THE HYDROPOWER

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INTRODUCTION

Hydropower is an extremely flexible technology for power generation. Hydro reservoirs provide built-in energy storage, and the fast response time of hydropower enables it to be used to optimise electricity production across grids, meeting sudden fluctuations in demands. The aim of this article was to analyse the world hydroelectric power sector.

1. HYDROELECTRIC POWER STATION (HPS)

As we move into the twenty-first century, global economic prosperity is driving the consumption of energy to record levels, with electricity consumption anticipated to increase at rates faster than overall energy supply. The vast majority (80 per cent) of energy today is provided from thermal sources, i.e. coal, gas and oil; but there are growing global concerns regarding the lack of sustainabilit y of these forms of energy that bring into question their use in a long-term energy strategy.

Concerns over disruptive fossil fuel markets and uncertain pricing, the current decline of nuclear energy as a viable energy source and the significant environmental consequences of thermal energy sources have placed greater emphasis on sustainable energy policies that include the significant development of renewable energy supplies.

Renewable energy technology exists in many forms. Recent thinking often relates renewable energy to electricity from either wind energy, solar energy or geothermal energy. Yet the largest source of renewable energy comes from a proven technology, hydropower. Hydropower is renewable because it draws its essential energy from the sun which drives the hydrological cycle which, in turn, provides a continuous renewable supply of water. Hydropower represents more than 92 percent of all renewable energy generated, and continues to stand as one of the most viable sources of new generation into the future. It also provides an option to store energy, to optimize electricity generation. A study by the Utility Data Institute, USA, predicts that a world total of 695 GW of new electricity capacity will come on line in the next ten years from all sources, 22 per cent of which will be hydro, 26 per cent gas, and 27 per cent coal, with the remainder coming from a variety of sources.

The world's total technical feasible hydro potential is estimated at 14 370 TWh/year, of which about 8082 TWh/year is currently considered economically feasible for development. About 700 GW (or about 2600 TWh/year) is already in operation, with a further 108 GW under construction [Hydropower & Dams, World Atlas and Industry Guide, 2000]. Most of the remaining potential is in Africa, Asia and Latin America:

Table 1. The world's total technical feasible hydro potential, update 10.11.12.

	Technically feasible Economically feasible potential:	**Economically feasible potential:**
Africa	1750 TWh/year	**1000 TWh/year**
Asia	6800 TWh/year	**3600 TWh/year**
North + Central America	1660 TWh/year	**1000 TWh/year**
South America	2665 TWh/year	**1600 TWh/year**

At present hydropower supplies about 20 per cent of the world's electricity. Hydro supplies more than 50 per cent of national electricity in about 65 countries, more than 80 per cent in 32 countrie s and almost all of the electricity in 13 countries.

A number of countries, such as China India, Iran and Turkey, are undertaking large-scale hydro development programmes, and there are projects under construction in about 80 countries. According to the recent world surveys, conducted for the World Atlas & Industry Guide, published annually by Hydropower & Dams, a number of

Figure 1. The Sayano-Shushenskaya hydroelectric power dam, update 10.11.12

countries see hydropower as the key to their future economic development: Examples are Sudan, Rwanda, Mali, Benin, Ghana, Liberia, Guinea, Myanmar, Bhutan, Cambodia, Armenia, Kyrgyzstan, Cuba, Costa Rica, and Guyana.

2. CONSTITUENTS OF HYDROELECTRIC POWER STATION

Hydraulic structures in a hydro electric power station include dam ,spilways,head works,surge tank,penstock and accessory works.

a) *Dam.* A dam is a barrier which stores water and creates water head. Dams are built of concrete or stone masonary,earth or rock fill. This type and arrangements depend upon the topography of the site. A masonary dam may be built on a narrow canyon.An earth dam may be best suited for a wide valley. The type of dam also depends upon the foundation conditions,local material and transportations available,oocurance of earth quakes and other hazards.at most of sites more than one type of dam is suitable and the one which is most economical is chosen.

