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Microgenration Of Electrical Power using hydropower of Rainfall

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Abstract—

In this project the performance of using micro turbines to recover the waste energy in the buildings will be investigated where an extensive literature was obtained about the micro turbines and their applications, technology, and performance. The initial analysis was obtained according to different buildings highest to find the hydraulic power can be extracted. Applying energy balance on the system showed that the maximum power can be extracted from the microhydroulic turbine is 650W taken the efficiency of the whole system as 17%. It was found that there are some parameters should be considered during future work such as losses in pipe. The hydraulic and electrical power is proportional to the size of pipe where the flow rate at same head is high which leads to high potential energy.

Keywords— Waste energy, micro turbines, energy recovery, microhydroulic, hydroulic power, electrical efficiency

I. Introduction

The expression "micro-turbines" is defined as small incineration turbines which burnt either liquid or gassy fuels in order to operate an electric generator as well as micro-turbine has been commercially obtainable for more than ten years ago. Nowadays, due to the advanced function in small fixed and motorized gas turbines, support power apparatus and turbocharger, the technology of the micro-turbine has been appeared in the 1950s in the automotive manufacturing. The reason that led to industrial the micro-turbine constituents' machinery is that the enhanced design symmetry between its design and large motor turbocharger. After almost 40 years of that time, there were many firms have been improved challenging micro-turbines as well as they decided to introduce the mart. By means of the mart development, the manufacturing experienced a consolidation stage through the combination of firms or left the mart. In this time in US, it has directed to two major producers of static micro-turbines as well as Capstone Turbine Company and Flex-Energy [1].

II.LITERATURE REVIEW

A. Modelling of micro-turbine

Figure 1 presents a general micro-turbine generator system plan which is tracked by an AC/AC power convertor as well as the last is tracked by a filter if needed. That convertor fundamentally transforms AC which has high frequency into AC with frequency of either 50 or 60 Hz. In addition to that it can be intended in order to deliver beneficial

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auxiliary facilities either to micro-grid or power grid. Those facilities should contain static volt-amp-reactive which is symbolized as VAR, load following, voltage support,backup source as well as sag support, operational reserve such as non-spinning or spinning and finally domestic micro-turbine or micro-turbine start-up power [2].

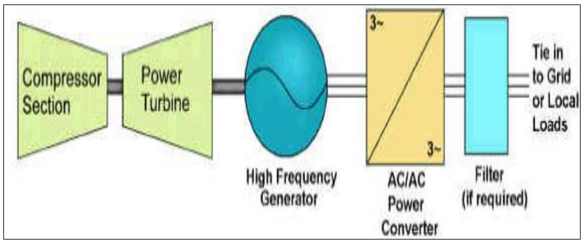

Figure 1: General micro-turbine generator system plan [2]

Using load following is utilized in the case of grid coupled process, whereas utilization of voltage support is popular in the case of grid separate process. Operational reserve ability must or must not be identified using the domestic electricity supplier which is governed by the current tax prices as well as the micro-turbine composition abilities. Furthermore, the backup source as well as start-up power obtainability changes either by the producer of micro-turbine or choices that must be boosted together with the micro-turbine. Due to that, it will be a debate subject together with producers [1].

In addition, a design of split-shaft utilizes a power turbine that its rotational speed is equal 3600 rev/min. as well as a traditional generator, which its type is typically induction generator, linked thru a gearbox. It is good to mention that the power electronic interfacing is considered not required here. Alongside the turbine, control systems which contain fuel flux and temperature control as well as acceleration and speed control. The power quantity that a micro-turbine can produce ranges between 25 kW to 500 kW. The diagram below shows the main constituents of a micro-turbine model.

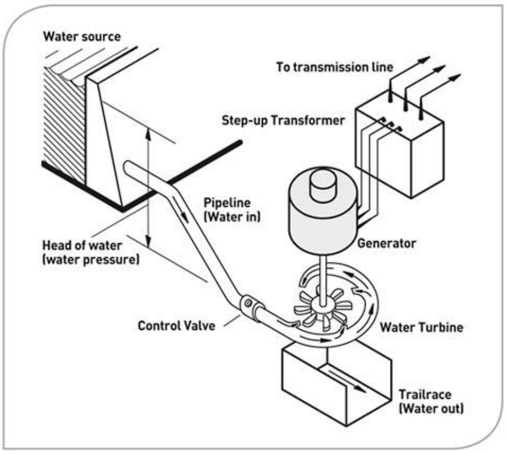

Figure 2: Micro-turbine Model [1]

