, offices, and also in the industries. With the integration of Pico hydro turbine and wind turbine more electrical power could be gained. Moreover the major advantage of this system is the elimination of the cost of fuel and it is an eco-friendly clean power generation method. The feasibility of the overall integrated system is analyzed in this research work.

Keywords- Pico Hydro Turbine; Wind Turbine; High Rise Building.

1. Introduction

Bangladesh is facing huge load shedding of electricity. Every summer Bangladesh faces enormous load shedding problem. According to the official statistics, the country’s electricity shortage has gone up 1000 megawatts (MW) to 1259 MW with the demand of 4806 MW on 2006. Authority said this year (2011) the country will face about 1400 MW to 1800 MW electricity shortage, which is almost twice more than last year and the country needs about 5000 MW [1]. Load shedding has become the flagship phenomenon of the country's electricity system due to lack of planned investment in the power sector, unplanned urbanization and excessive system loss. A reliable, affordable and secure supply of energy is important for economic development. This has been true for the past and present and will remain valid for the future. However, over time, changes have taken and will take place with regard to energy use, both with regard to the amount as well as with regard to the type of energy used. Many factors have played a role in bringing these changes. Availability, security of supplies, price, ease of handling and use, external factors like technological development, introduction of subsidies, environmental constraints and legislation are some of these factors.

In Bangladesh mostly the electrical power are fed from national grid where as in western countries additional power supply is provided by means of solar panel, wind turbine and so on. The scope of this research work gives attention to on an approach to provide additional power supply by the implementation of the integration of wind turbine and Pico hydro turbine which is basically installed at the roof of high rise building (A multi-story structure between 35-100 meters tall, or a building of unknown height from 12-39 floors [15]) over the storage tank where water is pumped from the ground floor of the building by the high capacity pump. From the recent literature survey it has been found out that research has already been carried out to implement Pico hydro turbine for the generation of electricity in the Northern part of the Lao People's Democratic Republic (Lao PDR) [2]. Research also has been carried out to develop the concept of pump as turbine as a viable technical and economical alternative for the further Pico-hydro development in the Lao PDR [3]. For low head sites in isolated areas, micro hydro is a cost-effective and better energy option [4]. In Japan, micro hydro technology is used to generate electricity by using rice irrigation water [5].

Hydropower is an eco-friendly clean power generation method. The scope of hydropower generation is very limited in Bangladesh because of its plain terrains except in some hilly region in the northeast and southeast parts of the country. However there are lot of canals, tributaries of main river Karnafuli, Shangu, Matamuhuri as well as tiny waterfalls having good potentials for setting up mini/micro hydropower unit. Micro-hydro power is a simple technology to convert hydropower primarily to mechanical power. They are generally 5-300 kW range. It is not feasible to supply electricity to the National grid from a micro-hydro power unit. Typically they provide captive power to just one rural community. The only hydro power station of our country is the Karnafuly Hydro Power Station with a generating capacity of 230 MW by 5 units (3×50MW + 2×40MW = 230MW) across the river Karnafuly which is large scale production [6] . LGED (Local Government Engineering Department) through Sustainable Rural Energy (SRE) Project has implemented first micro-hydro power unit in Bangladesh at Bamerchara, Chittagong. In this paper, concentration has been focused mainly to achieve additional power supply by the integration of wind turbine and Pico hydro turbine installed at the roof of high rise building. In high rise building water is thrown by the pump with a high velocity in the storage tank which is actually a waste of energy in the form of kinetic energy. This kinetic energy can be used to generate electricity. In hydroelectric power, the kinetic energy of the water depends on two aspects, head and flow. When water is pumped by the high capacity pump at the ground floor with sufficient flow rate it pushes the turbine to make it spin. The spinning of the turbine is turned into electricity by means of a generator. The electrical energy produced is usually stored in a battery which can then power electrical objects in house, such as appliances and lights. When the storage tank will be filled by water no more power can be extracted from Pico hydro turbine. A report prepared for the World Bank that compares different technology options, concludes that Pico hydro is the lowest cost option available for Off-grid electrical power, as can be seen in the chart below (Fig 1).

