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Extended Abstract

Small and Micro-Hydropower Plants Location by Using Geographic Information System †

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Abstract: Small-scale hydropower plants (SHP), and in particular the micro-hydropower plants (MHP) and pico-hydropower plants (PHP), are considering as an alternative energy resource based on the hydroelectric potential available in urban water cycle because of the excess of pressure existing in some urban water supply systems (WSS). Nowadays, pressure-reducing valves are necessary to reduce water pressure in WSS, so the use of a pump as turbine (PAT) can be considered as a proper way for reaching both an enough water head reduction and a hydropower generation possibility (self-consumption or energy recovery). MHPs are based on existing hydraulic resources where the PAT location is necessary, especially in those points with an excess of energy, which derives in an extra cost in terms of conservation and maintenance of the infrastructure or lead to the necessary installation of dissipation devices. The locations of these points are strongly influenced by the geographical and hydrological conditions, so a Geographic Information System (GIS) is a very useful tool for implementation of SHP and MHP or PHP projects. This paper describes the assessment and comparison of the methodology followed in the SHP and MHP locations: necessary data, GIS development, hydrologic model and hydropower potential.

Keywords: small-scale hydropower plants; micro-hydroelectric plants; hydropower; water supply energy; geographic information system

1. Introduction

The current worldwide energy system is based on obtaining energy from fossil fuels, such as oil, coal and gas. The generation of energy from these primary materials is being reconsidered because of several reasons: they are limited to resources which can only be found at specific points on the earth; serious effects about the environment and the health of human are being induced by their use on large-scale; the natural reserves are being depleted compromising the future of the next generations [1].

In that sense, the European Union's priority objective is the promotion of electricity from renewable energy sources -eolic, photovoltaic and hydropower, mainly-. Regarding to small-scale hydroelectric power plants, the National Action Plan for Renewable Energy in Spain [2] defined regulatory proposals focused on promoting new SHP plants and also, financial proposals for improving and updating those plants which are concluding their useful life. The Spanish energy sector's framework considers the two following possibilities in the micro-energy production: (1) non-critical uses, which may be disconnected from the electrical grid; and (2) low consumptions uses, promoting "self-consumption".

In the literature, several criterion can be found to categorize hydropower plant based on their electric power generation capacity, whereas other references proposed other definitions according to the hydropower plant size [3]. However, for small hydropower plants (SHP), the upper limit generally varies between 2 and 25 MW, although, up to 10 MW is the most widely accepted value. Whereas, Mini-hydro refers to schemes below 1–2 MW, micro-hydro below 5–1000 kW (MHP), and pico-hydro up to 5 kW (PHP) [4].

Usually, the pressure in urban fresh water supply system (WSS) is very high in order to guarantee a consistent water supply throughout the whole urban area. Currently, pressure reducing valves are necessary to reduce water pressure in the water supply system. This available hydroelectric potential could be used for obtaining electrical energy, for self-consumption or for energy recovery [5]. The use of a pump as a turbine appears to be an ideal manner to reduce water head as well as to generate hydropower in water pipelines. The feasibility and performance of this tentative idea was investigated by Du [6]. After the comparison between numerical and experimental results, Du [6] concluded that the simulation findings could be used for predicting the performance of a turbine in any WSS. Respect to energy recovery, Bousquet [7] developed a research about local hydropower generation. In this case, the small hydropower plant was located in wastewater system. This study exposed a methodology to assess the potential for hydropower in wastewater systems, either upstream or downstream of the wastewater treatment plant (WWTP). The proposed methodology was developed in two phases. First, the annual electricity production is estimated for some selected areas based on GIS data and the inflows to each WWTP. Secondly, an economic evaluation is carried out. In particular, an industrial development was carried out by SUEZ [5], named as hydroelectric power generation systems (HEPGS), which has been implemented at several cities in Murcia (Spain).

Since a location analysis for SHP and MHP projects are strongly influenced by geographical and hydrological conditions, the main objective of this study is the assessment and comparison of the methodologies usually followed, especially necessary data, GIS development, hydrologic model and hydropower potential.

2. Comparison of SHP and MHP Location Procedures

Different procedures are followed for the SHP and MHP locations, where Geographic Information System (GIS) can play a relevant role, since it allows to define the bounds of the required information for a decision-making process along the implementation of SHP and MHP projects. The application of GIS is developed in a wide collection of studies in the literature. Following, the most relevant researches related to this particular topic are exposed.

