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Hydropower Plant as Sustainable Energy Source: A Review of Opportunities and Technologies

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ABSTRACT: Water is the most important part of human day to day life and natural resources. Hydropower is an important renewable energy resource and clean as well as environment friendly. Energy demand increases due to rapid urbanization and increase in population growth. So, the time is not very far away when we will not have sufficient amount of electricity to fulfil our needs. To avoid such dark future, A sustainable hydropower project is solution. But it needs proper planning and well developed designs to overcome the challenges. The hydropower plant has a huge potential as it can be one of the best solutions for electricity generation. This is basically a review paper. This research paper intends to show the emerging concepts of hydroelectricity generated from hydro power plants. This will reduce the grid based demand of conventional energy currently utilised. The main motive is to generate electricity from efficient and non- conventional means available on site.

I. INTRODUCTION

Nowadays, due to large increase in population all over the world, demand of energy supply has been increased. The gap between demand and supply of power or energy is quite significant. The fossil fuels still dominate sources of energy for electricity generation. In 2009, they contributed to about 67%of the total global electricity generation capacity, with coal alone contributing about 40% of the capacity. Fossil fuels especially coal remains the largest source of energy generation. But there is a major disadvantage as it has many negative impacts on the environment. Coal burning energy plants are a major source of air pollution and greenhouse gas emissions. In addition to carbon monoxide and heavy metals like mercury, the use of coal also releases sulphur dioxide which has a major role in producing acid rain. In order to overcome the heavy power crisis throughout the world, there is a great need of sustainable energy source with considering economical and environmental aspects. Hydro power is the most widely used renewable energy. Department of Energy(DOE) has stated that these hydropower plants can be large, small and micro. According to DOE, Large Hydropower plants are plants having generation capacity of more than 30MW. Small hydropower plants are the plants which have generation capacity from 100KW to 30MW. Micro- power plants have a generation capacity in the range from 5KW to 100KW. In this paper, we have explored the potential of hydropower plants as a source of renewable and sustainable energy in order to tackle the current situation which would also conserve the natural fossil fuels and resources which are getting depleted at such a higher rate.

II. REVIEW OF LITERATURE

Some of the first innovations in using water for power were conceived in China during the Han Dynasty between 202 B.C. and 9 A.D. The availability of water power has long been closely associated with kick-starting economic growth. When Richard Arkwright set up Cromford mill in England's Derwent valley in 1771 to spin cotton and so set up one of the world's first factory systems, Hydropower was the energy source he used.

Some of the key developments in hydropower technology happened in the first half of the nineteenth century . In 1827, French engineer Benoit Fourneyron developed a turbine capable of producing around 6 Horsepower- the earliest version of the fourneyron reaction turbine. In 1849, British-American engineer James Francis developed the first modern water turbine - the Francis turbine – which remains the most widely used water turbine in the world today.

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FIRST HYDROPOWER PROJECT

The World's first hydropower project was used to power a single lamp in 1878 in the Cragside country house in Northumberland, England . Four years later, the first plant to serve a system of private and commercial customers was opened in Wisconsin, USA and within a decade, hundreds of these hydropower plants were in operation.

By the turn of century the technology was spreading around the globe, with Germany producing the first three- phase hydro-electric system in 1891 and Australia launching the first publicly owned plant in the Southern Hemisphere in 1895. In 1895, the world's largest hydro- electric power development of the time, the Edward Dean Adams power plant , was created at Niagra Falls.

A CENTURY OF RAPID CHANGES

The twentieth century witnessed the rapid innovation and changes in Hydropower facility design. Policies enacted by U.S President Franklin Roosevelt, including the New Deal in the 1930s, supported the construction of several multipurpose projects such as the Hoover and Grand Coulee dams with hydropower according for 40 percent of the century's electricity generation by the end of 1940.

From the 1940s to 1970s, spurred initially by World War II followed by strong post war economic and population growth, state- owned utilities built significant hydropower developments throughout the Western Europe, as well as the Soviet Union, North-America and Japan. Low cost hydropower was seen as one of the best ways to meet the growing energy demand and was often tied to the development of energy – intensive industries such as aluminium smelters.