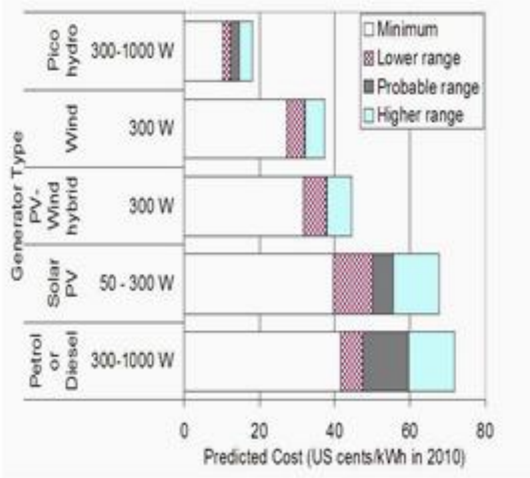

Fig 1. Comparison of predicted cost by adapting different technologies [7]

Fig 2. Complete set of Pico hydro package

In order to get a hold of smooth power supply a wind turbine could also be installed at the roof of the high rise building with the purpose of acquiring additional power supply as the wind velocity is generally higher at the roof of the high rise building. The prospect for wind energy in Bangladesh is not at satisfactory level due to low average wind velocities at different regions of the country however it has been proved that wind velocity generally increases with the increase of height. Thus on the roof of 20 or 25 storage building the wind velocity is much higher than the ground level. Researches have been carried out about the investigation on the feasibility and enhancement methods of wind power utilization in high-rise buildings of Hong Kong. The wind aerodynamics and wind flows over the buildings are investigated based on local meteorological data and local high-rise building characteristics. It is found that the concentration effect of buildings and the heights of buildings could enhance wind power utilization by increasing the wind speed by 1.5-2× and wind power density by 3-8×. For different wind conditions and different dimensions of roof with different building heights, the wind speed could be different [8].

2. The Present Scenario of the Dhaka City

Dhaka is one of the world's populated cities. During 2000-2015 it is expected to grow at a 3.6% annual growth rate and reach a total population of 21.1 million in 2015 [9]. At present Dhaka have around 570 ten-storied and higher buildings, which will cross 1000-mark within a few years if the present 'construction frenzy' goes unabated. The newly constructed high-rise buildings in the Dhaka city are ASA Bhaban at Shamoli, Nazarvalley at Badda near Gulshan, Hotel Westin at Gulshan, Apollo Hospitals at Bashundhara, Eunoos Centre at Dilkusha and Peoples Insurance Building at Motijheel and so on. Now a day's construction of 15-20 storage building is quite a regular practice. High rise culture is a new characteristic in city life. In these high rise buildings and in many industries especially in the power plant industries water is lifted to an extended height. The pumps that are used (output power above 10 horse power normally) have high discharge capacity thereby water is thrown with a high velocity which is actually a loss of energy in the form of kinetic energy. Installing Pico hydro turbine at the roof of the building is a novel approach. In high rise buildings generally the pumps are on operation for a certain period of time. During that time an appreciable amount of electrical power supply can be extracted from the Pico hydro turbine.

Being a tropical country, Bangladesh does have wind flow throughout the year. The field survey data indicated that the wind velocities are relatively higher from the month of May to August, whereas, it is not so for the rest of the year. Recent study and analysis on wind energy assessment in Bangladesh shows that some of the coastal areas are fairly potential for small scale wind electricity generation system. Wind speed varies from 4m/s to 5.5 m/s at the height between 25m to 50m [10]. Day by day wind energy activities in Bangladesh is growing up but slowly. A few number of small wind turbines only, wind-solar hybrid systems have been installed so far by Grameen Shakti, and Local Government Engineering Department (LGED) [11]. From five LGED stations it was found that the average annual wind speed values at different heights for the five wind stations vary from 1.73 m/s to 4.17 m/s. The highest average annual wind speed (4.17 m/s) was observed in Kuakata and the lowest value (1.32 m/s) was observed at Khagrachari. Maximum wind power density was in Kuakata (88kW/m2) at height 30m and minimum in Khagrachari (13kW/m2) [12]. So height from the ground level is an important in determining the wind speed. For example in a 15 storage building which is about 55m, a considerable wind speed can easily drive a wind turbine installed at the roof of the building.

