Hydro-Electric Power Generation

An Online Continuing Education Course for Engineers

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Introduction

Hydropower or water power is power that is derived from the force or energy of moving water, which may be harnessed for useful purposes. Prior to the widespread availability of commercial electric power, hydropower was used for irrigation, and operation of various machines, such as watermills, textile machines, sawmills, dock cranes, and domestic lifts.

Hydropower offers advantages over other energy sources but faces unique environmental challenges too. Hydropower is a fueled by water, so it's a clean fuel source. Hydropower doesn't pollute the air like power plants that burn fossil fuels, such as coal or natural gas. Hydropower is a domestic source of energy, produced in the United States. Hydropower relies on the water cycle, which is driven by the sun, thus it's a renewable power source. Hydropower is generally available as needed; the flow of water through the turbines can be controlled to produce electricity on demand.

Hydroelectric power plants provide benefits in addition to clean electricity. Conventional hydroelectric impoundment power plants create reservoirs that offer a variety of recreational opportunities, notably fishing, swimming, and boating. Most hydropower installations provide some public access to the reservoir to allow the public to take advantage of these opportunities. Other benefits may include water supply and flood control.

Hydroelectric power can be categorized into two broad categories: Conventional Hydroelectric power plants and marine energy-derived power plants. Conventional hydroelectric power plants include,

- Impounded water hydroelectric power plants,
- Run-of-the-river hydroelectricity, and
- Pumped-storage hydroelectricity.

Marine energy-derived power plants include,

- Tidal power,
- Wave power, and
- Ocean thermal energy.

Hydroelectricity is the most widely used form of renewable energy. Once a hydroelectric power plant is constructed, the project produces no direct waste, and has a considerably lower output level of the greenhouse gas carbon dioxide (CO_2) than fossil fuel powered energy plants.

Worldwide, an installed capacity of 777,000 MW supplied 2,998,000 MWh of hydroelectricity in 2006. This was approximately 20% of the world's electricity, and accounted for about 88% of electricity from renewable sources.

Humans have been harnessing water to perform work for thousands of years. The Greeks used water wheels for grinding wheat into flour more than 2,000 years ago. Besides grinding flour, the power of the water was used to saw wood and power textile mills and manufacturing plants.

For more than a century, the technology for using falling water to create hydroelectricity has existed. The evolution of the modern hydropower turbine began in the mid-1700's

In 1880, a brush-arc light dynamo driven by a water turbine was used to provide theatre and storefront lighting in Grand Rapids, Michigan; and in 1881, a brush dynamo connected to a turbine in a flour mill provided street lighting at Niagara Falls, New York. These two projects used direct-current technology. Of course, alternating current is used today. That breakthrough came when the electric generator was coupled to the turbine, which resulted in the first hydroelectric plant located in Appleton, Wisconsin, in 1882.

The following are a few of the major milestones in the evolution of hydroelectric power generation.

1880 Michigan's Grand Rapids Electric Light and Power Company, generating electricity by dynamo belted to a water turbine at the Wolverine Chair Factory, lit up 16 brush-arc lamps.

1881 Niagara Falls city street lamps powered by hydropower.

1882 World's first hydroelectric power plant began operation on the Fox River in Appleton, Wisconsin.

1886 About 45 water-powered electric plants in the U.S. and Canada.

1889 Two hundred electric plants in the U.S. use waterpower for some or all generation.

1907 Hydropower provided 15% of U.S. electrical generation.

1920 Hydropower provided 25% of U.S. electrical generation.

1933 Tennessee Valley Authority established.

1936 Hoover Dam built with 1,345 MW of capacity; the largest of the time.

1937 Bonneville Power Administration established.

1940 Hydropower provided 40% of electrical generation.

1942 Grand Coulee Dam built with 6,809 MW of capacity.

1980 Conventional capacity nearly tripled in United States since 1940.

1984 Brazil/Paraguay's Itaipu Dam built, with 14,000 MW of capacity.

2008 China builds the Three Gorges Dam with 22,500 MW of capacity.

The largest hydroelectric power plant in operation today is the Three Gorges Dam in China and is shown in the photograph on the right.

As Hydroelectricity has continued to develop it eventually has supplied countries like Norway, Democratic Republic of the Congo, Paraguay and Brazil with over 85% of their electricity.

The United States currently has over 2,000 hydroelectric power plants which supply about 7% of its national energy consumption.

The United States faces many challenges as it prepares to meet its energy needs in the twenty-first century. Electricity supply crises, fluctuating natural gas and gasoline prices, heightened concerns about the security of the domestic energy infrastructure and of foreign sources of supply, and uncertainties about the benefits of utility restructuring are all elements of the energy policy challenge. Hydropower is an important part of the diverse energy portfolio that is needed for a stable, reliable energy sector in the United States.

Responding to these national energy issues, the Department of Energy (DOE) is investigating the potential for new hydroelectric power generation in the United States and is focused on:

- Assessing new potential hydroelectric generation sites of which 5,677 sites have been identified in the United States with undeveloped capacity of about 30,000 MW,
- Developing new, cost-effective, advanced technologies that will have enhanced environmental performance and greater energy efficiencies, and

- Providing supporting research in power systems integration, resource assessment, innovative technology characterization, valuation and performance metrics, industry support, and technology acceptance.

While we probably will not see many new large scale hydroelectric power plants built in the United States, there is potential to increase the efficiency of the current plants and to develop new small hydroelectric plants.

In this course we will look at the basics of hydroelectric power generation, including the types of hydroelectric power plants and the types of turbines used in these plants. Conventional hydroelectric power generation will be reviewed in detail as well as the potential for marine power generation. Finally, the environmental benefits and concerns with hydro-electric power will be discussed.