MATHEMATICAL FORMULA

Hydro-electric power plants essentially capture the energy released by water falling through a vertical distance, and transform this energy into useful electricity. In general, falling water is channelled through a turbine which converts the water's energy into mechanical power. The rotation of the water turbines is transferred to a generator which produces electricity. An important calculation to consider when constructing and figuring out how much water flow is needed to achieve a certain KW of electric power per hydroelectric power plant is in the following equation :

Power equation : P= eHQgd -----(1)

Here, P stands for the electric power output in KW, e stands for efficiency,
H stands for head in meters(how for the water drop is), Q stands for discharge (m^3/s), d stands for density of water (kg/m^3) and g stands for the acceleration due to gravity, ($9.81m/s^2$)

DESIGN OF A SMALL HYDROPOWER PLANT

The basic components of a hydropower plant are weir, desilting tank, penstock, turbine, generator and controls. Water from the river is diverted through an intake at the weir, which also controls the water flow. Water then enters a desilting tank where, if any impurities are present then are removed in it. A forebay tank is located between the intake and penstock, to store water. Water from the forebay tank is transported to a turbine through a pipe termed as penstock. The turbine converts the potential energy of the water into mechanical energy. The mechanical energy is then converted into electrical energy with the help of a generator. The power produced at the turbine shaft is determined using the (1) equation.

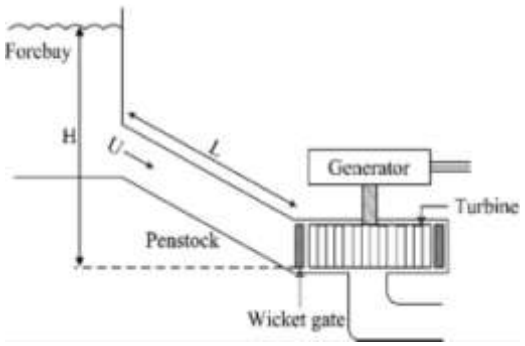

Fig. 1: A Small Hydropower Plant

ADVANTAGES

1. Hydropower plants are driven by water which is driven by sun, so they are clean and renewable sources.
2. Hydroelectricity plants increase the stability and reliability of electricity systems.
3. Hydroelectric power plants don't release pollutants into the air. They substitute the generation from fossil fuels, thus reducing acid rain and smog. Thus, they improve the air we breathe.
4. Hydropower enterprises that are developed and operated in a manner that is economically viable, environment friendly and socially responsible represent the best concept of sustainable development.

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5. Hydroelectric power plant reservoirs collect rainwater, which can then be used for consumption or for irrigation. Thus, they contribute to the storage of drinking water.

CHALLENGES

1. Hydropower plants projects are site specific.
2. Hydropower facilities can affect land use ,homes and natural habitats in the dam area. Reservoirs may cover people's homes, agriculture areas .
3. Scarcity of result oriented reputed contractors/workers.
4. Creation of new sanctuaries and national parks by forest department without consulting the Hydropower Department.
5. As these plants are located in interior far flung areas, hilly areas and landslides, these regions has extremely poor or no mobile connectivity thus they have lack of communication.
6. Hydroelectricity can cause changes in reservoir and stream water quality. So, operating them may alter the water temperature and may harm aquatic plants and animals .

TECHNOLOGY

The world's first hydroelectric power plant, located along the Fox river in Appleton, Wisconsin, started illuminating the home of plant builder H.J. Roger and a nearby building on Sep.30, 1882. After that, for the next hundred years, these hydropower plants grew in number. Today, more than 2,000 hydropower plants generate clean, reliable energy across America.

But for Hydro power to realize its full potential, new innovative technologies are needed to meet new challenges and resources from streams to the ocean. Here are some hydro power technologies that are under research so that future of power supply would be bright.

(a) MODULAR HYDROPOWER

The existing hydropower is among the least expensive sources of electricity. Still, building a new plant is expensive because cost of installation of new plants is very high. Thus, there is a need of a modern technology which would reduce the installation and civil work. One potential solution is Modular Hydropower, which uses separate, similar components that can be constructed off site and then easily integrated into new or existing sites and scaled to have greater capacities. The result is reduced installation and civil work which results in lower cost, improved performance of power plants as well as less impact on environment.