3. Basic Theory of Wind Turbine

W. J. M. Rankine and W. E. Froude established the simple momentum theory for application in the ship's propeller. Later, A. Betz of the Institute of Gotingen used their concept to the windmill [14].

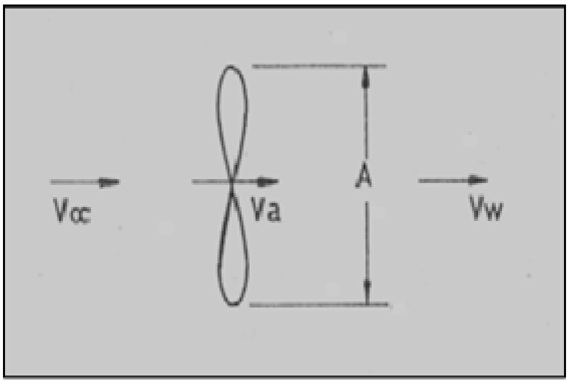

Fig 3. Flow velocities through a windmill [14].

As shown in the fig.3, the symbols, and respectively are the free stream wind velocity, induced velocity and wake velocity. When the flow occurs through the windmill, the flow is retarded and it is further retarded in the downstream side of the windmill. The flow velocity through the windmill is usually called the induced velocity, while the flow velocity in the downstream side is called the wake velocity because wake is formed there. According to the Newton's Second law of motion the thrust developed in the axial direction of the rotor is equal to the rate of change of momentum i.e.

$$\text{Axial Thrust} = m(V_\infty - V_w) \quad (1)$$

Where m is the mass of air flowing through the rotor in unit time.

Therefore, the power produced is given by,

$$P = m(V_\infty - V_w)V_a \quad (2)$$

The rate of kinetic energy change in the wind is,

$$\Delta K.E/\sec = \frac{1}{2}m(V_\infty^2 - V_w^2) \quad (3)$$

Now balancing the equations (2) and (3),

$$m(V_\infty - V_w)V_a = \frac{1}{2}m(V_\infty^2 - V_w^2) \quad (4)$$

After simplifying the equation (4), one obtains

$$V_a = \frac{V_\infty + V_w}{2} \quad (5)$$

Glauert determined the identical expression in his actuator disc theory. Here the flow is assumed to occur along the axial direction of the rotor and the velocity is uniform over the swept area, A of the rotor. Since m=ρAV∞ from the equation (2), one finds the expression of power extraction through the rotor,

$$P = \rho A V_a (V_\infty - V_w) V_a \quad (6)$$

Where, ρ is the density of air. Substituting the value of from the equation (5) in the equation (6),

$$P = \rho A V_a^2 (V_\infty - V_w) = \rho A (\frac{V_\infty + V_w}{2})^2 (V_\infty - V_w)$$

This can be rewritten as,

$$P = \frac{\rho A V_\infty^3}{4}(1+\frac{V_w}{V_\infty})[1-(\frac{V_w}{V_\infty})^2] \quad (7)$$

Inserting $x = V_w / V_\infty$ in the equation (7),

$$P = \frac{\rho A V_\infty^3}{4}(1+x)(1-x^2) \quad (8)$$

Now differentiating P of the equation (8) with respect to x and setting it to zero for maximum power, one obtains,

$$x = \frac{V_w}{V_\infty} = \frac{1}{3} \quad (9)$$

By simplifying, the expression of maximum power extraction is obtained as,

$$P_{\max} = \frac{8}{27}\rho A V_\infty^3 \quad (10)$$

The available energy in the wind is the kinetic energy per unit time,

$$K.E/\sec = \frac{1}{2} m_i V_\infty^2 = \frac{1}{2}\rho A V_\infty^3 \quad (11)$$

Here mass of air mi flowing through the rotor has been considered to be ideal i.e. full air flows through the rotor, as such . $m_i = A\rho V_\infty$