Bayazit [8] analyzed the application of GIS for computing the theoretical surface hydropower potential for a region in Turkey. The study shown 85 possible locations for a SHP, they were determined according to different annual energy production levels. Rojanamon [9] detailed the application of GIS to a particular area in Thailand in conjunction with different engineering criteria, economic and environmental conditions and social impact. Finally, different combinations of GIS with others algorithms developed in MATLAB [10] or with hydrological models [11] have been studied.

2.1. SHP Location

In the case of SHP, the first step to evaluate the potential site is by means of the head, supported by spatial data obtained from a digital elevation model (DEM) [8]. Then, the runoff at those possible locations is obtaining and finally, the corresponding hydropower potential is estimated. The scheme of the procedure followed for determining the hydropower potential is summarized in Figure 1. The equation to calculate the hydropower potential energy is given by Equation (1).

$$E = m \cdot g \cdot h \quad (1)$$

where E is the potential energy, m is the water mass or accumulate volume due to runoff, g is the gravity acceleration, and h is the head.

Respect to the estimation of the parameter m, accumulate volume of water due to runoff, two different approaches are considered in the literature. By means of evaporated volume [8] or by means of hydrologic model such as number curve [12].

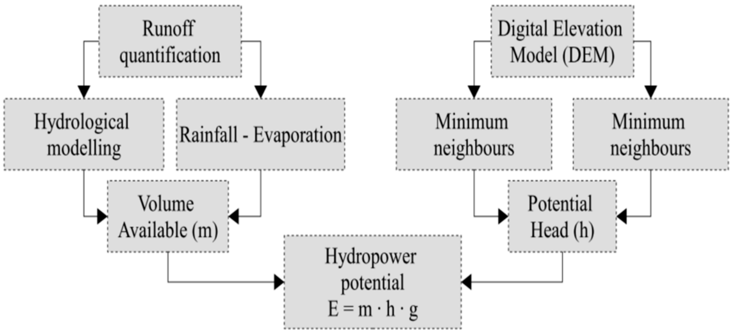

Figure 1. Methodology followed to assessment of SHP location.

2.2. MHP Location

The proposed methodology to evaluate MHP or PHP locations and their corresponding hydroelectric potential are based on the estimation of energy production potential in urban water cycle [6], where the fundamental parameters are estimated from GIS and demographic data. The methodology is divided in two main phases: (1) Estimation of energy production potential and (2) economic profitability assessment [6,7], as following, although in this paper, only the first phase is considered.

The available energy for a particular water supply system (WSS) can be obtained according to Equation (2).

$$E = \eta \cdot \rho \cdot g \cdot h \cdot V \tag{2}$$

where η is the efficiency, ρ is the water density, g is the gravity acceleration, h is the head available at the turbine, and V is the water volume consumed in a determined time by a WSS. Several of these essential parameters, such as head or water volume, are estimated from a GIS and demographic data, as shown in Figure 2.

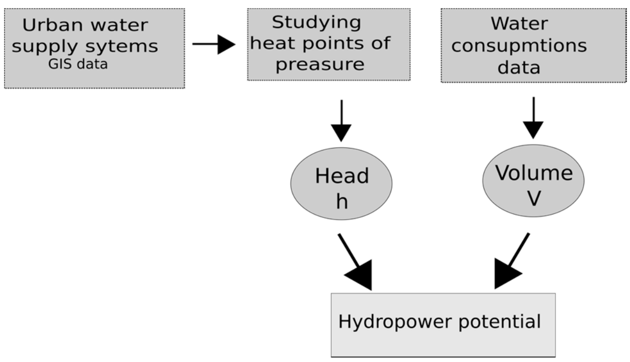

Figure 2. Methodology followed to estimation of energy production potential in a MHP location analyses process.

3. Conclusions

The quick increment of population in the last decades and the huge developments of industry have increased significantly the necessity of energy, so alternative ways of energy production must be considered and investigated trying to satisfy the constant increasing demand. In that sense, the production of electrical energy by means of turbine systems is considered. Pico-hydroelectric plants are supported on actual hydraulic resources with excess of energy, trying to locate points where problems due to unused energy imply extra costs in terms of conservation and maintenance of the infrastructure, or make necessary the collocation of dissipative devices for this energy. Although hydroelectric plants are not an original way of electricity production, the development carried out in this research for the evaluation of SHP and MHP do, which is based mainly in the infrastructure employed for the energy production and, in the methodology defined for the location of the potential plants. Since the results and conclusions obtained in SHP and MHP developments are strongly influenced by geographical and hydrological conditions, locations data must be managed with enough accuracy, which can be satisfied by a GIS. Taking into account that location analysis must be developed at the very early stages, it is very convenient to use the available geographical database, such as GIS, in order to reduce time and cost.

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Conflicts of Interest: The authors declare no conflict of interest.

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