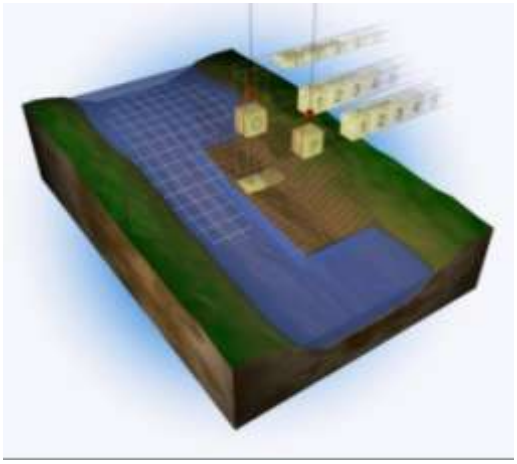

Fig. 2: A Module Hydropower

(b) POWERING NON-POWERED DAMS

Today, hydropower is the largest renewable energy source in the U.S. Still, approximately 80,000 dams in the U.S. don't produce power. Adding turbines to these sites could add up new hydropower capacity to the grid and using existing dam infrastructure can reduce the permitting time and cost of construction of new plants.

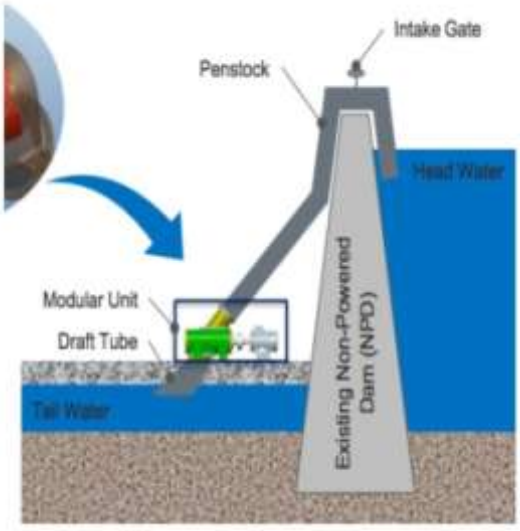

Fig. 3: Powering of Non Powered Dams

Development of non- powered dams by powering them represents a big opportunity in the field of hydro - electricity because 49% of hydro power capacity is owned the U.S. government. It is another focus area of America's Water Infrastructure Act of 2018.

(c) PUMPED- STORAGE HYDROPOWER (PSH)

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It works like a big battery, pumping water to a higher elevation, which can then be released at any time to turn turbines and meet the energy demand. As the largest form of utility – scale energy storage, PSH helps a lot in stabilizing America's power grid. The country's 42 PSH plants help in making the electric grid reliable and resilient. But research of DOE shows that we can add even larger amounts of new, flexible and low cost PSH.

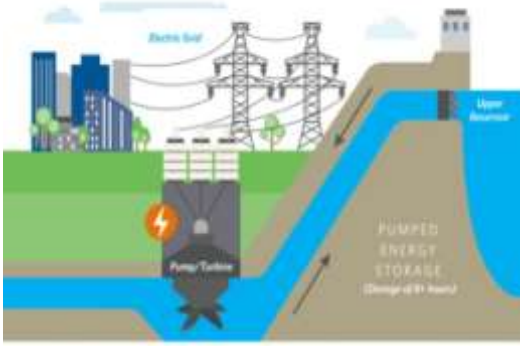

Fig. 4: A PS Hydropower Plant

(d) TIDAL ENERGY

Tidal power is one of the major renewable energy sources . Using the power of the tides, energy is produced from the gravitational pull from both the Moon and the Sun, which pulls the water upwards, while the earth's rotational and gravitational power pulls water downwards, thus creating high and low tides.

This movement of water from the changing tides is a natural form of Kinetic Energy. It takes a steam generator, tidal turbine or the more innovative Dynamic Tidal Power (DTP) technology to turn kinetic energy into electricity.

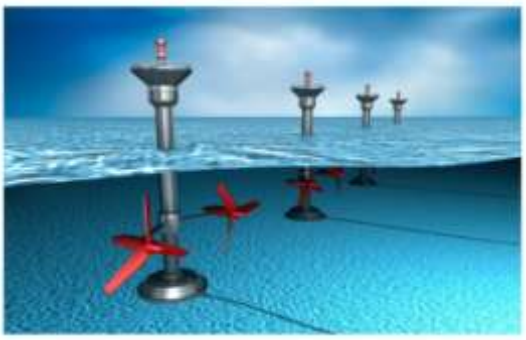

Fig. 5: Tidal Energy Power Plant

Tidal energy is a green energy source, as it emits zero greenhouse gases. It also does not take up so much place. The DOE is specifically looking to optimizing a way to deploy , retrieve three tidal turbines together as a single system with one on-water operation without any diver support.