Table 1. List of symbols used

Symbol	Meaning	Unit
m	Mass flow rate of air	(kg/s)
V_w	Wake velocity	(m/s)
V_∞	Free stream velocity	(m/s)
V_a	Induced velocity	(m/s)
P	Power	(Watt)
ρ	Density of air	kg/m^3
A	Swept area of rotor	(m^2)
K.E	Kinetic energy	(J)
Q	Flow rate	(m^3/s)
H	Head of water	(m)
ɣ	Specific weight of water	N/m^3

4. Schematic of the Proposed Model

The Fig 4 shows the schematic diagram of the proposed model. Generally in high storage building centrifugal pumps are used for lifting liquid from the ground level to the storage tank at the roof of the building and it has a high discharge capacity. When water is thrown with sufficient flow rate it will make the turbine to rotate. The generator is coupled with impeller shaft and the electrical energy produced is stored in the battery. The pump is operated for a particular period of time in a 24 hour day. When the storage tank is full of water electrical power cannot be extracted from the Pico hydro turbine. In order to acquire a smooth power supply a wind turbine can also be installed at the roof of the building. When the wind speed is above the cut in speed for a particular wind turbine it will give a power output which can be stored in a battery. The electrical power obtained both from Pico hydro turbine and wind turbine can be used to power electrical objects in house, such as appliances and lights and also in industries when load shedding occurs.

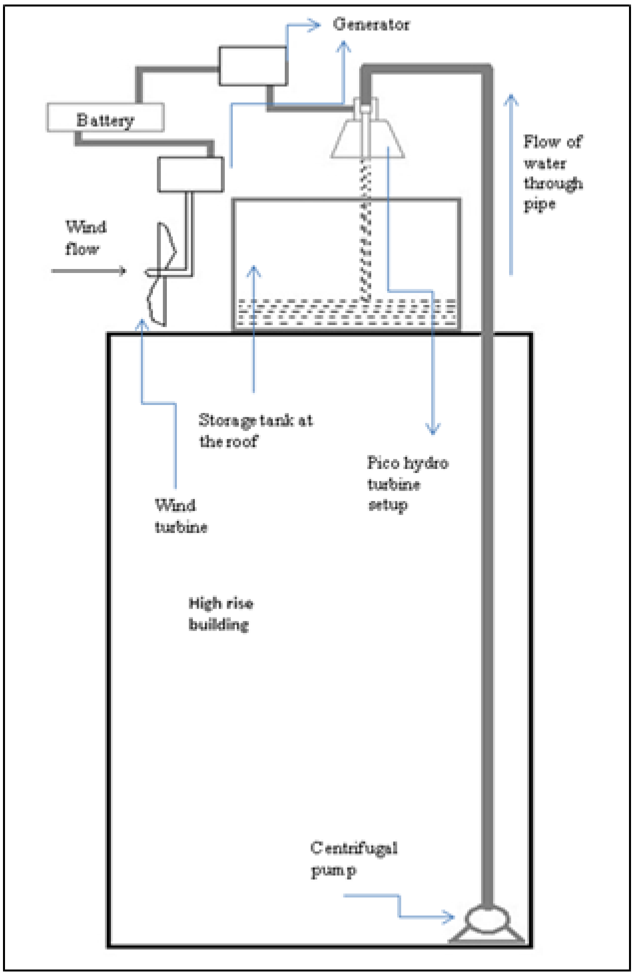

Fig 4. Schematic diagram of the proposed model

5. Schematic of the Experimental Methodology

In our university, an experiment has been performed as a prototype of a high rise building model. Here artificial head was created using a low capacity centrifugal pump. By varying the length of the delivery pipe results were obtained at different heights from the ground level so that the power output was found to be increased fairly in a linear manner with increase of head.The system was closed and water flowed back to the reservoir using a draft tube (Fig 5).

