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Hydropower: Its Amazing Potential- A Theoretical Perspective

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Abstract—*With the energy becoming the current catch phase in business, industry and society, energy alternative are becoming increasingly popular. Hydroelectricity exists as one option to meet the growing demand for energy and also a reliable renewable resource. In simple terms, inexpensive and reliable electricity is critical to the sustained economic growth and security of any nation. Today's world is dependent on reliable, low cost and abundant energy.*

In nature energy cannot be created or destroyed, but its form can change. People have been using water to their advantage for thousands of years. With the passage of the time they are now using moving water for power generation. By using water for power generation, people have worked nature to achieve a better life style.

In generating hydropower electricity kinetic energy of moving water is converted to electrical energy. Since water is the initial source of energy, we call this hydroelectric power or hydropower in short.

Worldwide, an installed capacity of 777 GWe (giga Watt electrical) supplied 2998 TWh of hydroelectricity in 2006. This was approximately 20% of the world's electricity, and accounted for about 88% of electricity from renewable sources. Although most energy in the India is produced by fossil-fuel, hydroelectricity is still important to the Nation, as about 114 TWh and 3.5% the world total power is produced by hydroelectric plants. The first hydro-electric power station in India was established in Karnataka at "shivana samudra".The potential for hydroelectric power in India is one of the greatest in the world.India was the 6th largest producer of hydroelectric power in 2008 after Norway.

The present study is a humble effort towards the review of hydropower energy and detailed theoretical investigation of generation of this energy.

Keywords*: Hydropower, Kinetic Energy, Electrical Energy, Turbine.*

1. INTRODUCTION

Water power-The term is amazing apart from the fact that it is renewable in nature.It can cut deep canyons, chisel majestic mountains, quench parched lands, and transport tons -- and to add to it, it can also generate enough electricity to light up millions of homes and businesses around the world.Hydropower, also known as hydroelectric power, is a reliable, domestic,emission-free resource that is renewable through the hydrologic cycle and harnesses the natural energy of flowing water to provide clean, fast, flexible electricity generation. According to different studies, hydropower, one of our nation's most important renewable energy resources, has grown over the last century from 45 hydroelectric facilities in 1886 to more than 2,000 facilities.Hydroelectric power captures the energy released from falling water. In the most simplistic terms, water falls due to gravity, which causes kinetic energy to be converted into mechanical energy, which in turn can be converted into a useable form of electrical energy.

Ancient Greeks used wooden water wheels to convert kinetic energy into mechanical energy as far back as 2,000 years ago. In 1882 the first hydroelectric power plant was built in the United States using a fast flowing river. Humans in time began creating dams to store water at the most convenient locations in order to best utilize power capacity. Additional engineering and structural changes have followed, providing for a much more complicated process in designing a hydroelectric power plant.

Hydroelectric power plants are categorized according to size. They fit into one of four different size ranges: Micro, Mini, Small, and Large. A Micro sized plant is one that generates less than 100 kW of electricity which in turn would be able to power only 1-2 houses. A Mini facility can serve an isolated community or a small factory by generating 100kW-1MW of electricity. A Small plant generates 1MW-30MW and can serve an area while supplying electricity to the regional grid. Lastly, a large facility generates more than 30MW of power. According to different reports, hydroelectric power accounts for about 10% of the total energy produced in the United States.

2. THE DEVELOPMENT OF POTENTIAL ENERGY

The development of natural sources of potential energy, the transformation of such energy into different forms can be utilized for power generation and its transmission to different points where it can be utilized for commercial purposes, constitutes a significant portion of the work of the Engineer. The water power engineering primarily deals with the energy in the form of flowing or falling water, but the knowledge must extend much further because of the other forms of energy which is to be encountered at every turn. Much of the energy available from the potential source will be lost due to friction in bringing the water to and taking it from the wheel. Much is lost in hydraulic and mechanical friction in the wheel, additional losses are sustained in every transformation and if electric and other forms of transmission are used or auxiliary power is necessary for maintaining continuous operation, the engineer will be brought in contact with energy in many other form.

3. DEFINITION OF ENERGY

Energy is the active principle of nature. It is the basic requirement for all life, all action and all physical phenomena. It is the ability to exert force, to overcome resistance, to do work, etc. All physical and chemical phenomena are manifestation of energy transformation and all nature would be rendered inactive and inanimate without these changes.

