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Pico Power: A Boon for Rural Electrification

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Abstract

Rural electrification is required to improve the subsistence of individuals that are located where centralized power grids do not reach. It is a known fact that India is very rich in water resources from where we can harness enough water for irrigation and huge amount of electricity. To harness electricity many big hydropower plants and irrigation projects are in the process of development. But there are numerous villages in India far away from reach of electrical grid connection system. Such villages are located in difficult terrain and high altitude having numerous small water resources such as rivulets, ponds, small rivers and springs. In most of these villages life is difficult due to high altitude but the same high altitude can prove as a boon if even a small water source is available there. There are numerous such sources having adequate height and flow rate for feasibly developing multipurpose pico hydropower project. Pico hydro, hydro systems of 5 kW capacity or less, can address this need at relatively low cost and with virtually no environmental or social impacts.

Recent innovations in pico hydro technology have made it an economic source of power even in some of the world's poorest places. It is also a versatile power source. AC electricity can be produced enabling standard electrical appliances to be used and electricity can be distributed to whole village. This paper will describe how multipurpose pico hydro power project can be developed for increasing living standard of household in rural areas along with some case studies.

Keywords: Pico; hydroelectric; head; rivulets; multipurpose.

1. Introduction

A hydropower system captures the energy of moving water for some useful purpose. Wherever there are mountains and streams, hydropower can bring low-cost electricity to isolated communities without polluting the air or water. Furthermore, hydropower is a proven technology; people have been obtaining energy from falling water for thousands of years. Hydropower is still being used on many different scales for many purposes, from small grain-grinding facilities to huge hydroelectric dams that provide electricity to entire cities. Most hydropower available around the world can be categorized as large hydro. The hydropower plant can be classified according to the size of electrical power it produces as shown in Table 1.

Table 1: Classification of Hydropower Plant .

Power	Class
> 10 MW	Large
< 10 MW	Small
< 1 MW	Mini
<100 kW	Micro
< 5 kW	Pico

Pico-hydro is a term used to describe the smallest systems, covering hydroelectric power generation under 5kW. Depending on its size, a pico-hydro power system may provide a small, remote community with adequate electricity to power light bulbs, radios, and televisions, among other appliances.

2. Principle of Opeаration

Hydro Power is driven by extracting the potential energy from water over height difference. The energy in the water is converted to mechanical energy and can be used directly or can be converted to electrical by means of a generator. The term head, H, is the measure of pressure in the water. It refers to actual height difference the water travels. Power, P, is the energy converted over time or the rate of work being done. The Power, P, which can be extracted from a water flow; is

$$P = \boldsymbol{\eta Q H \rho} g$$

Where; η is the efficiency of the system, Q is the total volumetric flow, H is the head, ρ is the water density, and g is the gravitational constant (9.81m/s^2).

3. Components of Pico Hydro System

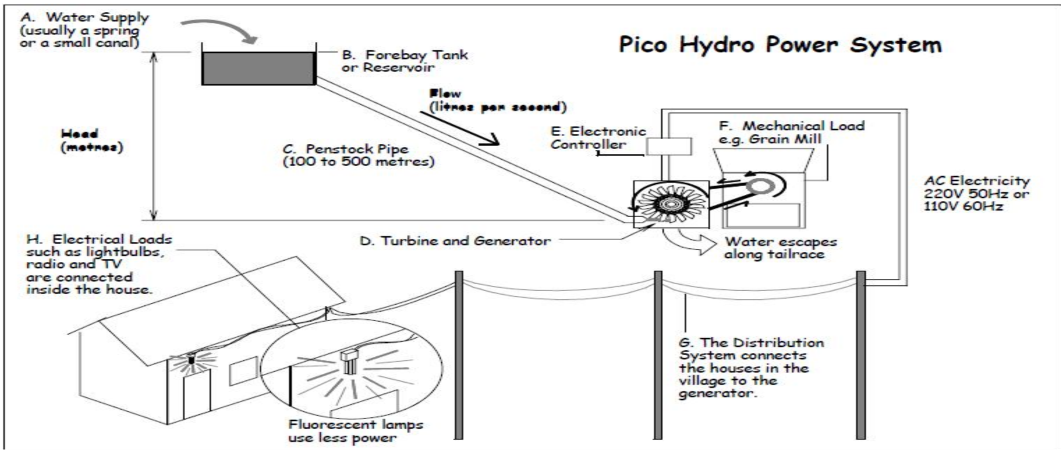

Figure 1: Basic Components of Pico Hydro Power System.

