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Mathematical modelling of Portuguese hydroelectric energy system

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Abstract

Hydropower is one of the most traditional renewable energy source and a major contributor for renewable energy production in many countries. In Portugal it was the only renewable energy source for many years but nowadays wind presents similar production levels and for example in 2015 wind was the main source producing 45.5 % of the total renewable energy. However hydro energy will continue to be important in the renewable energy production and in this work ranking of nine models for hydro energy production with various numbers of parameters was done using adjusted R-squared and corrected Akaike information criterion (AICc).

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1. Introduction

Sustainable development relies on renewable energy sources and hydro power energy is recognized as being very important for many countries [1]. Hydropower energy is based on a renewable source, reduces pollution and emissions of greenhouse gas and has positive impacts on the quality of life of populations [2].

However it has also some environmental negative impacts usually related to fauna and flora [3]. Hydropower technology is considered mature but recent studies showed that there is still scope for development and

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optimization, as for example for small hydropower [4]. In Portugal hydropower energy was the only meaningful renewable energy for a long time its. Nowadays the electricity mix of Portugal has another significant source of renewable energy that is wind, which accounts for more or less 50% of total renewable energy. However energy produced from wind is characterized by being intermittent and with low controllability, which does not apply to hydro power energy. A 100% RES electricity scenario for Portugal will rely heavily on hydro energy [5]. Since hydropower energy will play a key role in future energy system it is important to have models that can help to calculate or forecast hydro energy production.

In this work several models were proposed to study hydropower energy production. Those models were then mathematical analyzed and the best model was selected using the R-squared and Akaike information criterion.

Nomenclature

A	model parameter
AIC	Akaike information criterion
AIC _c	Corrected Akaike information criterion
B	model parameter
C	modelparameter
D	modelparameter
E	energy
F	model parameter
G	model parameter
k	number of parameters
n	number of observations
P	installed power
P _c	precipitation
R ²	R-squared
R ² _{adj}	adjusted R-squared
SS	sum of squared differences
SST	total sum of squares

2. Method and data

2.1. Hydro energy real data

For this work the hydro energy production from 1995 to 2015 was considered [6]. After analyzing the problem, several variables were considered to explain the hydro energy produced namely hydro installed power, precipitation and the production of wind and photovoltaic energy [6, 7]. The inclusion of the first two factors above mentioned is easily understandable because they are directly linked to the production of hydro energy. The wind and photovoltaic energy production was considered because due to regulations the production of this type of energy has priority over the other ones in Portugal. Fig. 1 presents the data concerning hydro energy production and hydro installed power in Portugal over the period considered. From the analysis of this figure it is possible to conclude that there was an increase of around 40% in installed power over the years.

Fig. 2 presents the hydro energy production and the annual precipitation. From the analysis of the figure, it seems that there is a similar pattern for the variation of these two variables.

Fig. 3 presents the hydro energy production and the wind and photovoltaic energy production over the period considered. Analyzing the figure it is possible to conclude that the energy production from wind and photovoltaic systems has increase significantly in the last decade, mainly due to the wind energy production. If this factor affects the hydro energy production it will only be relevant in the last decade because from 1997 to 2005 it is residual.

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