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Development of Pico-hydropower Plant for Farming Village in Upstream Watershed, Thailand

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Abstract

Research on the development of Pico-hydropower plant for a farming village in Thailand was carried out. It is one aspect given by the national plan for the renewable technology development with wisely energy utilization from natural resources included wind, water, solar energies, bio-gas, and farm waste according to the Ministry of National Energy reported, respectively. Since, some upstream watersheds in Thailand are potential for the development of the large scale hydropower plants by mean of the dam constructions. However, most of proposed dam sites in the upstream watershed are located within the restricted area as for the forestry and environmental conservation zone according to the national environmental law of conservation. Pico-hydropower plant is more suitable to develop for the economic and farming zones of such watershed. A waterfall site in Ban-Yaeng Village, Nakornthai District in Phitsanulok Province which locates at the upstream of Wangthong Watershed (Sub-basin of Nan River) was selected as the pilot project for the construction of the hydropower plant. The appropriated technology using the centrifugal pumping machine as for the water-turbine connected to a 3-phase motor producing electricity of 380 volts at revolution of 1500 rpm was applied. The system was based on low cost of construction, local materials, and easy construction and maintenance systems. Its performance of the overall systems by mean of the efficiency was found to 52% resulted by the effective head of 8.4 meters, flow rate of 15 liters per second, and electrical power production of 644 watts which can be used for the light, some house-ware appliances, and some farming equipments. It can be applied to other small farming villages in any upstream watershed with enough head and flow rate in the stream over the year round in order to save investment cost for farming systems with the clean technology. However, it can be transferred to larger farming villages if higher head and larger flow rate in the natural stream or river were found which depended on the country and topography.

Background and Aim of the Study

Phitsanulok Province locates in the lower-northern region of Thailand with 365 km north of Bangkok. According to the report by Chuenchooklin (2005), the average annual electric consuming in Phitsanulok is 500 million kilowatt-hours (kWH). Most of energy sources are come from outside the province such as fuel. These fuels can be produced from agricultural waste such as sugar cane and cassava etc. but the problem is limitation of planting area in this province. The government's policy concerning the limitation of natural resources such as oil for producing energy was stimulated. As they known, the energy demand and utilization have trended to increase everyday. Moreover, the world market price of gasoline fuel as main energy for most factory and vehicle engines have trended to increase day by day. The strategic planning for the renewable technology and development with wisely energy utilization from natural resources included wind power, hydropower, solar energies, bio-gas, and farm waste were proposed by the Ministry of Energy since a decade years. Fortunately, there are some potential areas at upstream watersheds which can be used as energy sources for producing electricity by the construction of hydropower plants such as waterfalls and dams or reservoirs. Even though some sites at upstream watersheds in Thailand are suitable for the multipurpose dam construction and installation with mini-hydropower plants. Unfortunately, most of them are located in the natural resource conservation zone where they are in charge of the Ministry of Natural Resources and Environment with the risk of environmental impacts. Therefore, Pico-hydropower plant is more appropriate development for better economic in mixed farming areas and conservation zones in such watershed with less environmental impacts (Khemmi, 2005; Phillip et al., 2001).

Though many small-scale hydropower systems have been designed and developed in some developing countries. These became economically feasible when the cost of power generation increased markedly because of the increased cost of fuel for thermal power plants. The basic principles for these small-scale plants are the same as for conventional hydropower developments. Some reduction in cost is achieved by purchasing standardized turbines and other equipment from manufacturers. It is also possible to use centrifugal pumps, operated in reverse direction, as turbine (Roberson et al., 1997). Micro hydropower plants are defined as having a capacity between 10 kW and 200 kW (Gulliver et al., 1991) which were developed in larger village area and more community groups (ITDG, 2000). However, the village in upstream watershed area in Thailand is mostly smaller size and seems to be individual; Pico-hydropower plant would be appropriated for the development. Pico-hydro is hydropower with a maximum electrical output of 5 kW (Taylor, 2004). Hydropower systems of this size benefit in terms of cost and simplicity from different approaches in the design, planning and installation than those which are applied to larger hydropower. Recent innovations in Pico-hydro technology have made it an economic source of power even in some of the world's poorest and most inaccessible places. It is also a versatile power source. AC electricity can be produced enabling standard electrical appliances to be used and the electricity can be distributed to a whole village. Common examples of devices which can be powered by Pico-hydro are light bulbs, radios, televisions, refrigerators and food processors. Mechanical power can be utilized with some designs for hilly and mountainous locations based on the guidebook (Phillip et al., 2001; Phillip et al., 2003).