b) *Spilways* there are times in which the river exceeds the storage capacity of the reservoir. Such a situation arises during heavy rainfall in the catchment area. In order to discharge the surplus water from the storage reservoir into the river on the down stream side of the dam spilways are used. Spilways are constructed of concrete piers on the top of the dam. Gates are provided between these piers and surplus water is discharged over the crest of the dam by opening of these gates.

c) *Head Works.* The headworks consists of the diversion structures at the head of an intake. They generally include booms and racks for diverting floating debris,sluices for by-passing debris and sediments and valves for controlling the flow of water to the turbine. The flow of water into and through headworks should be as smooth as possible to avoid headloss and cavitation. For this purpose,it is necessary to avoid sharp corners and abrupt contractions or enlargements.

d) *Surge Tank.* Open conduits leading water to the the turbine require no protection. However, when closed conduits are used,protection become necessary to limit the abnormal pressure in the conduit.For this reason,closed conduits are always provided with a surge tank. A surge tank is a small reservoir of tank(open at the top) in which water level rises or falls to reduce pressure swings in the conduit. A surge tank is located near the beginning of the conduit.

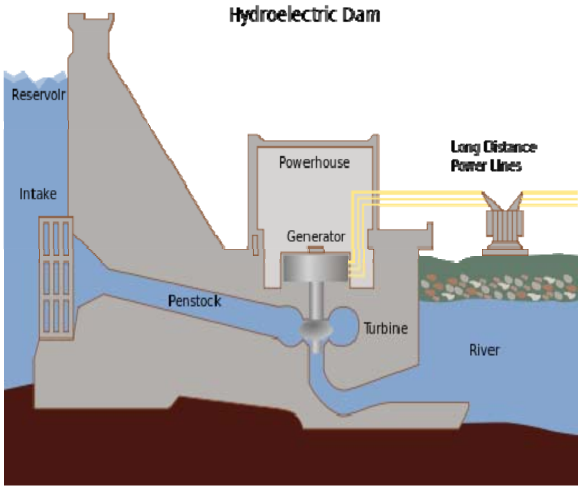

Figure 2. Hydroelectric dam cross-section diagram, update 10.11.12

When the turbine is running at a steady load,there are no surges in the flow of water through the conduit ie the quantity of water flowing through the conduit is just sufficient to meet the turbine requirements. However,when the load on the turbine decreases,the governor closes the gates of the turbine,reducing water supply to the turbine. The excess water at the lower end of the conduit rushes back to the surge tank and increases the water level. Thus the conduit is prevented from bursting.On the other hand when the load on the turbine increases, additional water is drawn from the surge tank to meet the increased load requirements. Hence a surge tanks overcomes the abnormal pressure in the conduit when load on the turbine falls and acts as a reservoir during increase of load on turbine.

e) *Penstocks*. Penstocks are opened or closed conduits which carry water to the turbines. They are generally made of reinforced concrete or steel.Concrete penstocks are suitable for low heads(<30m)as great pressure causes rapid deterioration of concrete. The steel penstocks can be designed for any head,the thickness of penstock increases with the head or working pressure,

Various devices such as automatic butterfly valve,air valve and surge tank are provided for the protection of penstocks. Automatic butterfly valve shuts off water flow through the penstock promptly when it reptures.Air valve maintains the air pressure inside the inside the penstock equal to the atmospheric pressure. When water runs out of a penstock faster than it enters,a vacuum is created which may cause the penstock to collapse.Under such situations,air valve opens and admits air in the penstock to maintain inside air pressure equal to the outside air pressure.

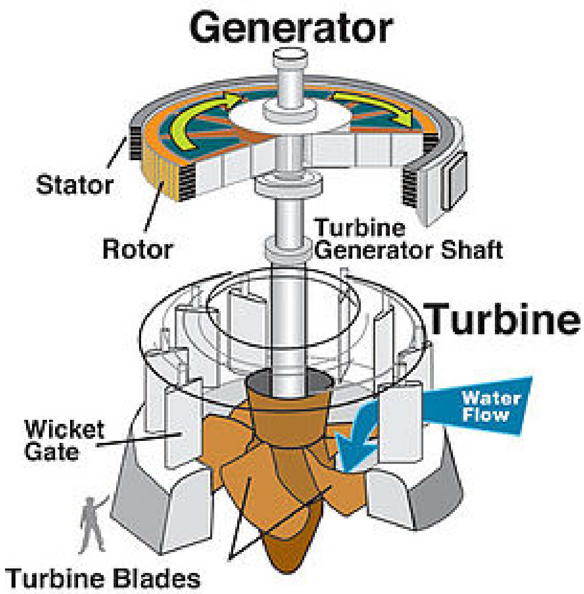

Figure 3. Hydraulic turbine, update 10.11.12.