3.1 Dam : The dam is the most important component of hydroelectric power plant. The dam is built on a large river that has abundant quantity of water throughout the year. It should be built at a location where the height of the river is sufficient to get the maximum possible potential energy from water.

3.2 Water Reservoir : The water reservoir is the place behind the dam where water is stored. The water in the reservoir is located higher than the rest of the dam structure. The height of water in the reservoir decides how much potential energy the water possesses. The higher the height of water, the more its potential energy. The high position of water in the reservoir also enables it to move downwards effortlessly.

3.3 Intake or Control Gates : These are the gates built on the inside of the dam. The water from reservoir is released and controlled through these gates. These are called inlet gates because water enters the power generation unit through these gates. When the control gates are opened the water flows due to gravity through the penstock and towards the turbines. The water flowing through the gates possesses potential as well as kinetic energy.

3.4 Penstock : The penstock is the long pipe or the shaft that carries the water flowing from the reservoir towards the power generation unit, comprised of the turbines and generator. The water in the penstock possesses kinetic energy due to its motion and potential energy due to its height. The total amount of power generated in the hydroelectric power plant depends on the height of the water reservoir and the amount of water flowing through the penstock. The amount of water flowing through the penstock is controlled by the control gates.

3.5 Water Turbines : Water flowing from the penstock is allowed to enter the power generation unit, which houses the turbine and the generator. When water falls on the blades of the turbine the kinetic and potential energy of water is converted into the rotational motion of the blades of the turbine. The rotating blades causes the shaft of the turbine to also rotate. The turbine shaft is enclosed inside the generator. In most hydroelectric power plants there is more than one power generation unit. There is large difference in height between the level of turbine and level of water in the reservoir. This difference in height, also known as the head of water, decides the total amount of power that can be generated in the hydroelectric power plant. There are various types of water turbines such as Kaplan turbine, Francis turbine, Pelton wheels etc. The type of turbine used in the hydroelectric power plant depends on the height of the reservoir, quantity of water and the total power generation capacity.

3.6 Generators**:** It is in the generator where the electricity is produced. The shaft of the water turbine rotates in the generator, which produces alternating current in the coils of the generator. It is the rotation of the shaft inside the generator that produces magnetic field which is converted into electricity by electromagnetic field induction. Hence the rotation of the shaft of the turbine is crucial for the production of electricity and this is achieved by the kinetic and potential energy of water. Thus in hydroelectricity power plants potential energy of water is converted into electricity.

3.7 Electronic Controller: An electronic controller is connected to the generator. This matches the electrical power that is produced to the electrical loads that are connected and stops the voltage from changing as devices are switched on and off.

3.8 Mechanical load : The mechanical load is a machine connected to the turbine shaft using a pulley system so that the power can be drawn directly from the turbine. The rotating force of the turbine runner can be used to turn equipments such as grain mills or woodwork chinery.

3.9 Distribution System : It connects the electrical supply from the generator to the houses or schools. This is the most extensive part of the system.

4. Need of Pico Hydro System

- Often small communities are without electricity even in countries with extensive grid electrification. Despite the high demand for electrification, grid connection of small communities remains unattractive to utilities due to relatively low power consumption.
- Only small water flows are required for pico hydro so there are numerous suitable sites. A small stream or spring often provides enough water.
- Pico hydro equipment is small and compact. The component parts can be easily transported into remote and inaccessible areas.

- The number of houses connected to each scheme is small, typically under 100 households. Therefore it is easier to raise the required capital and to mange maintenance and revenue collection.
- Carefully designed pico hydro scheme have a lower cost per kilowatt than solar or wind power. Diesel generator systems, although initially cheaper, have a higher cost per kilowatt over their lifetime because of associated fuel costs.
- Local manufacture is possible. The design principles and fabrication can be easily learned. This keeps some equipment costs in proportion with local wages.
- It is easier to establish and maintain agreements regarding ownerships, payments, operations and maintenance and water rights, as the units supply power for a small number of households.

