IoT-based Pico-Hydro Power Generation System using Pelton Turbine

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***Abstract*—The local rural electric power generation is necessary to promote progress of the localities especially on those hard to reach communities. The Philippine archipelago is rich in water resources, harnessing this ample amount of water is enough for irrigation and electrical generation especially on those far located areas that are hard to reach by electrical grid connection system. This paper presents an alternative source of electrical energy. The designed pico-hydro power generation system is well suited in remote areas where the transmission of power seems to impossible. To maximize the designed concept, the Pelton turbine is utilized because it is suited especially in the Philippines for high and low flow rate of water. Moreover, an IoT-based system that can easily monitor any unwanted problems. This pico-hydropower system is much economical compared with other sources of electricity.**

***Index Terms*— Alternative Energy; IoT-Based System; Pelton Turbine; Pico-Hydro.**

I. Introduction

Nowadays, a sustainable source of electricity is necessary not only to supply the needed economic development but also to maintaining the environmental management in our society. Renewable power generations can help countries to meet these requirements. The importance of renewable energy for sustaining power generation in relation to its capacity to contribute towards alleviating needs in rural areas for electricity supply is highly applicable.

Solar systems, Biomass and Hydro power are found as high potential energy sources. However, Pico and micro hydro power systems are most reliable one among potential renewable energy resources. The dynamic force of natural water can be found available in springs, streams, creeks, water-falls, tributaries and rivers. Pico hydro power generation systems [1, 2] are capable of producing an output power up to 5 KW, enough to supply a rural community village which has small electricity consumption. Furthermore, this system does not use fuel and it is free from any pollution [3]. In future, a pico-hydro system will become minimize the investment cost, especially in maintenance. A system like a portable pico-hydro is applicable and beneficial on those homeowners who does not have a convenient a convenient source of river or dam [4]. The typical set-ups are rerun water from the rivers and needs little or no reservoir for the engine to be operated [5]. The main parts are intake from the stream or river, pipe (known as penstock), water turbine, electrical generator, controller and electrical power distribution.

Numerous areas in the Philippines are far located to reach electrical grid connection system. Also, some communities are situated on terrains with a small water resources such as small rivers, and springs. Additionally, in most of these villages, the difficulties due to high elevation can lead to a small water sources. However, these drawbacks are ideal for pico-hydro power generation system. Moreover, the Internet of Things (IoT) connectivity offers a host of development opportunities in control, monitoring, and maintaining remote systems.

The rest of this paper is ordered as follows. In Section II, a relatively comprehensive review of hydropower technology and review of some related works is presented. Section III presents our proposed system and its description. Experimental results and implementation are shown in Section IV. Finally, in Section V, we conclude this paper.

II. Review of Related Works

A. Hydro Power Generation

Hydro Power is extracted from the energy in the free flowing water resources and transformed to mechanical energy. And this energy can be used directly or can be converted to electrical using a generator [6]. Also, the differential velocity of falling water or its pressure or both on the turbine blade surfaces produces a force thereby causing rotary motion [7]. The water cycles such as nature and hydraulic power plant help to generate the electricity. The water used in a hydropower system can still be consumed for other purposes. The concept of hydroelectric power generation system is shown in Figure 1 [8]. In order to generate electricity, the turbine output shaft is connected to the generator. The generator produces electricity using electromagnetic induction. The generated electricity is transmitted to application loads. Table 1 shows the several types of hydropower generation and its power capacity.

Table 1
Types of Hydropower Generation

Hydro Power	Capacity
Large-Hydro	More than 100MW
Medium-Hydro	15 – 100 MW
Small-Hydro	1 – 15 MW
Mini-Hydro	100 kW – 1 MW
Micro-Hydro	Up to 100 kW
Pico-Hydro	Under 5kW

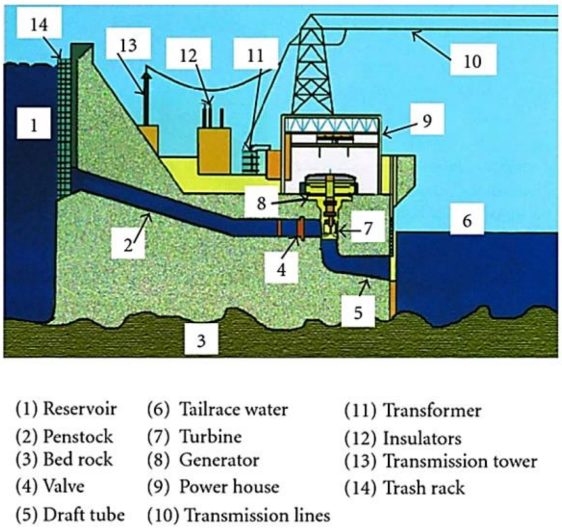

Figure 1: Hydroelectric power generation system

B. *Pico-Hydro Power Generation System*

Hydro power plants can be classified according to its capacity, head, purpose, facility types, hydrological radiation, and transmission system. Under the classification on capacity, the pico-hydro power generation system is appropriate and useful in local rural areas that needs only a little amount of electricity. Normally, pico-hydro power generation system can generate of under 5 kW. This system set-up is typically run-of-the-river, which uses pipes to divert the flow of water and can be found in rural areas [9, 10].