Water Turbines

Water turbines are used to convert the energy of falling water into mechanincal energy.The principal types of water turbines are:

a) Impulse Turbines

b) Reaction Turbines

a) Impulse Turbines

Such turbines are used for high heads.In an impulse turbine entire pressure of water is converted into kinetic energy in a nozzle and the velocity of the jet drives the wheel.The example of this type of turbine is the Pelton Wheel. It consists of a wheel fitted with elliptical bucket along its periphery. The force of water jet striking the buckets on the wheel drives the turbine. The quantity of water jet falling on the turbine is controlled by means of a needle or spear placed in the tip of the nozzle. The movement of the needle is controlled by the governor.If the load on the turbine decreases,the governor pushes the needle into the nozzle,there by reducing the quantity of water striking the buckets.Reverse action takes place if the load on the turbine increases.

b)Reaction Turbines. Reaction turbines are used for low and medium heads. In a reaction turbine water enters the runner partly with pressure energy and partly with velocity head. The important types of reaction turbines are:

i) Francis Turbines;

ii) Kaplan Turbines.

A Francis turbine is used for low to medium heads.It consists of an outer ring of stationary guide blades fixed to the turbine casing and an inner ring of rotating blades forming the runner. The guide blades control the flow of water to the turbine. Water flows radially inwards and changes to a downward direction while passing through the runner. As the water passes over the rotating blades of the runner,both pressure and velocity of water is reduced. This causes a reaction force which drives the turbine.

A kaplan turbine is used for low heads and large quantities of water.It is similar to Francis Turbine except that the runner of Kaplan turbine receives water axially. Water flows radially inwards through regulating gates all around the sides, changing direction in the runner to axial flow. This causes a reaction force which drives the turbine.

3. THE CALCULATIONS

Below are equations used for calculations involving this kind of power station:

Weight of the water head:

$$W = (Volume\ x\ density) = V\rho \quad [Kg] \qquad (1)$$

The potential energy of the water head:

$$Epotential = mgh \quad [Joules] \qquad (2)$$

Thus the equivelent electrical energy will be:

$$E_{Electrical} = Epotential/(36 \times 10^5)\ [kWh] \qquad (3)$$

Electrical energy can also be expressed as:

$$E_{Electrical} = WH\eta_{overall} / (3600.sec \times 1000)\ [kWh] \qquad (4)$$

Where:

- m = mass (in Kg)
- g = constant ≈9.8 $m.s^{-2}$

- h/H = water head height (metres)
- ρ = density of water (m^3)

4. ADVANTAGES AND DESADVANTAGES OF HPS

Hydro Power is one of the largest sources of energy accounting for roughly 20% of the worldwide demand of electricity and for well resourced countries it accounts for majority of the energy. For Paraguay 100% of the electricity comes from hydro power and lot of it is exported as well.Compared to other sources of Energy, Hydroelectric Power is one of the cheapest,non Carbon Emitting,non Polluting,Mature Energy Sources. Hydro Power plants have been developed to almost full potential in developed countries because of their superior characteristics and many more are being constructed by developing countries like China and India. However Hydro Power like all other thins in life suffers from disadvantages as well. The failure of a Hydro Dam can result in massive losses of human life and cause widespread devastation.Large Dams have always been controversial leading to displacement of people and ecology. They have also been cited as the reason for earthquakes due to large land changes. Here is a list of the advantages and disadvantages of Hydro Power.

