Brief Review on Hydro Power Plant

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ABSTRACT

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. Hydropower is not only a renewable and sustainable energy source, but its flexibility and storage capacity also makes it possible to improve grid stability and to support the deployment of other intermittent renewable energy sources such as wind and solar power.As a result, a renewed interest in pumped-hydro energy storage plants (PHES) and a huge demand for the rehabilitation of old small hydropower plants are emerging globally. As regards PHES, advances in turbine design are required to increase plant performance and flexibility and new strategies for optimizing storage capacity and for maximizing plant profitability in the deregulated energy market have to be developed. During the upgrading of old small hydropower plants, the main challenges to be faced are the design of new runners that had to match the existing stationary parts, and the development of optimal sizing and management strategies to increase their economic appeal. This paper traces an overview of the prospects of pumped-hydro energy storage plants and small hydro power plants in the light of sustainable development. Advances and future challenges in both turbine design and plant planning and management are proposed. Peculiarities of the new design strategies based on computational fluid dynamics, for both PHES and small hydropower plants.

Keywords: Hydropower Pumped-hydro energy storage plant, Small hydro power plant, CFD, Variable-speed pump-turbine, optimal management strategies

INTRODUCTION

Small scale hydro power is an important energy source with multiple advantages over other forms of renewable energy if designed and installed correctly. The kinetic energy of moving water is readily available 24 hours a day, *small scale hydro power* systems can exploit this free energy providing a low cost and reliable source of “green electricity”.

Generally, all you need for a “small scale hydro power” system is a stream or a river with enough water running through it at the right volume or pressure that can feed a water turbine connected to a generator that will supply power your home. Just as you can with a solar energy or a wind energy renewable system, you can also design a small hydro energy system that is either grid connected, grid connected with battery backup or stand alone.

But what do we mean by a "small scale hydro" system. Small scale hydro power systems are scaled down versions of the much larger hydro generating stations we see using big dams and reservoirs to supply power to millions of people. Depending upon the physical size, head height and electrical power generating capacity, small hydroelectric schemes can be categorized into small, mini and micro scale hydro schemes as follows:

- Small Scale Hydro Power: is a scheme that generates electrical power of between 100kW (kilo-watts) and 1MW (mega-watts) feeding this generated power directly into the utility grid or as part of a large standalone scheme powering more than one household.
- Mini Scale Hydro Power: is a scheme that generates power between 5kW and 100 kW, feeding it directly into the utility grid or as part of a battery charging or AC powered standalone system.
- Micro Scale Hydro Power: is usually the classification given to a small homemade run-of-river type scheme that use DC generator designs to produce electrical power between a few hundred watts up to 5kW as part of a battery charging standalone system.

Hydropower, or hydroelectric power, is a renewable source of energy that generates power by using a dam or diversion structure to alter the natural flow of a river or other body of water. Hydropower relies on the endless, constantly recharging system of the water cycle to produce electricity, using a fuel—water—that is not reduced or eliminated in the process. India has a history of about 120 years of hydropower. The first small hydro project of 130 kW commissioned in the hills of Darjeeling in 1897 mark the development of hydropower in India. The Sivasamudram project of 4500 kW was the next to come up in Mysore district of Karnataka in 1902, for supply of power to the Kolar gold mines. Following this, there were number of small hydro projects set up in various hilly areas of the country. Till the Independence (1947), the country had an installed capacity of 1362 MW, which included 508 MW hydropower projects, mainly small and medium. As per MNRE, the estimated potential of small hydro power plant is 20 GW across the county.

Hydropower is based on the principle that flowing and falling water has a certain amount of kinetic energy potential associated with it. Hydropower comes from converting the energy in flowing water, by means of a water wheel or a turbine, into useful mechanical energy. This energy can then be converted into electricity through means of an electric generator. The energy from the flowing/falling water can also be used directly by suitable machines to avoid the efficiency loses of the generator. Recently, small-scale hydropower systems receive a great deal of public interest as a promising, renewable source of electrical power for homes, farms, and remote communities. Micro hydro systems refer specifically to systems generating power on the scale of 5 kW to 100 kW. Small Hydro is the development of hydroelectric power on a scale serving a small community or industrial plant. The definition of a Small Hydro project varies but a generating capacity of up to 25 megawatts (MW) is generally accepted as the upper limit of what can be termed Small Hydro. In hydroelectric power plants the potential energy of water due to its high location is converted into electrical energy. The total power generation capacity of the hydroelectric power plants depends on the head of water and volume of water flowing towards the water turbine.