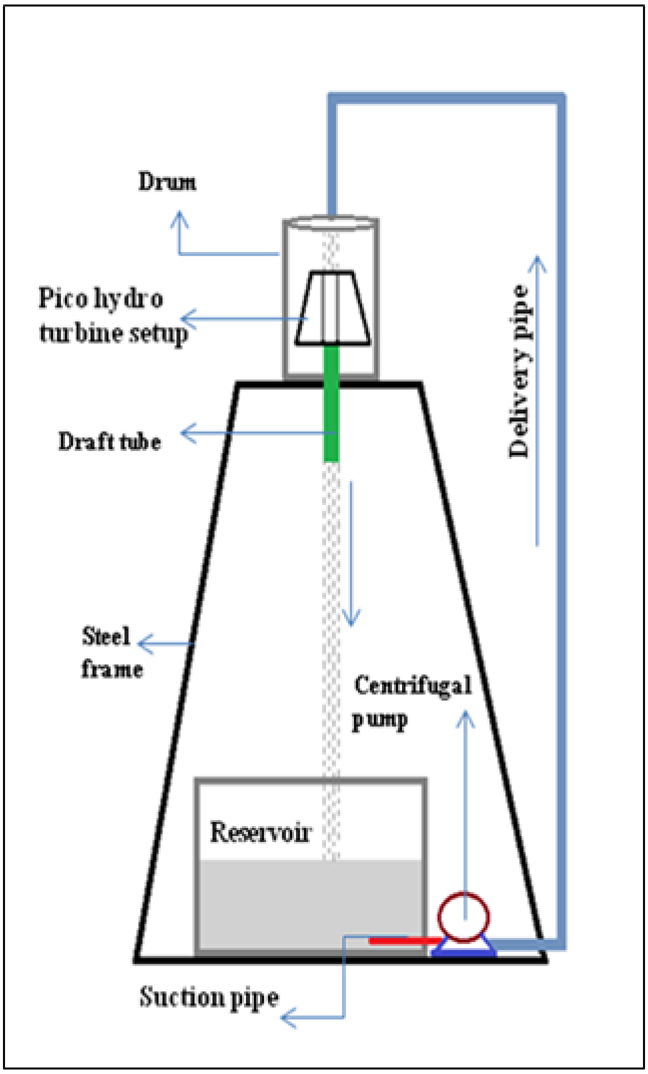

Fig 5. Schematic of experimental setup

6. Setup of the Experiment

The setup of the pico hydro turbine was installed in our university laboratory to validate the concept. From the experimental setup (fig. 6) it is clear that pump extracts water from the reservoir and delivers the water to the Pico hydro turbine. Pico hydro turbine is run by the low head generated by the pump. The system is closed here. The flow of water again returns to the reservoir with the help of a draft tube. Comparing with the proposed model in fig.4, the experiment considers the pico hydro turbine setup placed at the roof of the high rise building (fig. 6) which is installed at a certain level from the ground. The pump used in this experiment can be compared with the pump which is practically used in the high rise building to deliver water to the storage tank at the roof of the building.

Specifications of the Pico hydro turbine used in the experiment:

Head of Water, H= 1.4 - 1.6 m
Flow Rate, Q= 25 - 30 l/s
Rotation, n= 1500 rpm
Capacity, N= 180 - 220 w
Voltage, U= 220 v

