

263. In-Pipe Hydropower, an Unexplored Green Energy

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Abstract

The development of urban areas has rapidly increased the global energy demand. Of which renewable energy system can provide clean, reliable, secure, competitive energy to meet this demand. Despite of various renewable resources available, the in-pipe hydropower is one of the unexplored green forms of energy. These in-pipe water-to-wire power systems are considered to be more interesting and innovative for the generation of power from excess head pressure of water pipelines that can be the solution for the growing energy demand. The in-pipe power systems already proved to be successful. The in-pipe water-to-wire power system would be helpful to recover the energy that is used to treat or supply water. The energy is obtained from the pipe water; where the turbine will rotate due to flow and pressure of water, and the rotating turbine is connected to a generator to generate electricity. This paper illuminates one of the important pragmatic aspects of production of green energy and its integration to grid and other green energy sources.

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1. Introduction

Energy and water are strongly linked. A lot of energy is consumed to deliver water and a lot of water is needed to produce energy. The cost of Energy is a big issue for municipal water utilities—waste and drinking water facilities consume a lot of energy to treat water. To recover the consumed energy a new technology known as in-pipe or in-conduit hydropower has been introduced. The in-pipe hydropower system is water to wire energy recovery based solution. This renewable power system enables agricultural industrial and municipal facilities to produce low cost, clean and reliable electricity from gravity fed water pipes. The system includes in-pipe hydrodynamic turbine and generator to capture clean energy from fast flowing water of large gravity fed pipes, converting the in-pipe water into continuous source of electricity. The recovery of untapped energy is done by the excess head pressure in gravity fed pipelines without affecting the operations. The hydrodynamic turbines are designed and tested in order to maximize the power production without disturbing the flowing water. A company named Lucid energy is testing and designing this in-pipe system since 2007. The company developed and installed lucid pipe (in-pipe) power system in Portland. They have installed 200kW power system in water pipelines of Portland. Which is able to produce an average of 1100Mwh of clean energy per year, enough energy to light up to 150 houses? [1][2]

1.1 Advantages

- It produces neat and clean energy (it does not affect environment).
- It does not depend upon weather (like solar system depends upon sun and wind system depends upon air).

- It does not affect the quality of drinking water.
- It is the one of the cheapest way to produce power (where as in case of solar and wind they will cost 3 or 4 times more to produce same amount of energy)
- It can also be installed in Agricultural, industrial, wastewater pipeline.
- Electricity can be produced all the time with the flow of water.
- Quick installation
- Recovers process-based energy

1.2 Applications

The system can be installed in:

- Water pipelines
- Waste water pipelines
- Tap pipes
- Agricultural
- Industrial

2. The system

The system depends upon two main components [4]

- In-pipe hydrodynamic turbines
- generators

The idea of the system is that one can fix hydrodynamic turbines in gravity fed water pipes that would start rotating as the water flow through the pipe. More the velocity of water more will be the speed of rotation of the turbine, which will result more extraction of energy. The turbine shaft is connected to generator set. Voltage is generated at the terminals of generator. The design of system is main concern. It consists of a hydro-electric generator which is connected externally and a hydrodynamic turbine that is placed inside the flowing water of pipe. The turbine rotates with the flow of water and the shaft of rotating turbine rotates the rotor of generator, in result the electricity is generated. Then the generated electricity is transferred to the grid. The design of turbine is key point to obtain more clean energy from the flow of water. A number of blades and a shaft at the central part are combined to form a hollow turbine. The blades are specially designed to reduce the resistance to the flow of water. The blades are sized according to the need of project (the thinner, the better).