B. Basic operation

Micro-turbine functions as same as thermodynamics cycle but with greater gas turbines as well as parts several elementary constituents. In that cycle, atmospheric air is passed through various stages from compression to heating, which is typically done through entering and burning fuel, after that those heated gases push an expansion turbine which pushes the inlet compressor as well as a drive shaft which is efficient to give electric or mechanical power. Excluding the variation in the volume, micro-turbine fluctuates from greater size gas turbine in that it normally has less compression ratios as well as functions at less temperatures of incineration. Also there is a micro-turbine type that is known as recuperator that recovers a part of the consumed heat in a heat exchanger. This recuperator is usually used to raise the productivity. Micro-turbine works at great rotational speeds those are reach to 60,000 rpm. Capstone Turbine Company connects that output in a straight line with a high speed generator as well as it utilizes power electronics in order to yield electricity with frequency equal to 60 Hz. Whereas Flex-Energy utilizes a gearbox in order to decrease the drive speed to 3600 revolutions per

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minutes in order to run a concurrent electrical generator [3].

C. Hydropower generation

There is an ideal micro-turbine's usage which is in the production of hydropower. The technology of micro-turbine gears utilizes the superlative potential energy provider which is discharge flux of secondary flows which means that they create cleaner, greater environmental options to the lowest adequate generators which consumed fossil fuel. Generally, micro-turbines check just a small part of flow of stream which is directed by a penstock. Also the technology of micro-turbine must be fitted small discharge flow rivulets. Moreover, in the situations of low drop fall of stream or river, micro-turbines are competent as well as that turbines produce electricity of 1m hydraulic head [4].

D. Effectiveness of hydroelectric power production

The hydroelectric power production is considered the furthermost effective procedure of great scale electrical power production. Energy flux is concentrated as well as it can be organized. Electrical energy is produced through converting the kinetic energy that is captured by the transformation operation. This process doesn't contain any incompetent intermediate chemical or thermodynamic operations as well as there aren't any heat losses. At the case of extracting 100% of the kinetic energy of the fluxing water denotes that the flux would be stopped which represents that the complete efficiency cannot reach to 100%. The hydroelectric power plant efficiency is essentially governed by the used water turbine kind as well as it can up to 95% in the case of great connections. The efficiencies of the plants which generate power that lower than 5 MW range between 80 – 85 % but it is hard to generate power of small flow rates. Moreover, there is a progressing tendency with regard to heat generation as well as decentralized electricity all around the world. Gas turbine as well as reciprocating motor have a critical part in the worldwide decentralized energy shops in addition to that any enhancements in their electric efficiencies have an important effect due to the economic and environmental lookouts [5].

This work introduces a recuperated and intercooled two-shaft micro-turbine at electric output ranges equal 500 kW. The micro-turbine was optimized to realize an integration of the inlet temperature of turbine, the pressure ratio and the recuperation rate. The design of new micro-turbine aims to increase and improve the performance during the micro-turbines range as well as even the efficiencies is competing to be achieved in the large gas turbines used in industrial applications [4].

The efficiency Improvement for power (CHP) systems and combined heat can significantly reduce the operating and emissions costs of electricity production and decentralized heat. Cost-effective, environmentally friendly small- and micro -scale systems of CHP turbine and compact with high efficiency can have a chance to compete the reciprocating types of engines that are used today in power and heat generation for the world as well as produced in large series of production. This shows a process of small-scale gas turbine, electrical efficiency in terms of competing capable with reciprocating engine.

E. Micro-generation

Micro-generation is the process of power or heat production on small scales, as compared to typical fossil-fuelled outputs from power station.

Micro-generation stations are different from the large power stations that were generally placed hundreds miles away from the place that need power, micro-generation systems can use the power in the made place. This make the micro-generation system has more transmission efficiency as well as losses of distribution can virtually be eliminated. There are

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several micro-generation technologies as well as the green types are the majority of them that use renewable energy sources and do not use fossil fuels to generate energy [5].

Micro-generation technology is considered environmentally friendly. Furthermore, they do not consume the natural resources of earth as well as it is not generally release carbon to the atmosphere. (The emission of CO_2 is causing the climate change and global warming). As micro-generation technologies uses the power produced from the sun, natural flow of river and the wind energy all of that can be available freely, they can also reduce the costs of overall energy in the different applications.