(e) WAVE ENERGY

Wave energy is the transport and capture of energy by ocean surface waves. The energy captured is then used for electricity generation. Ocean waves release immense energy but researchers have yet to identify a technology that can safely, reliably, properly and cost effectively convert the wave energy into usable electricity.

If we get success in finding such technologies of power then our future generations may have a renewable power which ultimately will help in making the environment pollution free.

ENVIRONMENTAL EFFECTS

Although hydropower makes it possible to produce electricity without using or emitting fossil fuels, there are various environmental consequences that come with this technology.

BAD IMPACTS

(1) Large reservoirs are required for the operation of hydro electric power stations, which can create flooding of river banks which can destroy the biologically rich areas such as Wildlife habitat, forests and zoological parks.

(2) Operating the power plants may also raise the temperature of the water in the reservoir which can lead to migration of plants and animals near the dam to elsewhere, thus changing the local natural habitats of the region.

(3) They can disrupt the aquatic ecosystems both upstream and downstream of the plant site.

(4) Hydropower often entails changes to the natural vibrations in the water in a given natural watercourse. These changes in the water level throughout the year can cause erosion and other problems in the surrounding land area.

GOOD IMPACTS

(1) It is fuelled by water so it is a clean fuel source and does not harm nature.

(2) It would not pollute the air like power plants that burn fossil fuels such as coal and natural gas.

(3) Hydropower efforts produce a number of benefits such as flood control, irrigation and water supply.

ECONOMICAL EFFECTS

Hydroelectricity has various factors that contribute to its overall cost structure and economics. These costs include –

1) Investment expenses (buying the land, building the dam, purchasing the turbines, A.C generators and other electric equipments etc.

2) Operating expenses (maintenance and cost of salary to the workers).

In terms of its cost structure, hydro-electric power has high initial costs. The average initial cost to set up a dam or a hydro electric power plant is around $1.2 million while the annual costs for maintenance is about $12,368. However the initial costs are all dependent on the size and power generation capacity of the dam. The plant life can be extended economically by relatively cheap maintenance and the periodic replacement of equipments. Typically a hydropower plant in service for 40-50 years can have its operating life doubled. In terms of its fuel, hydro energy does not require any fuel like most sources of energy. This is a huge advantage over other fossil fuels whose costs are increasing at a drastic rate every year. In terms of transportation, transport of hydroelectric power is not an issue. Electricity is generated at the dam itself, and then transported to cities through electric cables.

Essentially, the main costs of hydroelectric plants are largely the cost of construction of the plant, with no further cost for fuel and its transportation. Hydropower is one of the cheapest way of electricity generation. By refurbishing the equipment on the hydro plant, we can increase its efficiency. An improvement of only 1% would supply electricity to an additional 300,000 households.

FUTURE PROJECTION

Despite its expected growth, the future of hydroelectric power in the U.S. as well as worldwide, is complicated. As we know, the capabilities of hydro -electric power have been mixed out in the United States, however this is not the same case in other countries. There are a range of large scale hydro electric plants construction projects in progress in the developing industrial nations worldwide. The real future of hydroelectric power depends upon the abilities of scientists to make advanced technological breakthroughs. Some benefits which can be gained in future are as follows –

1) Hydropower has the potential to support more than 195,000 jobs across the nation in 2050.

2) By 2050, hydropower can reduce cumulative greenhouse gas emissions by 5.6 gigatonnes - equivalent to nearly 1.2 billion passenger vehicles driven in a year, saving $209 billion from avoided global damages from climate change.

3) By 2050, hydropower can save 30 trillion gallons of water, equivalent to roughly 45 million Olympic- size swimming pools.

4) By 2050, hydropower can save $58 billion from avoided healthcare costs and economic damage from air pollution.

III. CONCLUSIONS

This paper focused on hydro power systems and technology in renewable energy fields. It indicated that hydro plant is a corner stone of the electric generation power plant which would achieve a great significance in future. This paper also showed the different types of technologies that are going to bring an advancement in power supply field. It presented a general description of a hydropower plant, there designs and performance. It represented the advantages and challenges of a hydropower plant. It also showed the environmental and economical impacts of hydropower plant. It also contains the idea of future projection of hydro power plants in the field of electricity.

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