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Optimal installation of small hydropower plant—A review

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ABSTRACT

Most of the countries have access to large amounts of water through rivers and canal. With this renewable resource, electricity can be generated without polluting the environment. Because of the increasing in electricity demand, it is important to estimate the future potential of hydropower. It would then be possible to plan development through mix of energy and implement measures to control the development of the electricity market by the use of sustainable small hydropower projects.

In the present paper attempt has been made to review the different types of model developed to evaluate the cost of the small hydropower projects. A review on the different types of correlations developed by earlier investigators has also been presented. The present review attempts to cover the benefits such as clean development mechanism (CDM), internal rate of return (IRR) for financial viability of such projects. A review on the different types of optimization techniques is also been presented to minimize the cost of the installation of SHP projects.

Contents

1. Introduction

Energy and development are closely intertwined. Increasing fossil fuel-based energy generation contributes significantly to environmental related problems both locally and globally. Power sectors are facing problem of increasing electricity demand as well as regulation on greenhouse gas emissions. It is crucial to find sustainable generation methods with high efficiency and broad application. Following this criteria there are few possibilities of power generation, such as solar, wind and small hydropower. Hydropower schemes can contribute with a cheap source, as well as to encourage the development of small industries across a wide range of new technologies. The energy of flowing water is the, renewable and clean source of electricity. The hydraulic power is one of the oldest forms of energy to mankind and used for irrigation and industry. Nowadays, small hydropower is one of the most valuable sources of rural electrification, which can improve the quality of their life. Multiple propose projects for drinking water and irrigation systems can take the advantage to install small hydro schemes [1,2].

Small hydropower systems allow achieving self-sufficiency by using the best possible scarce natural resource that is the water, as a decentralized and low-cost of energy production.

The small hydropower schemes can be associated with different water uses such as:

Power generation and water supply: Water conveyance system used to feed water is supplied to a town through a pressure pipe, from the reservoir to treatment plant are normally equipped with pressure reducing valves (PRV) in order to dissipate excess energy. A turbine can substitute this energy dissipation system if hydropower station is installed in water supply systems to utilize excess energy.

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Power generation and irrigation: Canals take off from the rivers to feed the irrigation system in the alignment of canal, falls are created to negotiable the difference in topographic level of canal and surrounding ground. These falls and the flowing water become the source of small hydropower.

Power generation and flood prevention: Dams can be used to prevent floods by creating reservoirs that should be emptied ahead of the rainy season. The level difference and water releases from the reservoir can be used to generate power.

Power generation and environment protection: Most hydropower projects have dams. Therefore the river habitat is often replaced by a lake habitat. The exploitation of a small hydropower has negligible effect on the environment particularly on the water quality as compared to other power systems. Thus, the hydropower is non-polluting energy source comparing with traditional energy generation systems based on fossil fuels or radioactive components [3,4].

2. Small hydropower technology

The hydro turbines convert water pressure into mechanical shaft power that can be used to drive an electric generator. The power available is proportional to the product of head and discharge. The mechanical power, P (in W), produced at the turbine shaft can be estimated as

$$P = \eta_t \rho_w g Q h \tag{1}$$

where η_t is the hydraulic efficiency of the turbine, ρ_w the density of water (kg/m^3), g the acceleration due to gravity (m/s^2), Q the discharge (m^3/s) and h is the head of water acting on the turbine (m).

In a typical small hydropower scheme, water is taken from the river by diverting it through an intake weir. The weir is a man made structure constructed across the river, which maintains a continuous flow through the intake. The water passes through a desilting tank in which the water is slowed down sufficiently for suspended particles to settle down before descending to the turbine. In medium or high-head installations, water is carried to the forebay by a canal. In low-head installations, generally water entering the turbine is directly from the weir. A pressure pipe, known as a penstock, conveys the water from the forebay to the turbine. All installations need to have a valve or gate at the top of the penstock to regulate the flow. The turbines have hydraulic efficiencies in the range 90% [2,4].

3. Research review

An attempt has been made to briefly review the previous works related to technologies and cost optimization of small hydro power plant.

3.1. Technology

The basic components of small hydro scheme are broadly classified as civil works and electromechanical equipments. The civil work of a small hydropower scheme generally comprises of; structure for water storage and/or diversion, like a dam/barrage or weir; Desilting tank – to remove the silt from diverted water to minimize erosion; Forebay – a simple structure provided at the end of water conductor with some storage capacity for meeting immediate water demand; Penstock – a water conveying system to transport water to the turbine. Spilling arrangement is also provided to spill the excess flow from the forebay in case of shut down of the power house or running at partial load; Power house Building – is a simple structure housing the generating units and control arrangement; A tailrace flow discharging conduit of open channel that conveys the water out of the turbine to the river. The electromechanical equipment of a small hydropower scheme comprises of: turbines, coupled with generators and control equipment [5].

Barros Carlos and Peypoch [6] analysed the technical efficiency in the hydroelectric generating plants, investigating the role played by increase in competition and regulation. The analysis was based on a random frontier model. This model allows the incorporation of multiple inputs and outputs in determining relative efficiency, alongside the separation of homogenous and heterogeneous variables in the cost function.

Paish [7] studied the present technology and current status of small hydropower. It was found that hydropower on small scale is one of the most effective energy technologies. Survey was done on the current status of hydro potential, i.e. how much is technically available and how much is economically viable and how much is yet to be exploited. Although the initial capital cost in setting of a hydro plant may be high, but its long term reliability and lesser environmental effects cannot be ignored.

Williams and Simpson [8,9] discussed about the pico hydro scheme, which are cost effective option for remote off grid rural electrification. Pico hydro scheme, generation cost is lower than small petrol or diesel generators, wind turbines or photovoltaic (PV) systems. It was also discussed that to get low installation cost per unit power output, it is necessary to select the components of the schemes which can reduce the cost and increase the reliability and efficiency of the system.

Wu and Wu [10] presented a case study of ZhongDaSanChuan (ZDSC) hydropower station whose strategy is based on the SWOT analysis. The social environmental effect faced by small hydropower enterprises (SHEs) due to political, economic, social, cultural, technological and natural environments is analysed based on the theory of strategic environmental analysis.

Dursun and Gokcol [11] and Yuskel [12,13] investigated present status of hydroelectric power in Turkey and illustrated the benefits of hydropower, which led to the sustainable economic development and increase in the quality of life. Further Akpınar et al. [14] studied the development of hydropower plant in the Çoruh river basin of Turkey. Author also presented comparison of the hydropower potential of Turkey and Europe with respect to World's potential.

3.2. Simulation model

Karlis and Papadopoulos [15] developed a computer program for performing a preliminary evaluation of small hydroelectric (SHE) system installations. This program provides the user with sufficient technical and financial information in order to justify further investment. It also accessed precise non-financial attributes, such as local/national environmental and socio-economical impacts. This program also takes into account the specific techno economical constraints.

Garrido et al. [16] developed a new simulation tool for small hydropower plants with a run of river scheme and presented the design of a component library for modeling hydropower plants. A general model of hydropower plant with run of river scheme was created. The component library for hydropower plants was designed using OOM (Object Oriented Modeling) language, like EcosimPro software. The result obtained from the simulator exhibit good agreement between the developed tool and the real data. It also presented that simulator can also be used to study an approximated way the behavior of the plant in unusual or unexpected conditions like a great flood of the river.

Anagnostopoulous and Papantonis [17] and Liu et al. [18] presented numerical method used for the optimal sizing of a plant comprising two hydraulic turbines operating in parallel. An analy-