3.1 Solar Energy- The Ultimate source of Energy

A brief consideration of the various sources of potential energy makes the fact manifest that solar energy is the ultimate source from which all other forms are directly or indirectly derived. The variations in solar heat on the earth's surface produces the atmospheric currents, often of tremendous power. This form of energy may be utilized in its more moderate form, to drive the sailing vessel and the wind mill and in other ways to be of service to man. The energy of fuel is directly traceable to solar energy.

4. HYDRAULICS

4.1 Basics of Hydraulics

The science of hydraulics is an empirical science, not an exact science, but it is based on the exact science of hydrostatic and dynamics. Its principal laws are therefore founded on theory but on account of multitude of modifying influences and of our necessarily imperfect theoretical knowledge of their varying characters and extent, the formulas used must be derived from or at least modified by observation and experience and cannot be founded solely on theoretical considerations. The conditions under which hydraulic laws must be applied are so versed in both number and kind that the applications of the laws must be modified to suit those various conditions and for this reason their successful application depends largely on the practical experience of the engineer.

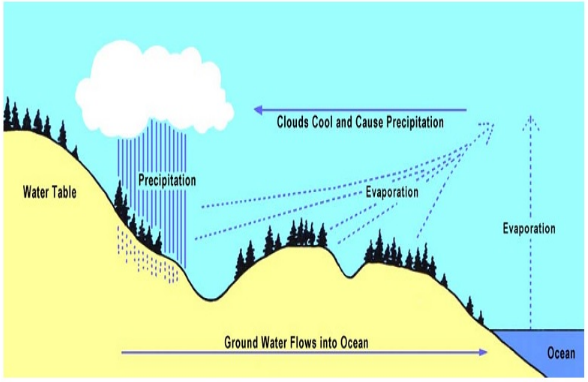
4.2 Mathematical Expression for Energy

Mechanically, energy is the exertion of force through space. The amount of available energy of water that may be theoretically utilized is measured by its weight (the force available) multiplied by the available head(the space through which the force is to be exerted) i.e**. E=wh.** From this it will be noted that the energy of water is in direct proportion to both the head and quantity.

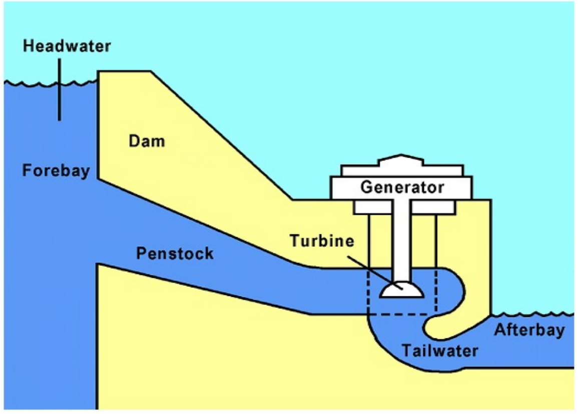
5. HOW HYDROPOWER WORKS

5.1 Generating Power

In nature, energy cannot be created or destroyed, but its form can change. In generating electricity, no new energy is created. Actually one form of energy is converted to another form.



To generate electricity, water must be in motion. This is kinetic (moving) energy. When flowing water turns blades in a turbine, the form is changed to mechanical (machine) energy. The turbine turns the generator rotor which then converts this mechanical energy into another energy form -- electricity. Since water is the initial source of energy, we call this hydroelectric power or hydropower for short.



At facilities called hydroelectric power plants, hydropower is generated. Some power plants are located on rivers, streams, and canals, but for a reliable water supply, dams are needed.

Dams store water for later release for such purposes as irrigation, domestic and industrial use, and power generation. The reservoir acts much like a battery, storing water to be released as needed to generate power.

The dam creates a “head” or height from which water flows. A pipe (penstock) carries the water from the reservoir to the turbine. The fast-moving water pushes the turbine blades, something like a pinwheel in the wind. The waters force on the turbine blades turns the rotor, the moving part of the electric generator. When coils of wire on the rotor sweep past the generator’sstationary coil (stator), electricity is produced.

