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An overview of research and energy evolution for small hydropower in Europe

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ABSTRACT

Europe has a large tradition of Small Hydropower stations (SHP); these proliferate wherever there was an adequate supply of moving water and a need for electricity. As electricity demand grew many of these plants were abandoned. Today with the rising price of energy, SHP can be a solution to help rural electrification, furthermore SHPs do not consume the water that drives the turbines. The advantage of this technology is extremely robust and systems can last for 50 years or more with little maintenance. This paper summarizes an overview of SHP Hydropower in Europe. Hydropower on a small scale, or micro-hydro, is one of the most cost effective energy technologies to be considered for rural electrification in less developed countries. Europe is a market leader of SHP technology. Optimal turbine designs are available and new technical developments offer automated operation of SHP. The present role of SHP in Europe in the development of renewable energy sources is discussed through this paper. The main producers of SHP electricity in Europe are Italy, France, Spain, Germany and Sweden. On the other hand, 10 European countries are ranked based on the total numbers of SHPs: Germany (7,512), Italy (2,427), France (1,935), Sweden (1,901), Spain (1,047), Poland (722), Romania (274), Portugal (155) and UK (120). The research shows that there is a considerable scope for development and optimization of this technology. This opens new perspectives because it has a huge, as yet untapped potential in most areas of Europe and can make a significant contribution to future energy needs.

1. Introduction

Hydroelectric energy is a continuously renewable electrical energy source, it is non-pulling, It has no fuel cost and is advantageous for its low operation and maintenance. Hydropower is that generated by the movement of water bodies. The water flows via channel or penstock to a waterwheel or turbine where it strikes the bucket of the wheel, causing the shaft of the waterwheel or turbine to rotate. When generating electricity, the rotating shaft, which is connected to an alternator or generator, converts the motion of the shaft into electrical energy. Hydroelectric plants are more cost effective compared to other types because; although its construction cost is higher, once put into operation have some operating costs and relatively low maintenance provided that the average year rainfall conditions are favorable [1]. The inherent technical, economic, and environmental benefits of hydroelectric power make it an important contributor to the future world energy mix, particularly in the developing countries [2]. The hydropower is the leading source of renewable energy, providing more than 97% of all electricity generated by renewable sources [3] Village-scale hydro-electric programmes exist in many developing countries throughout the world [4]. Technically feasible hydropower estimated at nearly 15,000 TWh/year still exists in the world today, mostly in countries where increased power supplies from clean and renewable sources are most urgently needed to progress social and economic development [2]. As far as Europe is concerned, technical potential in Europe in terms of annual generation hydroelectric energy is 1,021 TWh/year and the Technical potential installed capacity was 338 TWh/year in 2009 [5]. Countries with the largest production hydroelectric energy during the years 1995–2011 were: Norway (an average of 120 TWh, which accounts for 21.81% for Europe and 3.54% for the world), Sweden (66 TWh on average, which represents 12.03% for Europe and 1.95% worldwide) and France (61 TWh on average, 11.08% for Europe and 1.80% for the world) [6]. Europe has developed 75% of hydropower potential, whereas Africa has only developed 7%

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Table 1
Detail of Small-scale hydropower classification by installed capacity (MW) in some countries and organizations.

Installed capacity (MW)	Countries	Organizations
≤10	France, Norway, South Africa, Czech Republic, Spain, Italy	International Energy Agency, World Commission on Dams, ESHA (European Small Hydropower Association), IEA Small Hydro
≤15	Sweden, UK	
≤20	EU	
≤25	India	
≤30	Brazil	
≤50	New Zealand, Philippines	
≤100	USA	

[7].

In this article, SHP refers to hydraulic power plants with less than 10 MW installed power, which is commonly called "Small Hydropower" in a majority of institutions or international agencies. However, in some countries like China or India this value increases to 25 MW [8]. Table 1 shows a brief detail of Small-scale hydropower classification by installed capacity (MW) in some countries and organizations. International organizations generally opt for 10 MW as the limit for SHP. Small hydroelectric plants have individual capacities of 10 MW or less [9], and very small 5 kW [10].

The contribution of SHP to the worldwide electrical capacity is more of a similar scale to the other renewable energy sources (1–2% of total capacity) amounting to about 47 GW (53%) of this capacity in developing countries [11]. We have to take into account that hydropower technology is regarded as the most mature of all considered RESs [12]. In electric power generation, small SHPs have special importance thanks to their low administrative, executive costs, and short construction time compared to large power plants [13]. Small Hydropower electricity supplies electricity for over 13 million households in Europe, which contributes to 29 million tones of CO_2 avoidance annually [14].