5. Planning A Hydro Scheme

It is important to conduct a feasibility study in a proposed area to determine what is required to implement a pico hydro project for village electrification.

- *Overview* : Establish the demand, willingness to pay, local ability to manage a scheme and grid electricity available or planned.
- *Location* : A suitable geographical location for a pico-hydro scheme is one with steep rivers that have an all year flow.
- *Demand Survey* : Estimate the number of houses within 1 km from the water supply and those who are willing to pay. A 1km radius is the distance that electricity can most easily be transmitted.
- *Power Estimate* : The head and flow rate should both be measured to determine the possible power output and to help in choosing equipments.
- *Head and Flow* : Decide on a suitable combination of head and flow to produce the required power. Assumptions should be made on system efficiency, but if in doubt, assume an overall efficiency (water power to electrical power) to 45 percent.
- *Cost and Availability* : Estimate the size of the generator needed to meet the energy demand, based on the head, flow and power outputs of the available equipment. Typically, the higher the head, the lower the cost per installed kilowatt. The initial investment is high, but running cost and maintenance, are low because there is no need to buy fuel.
- *Viability* : Comparing the likely annual income with capital cost gives a rough guide to financial viability. If the annual income is less than 10 per cent of the capital cost, the project is not viable. If it is 10-25 percent of the scheme, could be possible. If annual income is more than 25 percent, the scheme is viable.
- *Village Meeting* : Present the findings of the survey to the community at an open meeting. Local government staff should be encouraged to attend.

- *Other Steps* : A number of other steps need to be taken, including a detailed site survey, finalizing power output, producing a scale map and scheme layout, a detailed costing. Once this has been done the scheme can get under way. Ordering materials, installation and training can all be undertaken.

6. Case Studies

Case Study 1 - Kirinyaga District, Kenya.

A typical pico hydro power plant has been installed in Kathamba, Kirinyaga District, **Kenya**. This scheme was installed as part of a program implemented by The Micro Hydro Centre at Nottingham Trent University to demonstrate Pico Hydro technology in Sub Saharan Africa. The cost of the penstock, turbine and generator equipment was met by the project funders (European Commission) and all other costs were contributed by the 65 households which the scheme now supplies with electricity.

This case study describes a pico hydro plant using a Pelton turbine directly-coupled to an induction generator which has an electrical output of 1.1kW. The penstock is 158m in length, 110mm diameter PVC pipe. The electrical output of 1.1kW corresponds to a turbine generator efficiency of 48%. The water source is a small spring with a flow around 90% of the year and has never been known to run completely dry.

Case Study 2 - Few Steps Taken In India

In Mankulam**,** an isolated village in **Kerala**, an INFORSE member, the Malanadu Development Society, has installed two pilot units of 200 watt pico hydro plant. The plant has been operating well for the past last year. Based on this MDS, is proposing to install 30 units for 30 poor and low income families in the village. The beneficiaries have agreed to contribute small amount to proposed project.

In **Karnataka**, many rural areas, especially in hilly regions of Malnad and costal areas of Udupi, Dakshina, Kannada. The terrain conditions make grid electricity supply unreliable. However, these areas provide ideal sites for small pico hydro systems. There has been a significant change perceived in the energy scenario after the deployment of Pico Hydro Projects in Karnataka in the last 4 years. Pico Hydro are projects with a capacity upto 5kW especially targeted to benefit rural communities with access to small streams and rivulets. The developers of these projects are based in UK and from 2007 till date have installed around 400 Pico Hydro projects with the numbers increasing steadily.

7. Conclusion

The energy demand and utilization have trended to increase everday. Moreover, the world market price of gasoline fuel as main energy for most factory and vechile engines have trended to increase day by day. The strategic planning for the renewable technology and development with wisely energy utilization from natural resources included wind power, hydro power, solar energies, bio-gas and farm waste has been proposed by Ministry of Energy. A source of water with lower flow rate compared to its head is efficiently utilized to generate power in the installed system. The runoff water can be utilized for household system. Places having larger water sources but difficult terrain can be benefited from water supply, electricty and income generation activity if this project is done in bigger scale. This project is very suitable and feasible in contex of India and if listed out it clearly has numerous advantages over any other projects related to renewable energy and rural development.

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