OBJECTIVES

- To increase the percentage contribution of hydroelectricity to the total energy mix.
- To extend electricity to rural and remote areas, through the use of mini and micro hydropowerschemes.
- To conserve non – renewable resources used in the generation of electricity.
- To diversify the energy resources base.
- To ensure minimum damage to the ecosystem arising from large hydropower development.

POWER WHICH A SMALL SCALE HYDRO DESIGN CAN EXTRACT

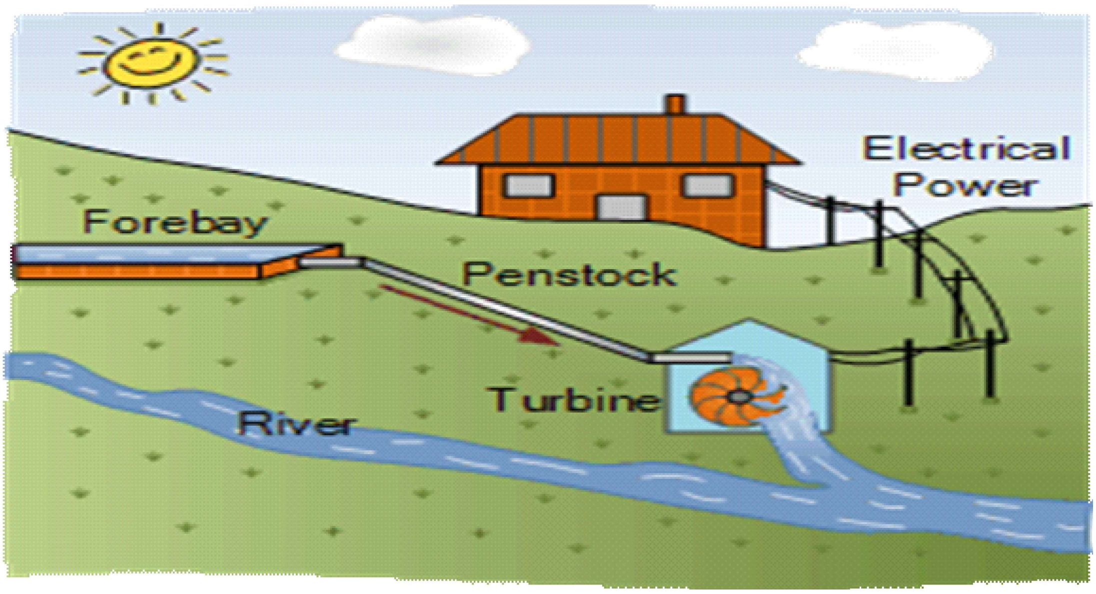
Waterwheels and water turbines are great for any small scale hydro power scheme as they extract the kinetic energy from the moving water and convert this energy into mechanical energy which drives an electrical generator producing a power output.

The maximum amount of electrical power that can be obtained from a river or stream of flowing water depends upon the amount of power within the flowing water at that particular point. As the water is moving a hydroelectric system converts this kinetic input power into electrical output power.

In order to determine the power potential of the water flowing in a river or stream, it is necessary to determine both the flow rate of the water passing a point in a given time and the vertical head height through which the water needs to fall. The theoretical power within the water can be calculated as follows:

Power (P) = Flow Rate (Q) x Head (H) x Gravity (g) x Water Density (ñ)

Where Q is in m^3/s, H in meters and g is the gravitational constant, 9.81 m/s^2 and ñ is the density of water, 1,000kg/m^3 or 1,0kg/litre.



MICRO HYDRO POWER PLANT MAIN PARTS

Then we can see that the maximum theoretical power that is available in the water is proportional to the product of "Head x Flow", as the pull of gravity on the water and the water density is always a constant. Therefore, P = 1.0 x 9.81 x Q x H (kW).

But the water turbine is not perfect and some input power is lost within the turbine due to friction and other such inefficiencies. Most modern water turbines have an efficiency rating of between 80 and 95%, depending upon the type, *reaction* or *impulse* so the effective power of a small scale hydropower system can be given as:

Importance of hydro power plant : Small hydro power Projects (SHPs) are an important, appropriate and profitable than other energy supply options and is a part of the full menu of energy options to be considered in meeting the needs of rural people more so in the remote and isolated locations in the hilly terrain of the state of Uttarakhand. SHPs compare well with the alternative energy supply options and has an important niche in the range of decentralized energy supply options. This niche is tightly demonstrated defined by the availability of adequate small-scale resource and as sufficiently concentrated density of demand, consisting of a need combined with purchasing power, to take advantage of a centralized, albeit small, power plant. SHPs have a great social bearing as it can provide rural people with electricity and create a sense of belonging to the modern world besides providing energy that can assist in securing the livelihoods of marginalized people. The SHPs are financially sustainable under the following conditions:-