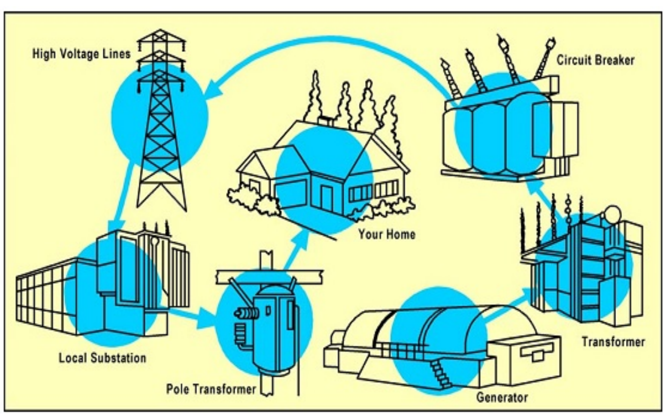
This concept was discovered by Michael Faraday in 1831 when he found that electricity could be generated by rotating magnets within copper coils. When the water has completed its task, it flows on unchanged to serve other needs.

5.2 Transmitting Power

Once the electricity is produced, it must be delivered to where it is needed -- our homes, schools, offices, factories, etc. Dams are often in remote locations and power must be transmitted over some distance to its users.

Vast networks of transmission lines and facilities are used to bring electricity to us in a form we can use. All the electricity made at a power plant comes first through transformers which raise the voltage so it can travel long distances through power lines. (Voltage is the pressure that forces an electric current through a wire.) At local substations, transformers reduce the voltage so electricity can be divided up and directed throughout an area.

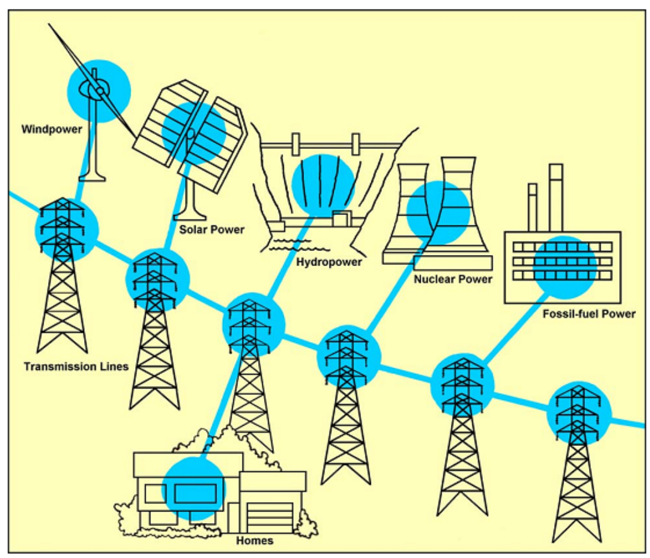
Transformers on poles (or buried underground, in some neighborhoods) further reduce the electric power to the right voltage for appliances and use in the home. When electricity gets to our homes, we buy it by the kilowatt-hour, and a meter measures how much we use.



While hydroelectric power plants are one source of electricity, other sources include power plants that burn fossil fuels or split atoms to create steam which in turn is used to generate power. Gas turbine, solar, geothermal, and wind-powered systems are other sources. All these power plants may use the same system of transmission lines and stations in an area to bring power to you. By use of this “power grid,” electricity can be interchanged among several utility systems to meet varying demands. So the electricity lighting your reading lamp now may be from a hydroelectric power plant, a wind generator, a nuclear facility, or a coal, gas, or oil-fired power plant or a combination of these.

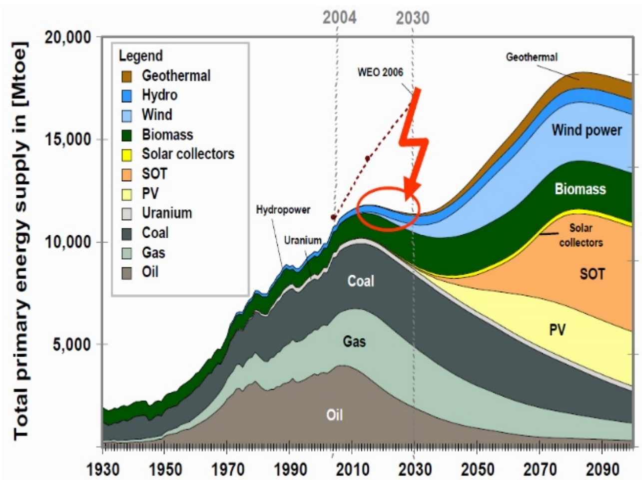
The area where we live and its energy resources are prime factors in determining what kind of power we use. According to various reports, in Washington State hydroelectric power plants provided approximately 80 percent of the electrical power during 2002. In contrast, in Ohio during the same year, almost 87 percent of the electrical power came from coal-fired power plants due to the area's ample supply of coal.