Micro-generation has also a role of promoting the diversity of energy as well as alleviating concerns associated with the supply security, power cuts and energy shortages [6].

Heat generation technologies are:

- Ground source heat pumps
- Solar thermal hot water
- Air source heat pumps
- Electricity generation technologies:
- Biomass
- Solar PV (photovoltaic)
- Small hydro
- Wind turbines

Micro-generation could be individually made solutions for the heat as well as electricity generation which technologies listed above [5].

F. Turbine / generator description

It is generally fairly straight forward and simple. Coal as well as hydroelectric power plants is generated electricity in identical method. Both are used a source of power to turn the machine propellers that called a turbine. When the turbine is spinning, it leads to rotate a metal shaft which connected to an electric generator that is typically a motor which generates electricity [6].

In the hydroelectric dam case, it contains flowing water which can be used as a source of power to rotate the turbine. Furthermore, hydroelectric dams can be constructed that having a special water passage way. These passages are typically sloped downward in order to produce a falling water stream.

When the water is falling in the down of passage way, it is directly pass the turbine propellers. The flowing water a produce force which able to turns the turbine that rotates the generator metal shaft that generate electricity. Hydroelectric dams could be constructed near large rivers which have a high drop elevation. Moreover, the dam can store water which controlled by engineers in order to control the flow of water to generate electricity.

The coal is burned in the power plant to make a steam to rotate the turbines. Furthermore, the used water in hydroelectric dams possesses flowing.

G. Current micro-turbine state-of-the-art

Micro-turbines considered as small combustion turbines having approximately between 20 kW and 400 kW outputs. There is a lot of competing systems stays under development and improvement with commercial production that initiated by several developers. Moreover, designed to have the auxiliary power systems reliability which utilized boarder in commercial aircraft types with the economies manufacturing and design of turbo chargers, prime power applications used in light industrial applications and commercial buildings as well as CHP targeted units and several fuel applications like gas and oil fields, wastes and biomass. There is not

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size limit which differentiate micro-turbines of small gas turbines. Furthermore, different design properties characterize micro-turbines are [7]:

- Low temperature materials which have low production cost.
- Radial flow compressors
- No blade cooling
- Low compression ratios (two possibly compression stages)
- Recuperation

In most types, a high turbine speed (100,000 rpm) are driving a very high speed generator that high frequency power or producing direct current which is inverted electronically to 50 Hz or 60 Hz and AC. modern commercial systems of micro-turbine can produce power having between 25 and 33% efficiency using a recuperator which transfers back the exhaust heat to the new air stream. Moreover, the system is cooled by air as well as some designs include air bearings to eliminating both oil and water systems utilized in reciprocating engines. Generally, combustion low emission systems are typically demonstrated that provide higher emissions performance than the large combustion turbine types. The ability of reducing maintenance cost and maintains high reliability as well as durability to be efficiently used in a commercial environment [8].

H. Currently micro-turbine products

There are several micro-turbines types include:

- Steam micro turbines.
- Hydro micro turbines.
- Aero-derivative turbines.

An aero-derivative turbine types are engines that derived from conventional jet engine that works at elevated compression ratios and that are very compact. In addition, Aero-derivative technology can enable the manufacture to use high efficiency generators of gas turbine. Micro steam turbines are devices which used to convert high-pressure steam energy which generated by a boiler to mechanical energy that can be utilized for electricity generation. Micro-turbines like the hydro micro turbine type are used to generate electric energy from the different water sources.

The cogeneration of the micro-turbine is defined as the utilization of single fuel supply to give heat and electricity as a cogeneration. This method is widely utilized in wooden dry ovens, retail stores, green houses, and apartment building; in addition to any implementation somewhere electricity and heat are utilized. Micro-turbines provides many potential benefit when compare it with other available technologies of tinny-range power production. All of these benefits involve a little number of stirring portions, lightweight, lower emissions, provides chances to use unwanted fuels, compact size, generate efficiency, and lower costs of the electricity [5].

