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Design of Hydraulic Micro Turbine and Application in Plumbing System

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***Abstract-* Energy is one of the most important components of economic infrastructure. In order to reduce the burden on energy sources, the thought of design of the micro turbine can be the ideal one, installing it in plumbing network having the effective head. Turbine generates the electrical energy which is further used as lighting of garden and parking. The turbine is created using plastic waste which is cheap and easily available. Considering today's scenario, it is very important to maintain the quality parameters of the water because turbine has to be installed in domestic plumbing system. Turbine is tested to find optimum head, velocity and losses that can be caused in plumbing system. All the losses are minor and negligible. It efficiently works in domestic plumbing system. This paper contains the review of hydraulic micro turbine. It is focusing on the design, working and environmental sustainability.**

Key words- Micro turbine Mechanism, Environmental Sustainability, Electricity generation.

INTRODUCTION

Water supply is the provision of water by public utilities, commercial organizations, community endeavors or by individuals, usually via a system of pumps and pipes. The hydraulic head in the water supply system is completely ignored .This hydraulic head can be used as hydropower generation media. Hydropower is cost-competitive renewable energy source that plays a strategic essential role in 21st century electricity crisis. Hydraulic head can be used to rotate the turbine which is installed in the domestic piping system. As the turbine rotates the energy will generate that energy is stored and further will be utilized as lighting purpose for gardening and parking. Need for generating electricity from hydropower is not a new concept but increasing demand of electricity these days give rise to the ideas for the innovation by using renewable energy resources i.e. Hydropower .Society is becoming more dependent on the exhaustible energy sources due to the industrialization and globalization. Due to this the danger of energy crisis is developing all over the world. So it is becoming very important to think upon the utilization of renewable energy sources to decreases the burden on exhaustible energy sources. Energy conservation and efficiency measures reduce the impact of energy development and can have benefit to society with changes in economic cost and with changes in the environmental effects. Contemporary industrial societies use primary and secondary energy sources for transportation and the production of many manufactured goods. Also, large industrial populations have various generation and delivery services for energy distribution and end user utilization. Level of use of external energy sources differs across societies, along with the convenience, levels of traffic congestion, pollution sources and availability of domestic energy sources.Thousand of people in society are employed in the energy industry, of which subjectively influence and impact behaviors. The conventional industry comprises the petroleum industry the gas industry the electrical power industry the coal industry, and the nuclear power industry. New energy industries include the renewable energy industry, comprising alternative and sustainable manufacture, distribution and sale of alternative fuel.

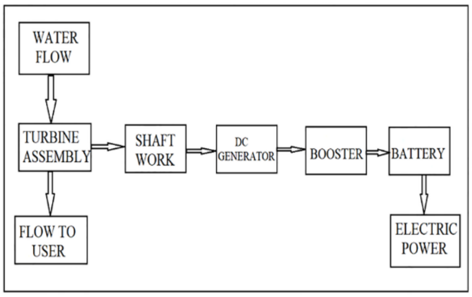

Fig.1 Block Diagram of Assembly.

LITERATURE REVIEW

D Hoffmann et al. (2013) [1] :

In this paper, the authors used a rotational; radial-flux energy harvester incorporating a three-phase generation principle is presented for converting energy from water flow in domestic water pipelines. The energy harvester together with a power management circuit and energy storage is used to power a smart metering system installed underground making it independent from external power supplies or depleting batteries. The design of the radial-flux energy harvester is adapted to the housing of a conventional mechanical water flow meter enabling the use of standard components such as housing and impeller. The authors suggest a low-cost rotational radial-flux energy harvester based on a flow-driven impeller wheel and an electromagnetic energy converterincorporating a three-phase coil circuit. The energy converter was designed for easy integration with commercial water flow meters to harvest energy from water flow in domestic water pipe lines. The harvested energy is used for powering smart water meter systems.