- A high load factor
- A financially sustainable end-use
- Costs are contained by good design and management. Government of Uttarakhand as well as Government of India are facilitating the development of small hydro projects in the state of Uttarakhand. The Small hydro projects have following distinct advantages:
- Hydro power involves a clean process of power generation.
- It is a renewable source of energy and contributes to the upliftment of the rural masses, especially projects located in remote and inaccessible areas.
- It is the most cost effective option for power supply because it does not suffer from the limitation on account of fuel consumption.
- Most small hydro projects in Uttarakhand are being developed in remote and backward areas where substantial support for economic development is actually needed.
- Small hydro power contributes in solving the low voltage problem in the remote hilly areas and helping reducing the losses in transmission and distribution.
- In certain cases projects are helpful in providing drinking water and irrigation facilities.
- It helps in promoting the local industries in remote areas.
- The development of small hydro projects requires minimum rehabilitation and resettlement as well as environmental problems.
- Small hydro projects help in generating self-employment in remote areas of the state.
- Small hydro power projects helps in providing stable electricity supply at remote areas where such facility by other source shall be much costlier and unreliable.

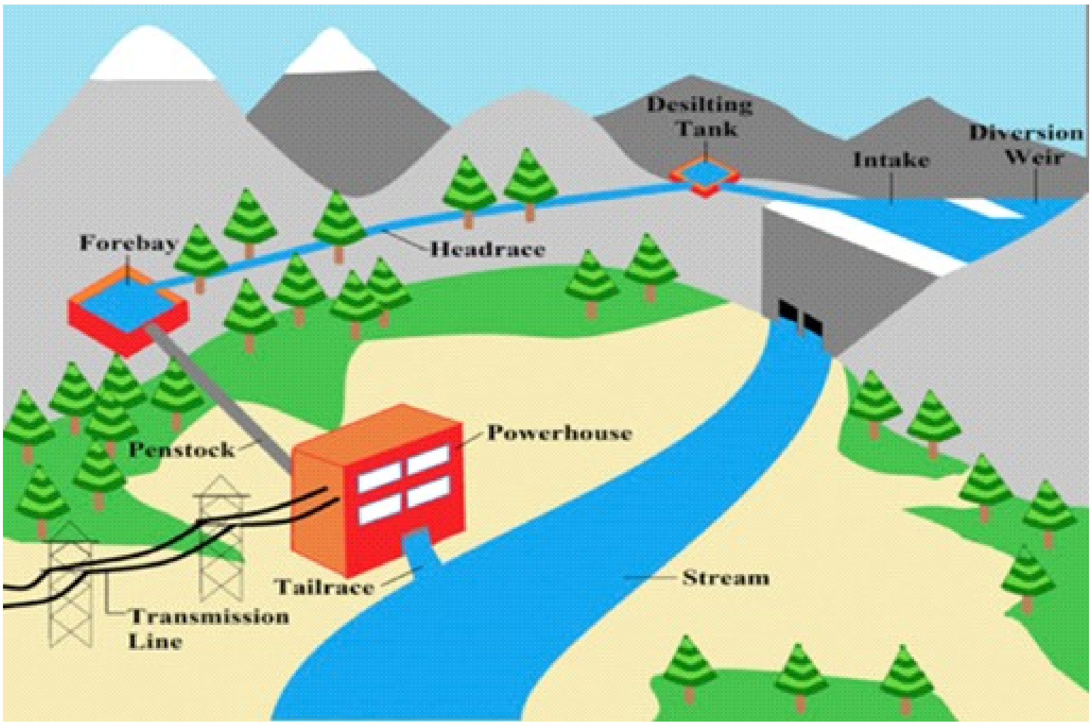
In Short we can say that SHP’s are

- Simple to operate
- Non Polluting

- Minimum Maintenance
- Environment friendly
- Utilizes local resources
- Take less time in construction
- Can be used at places where grid is not possible.
- The viability can be improved by incorporating the benefits of Carbon Trading