Methods

The aim of this paper is to explain of an implementation of adaptive hydro technology for producing the electrification of a small village in hilly or mountainous region. A 20 m height of waterfall in Khek River located at the upstream of Wangthong Watershed (Sub-basin of Nan River) in Ban-Yaeng Village, Nakornthai District in Phitsanulok Province

(Lat. 16°-52'-15.8" N, Lon. 100°-50'-07.5" E, alt. +403 m above mean sea level). This place was selected as the pilot project for the construction of the Pico-hydropower plant. It is located in Thung-Salangluang National Park which is one of the most tourists famous the national parks in Thailand. The tourist center had not the electricity to be supplied to the building yet. But indoor electric lamps without electricity were set in already. This research developed the hydro electrical generator and supplied for this building as the first demonstration Pico-hydropower's project in Thailand. This project can be further transferred to any farming village having the same topography to this site.

The head of water between upstream and downstream of the waterfall in Khek River is normally 20-25 m with the low flow during dry season approx. 500 liters per second (lps), and high flow during flood season with flow rate of 1000 cubic meters per second (cms), according to the records nearby the site (Chuenchooklin, 2005).

The designed of the systems for selecting reversed centrifugal pump as turbine was based on Sharma as the following equations of discharge and head (Sharma, 1985).

$$Q_t=Q_{bmp}/(n_{max})^{0.8} \quad (1)$$

Where: n_{max} is maximum efficiency of pump,
Q_t is the average flow rate through the pump (cms),
Q_{bmp} is the maximum flow rate through the pump (cms)

and

$$H_t=H_{bmp}/(n_{max})^{1.2} \quad (2)$$

Where: H_t is the average head of water above pump (m)
H_{bmp} is the head of water above pump at maximum efficiency (m)

The total head loss through the pipe system in (2) was calculated according to the Darcy-Weisbach's formula and Moody's diagram (Roberson et al., 1997).

The construction of a conveyance water system from upstream side of waterfall to the pump and power systems at downstream side of waterfall using PE-pipe type was installed with the inner diameter of 100 mm, total length of 138 m, and the actual water levels drop of 21 m. The reversed Australian pump model (Monoflo MF 65-16) was applied to install with ordinary motor as an electricity generator which can produce the electricity of 3-phrease voltages of 380 Volts (V) with frequency of 50 Hertz (Hz), and required maximum capacity of 3 horse power (hp) at revolution 1500 round per minute (rpm), respectively. The electrical controller system to be adapted at normally voltage of 220 V was installed by using the parallel systems and series capacitor sets of 8 and 310 microfarads each to be kept as constant voltage without and with workloads, respectively.

Results and Conclusion

The results during the designed phase showed that the computed maximum efficiency of this system was 81.5% at the required net head of 8.4 m and flow rate of 18 lps. The actual gross power after completely workloads installation was produced to 1.116 kW with the net head of 10.74 m and flow rate of 21 lps. However, after the completion of the installation of the Pico hydro power systems and installation with the electrical transformer at the site, the flow rate reduced to 15 lps at net head of 10 m because it was very dry period during system performances. The electricity production was 280 V at 50 Hz during no workload applied. It had been reduced to 230 to 280 V and frequency of 45 to 46 Hz, after applying fully down to some workloads during the performance testing period with the averaged efficiency of 52% and produced capacity of 0.644 kW, respectively. Therefore, system improvement needed to be installed with the diversion load-control charger and inverter sets. It was found that the voltage was returned to 220 V and frequency of 50 Hz produced by the systems after applying fully workloads in the building. Therefore, the recommendation for the operator should try to keep constant workloads or voltage by using the installation of trial capacitors and a gate valve at the end of conveyance pipe to be ensured that the flow rate would be constant.

These results showed that the produced electricity was enough for the electricity consuming with indoor electrical appliances such as electric light and some house-ware appliances in this tourism center. The construction cost of this project was approx. US 4000 dollars (most expense of 45% for pipe systems, 37% for control and electricity systems, and 18% for pump and turbine systems) with 6 year for the economically recovery based on overall consuming electricity of 8760 kWH per year with electric charge unit of US 0.75 cent per kWH (unit). It can be further apply to other small farming villages in any upstream watershed with enough head and flow rate in the stream over the year round in order to save investment cost for farming systems with the clean technology. Moreover, it can be transferred to larger farming villages if the higher head and larger flow rate via waterfall using larger Pico-hydropower as micro or mini-power systems were investigated depending on their topography characteristics.

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