3. Methodology

To give a recovery based and green energy solution to the crisis of energy in Pakistan, we had done this research. Research was done from the reports and findings of lucid energy's Portland project and Toronto's sewerage pipeline project. The project is water to wire hydropower system, consisted of turbine and generator. Lucid energy had installed this system in Portland's water pipelines and Toronto in sewerage pipelines, turning the pipelines into continuous source of generating electricity. Lucid energy is testing this system since 2007. They had tested 9 turbines in 2011, measuring their vibrations with piezoelectric accelerometer, changes in pressure with piezoelectric pressure sensor and working speed with tachometer. The tests had been conducted to make the design of system less noisy and more sufficient for the production of electricity without disturbing the flow of water. All the 9 turbines had different swept area; their resulted concluded that swept area is one of the major factors for the increase in output power. The swept area of turbine should be smaller than area of remaining pipe. The smaller swept area will cause the increase in velocity of water, which will result in more production of power (higher the velocity, higher will be the power generated). The analysis and calculation for the extractable power were made on data provided by lucid energy reports and their present work, the data includes formula for the extractable power and parameters like head, flow rate and hydropower system efficiency. We had also done a case study for Jamshoro, based on data provided by lucid energy. The case study of Jamshoro is just to give idea that this system can be installed in Pakistan for producing clean energy with low cost. We had calculated the power extractable from this system, if it is installed in Jamshoro. The parameters included in calculations are flow rate, efficiency of system and head of Jamshoro which is 13m. [5] [6] [7].

3.1 Results

The case study has been considered for Jamshoro.

(Case study - Jamshoro)

Table 1. Values for parameters [1]

S#:	Parameters	Formula	Values
1	Flow rate	Velocity x pipe area	1.784m ³ /s
2	Head	Elevation	13m [7]
3	Efficiency	Output/Input x 100%	90%

3.1.1 Formula for extracted power from system. [5]

$$\text{Total energy available (kW)} = \frac{H \times F \times \text{Efficiency}}{11.8}$$

Where:

H = available head in feet

F = flow rate in cubic feet per second

Efficiency = efficiency of turbines

11.8 is a constant for converting the equation to kW

$$\text{Total energy available (kW)} = \frac{[13m \times (3.28 \frac{ft}{m})] \times [1.784 \frac{m^3}{sec} \times (3.28 \frac{ft}{m})^3] \times 0.9}{11.8}$$

$$\text{Total energy available (kW)} = 204.27kW \quad (\text{it is energy extracted per pipe})$$



Fig-1 lucid in-pipe power system [1]

