International Journal on Recent and Innovation Trends in Computing and Communication
Volume: 2 Issue: 8
ISSN: 2321-8169
2431 – 2435

Integrated Renewable Energy - A Green Source of Energy for The Future - A Review

Dr Himani Goyal , Y.Bhulakshmi, Srivalli Pavana Gayathri, T.Surekha
Dean ECE, MLR Institute of Technology, Dundigal, Hyderabad-43
e-mail: goyalhimani@gmail.com,gayathri94hari@gmail.com

Abstract: During 2008 small hydro installations grew by 28% over year 2005 to raise the total world small hydro capacity to 85 gigawatts. Over 70% of this was in China (with 65 GW), followed by Japan (3.5 GW), the United States (3 GW) and India (2 GW).[3] China plans to electrify a further 10,000 villages by 2010 under their China Village Electrification Program using renewable energy, including further investments in small hydro and photovoltaics**.**

Index Terms: *Small Hydro power plants, control systems, controllers, governors, turbines, s peed sensing.*

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1. Introduction

Hydro power has had a long and important historical role in providing mechanical and electrical power. Small hydro provides an effective and economic means of power generation. It generates more power than all other renewable sources, and has terrific potential worldwide. Nevertheless hydro has a low profile among the renewable sources with most governments and development agencies, and is often perceived in various negative ways. It is not really enjoying the boom in development and increased deployment that it deserves. Despite fine rhetoric from many sources about the need to combat global warming, hydro, which is by far our most effective means for greatly expanding the production of clean energy, is not yet getting the official support it needs and deserves.

Hydro power is responsible for some 2600 TWh of electricity output per year, which is about 20 % of the world' s entire electricity demand. Although it may be surprising but it is true, that the other renewable sources, remain of negligible importance by comparison. But that does not mean that the others are not important, yet it will be many years before they can even catch up , let alone overtake hydro power [1-4].

Electricity Generation From Renewable sources (Global) (Data from 1993) [1-4]

Large hydro (plants over 10 MW)	86 %
Small hydro(plants less than10MW)	8.3 %
Wind and solar	0.6 %
Geothermal	1.6 %
Biomass	3.5 %

2. Installed Capacity

Small Hydro Power	< 10 MW
Mini Hydro Power	< 1 MW
Micro Hydro Power	< 500 kW
Pico Hydro Power	< 10 kW

Both Micro Hydro and Pico Hydro power plants are subsets of Small Hydro Power Plants (SHP) [5].

3. Constraints for the development of SHP

The development of SHP suffers a setback in terms of R & D support and also due to the following reasons:

- There is no significant level of institutional encouragement or support [1-4].
- Economic analysis highlights more on the high capital investment [5-6].
- Also there has been a tendency to develop SHP in exactly the same way as large hydro, which leads to faulty optimization of systems
- Also there are many institutional barriers too [7].
- Principal barriers are of political – legislative type [8-14].
- Due to presence of insufficient and contradictory information on SHP [8].
- Further there is also lack of information in mass media too and limited educational efforts in the field of Renewable Energies in Universities and Research Institutes.
- The main unknown factor is the input energy availability throughout the year [8].
- The environmental impact of SHP plants is limited: the principal barriers from this point of view are the compensation flow of aquatic life preservation and the visual impact on the landscape.

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- Last but not the least, much of the responsibility for the development of SHP lies with the small uninfluential organizations that fail to make an impact on the governments.

4. Comparison of Large and Small Hydro power plants

4.1 Definition**:**

Large Hydro power plants: They involve high costs, construction of large dams with large storage capacity of water throughout the year. [1-4].

Small Hydro power plants: SHP are mostly ' run–of–river 'type constructed on flowing water, with low running cost.

5. Some Disadvantages associated with Large Hydro

Large Hydro power plants have significant negative environmental impact in terms of displaced populations, loss of land, blocking of fish migration, and even considerable greenhouse gas production due to rotting vegetation in the lakes. Many of these systems are often not totally sustainable, since the lakes can gradually silt up, eventually to become malarial marshes with greatly reduced capacity for water storage. Thus, in a way they are considered as Non-Renewable sources of energy with shorter life span.