P. Padmarasan et al. (2016) [2]:

In this paper author did a research work on how to generate power from metro water pipeline. The study showed that as the water moves from high to low elevation pressure builds in the pipe. The turbines convert that pressure into electricity via a generator on top of the pipes. The pressure in water flow produces potential energy which gets converted into mechanical energy which is further converted into electrical energy by generator. The generated power will be stored in the battery sources for the future use and also to satisfy the domestic needs. This project can also be implemented on any kind of environment such as urban areas and tall buildings where the velocity of water flow is higher. The purpose of their project was to capture unused energy in the drinking water systems of cities and towns and to turn that energy into useful electricity.

B. Kowalska et al. (2016) [3] :

They checked the possibility of energy utilization generated by drinking water as it flows through turbines integrated into pipes to power measuring devices for monitoring water networks. Apart from large turbines with relatively large diameters installed in transit pipes, they have started to appear solutions to be used in the case of smaller distribution pipes. Electricity obtained with their assistance may be used to power the monitoring devices (sensors).The authors suggest the power supply system for monitoring devices, a micro turbine integrated with electric generator and a system enhancing temporary flow rates via the turbine.

Roshan Varghese Rajan et al. (2016) [4] :

Author recommended the design and development of pico-hydro generation system using consuming water from water tank of residential buildings. Water flow in the domestic pipes has kinetic energy that has the potential to generate electricity for energy storage. An introduction of three new mechanical arrangements namely the air bladder for water pressure maintenance, U-tube piping and broad nozzle pipe end are included for better working and energy generation. It produces electricity with no fuel cost and low maintenance. They installed a mechanical arrangement to generate electricity from the potential energy possessed by water storage tank from a water head of even 3m and above very easily. This could be a reliable and eco-friendly form of energy, which can be generated to develop small scale hydro generation. This is very versatile power source that could be used to generate AC electricity even at remote places along around the globe.

Marco Casini et al. (2015) [5] :

In this paper authors recommended instead of photovoltaic and wind systems, nowadays in-pipe water to wire power systems are becoming particularly interesting for the integration of renewable resources at urban and building scale because of the potential to harness clean energy from excess head pressure in urban and domestic water pipelines. The article presents an overview of the different types of in-pipe hydro systems available on the market and illustrates their possible applications at the urban and building scale and the benefits achievable in terms of energy production compared to other renewable such as photovoltaic and wind systems. In addition to providing clean energy, the application of these systems can help improving the management of water networks, allowing to monitor and adjust the water flows and to optimize overpressure, thus lengthening service life of all equipment.

Salma Alarefi (2015) [6]:

Authors suggested idea of harnessing power from water supply is to use the velocity or force (kinetic energy) of water flow to turn the micro turbine and generate electricity. The amount of power that can be generated depends on the water flow rate, water consumption, pressure as well as the generator. The system proposes embedding small turbines into water pipes to generate electricity. In this paper, a review of the available domestic micro- hydropower generation systems has been summarized. An experimental evaluation system of micro-hydropower generator for professional formation and research has been proposed. The paper details the design and construction of the proposed system including the design optimization. The author investigated the water consumption for a scenario of two occupier household relative to the electricity consumption.

➢ *Micro turbine mechanism:*

The effective hydraulic head in the plumbing system is completely ignored. To utilize that head in effective manner we created a micro hydraulic turbine. The created turbine is installed in domestic plumbing system. The stored water from the overhead water tank flows through the plumbing network and the water jet hits the blades of turbine, turbine rotates and hydraulic energy is generated that energy is converted into mechanical energy and this energy is further converted into electrical energy by using DC motor. Initially only 2-3V voltage is generated. For increasing the voltage we used step-up booster which boost the voltage up to 11-13V. The battery is used to store the surplus power produced during operation of the turbine. The power produced may vary according to the flow of water. If the flow of water is varying during the day, the power produced by the turbine may also vary. Therefore, to maintain the continuous power supply battery along with an inverter and rectifier may be used. Electrical power is given by the product of mechanical power and the generator efficiency. The in-pipe water generator is an electrical power generating pipeline which can produce renewable energy completely clean, reliable low-cost electricity.