FUTURE POTENTIAL

What is the full potential of hydropower to help meet the Nation=s energy needs? The hydropower resource assessment by the Department of Energy=s Hydropower Program has identified 5,677 sites in the United States with acceptable undeveloped hydropower potential. These sites have a modeled undeveloped capacity of about 30,000 MW. This represents about 40 percent of the existing conventional hydropower capacity. A variety of restraints exist on this development, some natural and some imposed by our society. The natural restraints include such things as occasional unfavorable terrain for dams. Other restraints include disagreements about who should develop a resource or the resulting changes in environmental conditions. Often, other developments already exist where a hydroelectric power facility would require a dam and reservoir to be built. Finding solutions to the problems imposed by natural restraints demands extensive engineering efforts. Sometimes a solution is impossible, or so expensive that the entire project becomes impractical. Solution to the societal issues is frequently much more difficult and the costs are far greater than those imposed by nature. Developing the full potential of hydropower will require consideration and coordination of many varied needs.



SIMPLE LAYOUT SMALL HYDRO POWER PLANT

HYDROPOWER, THE ENVIRONMENT AND SOCIETY

It is important to remember that people, and all their actions, are part of the natural world. The materials used for building, energy, clothing, food, and all the familiar parts of our day-to-day world come from natural resources. Our surroundings are composed largely of the Built environment@ — structures and facilities built by humans for comfort, security, and well-being. As our built environment grows, we grow more reliant on its offerings.

To meet our needs and support our built environment, we need electricity which can be generated by using the resources of natural fuels. Most resources are not renewable; there is a limited supply. In obtaining resources, it is often necessary to drill oil wells, tap natural gas supplies, or mine coal and uranium. To put water to work on a large scale, storage dams are needed. We know that any innovation introduced by people has an impact on the natural environment. That impact may be desirable to some, and at the same time, unacceptable to others. Using any source of energy has some environmental cost. It is the degree of impact on the environment that is crucial.

Some human activities have more profound and lasting impacts than others. Techniques to mine resources from below the earth may leave long-lasting scars on the landscape. Oil wells may detract from the beauty of open, grassy fields. Reservoirs behind dams may cover picturesque valleys. Once available, use of energy sources can further impact the air, land, and water in varying degrees. People want clean air and water and a pleasing environment. We also want energy to heat and light our homes and run our machines. What is the solution? The situation seems straightforward: The demand for electrical power must be curbed or more power must be produced in environmentally acceptable ways. The solution, however, is not so simple. Conservation can save electricity, but at the same time our population is growing steadily. Growth is inevitable, and with it the increased demand for electric power. Since natural resources will continue to be used, the wisest solution is a careful, planned approach to their future use. All alternatives must be examined, and the most efficient, acceptable methods must be pursued.

1. Hydroelectric facilities have many characteristics that favor developing new projects and upgrading existing power plants:
2. Hydroelectric power plants do not use up limited nonrenewable resources to make electricity. They do not cause pollution of air, land, or water.
3. They have low failure rates, low operating costs, and are reliable.
4. They can provide startup power in the event of a system wide power failure.

LITERATURE REVIEW

Zubli et al-Renewable energy is a common topic that has been discussed continuously since the past few decades. The process of generating and restoring energy needs to be developed, without neglecting the effect towards the environment itself. As for this research, the basis is to verify a concept; whether the fluid motion in normal pipeline; is able to be utilized and converted into sufficient electrical output or not. In this concept, each time the user runs the taps, the water flow shall initiate the system by moving the inner mini blades and convert rotational motion to the shaft, which links to the DC generator. The changes from kinetic energy shall then be converted to electrical energy, which shall be preserved for later use. As a result, this system is able to provide an economical way to produce electrical energy without affecting the environment.

Bilal ***et al*** - Micro-hydro power plant is a type of renewable power plant that is environment friendly, easy to be operated and low operation cost. Hink River is a river in Manokwari, Indonesia. The result of initial survey shows that the river has hydraulic potency about 29.5 kW. According to the result, a micro-hydro power plant has been planned to this location. The power plant will use 25.2 Kw of the hydraulic potency based on flow rate 0.3 m3/s and head height 8.6 m. Turbine for the power plant is cross flow turbine type T-14 D-300 and the turbine will be coupled with a 3 phases synchronous generator to produce electrical energy about 17.32 kW. The energy will be transferred via 3 phase distribution lines to some villages around the power plant in radius of 4km According to economic analysis, payback period of this power plant is about 17.32 years at benefit factor 1.94; therefore the power plant has feasibility to be built.