6. Advantages and Disadvantages of Small Hydro Generation

- Power is continuous.
- Zero fuel.
- Concentrated energy source (with reasonable head).
- Energy available is predictable.
- Limited maintenance and low running costs.
- Long life, generally greater than 50 years.
- Site specific, may not be near demand.
- Has a maximum power "ceiling", unable to cope if demand exceeds this.
- Lack of knowledge stops existing structures being utilized. These include weirs and water supply reservoirs.
- It does not produce any gas emission or particulate pollutant [8].
- Small plants, in addition, possess an excellent environmental compatibility, with a limited impact on the surrounding landscape.
- Since SHP plant already reaches technical maturity during its century, it is characterized by high performances and reliability, long working life, products of International standards, reasonable installation costs and low O & M costs.
- One of the major gaseous emissions from fossil fuel burning is carbon dioxide, a gas that is one of the major reasons for the 'greenhouse effect'. On the contrary, energy generated from hydropower is free from greenhouse emissions.

7. Site Selection for Small Hydro Power Plants

Broadly speaking, there are two types of sites suitable for small-scale hydro plants. The first is in existing water works, which control water supplies and waterways in the form of existing dams, weirs and reservoirs. These take advantage of existing civil works making such schemes cheaper and more environmentally acceptable. The second is run-of-the-river schemes where water is diverted from a stream or river to power a generator. This involves building entirely new civil works increasing the initial capital cost of the scheme further. Such schemes also often come up against strong environmental opposition at the planning stage

8. Basic Principles

Hydro power depends on the hydrological cycle, in which water vapour evaporated from the seas by incoming solar energy, is deposited as rain, or snow on land. This precipitation either evaporates, sinks into the soil, but mostly it takes the form of 'run-off', flowing into small streams, which merge with larger ones, which eventually reach the sea [16].

The basic principle of hydro power is extract energy inherent in this run-off. Thus, it involves tapping the water from a river at a certain level, passed through a turbine and then discharged back into the stream or river at a lower level.

Thus, if

P = power output
η_g = generator efficiency
η_{gr} = gear efficiency
η_t = turbine efficiency
g = acceleration due to gravity (m/s^2)
v = volume of water per unit mass (m^3/kg)
Q = discharge (m^3/s)
H_n = net head (m)

Energy output from this kind of generating scheme can be found from the following formula:

$$P = \eta_g \eta_{gr} \eta_t (g/v) Q H_n 10^{-3}$$

In practice the following values may be used [17-25]:
$\eta_g = 0.95$, $\eta_{gr} = 0.85$, $\eta_t = 0.99$, g = 9.81, $v = 0.001$

Thus, if it is a direct-driven generator set, the output is given by:
$P = 7.92QH$ kW

In general, water wheels can have efficiencies from 20 to 80 %. Nowadays, turbines are more often used than water wheels primarily because they can handle much higher power levels through the use of a smaller and faster running form of technology (smaller size and higher speed equate with lower costs) [7].
Thus, as seen from above equation, power output is directly proportional to the discharge and net head. This obviously varies from site to site. Ultimately what governs the maximum power output is the flow of the water source. This must always exceed the amount of water extracted for generation purposes.

9. Turbine

A turbine converts the energy of falling water into rotating shaft power. The selection of the best turbine for any particular hydro site depends on the site characteristics, the dominant factors being the head available and the power required. Selection also depends on the speed at which it is desired to run the generator or other device loading the turbine [26-27].

A turbine's correct design speed depends upon:

- The power rating (size);
- The site head;
- The type (shape of turbine).

Many types of turbines exist, but there are two broad categories depending on which of two methods for extracting energy are used. These are Impulse Turbines in which a jet of water impinges on the runner, which is designed to reverse the direction of the jet and thereby extract momentum from the water, and Reaction Turbines (notably Francis and Kaplan), that in effect generate hydrodynamic' lift ' forces to propel the runner blades.

9.1 Impulse Turbines

Impulse turbines are distinguished by the runner being mounted in an air–filled casing. There are three main types of impulse turbine in use: the Pelton, Crossflow (also known as the Banki or the Mitchell turbine) and Turgo [14].

The Pelton Turbine consists of a wheel with a series of split buckets set around its rim; a high velocity jet of water is directed tangentially at the wheel. This jet hits a bucket and is split, turned and deflected back almost through 180° from each side of the bucket. Nearly all the energy of the water goes into propelling the bucket and deflected water is reduced in speed and simply falls into a discharge channel below. It is mostly suitable for high and medium heads.

The Crossflow turbine has a drum – like rotor with a solid disk at each end and gutter – shaped 'slats' joining the two disks. A jet of water is aimed at the middle of the rotor and enters it through the curved blades, emerging on the far side of the rotor again through the blades. The shape of the blades is such that on each passage through the periphery of the rotor the water transfers some of its momentum to the rotor, before falling away with little residual energy. It is suitable for medium and low heads.

In Turgo turbine, the jet is designed to strike the plane of the runner at an angle (typically 20°). In this turbine, water enters the runner through one side and exits through the other. As a consequence of this, the flow that a runner can accept is not limited by spent fluid interfering with incoming jet. It is suitable for high head.