Hydroelectric Energy Advantages:

1. No Fuel Cost - Hydro Energy does not require any fuel like most other sources of energy. This is a huge advantage over other fossil fuels whose costs are increasing at a drastic rate every year. Electricity prices are increasingly rapidly in most parts of the world much faster than general inflation. Price shocks due to high fuel costs are a big risk with fossil fuel energy these days

2. Low Operating Costs and little Maintenance - Operating labor cost is also usually low, as plants are automated and have few personnel on site during normal operation.

3. Low Electricity Cost – The Electricity produced from Hydro Power is quite low making it very attractive to construct hydro plants.The payback period is estimated to be between 5-8 years for a normal hydro power plant.Hydro Plants also have long lives of between 50-100 years which means that they are extremely profitable

4. No Greenhouse Gas Emissions/Air Pollution – Hydroelectricity does not produce any GHG emissions or cause air pollution from the combustion of fossil fuels unlike coal,oil or gas. This makes them very attractive as a source of cheap,non carbon dioxide producing electricity.

5. Energy Storage – Pumped Hydro Storage is possible with most of the hydro power plants.This makes them ideal storage for wind and solar power which are intermittent in nature. Hydro Dams can be modified at low costs to allow pumped storage.

6. Small Size Possible - Hydroelectricity can be produced in almost any size from 1 MW to 10000 MW which makes it very versatile. Small Hydro Plants are being encouraged by government as they cause less ecological affects than large hydro plants. Even micro hydro plants are possible

7. Reliability - Hydro Power is much more reliable than wind and solar power though less than coal and nuclear as a baseload source of power.Hydroelectricity is more or less predictable much in advance though it can decrease in summer months when the water is low in the catchment areas.

8. High Load Factor - The Load Factor for Solar and Wind Energy ranges from 15-40% which is quite low compared to Fossil Fuel Energy. Hydroelectricity on the other hand has a load factor of almost 40-60% .

9. Long Life - Hydro Plants has a very long life of around 50- 100 years which is much longer than that of even Nuclear Power Plants. The long life implies that the lifecycle cost of a Hydel Power Plant becomes very low in the long term

Hydroelectric Energy DisAdvantages:

1. Environmental, Dislocation and Tribal Rights - Large Dam construction especially in populated areas leads to massive Tribal Displacement,Loss of Livelihood and Religious Infringement as potentially sacred Land is occupied by the Government.

2. Wildlife and Fishes get Affected - The Fishes are the most affected species from Dam Construction as the normal flow of the river is completely changed form its river character to a lake one. Submergence of land also leads to ecological destruction of the habitat of land based wildlife.

3. Earthquake Vulnerability – Large Dam Construction has been linked to increased propensity of Earthquakes. Massive Earthquakes in China and Uttarakhand in India were linked to the building of Massive Dams in these countries

4. Siltation When water flows it has the ability to transport particles heavier than itself downstream. This has a negative effect on dams and subsequently their power stations, particularly those on rivers or within catchment areas with high siltation

5. Tail Risk, Dam Failure - Because large conventional dammed-hydro facilities hold back large volumes of water, a failure due to poor construction, terrorism, or other cause can be catastrophic to downriver settlements and infrastructure. Dam failures have been some of the largest man-made disasters in history.The Banqiao Dam Failure in Southern China directly resulted in the deaths of 26,000 people, and another 145,000 from epidemics.

6. Cannot be Built Anywhere - This disadvantage of Hdyro Energy is present with other forms of Energy as well. Some forms of Energy are just better suited to some places.For example you can't build a nuclear plant on top of an earthquake prone region, you can't build a wind farm near the Dead Sea etc.Hydro Energy can only be built in particular places though enough of those places exist globally.

7. Long Gestation Time - The time to construct a large hydro power project can take between 5-10 years which leads to time and cost overruns.

CONCLUSION

Hydro electricity is good because water is all around us. This means that we do not need to change the entire landscape dramatically. Next we have the fact that it is cheaper due to the fact that at one time there are very little personnel on the floor resulting in lower costs for the customers. Now I look at the structure of the dams they use. The dams are strong and some built hundreds of years ago are still in use today. There are also low emissions, however, the emissions are only from the building process. Finally I turn to how much power hydro-electricity makes. With the amount of dams we have today we could power the world two times over! And for all those tax payers and people that want to keep their money, going to hydro electricity is a very good decision to make.

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