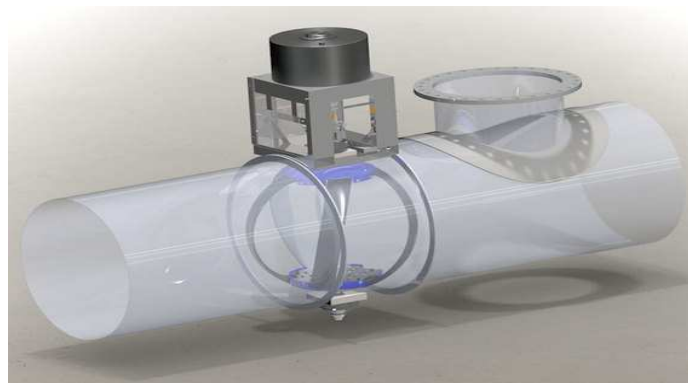


Fig.2. lucid in-pipe power system model

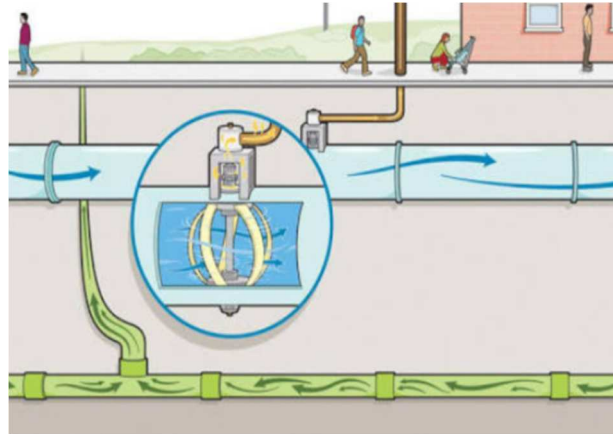


Fig.3. transferring the power to grid

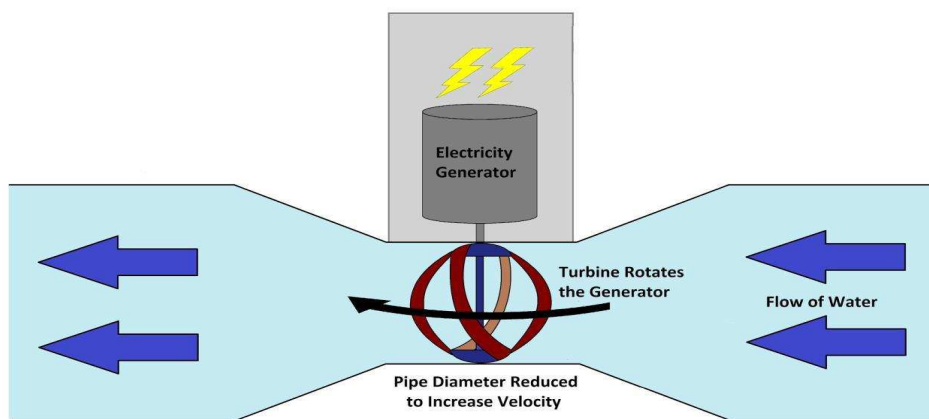
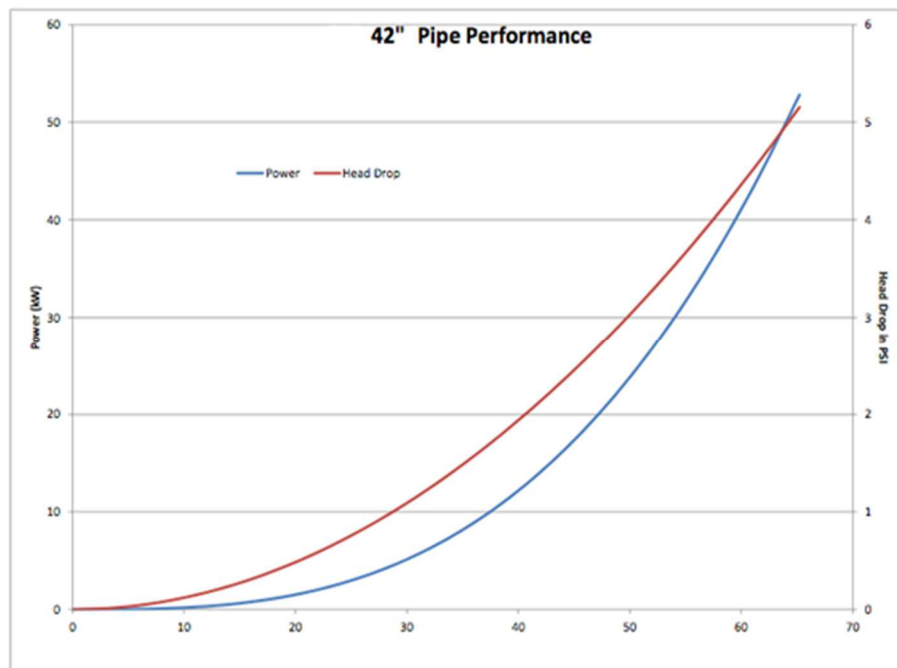


Fig.4. In-power system model of Toronto waste water pipeline



3.1.2 Graph showing relation between Powers generated and Head drops:

4. Conclusion

In-pipe power system is one of the cheapest way to produce clean energy. Once the system is installed it will produce energy with even lower cost. The system can be installed in water pipes and sewerage pipes, making it the reason of recovery of energy that is wasted to treat and supply water through the pipe. The process of recovery of clean energy can be done all the time with the flow of water as it is independent of weather. The other advantage of system is its efficiency, which is 90 percent as it is a hydropower system. The installation of system will also help us in management of all water networks without affecting the quality of water. This system can be the solution for crisis of energy in Pakistan, as it will produce clean energy from the already following water in pipes so there will be no need of any other source. This idea will be helpful in retrieving the energy, previously consumed on the supply of water in industrial and agricultural work, which will reduce the cost of farming and industrial work. [3] [6]

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