Yuliane ***et al*** - India is a developing nation with 1.35 billion populations living in varied strata of living standards. Therefore, the energy demand is constantly increasing in an effort to accelerate industrial activities and boost the economy. The country mostly meets its electricity demand from fossil fuel. It has large generation capacity but in some remote and rural areas only 53% of the villages get electric supply for less than 12 hours a day. This is because of hilly and mountainous terrains especially in the north and north-eastern regions of the country and absence of utility grid owing to economic reasons. It is estimated that about 15% of country's population do not have access to electricity. With huge hydro potential in the country, especially in the Himalayan States, hydropower generation may be emphasized and pressed in to augment ever increasing energy demand. The emphasis should be on small hydropower (SHP) as construction of large hydropower involves huge capital cost and they are associated with various techno-economic and social issues. The article aims to provide important information for appropriate policy making in developing small hydropower in India.

Emmanual ***et al*** - Nigeria as of today generates less than 4000MW of electricity but has the capability of increasing her generation through small hydropower (SHP) considering unharnessed potentials in the country. In other to increase the percentage contribution of hydroelectricity to the total energy mix and to extend electricity to rural and remote areas, considering the economic, social and environmental benefits, this paper presents verifiable data to show that generated power can be increased by over 80 percent if areas of SHP potentials in different states of the federation of Nigeria are properly harnessed

Jahindual ***et al*** - Depletion of fossil fuel and the inability to meet the rising demand of electricity are some drawbacks for the economic development of Bangladesh. Carbon emission done by developed world is also troubling the country. This paper focuses on the potential of Micro-hydropower plant in Bangladesh due to its numerous rivers and canals providing off-grid power to the remote areas and also to the areas that are still outside the main grid network. This paper reflects on the current energy scenario in Bangladesh, the need to explore green energy thus proving how the establishment of widespread micro-hydropower plant can help overcome the current power crisis and play a role in the economic progress of the country. The existing potential sites are mentioned and the means to identify new sites are outlined by performing hydrology studies, topographic studies, head calculations, turbine selection, and so forth.

Pinto agrwal ***et al*** **-** This study investigates the climate change impacts on micro hydro power generation in Bayang catchment, KabupatenPesisir Selatan, West Sumatra. There are three micro hydro power systems in operation today, namely Pancuang Taba (40 kW); Mauro Air (30 kW); and Koto Ramah (30 kW). The Water Evaluation and Planning (WEAP) system is applied to simulate hydrological model and micro hydro power projection under different scenarios of greenhouse gas emissions (A_2 and B_2) from IPCC reports. The model is performed for the 2013–2025 period. Results demonstrate that climate change will reduce micro hydro power production. Changes in power generation vary up to 7.6% under B2 scenario and up to 15.7% under A_2 scenario at the last projection year.

MATERIAL AND METHODS

The major components of a Hydroelectric Power Plant are:-

- Dam/Barrage

  Head works i.e. power intake, head regulator and desilting chambers etc.
- Head race tunnels/channels
- Surge shaft/surge chambers
- Pressure shaft/Penstock
- Underground and surface power house
- Tailrace channel or tailrace tunnel.

Hydro Projects based on Installed Capacity?

Micro : up to 100 KW

Mini : 101KW to 2 MW

Small : 2 MW to 25 MW

Mega : Hydro projects with installed capacity >= 500 MW

Thermal Projects with installed capacity >=1500 M

ENERGY IS GENERATED IN HYDROELECTRIC POWER PLANT?

A hydroelectric power plant consists of a high dam that is built across a large river to create a reservoir, and a station where the process of energy conversion to electricity takes place.The first step in the generation of energy in a hydropower plant is the collection of run-off of seasonal rain and snow in lakes, streams and rivers, during the hydrological cycle. The run-off flows to dams downstream. The water falls through a dam, into the hydropower plant and turns a large wheel called a turbine. The turbine converts the energy of falling water into mechanical energy to drive the generator After this process has taken place electricity is transferred to the communities through transmission lines and the water is released back into the lakes, streams or rivers. This is entirely not harmful, because no pollutants are added to the water while it flows through the hydropower plant.

The hydro power potential of India is around 1,48,701 MW and at 60% load factor, it can meet the demand of around 84,000 MW.