Electrical utilities range from large systems serving broad regional areas to small power companies serving individual communities. Most electric utilities are investor-owned (private) power companies. Others are owned by towns, cities, and rural electric associations. Surplus power produced at facilities owned by the Federal Government is marketed to preference power customers (A customer given preference by law in the purchase of federally generated electrical energy which is generally an entity which is nonprofit and publicly financed.) by the Department of Energy through its power marketing administrations.



5.3 How Power is computed

Before a hydroelectric power site is developed, engineers compute how much power can be produced when the facility is complete. The actual output of energy at a dam is determined by the volume of water released (discharge) and the vertical distance the water falls (head). So, a given amount of water falling a given distance will produce a certain amount of energy. The head and the discharge at the power site and the desired rotational speed of the generator determine the type of turbine to be used.



The head produces a pressure (water pressure), and the greater the head, the greater the pressure to drive turbines. This pressure is measured in pounds of force (pounds per square inch). More head or faster flowing water means more power.

To find the theoretical horsepower (the measure of mechanical energy) from a specific site, the formula used:

THP = (Q x H)/8.8

Where,

THP = theoretical horsepower

Q = flow rate in cubic feet per second (cfs)

H = head in feet

8.8 = a constant

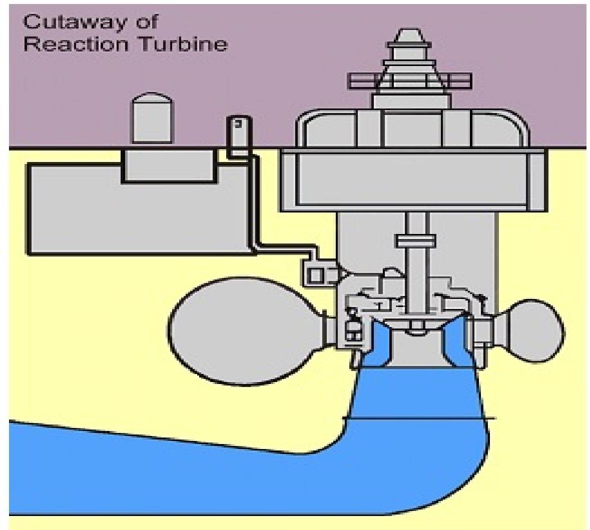
A more complicated formula is used to refine the calculations of this available power. The formula takes into account losses in the amount of head due to friction in the penstock and other variations due to the efficiency levels of mechanical devices used to harness the power.

To find how much electrical power we can expect, we must convert the mechanical measure (horsepower) into electrical terms (watts). One horsepower is equal to 746 watts.

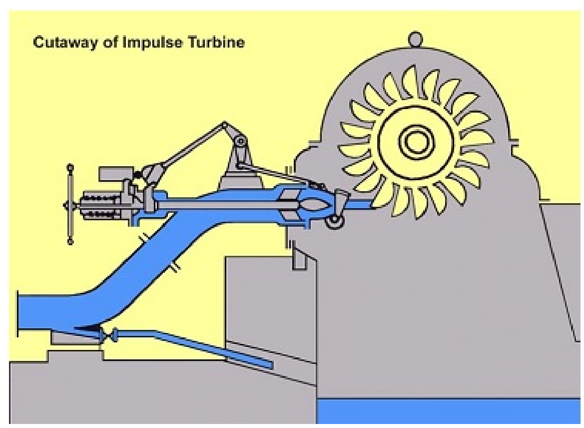
5.4 Turbines

While there are only two basic types of turbines (impulse and reaction), there are many variations. The specific type of turbine to be used in a power plant is not selected until all operational studies and cost estimates are complete. The turbine selected depends largely on the site conditions.

A reaction turbine is a horizontal or vertical wheel that operates with the wheel completely submerged, a feature which reduces turbulence. In theory, the reaction turbine works like a rotating lawn sprinkler where water at a central point is under pressure and escapes from the ends of the blades, causing rotation. Reaction turbines are the type most widely used.