I. Dimensions of micro-turbine

Using the improvement of the investigations in the since on the topic of energy administrations by enhancing recent power oversight methods, wanting to maximize the efficiency rate and put down power lack quantity, the concentration on the researches is to enhance the integration and design of micro-system and it is really included in the industrial operations. Using the advances of the simulation in the scientific provides and the linked production technologies are newly it available for the entire micro-flow implementation get role in different engineering domain like fuel cells, pumps, heat exchangers, and also in the gas turbines.
Presenting the similarity, both of researches feedback and the industrial results shows the role of surface force in the micro-pipe flux by linking the force with based on the viscous property to improvement the temperature and speed profiles,

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flux-transformation action, entropy production and power lack rates. Consequently, based on industrial supplies and scientific fundamentals, the research study, and concentrating on the importance of the surface force in the micro-pipe flux, should be designed on the three main parts [6]:

- Heat transition process.
- Flow properties and frictional actions.
- Second-law analysis.

The important of surface force on the friction properties, flow activity and transferral action in the micro-pipe flux have introduced in the schedule of many researchers and they are including many exported reports which involve many numerical and experimental techniques. The importance of frictional action on the older transformation the flow from laminar to turbulent style and the increased of the surface roughness lead to increase of surface friction.

The range of the micro-pipe diameters is d < 100 µm and the unit less roughness of $\varepsilon^* < 0.01$, the friction factor is resort to diverge from a poiseuille law at the same time of Re > 1300 that can be referred to the acceleration linked with the effect of compressibility. As change of energy for the near-wall, micro-fluidic transfer was investigated in numerical way to slip-flow situations, involving various channel part ratios, slip-flow situations and pressure coefficients.

By studying the wall force effects in micro-pipe flux and estimated significant shifts from the theory of the conventional laminar flux. Transitional and laminar flux tests in the dimpled pipes were provided by Vicente et al. Who reported a nearly less transition (Re) Reynolds number is relatively equal 1400, otherwise the roughness involve friction factors which 10 percentage higher than the smooth pipes. In the same work, Kadlikar et al. focused on the surface roughness and its effect in the pressure decrease specially in the circular tiny diameter pipe in his studies, where the transformation onset shown at (Re#) values less than 2300 [7].

Using experiment investigated the notation was the increase of pressure decrease properties since the various strip-type provide in small pipes. Many experimentally and numerically studies show the effect of viscous wasting for the friction factor, the importance of surface force of the viscous wasting and maximize friction factor.

J. Improvement of micro generation within buildings

Systems called micro-CHP are widely efficient plants which could source building with heat and electricity. The best way of process can develop the economic efficiency. Existing micro-CHP methods are usually heat-led. Electrical energy produced in the same forward of the heat is included in the electricity net in the case of there is an extra power. In addition, electrically drove process, the production can be familiar for the electricity needed for the building which sourced, that enhancing the financial efficiency. A most important part in this consideration is the thermo store system which useable the heating obligation to be separated from an electricity production. This will usable of micro-CHP systems, in future, to be processed as lively members in the smart nets.

By nearly 2020, it is intended to maximize the amount of electricity produced by CHP plants to approximately 25 %. With all of the decrease in the heating required, this amount will just be reached if, also to huge middle area heating system, little, decentralised plants are diffused. Mini-CHP plants that include electrical capacities among nearly (5-10) KW and all thermo capacities among (10-25) KW were existed on the stores among many years. Also, the micro-CHP which including the electrical capacities of nearly 1 KW and thermo capacities among (1-5) KW are now being provided to all stores, electrical and heating requirements in the building and their users are faced many changeable fluctuations among the time. These are just partially related, that mean when utilizing CHP methods it is

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attractive to separate the electricity production from the heating needs in building being sourced. The most important member in this consideration is a system which called thermal energy system, which was improved as an element of a whole project. This make the situation of heat storage method is useable to be included in the small effort. That led to easiness of planning the plants processes [8].

III. ANALYSIS

In this project, the benefit of using micro turbines to extract the waste energy in the building was investigated where the micro turbine assumed to be used in the flow water in pipes, the following figure show the explanation of the idea , where the idea suggested to be used with high rising buildings.

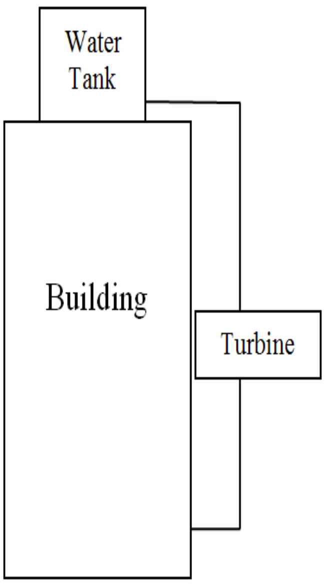

Figure 3: Suggested idea

The following constrains will be considered during the implementation of the suggested idea.

