Investigation of the effects of turbine and pipe design on pico-hydropower generator system performance in flowing water

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Abstract

Pico-hydropower (PHP) is a small hydroelectric power plant system that can be used in rural areas to generate electricity. The purpose of this research is to investigate the impact of turbine and pipe design on the performance of a PHP generator system in flowing water. This is owing to the objective of developing a PHP generator system that can easily be installed and operated at an affordable rate to generate electricity for daily usage. Fabrication of the turbine and pipe is done with a 3D printer. The performance of PHP based on the turbine and nozzle pipe design is then assessed by determining the output in terms of voltage and power. The potential energy of the water stream will strike the turbine, which will rotate the generator, converting mechanical energy into electricity. The preliminary investigation results revealed that suitable numbers of blades, that is, 8 blades of a Pelton turbine, can generate up to 5.89 V of voltage as compared to 16 blades of a Pelton turbine, which produces 5.35 V of voltage output. The highest power produced was 530.1 mW which was given by 15^{o} gradually reduced nozzle pipe type that was implemented together with an 8-blade Pelton turbine.

1 Introduction

Hydropower is a renewable energy source that converts the potential energy of water into electricity. Hydropower converts 90% of the energy from moving water into electricity, making it more efficient than fossil fuels, which only convert 60% of the energy [1,2]. In 1882, a water wheel on the Fox River in Wisconsin was the first hydropower plant to generate electricity [3]. Hydropower can be classified according to its energy production or power output, as shown in Table 1.1. The potential energy of a dam is represented by large, small, and mini hydropower generators that are typically connected to the national power grid. Micro-hydropower is the most cost-effective for rural area electrification, which is mounted separately or connected to the micropower grid [4]. While, pico-hydropower can be classified as the smallest stand-alone power generation system, which is typically installed for small appliance loads [4].

Pico-hydro is hydropower that produces an electrical output ranging from zero watts to five kilowatts (5 kW). The size of a pico-hydropower (PHP) generator system can be more cost-effective and simpler when it comes to design, planning, and installation than a larger hydropower generator system [1]. PHP is regularly used to power devices such as light bulbs, radios, TVs, and battery chargers [5]. The quantity of electricity produced by PHP depends on three main factors, which are: height of the water head, water flowrates, and turbine design. The power output from the system is proportional to these three factors. Due to the high capability and potential of PHP to be an alternative energy source to produce electricity, researchers are interested in utilising PHP to have an ideal solution to increase demand for electrification, particularly in rural areas and also for the residential sector, which can utilise the water that is wasted every day, such as from laundries, washing activities, or storing water in the water tank, by generating electricity using PHP technology [6].

Table 1.1 Classification of hydropower generator [7].

Hydropower type	Capacity	Feeding
Large	≥10–30 MW	National power grid
Small	1 MW to 10–30 MW	National power grid
Mini	100 kW to 1 MW	Micropower grid
Micro	1 kW to 100 kW	Small community or remote industrial area
Pico	≤ 5 kW	Domestic and small commercial loads