The head and the flow are two important components needed in this particular system [2]. The head component refers to the water pressure that determines the vertical fall of water. Also, this component develops an altitude for the water opening and turbine. The flow plays a vital part in harnessing the water power. It specifies the water quantity or the water flow rate. In a normal case, the maximum flow is calculated to be less than maximum stream flow. This proposed project will be implemented in the provinces of Ifugao and Aurora in the Philippines because a continuous flow of water as a source is determined to power-up the Pelton turbine. The basic design concept is shown in Figure 2.

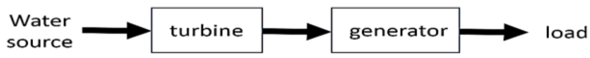

Figure 2: Design concept of pico-hydro power generation

C. *Turbine*

The task of a turbine converts water power into rotational force to drive the generator. Choosing a right turbine is very important because the over-all efficient of the system depends on this part. The required relation of the generator speed to turbine should not be above 3:1 [11]. The main components of a hydro-electric system are classified into two groups: the hydraulic system parts that consist of a turbine, the associated conduits like penstocks, tunnel and surge tank including its control system. On the other hand, the electric system components made by the synchronous system generator and its control system. The Hydraulic turbines are generally classified as impulse and reaction turbine. In this proposed paper, we used a Pelton turbine under the impulse classification.

The Pelton turbine was introduced by the American engineer L.A. Pelton, he describes that the energy obtained from the inlet of the Pelton turbine is a kinetic energy. And the pressure at the inlet and outlet of the turbine is atmospheric pressure. The flow of energy in impulse turbines is fully transformed to kinetic energy before the conversion in the runner. The impulse forces are being transmitted by the direction changes of the flow velocity. The flow enters the runner from the jet spaced around the rim of the runners. Figure 3 shows the various parts of the Pelton turbine.

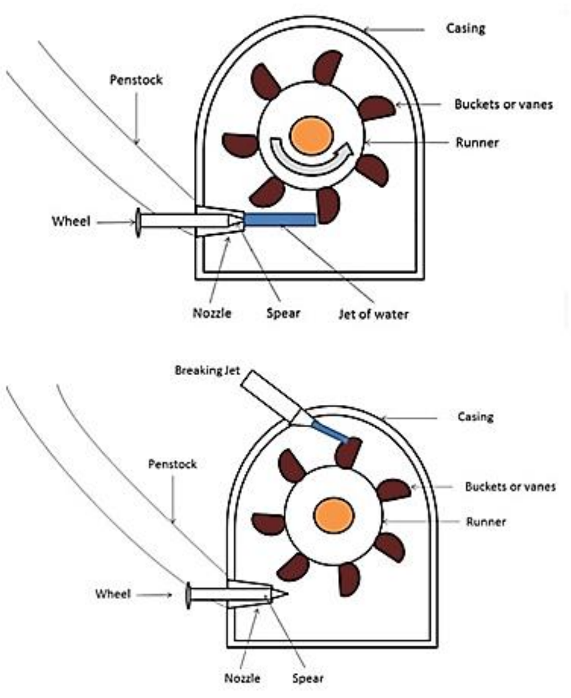

Figure 3: The various parts of the Pelton turbine

D. IoT System

The proposed system design has an attached low cost embedded system device for real time monitoring of water level, flow rate, and even pH sensor in Internet of things (IOT) platform. IOT is a new technology paradigm to link a real time communication in able to monitor, control or even analyze the shared information from certain applications over a public or private internet protocol (IP) networks [12].

III. PROPOSED SYSTEM

The major concern for the implementation pico-hydro power generation systems is the environmental and even social impacts associated with such projects. Before the actual implementation of this proposed system in Ifugao and Aurora, we identified some appropriate parameters to fit into our design, such as the continuous flow of water sources (water rate, quantity and some sections of the river experience varied hydrologically), the load recipient's location (copper loss), even the water pH content (that might corrode our system). Moreover, the proposed system is consist of a programmable controller, sensors, and a GSM module. A real-time monitoring and controlling is possible using this system.