METHODOLOGY

1) *Material Specifications: -*

A) Casing – A PVC pipe casing of 6.5 cm diameter is provided, which is easily available, cheap in cost and non corrosive. The casing has inflow and outflow openings.

B) Casing Pipe - Casing has inflow and outflow opening diameter of 2.5cm.

C) Shaft - A 3.5mm diameter shaft is placed at the centre of turbine in the casing. Other side of shaft is

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connected to DC motor which converts mechanical energy into electrical energy.

D) DC Motor - A DC motor of 12V and speed of 1200 rpm used for converting mechanical energy into electrical energy.

E) Turbine - A Hydraulic turbine is created from plastic material, having 8 numbers of blades.

F) LED - It is used to check generation of electricity.

G) Booster - A step-up boost converter is used, it converts input voltage of 2-3V DC to an output voltage of 11-13V DC.

H) Resistor - 1KΩ resistor is used to control the flow of current in circuit.

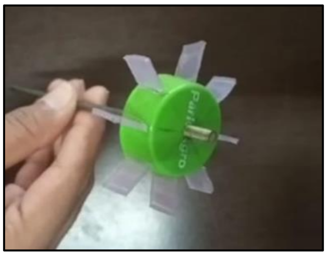

Fig.2: Shaft with Blades fixed on it

Fig.3: Turbine Enclosed in Casing

2) *Calculations: -*

i) Calculation for Head & Velocity of jet–

Area of measuring tank = 0.12 m^2

Volume = A X h = 0.012 m^3

Time (t) = 14.6 sec

Q = Volume / Time = 8.2 x 10^{-4} m/s

Dia. Of Pipe = 18 mm = 18x10^{-3} m

a = (3.142/4) x d^2 = 2.54x 10^{-4} m^2

Q = a x v

V = 3.22 m/s

$V_{th} = (2gh)^{1/2}$

h = 0.528 m

ii) Calculation for velocity of vane –

The type of impact of jet is series of plate mounted on the periphery of a wheel. The plates of wheel are normal to the jet.