- The turbine will reduce the potential pressure so it will be installed over the pipes feed the first floors in the building.
- The turbine output power is not high so it can be used to operate small appliances like lights
- The turbine will be operated during water discharge from the pipes, so a storage kit should be added. The available hydraulic power in the flow which can be used to run the turbine is calculated using the following formula

$$P_h = QP \qquad (1)$$

Where

P_h : The hydraulic power
Q: flow rate
P: the pressure
The pressure can be calculated according to Bernoulli equation as following equation

$$P_1 + \frac{1}{2}\rho V1^2 + \rho g h_1 + hl = P_2 + \frac{1}{2}\rho V2^2 + \rho g h_2 \qquad (2)$$

Where:
P_1, P_2 : Static pressure (Pa)
ρ : Water density (kg/m^3)
$V1, V2$: Water velocity (m/s)
g: the gravity (9.81 m/s^2)
h_l: head losses which are major and minor losses (m)
h_1, h_2 : the height (m)
however the static pressure P_1, P_2 is equal , and the glow is vertical so the effect of hl can be neglected , but when the turbine is added the value of hl will increase, by simplifying the Bernoulli equation as shown in equation (3) where the locations (1, and 2) are specified as shown in the following figure , as:

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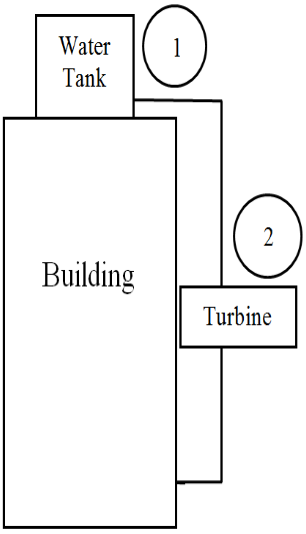

Figure 4: locations (1, 2) for Bernoulli equation

$$\rho g h_1 = \frac{1}{2}\rho V2^{\,2} + \rho g h_2 = P_h \qquad (3)$$

h_1 will be measured according to turbine location. The heights of buildings were taken for different buildings as based on the number of floors where the height of each floor was taken as 3.9 m [9]. So 5, 10, 15 and 20 floors buildings will be used in this analysis, the height of these building are shown in the following table using equation (4) for office buildings [9].

$$H = 3.9S + 11.7 + 3.9\left(\frac{S}{20}\right) \qquad (5)$$

Where (S) the number of floors

Table (1): The height of the proposed buildings

Number of floors	Height (m)
5	32.175
10	52.65
15	73.125
20	93.6

The total head pressure in the water for each building at the top is calculated as shown in the following table.

Table (2) : the total head pressure of the proposed buildings

Number Of Floors	Height (M)	Total Head Pressure (kPa)
5	32.2	315.6
10	52.6	516.5
15	73.1	717.4
20	93.6	918.2

Assuming the turbines will be installed at the mid distance of the highest in order to avoid pipes blockage for the high floors where the water speed in pipes already is low, so as mentioned in the design constrains the flow will applied for the first floors. The head pressure available at the half of the head is plotted in the following figure.

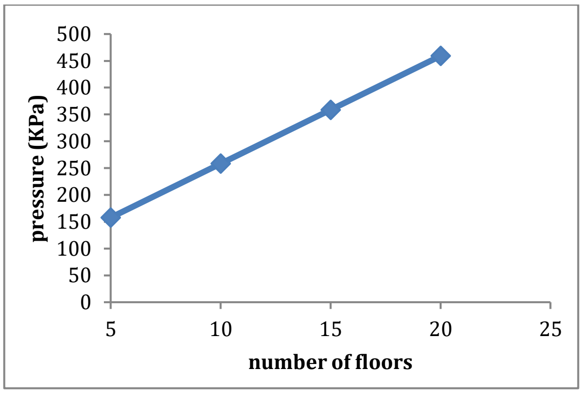

Figure 5: The pressure at the half of height

The available hydraulic power can be calculated according to equation (1) , with considering the flow rate , the flow rate was calculated according to variation in the pipe diameter, where the velocity of

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the flow is calculated as shown in equation (6) which is a simplification for Bernoulli equation.

$$v = \sqrt{2gh} \qquad (6)$$

Table 3 shows the velocity in m/s at different floor numbers based on equation 6.