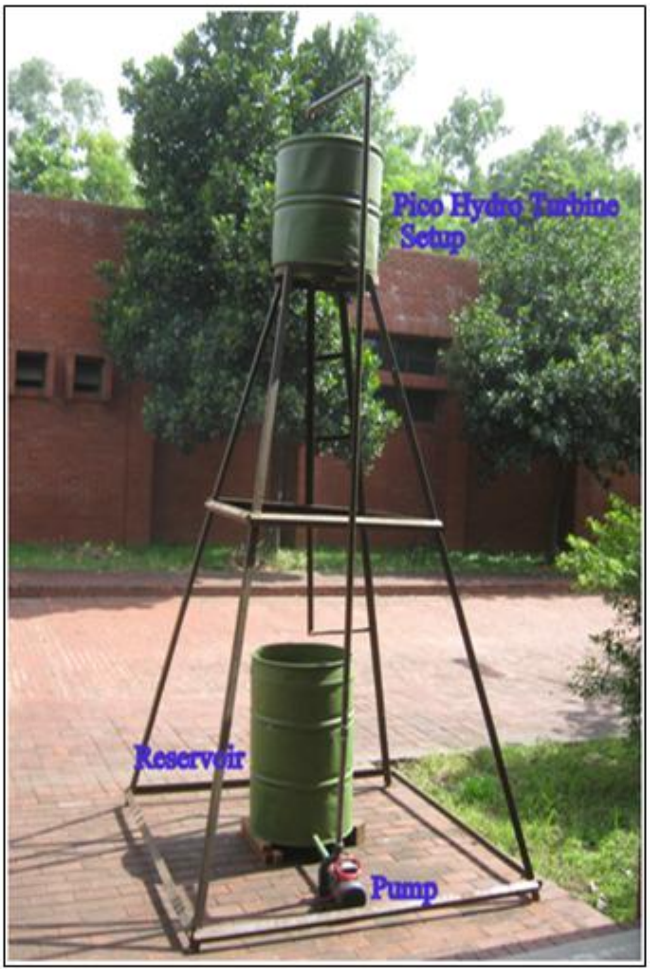

Fig 6. Experimental setup

Fig 7. Inside view of the drum which is mounted upper where generator and impeller shaft are seen

Fig 8. Impeller of the Pico hydro turbine

Table 2. Experimental Result

Head, (m)	Output Power,(W)
0.6	50
0.9	85
1.1	150
1.3	165
1.6	200

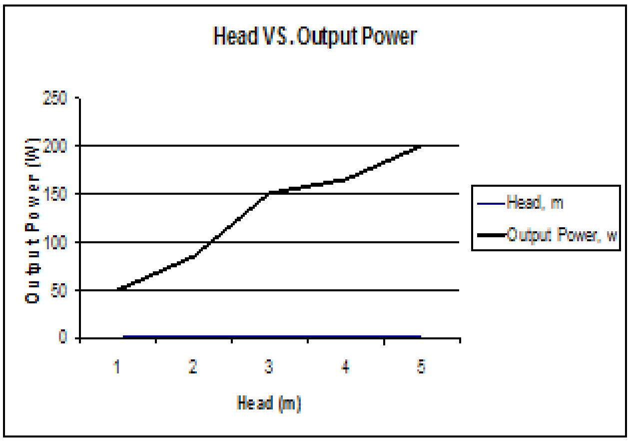

Fig 9. Graphical Representation of Experimental Result

7. Feasibility Analysis of the Modified System

The feasibility analysis of the modified system is based on theoretical calculations. In Dhaka city at jigatola, Dhanmondi one of the 15 storage building (Latitude 23.739^o and longitude 90.373^o) has been considered as a model of a high rise builing.There is one storage tank at the roof of the building and one centrifugal pump installed at the ground floor. Normally in a 24 hour day the pump is used to operate for more or less than 3 hours. The specification of the pump is given below.

Flow rate=1000 L/min or 0.02 m3/sec
Pipe diameter=150 mm
Output power=20 horse power (15 kilowatt)
Voltage=220 volt.
Operating head=up to 270 feet.
Operation Hour of pump =3 hours/day

Micro hydro power is generally identified as system which power is under 100kw. Micro hydro could supply power solutions for the remote mountain residents, national park high rise building, power plant industries, rural village, school, military camp, outdoor camp etc which possess micro hydro resources. 0.1kw power could satisfy lighting, TV, electronic device charging and other basic needs; higher power could make the house or village uses different electrical household appliances, meanwhile it could supply power for small plant for manufacture use. One of the specifications of the Pico hydro turbine setup has been taken for our theoretical calculation which can satisfy the requirement of the proposed model.

Model= WMQ-LZ-12-0.55KW
Required flow rate= 0.020-0.050 m3/sec
Required head=2-5 m.
Permanent magnet generator=550watt
Voltage: 110V 220V 380V AC
Frequency: 50Hz OR 60Hz
Speed=1500 rev/min

In our proposed model the distance from outlet of the discharge pipe to the inlet of the Pico hydro turbine will be required head. According to the specification this head must be within 2-5 m.Let us assume the head, H=2.5 m

Flow rate, Q=0.02 m^3/sec

Specific weight of water, ɣ=9800 N/ m^3

Power output from Pico hydro turbine,

P1=ɣ Q H

=9800*0.020*2.5

=490 Watt=1764KWHr

Total Unit Generation in a 24 hr day,

P = 1764 x 3

= 5292 KWHr

Wind power calculation:

The specification of one of the wind turbines model no. D400 has been considered for theoretical power calculation. The noise and vibration usually associated with small wind turbines have been designed out of the D400. The D400 utilises a 12-pole, 3 phase axial field alternator of very high efficiency. The specification is given below:

Diameter of the wind turbine=1.1 m

Cut in speed= 5 knots or 2.5 m/s

Rated output 400 Watt at 32 knots (16 m/sec)

In Dhaka city the average wind velocity throughout the year at 20 m height is 4.52 m/sec.The average wind speed at different region of Bangladesh is given below.