A. Pelton Turbine

In this project, the Pelton turbine was utilized due to its appropriateness especially for high head [13] and low flow rate of water. Figure 4 shows the Pelton turbine that we used during the experimental testing and has a diameter of 0.16m with 20 buckets of 18 degrees for each blade mounted and a shaft to give a smooth rotation.

Figure 4: Pelton turbine enclosed in a chamber

B. Generator

The generator converts the rotational energy from water energy converted into mechanical to electrical energy, the AC induction generator was used. We developed our induction generator having a 1,400 turns using the SWG26 magnetic coil. It generates an AC output and to be feed in a boost converter to achieve an appropriate needed power for transmission to remote communities.

C. IoT System

This system consists of a sensors, an ASIC-microcontroller, and a GSM module. The three sensors: the level sensor detects the appropriate water level due to seasonal fluctuating water levels because the unit will not generate power when there is too little water and cannot power-up the Pelton turbine; the water flow sensor measures how much water has moved through; the pH sensor measures the hydrogen-ion activity in water to maintain the durability of the system over-time. The ASIC microcontroller is a Raspberry Pi microcontroller that reads the inputs from the three sensors and send the information via IoT for monitoring purposes. The GSM module or any telemetry system to feedback the community for monitoring.

The proposed system is shown in Figure 5. The three sensors, Raspberry Pi microcontroller and the transmitter are powered by an independent power source.

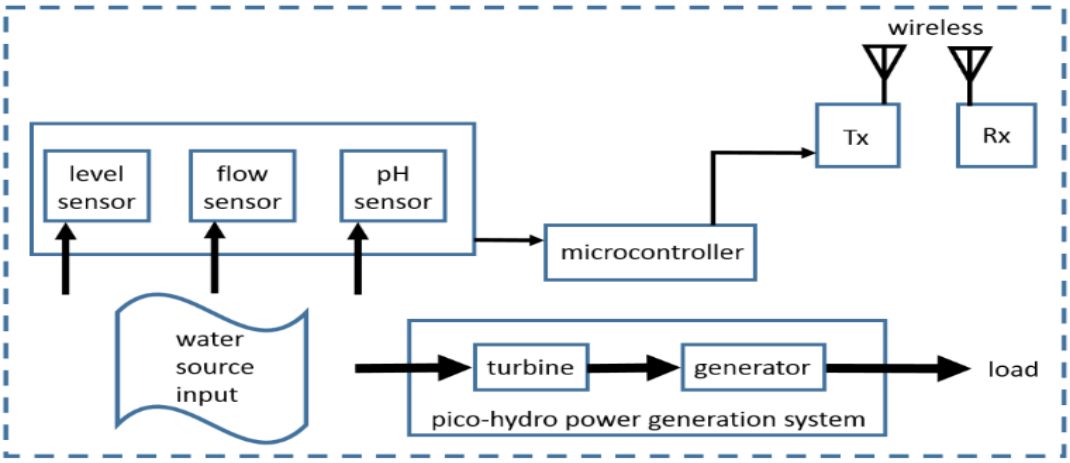

Figure 5: Proposed system

IV. EXPERIMENTAL RESULT

During the testing, we already set up certain parameter on the Pelton turbine chamber to achieve our aim on the output power. Initially, the Pelton turbine chamber was set on the water flow rate of 0.2 per second with 600 rpm and resulted to an output power of 12.56 W. As we increase twice the water flow rate and the turbine velocity, and observed a direct proportional increase on the output power. Based on the gathered testing results, the output power increased proportionately to the speed of turbines and the water flow rate.

Table 2 shows the experimental results during the testing conducted on the Pelton turbine chamber. The set-up settings were varied and arises a directly proportional output power.

Table 2
Pelton Turbine Input Set-up

Flow Rate (per second)	Turbine Velocity (rpm)	Output Power (Watts)
0.200	600	12.56
0.100	600	18.49
0.100	800	22.06
0.075	800	26.45
0.075	1,200	38.60
0.050	1,200	42.69

V. CONCLUSIONS

A pico-hydro power generation system offers an alternative source of energy from a natural free flowing water to residential communities in a low cost but having an efficient system. The system is a configurable power source that could be used to generate AC electricity even at remote places.

The pressure and the flow rate are the important input parameters to ensure an efficient system to function properly. Also, for the desire implementation and development of a pico-hydro power generator system, the design of the turbines and power generator must be considered. Choosing the appropriate turbine is necessary. Moreover, the IoT module allow us in real-time to control to maintain service reduction and to optimize the process.

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