Table (3): the water velocity at different height

Number of floors	velocity (m/s)
5	17.77
10	22.73
15	26.78
20	30.30

The hydraulic power was calculated for pipe diameter (½, ¾, and 1 inch) as shown in the following plot.

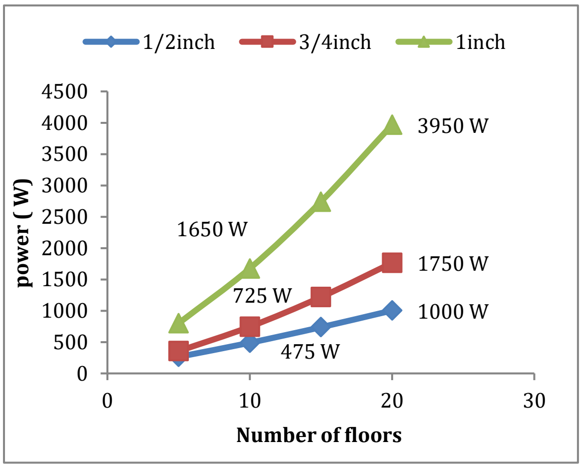

Figure 6: The hydraulic power at different floors

Based on figure 6, the available of hydraulic powers in floor 20 of the building are 1000 W, 1750 W and 3950 W for (½, ¾, and 1 inch) pipelines respectively.

According to [11], the electrical efficiency of hydro turbine that can be used to generate electricity is 17%. This means that 100 Watt of hydraulic power is required to generate 17 Watt of electrical power. This value considers the losses due mechanical parts and internal electrical generator.

Based on this efficiency, the electrical power at 10th floor and 20th floor were calculated based on equation (7):

$$P_e = \eta \, P_H \qquad (7)$$

Where:

P_e: Electrical power (W)

P_H: Hydraulic power (W)

The hydraulic power can be read from figure 6 and the results can be summarized as follows:

Table (4): The hydraulic power at different pipeline size at 10th and 20th floor of a building

Pipeline size (inch)	Hydraulic power (W)	
	10th floor	20th floor
½	475	1000
¾	725	1750
1	1650	3950

Now, equation 7 was applied for the data in Table 4 and the results summarized in Table 5:

Table (5): The electrical power at different pipeline size at 10th and 20th floor of a building

Pipeline size (inch)	Hydraulic power (W)	
	10th floor	20th floor
½	80.75	170

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¾	123.25	297.5
1	280.5	671.5

Table (5) shows that the maximum net electrical power can be extracted from a turbine installed in a building with 20 floors above the turbine is 650 W approximately.

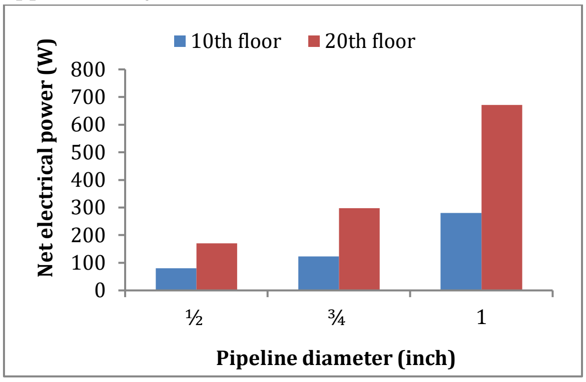

Figure 7: Net electrical power for 20 and 10 floors above the turbine for ½, ¾, and 1 inch pipelines

IV. Conclusion

The loss in energy in any real system is high due to efficiency of energy conversion. The sustainable and green building design requires using the maximum amount of energy that dissipates to the environment. For example, the hydraulic energy of falling water in pipelines of high rise building is lost due to using damper to minimize the water flow in first floors. This project aims to recover this hydraulic energy and generate electrical power using micro hydro turbine. Bernoulli's equation was used to apply simple energy balance and calculate the head pressure, velocity and flow rate at each floor in a 20-floors building. The flow rate was multiplied by elevation to calculate the potential energy which is equal to hydraulic energy based on conservation of energy principle. The net electrical power was calculated at 20th and 10th floors for 3 different pipeline sizes (½, ¾, and 1 inch) using minimum efficiency of 17% from literature. It was found that the maximum electrical power can be produced using 1 inch pipe with 20 floor building is 650 W. this electricity can be used for lighting and other simple applications in the building.

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