We have proposed a method of using water energy from a stream passing through a structure in the form of a new patented micro-hydro power plant design with Banks on flat gates of a hydraulic structure [20], which will allow more rational use of energy systems. Flat gate of hydraulic structures serves for blocking the outlet opening and water passage from the upper to the lower one according to the task of the control center. The disadvantage of this shutter is the inability to use the hydraulic energy of the transmitted water to produce electrical energy [2, 3, 4]. The task is solved by the fact that the gate containing the super structure, the under carriage additionally contains guide covers and a thre shold, a well for placing electric power equipment and a micro hydroelectric power station that has Banks as a hydro engine. The gate of the hydraulic structure contains the span structure 1, support and running parts 2, two turbines of the micro-hydroelectric power plant 3, installed at the bottom of the structure behind the span structure 1, generator 4, connected to the turbine by means of the transmission mechanism 5, a streaming cover 6 and a threshold 7, a well to accommodate the electric power equipment 8 (Figure1). The gate of the hydraulic structure works as follows. At opening of the gate span structure 1, water directed by the lid 6 and threshold 7 enters turbines of small hydroelectric power plant 3, which provides their rotation with generator 4 by means of transfer mechanism 5. Generator 4 and other equipment (pulleys, multiplier, ballast, etc.) are located in well 8, located in the center of the plumbing chamber between the turbines of small hydropower 2 E3S Web of Conferences 320, 04009 (2021) ESEI 2021 https://doi.org/10.1051/e3sconf/202132004009 plants. The well is hermetically sealed along the perimeter with metal walls, and its bottom is located at the bottom of the structure. To pass the water flow rate, which is larger than the capacity of the turbine, the lift of the span structure 1 of the gate is performed and the water is supplied to the lower elevator through the span located above the stream lids 6.

When performing repairs, it is possible to lift the turbines up, since their axis is installed in the embedded parts of the structure and the well, and the guide cover is removable. In the proposed design of the gate, guide covers and a threshold, a well for placing electric power equipment, and a Bank turbine are additionally installed. This ensures: a) the possibility of supplying large water flows to the lower stream during the growing season, which is not present in conventional gate designs; b) the efficiency of a small hydropower plant increases, since there is no turbine pipeline and valve, and the associated energy loss, in contrast to traditional designs of a small hydropower plant; c) the turbine is located directly in the receiving zone of the water flow without any intermediate elements and the use of the guide cover and threshold provides a high degree of energy supply to the turbine, and all this, as a result, increases the efficiency of micro hydroelectric power station; d) the use of the Bank's turbine due to the simplicity of manufacture and, accordingly, lower material costs of manufacturing, significantly reduces the cost of micro hydroelectric power stations. A prerequisite for the wide spread use of such hydraulic installations is their feasibility study, that is, the determination of the technical and economic parameters of micro hydroelectric power plants installed on the gates of hydraulic structures of hydroelectric power systems [2, 3, 11, 12]. The technical and economic parameters of micro-hydropower plants installed in the gate of the hydraulic structure of the hydroelectric power system should include [6, 7, 11, 12]:

1. head of micro-hydroelectric power station;
2. micro-hydroelectric power plant capacity;
3. annual electricity generated by micro-hydroelectric power plants;
4. capital investments to create micro-hydroelectric power plants at the existing gate;
5. operating costs for micro-hydroelectric power plants;
6. cost of electricity generated by micro-hydroelectric power plants;
7. saving fuel resources;
8. net profit from the use of micro-hydroelectric power plants;
9. payback period of micro-hydroelectric power plants.

DISCUSSIONS

The research and calculations made it possible to determine a number of technical and economic indicators that allow not only to recommend approaches to the selection of parameters of micro-hydroelectric power plants at hydraulic structures, but also to justify their application in specific conditions of the region.

CONCLUSION

The conducted calculations allowed us to justify the use of micro-hydroelectric power plants in specific conditions of the region on the basis of a number of technical and economic indicators. The use of micro-hydroelectric power plants is almost always profitable, where watercourses provide installation of micro-hydroelectric power plants with a capacity of more than 10 kW. At the same time, it is desirable to divide micro-hydroelectric power plants into two groups, the first group – with a capacity of up to 10 kW and the second group with a capacity of more than 10 kW. Micro-hydroelectric power plants of the first group can be installed on small watercourses with a flow rate of up to 1 m3 / s, and the second group - on watercourses of more than 1 m3 /s.

Micro-hydroelectric power plants of the second group with a capacity of more than 10 kW can be installed on almost all hydraulic structures with flat gates, on many water intake and culvert structures of water nodes, rivers and channels. Moreover, many water intake and culverts in our Republic can be installed micro –, mini-and small hydroelectric power plants with a capacity of 100 kW or even more, up to 500 kW.

With such plants, i.e. the use of micro hydro on gates hydraulic structures, it is possible to solve the issues of energy supply, conservation, and preservation of ecological purity, rural area problem etc

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