An impulse turbine is a horizontal or vertical wheel that uses the kinetic energy of water striking its buckets or blades to cause rotation. The wheel is covered by a housing and the buckets or blades are shaped so they turn the flow of water about 170 degrees inside the housing. After turning the blades or buckets, the water falls to the bottom of the wheel housing and flows out.



5.5 Modern Concepts and Future Role

Hydropower does not discharge pollutants into the environment; however, it is not free from adverse environmental effects. Considerable efforts have been made to reduce environmental problems associated with hydropower operations, such as providing safe fish passage and improved water quality in the past decade at both Federal facilities and non-Federal facilities licensed by the Federal Energy Regulatory Commission.

Efforts to ensure the safety of dams and the use of newly available computer technologies to optimize operations have provided additional opportunities to improve the environment. Yet, many unanswered questions remain about how best to maintain the economic viability of hydropower in the face of increased demands to protect fish and other environmental resources.

Reclamation actively pursues research and development (R&D) programs to improve the operating efficiency and the environmental performance of hydropower facilities.

Hydropower research and development today is primarily being conducted in the following areas:

- Fish Passage, Behavior, and Response
- Turbine-Related Projects
- Monitoring Tool Development
- Hydrology
- Water Quality
- Dam Safety
- Operations & Maintenance
- Water Resources Management

Reclamation continues to work to improve the reliability and efficiency of generating hydropower. Today, engineers want to make the most of new and existing facilities to increase production and efficiency. Existing hydropower concepts and approaches include:

- Uprating existing powerplants
- Developing small plants (low-head hydropower)
- Peaking with hydropower
- Pumped storage
- Tying hydropower to other forms of energy

Low-head Hydropower

A low-head dam is one with a water drop of less than 65 feet and a generating capacity less than 15,000 kW. Large, high-head dams can produce more power at lower costs than low-head dams, but construction of large dams may be limited by lack of suitable sites, by environmental considerations, or by economic conditions. In contrast, there are many existing small dams and drops in elevation along canals where small generating plants could be installed. New low-head dams could be built to increase output as well. The key to the usefulness of such units is their ability to generate power near where it is needed, reducing the power inevitably lost during transmission.

Advantages of Hydroelectricity

The water used in producing electricity is again returned to its source of origin. Hydroelectric power can be created 24/7 indefinitely assuming that the body of water it is utilizing never runs dry. It is also another absolutely clean source of energy. The power plants, once in place, do not create any waste by products in their conversion. Dams constructed can also shut their gates and conserve the water for use when power is in higher demand.

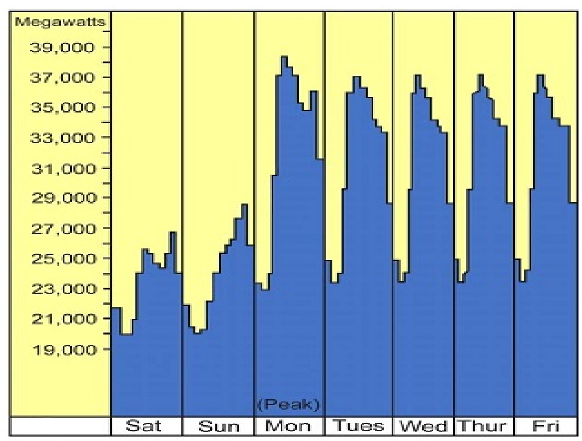
6. CONCLUSION

Demands for power vary greatly during the day and night. These demands vary considerably from season to season, as well. For example, the highest peaks are usually found during summer daylight hours when air conditioners are running.

Nuclear and fossil fuel plants are not efficient for producing power for the short periods of increased demand during peak periods. Their operational requirements and their long startup times make them more efficient for meeting baseload needs.

Since hydroelectric generators can be started or stopped almost instantly, hydropower is more responsive than most other energy sources for meeting peak demands. Water can be stored overnight in a reservoir until needed during the day, and then released through turbines to generate power to help supply the peak load demand. This mixing of power sources offers a utility company the flexibility to operate steam plants most efficiently as base plants while meeting peak needs with the help of hydropower. This technique can help ensure reliable supplies and may help eliminate brownouts and blackouts caused by partial or total power failures.

Today, many of Reclamation's power plants are used to meet peak electrical energy demands, rather than operating around the clock to meet the total daily demand.



Typical Weekly Load Curve of a Large Electric Utility

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