Available online at www.sciencedirect.com

SciVerse ScienceDirect

Procedia Engineering 51 (2013) 721 – 726

Procedia Engineering

www.elsevier.com/locate/procedia

Chemical, Civil and Mechanical Engineering Tracks of 3rd Nirma University International Conference (NUiCONE 2012)

Cost analysis of pump as turbine for pico hydropower plants – a case study

K H Motwani[a], S V Jain[b*], R N Patel[b]

[a]Faculty of Technology, Marwadi education foundation group of institutions, Rajkot-360003, India
[b]Institute of Technology, Nirma university, Ahmedabad-382481, India

Abstract

The energy scenario in rural, remote and hilly areas of India is characterized by inadequate, poor and unreliable supply of energy services. In such regions, the load density is low and extension of grid system is totally uneconomical, hence the small hydropower schemes can provide a solution for the energy problems besides solar photovoltaic, which is not available throughout the day. The main hindrance in implementing such hydropower schemes is high initial cost of conventional hydro turbines. The cost of these plants can be brought down by using centrifugal pump in turbine mode in context of various advantages associated with the pumps viz. low initial and maintenance cost, ready availability, simple construction etc. However, the efficiency of pump as turbine (PAT) is lower than that of conventional hydro turbines. For commercial justification of PAT technology, a cost analysis of 3 kW capacity pico hydropower plant was carried out by considering PAT and Francis turbine as a prime mover. The hydro turbine test rig was developed by installing PAT and its performance characteristics were plotted. The annual life cycle cost (ALCC) analysis was carried out based on initial cost of the project, capital recovery factor and annual expenses. Based on the analysis, the ALCC and the cost of electricity generated per unit were found to be very less for PAT than that of Francis turbine, which has justified the use of PAT for the case under consideration.

Keywords: Case study; cost analysis; pico hydropower; pump as turbine; renewable energy.

Nomenclature

g	acceleration due to gravity (m/s^2)
n	speed (rps)
D	runner diameter (m)
H	head (m)
L	life (years)
P	power (W)
Q	discharge (m^3/s)
Greek symbols	
Ψ	head number
ø	discharge number
π	power number
ρ	density (kg/m^3)
η	efficiency (%)

* Corresponding author. Tel.: +91-9998623087; fax: +91-2717-241917.
E-mail address: sanjay.jain@nirmauni.ac.in

doi:10.1016/j.proeng.2013.01.103

1. Introduction

The development of any country depends upon availability of electrical energy and its per capita energy consumption, which is regarded as an index of national standard of living in the present civilization. Therefore, energy is considered as the basic input for any country for keeping the wheels of its economy moving. In rural, remote and hilly areas of India, power scenario is characterized by poor and unreliable supply of energy. Out of total 138.27 million rural households in the country; only around 56 per cent are electrified so far. There are only six states with more than 75 percent of rural households electrified; however, these states account for a meager 6 percent of the country's total rural households. There are many states with about 80 per cent unelectrified households, which constitute 43 per cent of the total rural households in the country [1].

India is fairly rich in natural sources like coal, lignite, natural gas and has immense of water power resources. The current power installed capacity in India is 2,06,456 MW; in which thermal contributes to around: 67%, hydro: 19%, nuclear: 2% and other renewable energy sources: 12% [2]. A large number of thermal power plants are running throughout the world for electricity generation on petroleum products e.g. coal, oil, gas etc., but the fast depleting nature, continuously increasing prices and global warming issues are the major complications in fulfilling the power demands from these sources. Also, delivered cost of electricity produced by thermal power plants in remote areas located in the distance range of 5-25 km is found to vary from Rs. 3.18/kWh to Rs. 231.14/kWh depending on peak electrical load and load factor [3].

World has started running out of oil and it is estimated that 80% of the world's supply will be consumed in our lifetime. Moreover, the pollution hazard arising out of fossil fuel-burning has become quite significant in recent years. Thus, it has become utmost important to look for renewable energy sources such as hydro, solar, wind and energy from ocean tides. Among all the available renewable energy sources, hydropower is considered as the most promising source of energy. India's total mean annual river flows are about 1675 X 10^9 m^3 of which the usable resources are 555 X 10^9 m^3 [4].

Large hydropower plants suffers from several problems like long gestation period, ecological changes, loss due to long transmission lines, submergence of valuable forest and underground mineral resources etc. [5]. Due to all these factors, large hydropower plants are becoming unfavourable in the current era. On the other hand, small/micro/mini/pico hydropower projects are free from these aspects. Different countries are classifying small hydropower (SHP) according to the total capacity of the plant. In India, pico-hydro is defined as hydroelectric power generation under 5 kW capacity [6]. A pico-hydro power system can provide electricity to a small, remote community for basic requirements like lighting of bulbs, radios, televisions and can also be used for many other applications. These small units were not more in use for many years, but recent increase in the demand of energy has forced to use such energy from which power can be obtained easily and in cheaper form.

The cost of electro-mechanical components in large hydro is around 20% but in micro hydro it is relatively high and varies from 35-40% of the total project cost [7]. Hence, main hindrance in implementing such hydropower schemes is high initial cost of conventional hydro turbines. The cost of these plants can be brought down by using PAT in context of various advantages associated with the pumps viz. low cost, less complexity, mass production, availability for a wide range of heads and flows, short delivery time, availability in a large number of standard sizes, ease of availability of spare parts, easy installation etc. [8-9].

The efficiency of pump in turbine mode is usually lower than that of conventional hydro turbines; however, the efficiency of such machine is not the primary selection criterion and the operation of PAT is recommended at the maximum attainable efficiency. Also, up to 100 kW capacity power plants, the use of PAT may be justifiable because, even though efficiency of PAT is lower, its use may lead to significant reduction in the capital cost of the plant, of the order of 10 to 1 or even more [10]. In this range, the investment cost for conventional hydro turbines is relatively high and the payback period can be as high as 15 years which can be reduced to 3 years using PAT [11]. Also, if PATs are used in the range of 1 to 500 kW the payback periods can be further reduced to two years or less which is considerably less than that of a conventional turbine [12-13].

For commercial justification of PAT technology, it is utmost important to carry out cost analysis of hydropower plant between PAT and conventional hydro turbine. In this paper, experimental studies carried out on 3 kW capacity pico hydro turbine test rig by installing PAT at Institute of Technology, Nirma University, Ahmedabad are presented. The ALCC analysis carried out, between PAT and Francis turbine, based on initial cost of the project, capital recovery factor and annual expenses is discussed.

2. Pump as turbine

In pumping mode, the fluid enters at suction side of pump at low pressure and gets energized by the impeller, which is rotated by some external means, and leaves the casing at high pressure. Whereas in case of PAT, the pump rotates in reverse