Efficiency = η max = $\frac{2(v-u)u}{v^2}$ = 50%

Velocity of vane = u = $\frac{v}{2} = \frac{3.22}{2}$ = 1.61 m/s

iii) Calculation for losses –

a) Loss of head due to friction in pipe –

By using Darcy Weisbach Equation,

$$hf = \frac{fLv^2}{2gd}$$

Reynolds number (Re) = $\frac{\rho v d}{\mu}$ = 6.414× 10^4

Relative pipe roughness = $\frac{\varepsilon}{d}$ = 1X 10^{-4}

From Moody chart, Friction factor = 0.032

hf = 0.044 m

b) Loss of head due to obstruction in pipe –

$$\text{Head loss} = \frac{(Vc-V)^2}{2g}$$

$$= \left[\frac{v^2}{2g}\right]\left[\frac{A}{Cc(A-a)} - 1\right]^2$$

= 0.33 m

c) Volumetric losses –

V1 = 1000 ml, V2 = 980 ml

Loss = 1000-980 = 20

% loss = $\frac{20}{1000}$ x100

% loss = 2 %

iv) Calculation for Overall efficiency –

$$\eta_o = \frac{\text{Shaft power}}{\text{Water power}} X100$$

a) For motor,
Assume efficiency of 70 % i.e. 0.70

$\eta_o = \frac{\text{Electrical O/P}}{\text{Shaft power}} \times 100$

∴ Shaft power = $\frac{V \times I}{0.70} \times 100$ = 166.28 Watt

b) For turbine,

$\eta_o = \frac{\text{Shaft power}}{\text{Water power}} \times 100$

$= \frac{166.28}{\rho QgH} \times 100$

= 0.5968

= 59.68 %

≅ 60%

3) Process of Working of Micro Turbine –

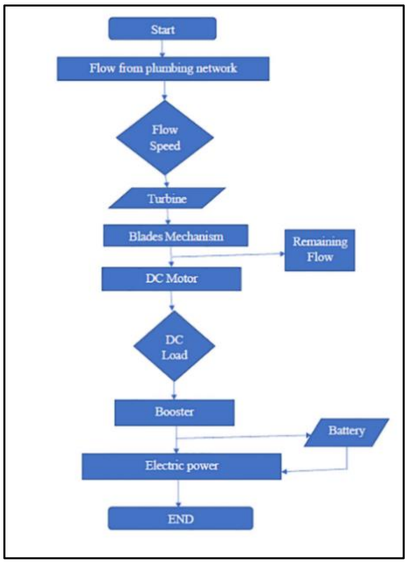

Fig.4 Flowchart of working Microturbine

RESULT AND DISCUSSIONS

1. Optimum Head = 0.528 m
2. Velocity of Vane = 1.61 m/s
3. Velocity of jet = 3.22 m/s
4. Calculation of losses:
   a. Loss of head due to friction in pipe (hf) = 0.044 m
   b. Loss of head due to obstruction in pipe = 0.33 m
   c. Volumetric losses = 2%
5. Overall Efficiency of Turbine = 60%

The algorithm for the evaluation of energy from the domestic plumbing system is a new concept. Above information provides the optimum head, velocity and all losses. But these all the losses are negligible. These losses are very minor losses don't effect on the overall efficiency of the turbine.

1. Advantages of System -

- It uses renewable source of energy.
- Free energy generation from pipe water.
- It is economical and does not require much investment.
- It requires very less maintenance.
- Design is simple and does not require any infrastructure.
- It generates clean, reliable, low cost electricity.

2. Cost Analysis :

Table 1: Cost Analysis

Sr. No.	Material	Specifications	Quantity	Cost(Rs)
1	Casing	Plastic- Dia. 6.5 cm	01	25
2	Shaft	3.5 mm Dia.	01	20
3	DC Motor	1200 rpm & 12 V	01	550
4	Booster	2 V to 12V Step-up Converter	01	80
5	Cutter	-	01	20
6	Fevikwik	-	04	20
7	LED Bulbs	5 mm Ultra Bright	02	05
8	Electric Wires	Length-10 cm	04	20
9	Resistor	1KΩ Carbon film	02	05
Total Cost =745Rs				

V. CONCLUSION

Hydro power was the one of the first renewable energy, and therefore the most developed currently. To meet the energy requirement, various units have examined because of its advantages of proposing good performance as compared to conventional fossil fuel. A hydraulic turbine is rotary machine that converts kinetic energy and potential energy of water into mechanical work. Energy is generated by applying water pressure, to rotate the blades of micro turbines. Available head, specific turbine speed, and water flow are the key factors for the selection of appropriate turbine type under certain parameters. In this study, micro hydraulic turbine is considered as most suitable turbine type under certain parameters which includes: low flow rate, low pressure head & specific turbine speed. Less leakage and maintenance cost, the ability to reduce system shocks will prolong component life, reduce leakage from pipe joint and minimizes hydraulic system maintenance cost. The design of hydraulic turbine parts mainly depends upon the specific speed. Turbine parts should be properly designed in order to avoid cavitation because it lowers the turbine efficiency. Any ambiguity in the design parameters for the selection of turbines can cause decrease in turbine efficiency. As the purpose of these this project is primarily the selection of turbine under specific design parameters, however turbine's efficiency cannot be ignored. As the micro hydraulic turbine the required pressure is low below 10 meter, so after the completion of literature review, assumptions and calculations it is decided that micro hydraulic turbine is suitable because it operate at low head and low flow rate and as it has shown better results according to the parameters as compared to other turbines. The theoretical design and experimental results are computed for the performance characteristics of turbine and efficiency test in state full opening and opening (25%, 50%, and 75%). Under full load condition, the turbine works efficiently as compared to part load. Also as load increases the unit power increase. Important amongst all, hydraulic turbines are feasible to environment because it has no harmful effects on the atmosphere i.e. ozone depletion potential is very less or negligible. Hydropower development can uplift the living standard of rural communities.

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