9.2 Reaction Turbines

Reaction turbines are distinguished from the impulse type by having a runner that always functions within a completely water filled casing. The Kaplan or propeller turbine is not unlike the propeller of a ship operating in reversed mode so the flow of water turns the propeller. It may be installed in a tube (known as a tube turbine if the generator is external with a long shaft to the runner, or a bulb turbine if the generator is in a bulb shaped nacelle immersed in the flow) or it can be mounted with its shaft vertical in a hole in the base of the open flume, so that water can fall through it. All reaction turbines have a draft tube below the runner through which the water discharges.

The draft tube slows the discharged water and reduces the static pressure below the runner and thereby increases the effective head.

Various configurations of propeller and Kaplan turbine exist; a key feature is that for good efficiency the water needs to be given some swirl before entering the turbine runner. With good design, the swirl is absorbed by the runner and the water that emerges, flows straight into the draft tube without much residual angular momentum. Without this arrangement, the water would emerge with swirl, which would represent water energy. Methods for achieving this include the use of a set of fixed guide vanes either mounted like a stationary propeller upstream of the runner or arranged around its periphery (in this case known as wicket gates) with water spiraling into the runner through them. Another method is to form a ‘snail shell‘ – shaped housing for the runner in which the water enters tangentially and is forced to spiral in to the runner. When guide vanes or wicket gates are used , these are often adjustable so as to improve efficiency at part load. In some cases the blades of the ‘propeller’ type runner can also be adjusted (in the so called ‘ Full Kaplan ‘). The mechanics for adjusting turbine blades and guide vanes can only be costly and tends to be more affordable for large systems, but it can greatly improve efficiency over a wide range of flows.

The Francis turbine is essentially a modified form of propeller turbine in which water flows radially inwards into the runner and is turned to emerge axially .In this case either the aforementioned wicket – gate arrangement is used or the runner is more commonly mounted at the centre of a snail shell shaped casing with internal adjustable guide vanes.

It is also important to note that Pelton turbines tend to be used at high heads, Francis and Crossflow turbines at medium heads and Open Flume Francis or Kaplan and Tube (propeller) turbines at low heads.[17-25]

10. Generator

Two types of generator are utilized in small hydro installations; synchronous and asynchronous [28]. Synchronous generators regulate their own speed and voltage as load varies with the use of a governor, allowing them to operate in isolation. The regulation is traditionally a mechanical system, although there has been development of electronic control systems employing Proportional-Integral controllers. These alter the pitch of runner blades and guide vanes altering the characteristics of the flow over the turbine and the turbine itself. This allows the unit to operate more effectively over a wider load range. The load is often controlled by dumping load across a resistive “ballast” and maintains electrical demand. The ballast is switched in and out as the output frequency changes e.g. a drop in demand causes the generator to speed up and thus more ballast load is used.

Asynchronous generators rely upon being connected to a system, which can provide it’s magnetizing current. This is generally the case as they are connected to a large grid. The turbine output need only be adjusted according to the availability of water [29-31].

11. Present State Of the Art: Promising Technical Developments

11.1 Review of recent technical developments: [13,14,15,6,7]

Some of the recent technical developments in the field of Small hydro power plants include use of standardized specially designed site specific systems, use of variable speed turbines at low heads, stress on greater electronic control, use of submersible turbo-generators, use of new materials, computer optimization of small systems, inflatable weirs, use of innovative turbines i.e. cost-effective pumps during installation, simplification and improvement in trash racks, stress on novel techniques to avoid interference to fish, and refurbishment of old sites etc.

12. Conclusion

Hydro power has had a long and significant past; it ought also to have at least as important a future - especially in the light of the growing realisation that we need to bring large - scale methods of clean power generation on stream as quickly as possible if we are to avoid some form of climatic catastrophe. It also offers one of the most promising energy resources for the long term sustainable development of many of the world's poorer countries [1-4].

SHP development must take place through triangular technical and economic cooperation among developing countries, developed countries and international organizations to supply the rural areas in developing countries with environmentally sound, affordable and adequate energy, which will lead to the increase of employment opportunities, improvement of ecological environment, poverty alleviation, improvement of local living and cultural standards and economic development in remote areas. Thus, this initiative aims to encourage the promotion and exploitation of abandoned hydro sites, as well as the realization of new power plants, by providing to local and regional administrations with a wide range of examples of successful projects achieved in the field of dismissed sites rehabilitation [32].

The future of SHP depends on effective use of a mixture of old concepts and the latest technological developments to exploit a huge clean energy resource as cost-effectively as possible.

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