The principal objective of this work is to study the evolution of the produced by small hydropower in Europe and the major field of investigation. Concretely, it brings deeper analysis on Dam and penstock, turbines, pumps and generators, control strategies and costs, socials aspects and environmental issues.

2. Small hydropower energy production in Europe

In this review, we have to understand Gross Installed Capacity as the maximum electric output that the whole of facilities can produce and Gross electricity generation as the amount of electricity that the facilities have produced over a specific period of time, usually one year.

The vast majority of installed SHP capacity (81.5%) in Europe is concentrated in 6 countries. According to the number of facilities installed, this is lead by Germany (7,512), followed by Austria (2,589) and Italy (2,427) as shown in Fig. 1. These largest EU producers of electricity from SHPs in recent years are Italy (2,751 GWh); accounting for about 21% of the total SHP installed capacity, followed by Spain (15.5%), Germany (14%), Austria (9.4%), Sweden (7.7%) and France (7.5%) [15] as shown in Fig. 1, data extracted from [14] in year 2010 (last year with full data for all analyzed countries).

2.1. United Kingdom

The negation of fuel costs, technology efficiency, low operating and maintenance costs and reduced environmental impact, contribute to make hydropower an attractive option [16]. Hydropower currently provides only 1.5% in the UK [17]. Micro-hydro is one of the most environmentally benign energy technologies available. The technology is extremely robust and systems can last for 50 years or more with little maintenance [18]. For 2002, the UK has 100 MW of small hydro capacity operating from approximately 120 facilities [8]. Fig. 2 shows the evolution of the installed SHP from 2007 to 2011, the total installed capacity and the electricity generation in the United Kingdom. So, the total number of power plants in UK increased through the period 2007–2011, the total of SHPs in 2007 (86 SHPs) and for year 2011 (183 SHPs). The Gross Installed Capacity was increased slightly in the same period (2007–2011), the maximum Gross Installed Capacity equals 218 (MW) in 2011. In addition, the maximum Gross electricity generation scores 697 (GWh/year) in 2011.

2.2. Portugal

As shown in Fig. 3, the total number of power plants in Portugal increased slightly through the period 2007–2011: the total of SHPs was 137 in 2007 and 157 for year 2011. The Gross Installed Capacity was increased slightly in the same period (2007–2011), the maximum Gross Installed Capacity equals 453 MW) in 2011. In addition, the maximum Gross electricity generation equals 1,605 (GWh/year) in 2010.

The hydropower capacity is foreseen, to be about 7,000 MW increasing the hydropower generating capacity potential from 46–70%, in Portugal for the year 2020. Promotion and development of small hydropower aim to increase by 50% the actual capacity [19]. The number of SHPs has increased from 137 in 2007 with an installed capacity of 399 MW to 157 plants in 2011 with an installed capacity of 453 MW [14].

2.3. Italy

The total number of SHP in Italy increased through the period 2007–2011, being the total of SHPs in 2007 about 1,835 and 2,601 for year 2011. The Gross Installed Capacity was increased slightly in the same period (2007–2011), the maximum Gross Installed Capacity equals 2,896 MW in 2011. Also, the maximum Gross electricity generation equals 10,958 GWh/year in 2010 (see Fig. 4).

In Italy, the potential energy production by SHP plants is expected to be 12,000 GWh/year by 2020 [14]. Italy is one of the largest producer of hydroelectric power in Europe in terms of reference to SHP. It increased since 2007 where it generated about 4,000 GWh to 10,958 GWh generated in 2011 with 2,601 SHPs.

2.4. Germany

The total number of power plants in Germany increased slightly through the period 2007–2011, the total of SHPs in 2007 was 7,503 and the total of SHPs in 2011 was 7,512 as Fig. 5 shows. Germany, since 2007–2011 has scarcely increased the number of SHP, been 7,512 in 2009 and 7,516 in 2011, with 1,723 MW installed that produced 8,352 GW/h/year in this year [14].

2.5. France

The history of hydropower is linked to France because the first hydropower plant was successfully built in this country around 1880 [20]. Hydropower is the second source of electric power generation in France [21]. In France, the total number of power plants increased slightly through the period 2007–2010, as shown in Fig. 6. The total of SHPs were 1,825 in 2007 and 1,935 for year 2010. France is one of the largest producer of hydroelectric power in Europe in terms of SHP and refers generating 6,820 GWh in 2010, but suffering a significant decline in 2009 for both installed capacity and electricity generation. The maximum Gross Installed Capacity equals 2,110 MW in year 2010 and