Table 3. Average Wind Speed (m/s) at 20 Meters Height at Different Locations in Bangladesh [13]

Stations	Average wind speed (m\s)	Available wind power density (W\m2)
Barisal	2.66	11.29
Bogra	2.88	13.45
Chittagong	4.65	60.33
Cox's Bazar	3.81	33.18
Dhaka	4.52	55.41
Dinajpur	2.82	13.60
Hatiya	3.74	31.39
Jessore	4.93	71.89
Khepupara	4.24	45.76
Khulna	2.89	14.18
Kutubdia	2.32	7.49
Patenga	7.48	251.12
Sandip	2.76	12.61
Shatkhira	4.37	50.07
Teknaf	3.17	19.11
Thakurgaon	6.59	171.71
Comilla	2.78	12.89
Mongla	2.20	6.38
Rangamati	2.15	5.96
Sylhet	2.38	8.09

As it is known that wind velocity increases with height. The rate of increase of velocity with height depends upon the roughness of terrain (Fig 10). So additional wind power could be generated at much higher height like high rise buildings, big towers in power plant industries where wind speed is relatively much higher.

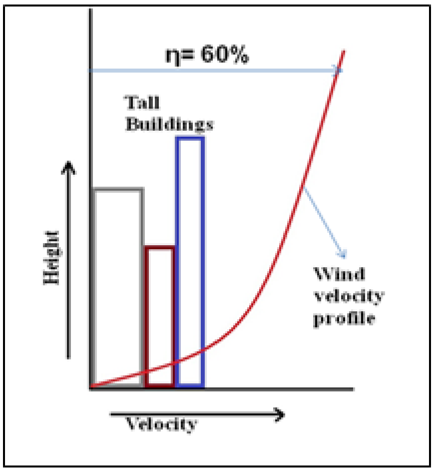

Fig 10. Effect of roughness on wind speed

In our proposed model the approximate height of the building is 55 m. At this height the wind speed increases significantly.Here the wind power is calculated with assumed wind velocity (V_∞= 8 m/s).

In our proposed model the approximate height of the building is 55 m. At this height the wind speed increases significantly.Here the wind power is calculated with assumed wind velocity (V_∞= 8 m/s).

According to the equation (10)

$$P_2 = \frac{8}{27}\rho A V_\infty^3$$

=173 Watt

=622 kWHr

Total power generation in 24 hour

= 622*24

= 14928 kWHr

The electrical power, obtained from both the generators one coupled with the Pico hydro turbine impeller and another with the wind turbine blade can be consumed in houses, offices, and also in the industries. The aim of the proposed system is to produce and provide electricity during the load shedding hours to run the basic appliance e.g. light, fan, television, electronic device charging etc.

8. Conclusion

Being an over populated country; Bangladesh faces one of the worst power crises in the world. Due to lack of planned investment in the power sector, load shedding has become the forewarning phenomenon of the country's electricity system. Unplanned urbanization and excessive system loss has compounded the problems. Some parts of the capital city of Dhaka may face black outs for more than 10 hours a day during the very hot summer. In our country mostly the electrical power are fed from national grid where as in western countries additional power supply is provided by means of solar panel, wind turbine and so on.

In this current research work a novel approach has been proposed which was validated by the ideal theoretical formulations. Installing Pico hydro turbine at the roof of the high rise building is completely an innovative idea which has never been practised in Bangladesh. Firm electrical power can be obtained with the integration of wind generator as the wind velocity is generally higher at the roof of the building. Moreover it is an eco-friendly clean power generation method. Subsequently, the feasibility of the modified system was also analyzed. Proper implementation of this proposed system can play an imperative role in the solution of load shedding problem in city life.

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