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Impact of drought periods on hydroelectric production in Portugal: A Study from 2015 to 2017

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Abstract

The production of hydroelectric power is strongly affected due to periods of drought. In Portugal there are about forty-nine hydroelectric plants with installed capacity of more than 10MW. In the year 2017 the generation of electricity in Portugal was 54.52 TWh, of which about 14% was hydroelectric production reflecting a year below normal in hydroelectric power production. This article discusses the impact of drought periods on hydroelectric power production in Portugal, which address the importance of hydroelectric production in Portugal. Among the factors influencing the production of hydroelectric power, a method is presented for analysis of a dry month through the monthly precipitation indicators, energy production by monthly technology and energy price. These indicators were presented and analyzed in three case studies presented in this article. A solution is also presented to reduce the impact of drought periods on Hydro production.

Keywords: importance of hydro power, hydroelectric generation, hydro power, power generation

1. Introduction

The hydroelectricity is a 100% renewable energy based on water energy and kinetic energy of water, taking advantage of an infinite resource obtained from nature. The main objective of this article is to focus on the impact of drought on the production of hydroelectric power in Portugal, so as to raise the awareness of the academic population and even the general population about the importance of renewable energies, especially the vital role of hydroelectricity in production of electricity [1]. Currently, although hydroelectric power has been increasing gradually, the national utilization potential is only around 50%.

Just because, compared to other European Community countries, Portugal is well below the European average, in some cases as France, Germany and Italy, around 90%. In order to be aware of the importance and impact that this type of energy has, Hydropower, which includes hydroelectricity, represents 28% of the installed electricity power in Portugal, more than Wind (22%), than Coal (11%) and then Natural Gas (18%) [2]. Hydroelectricity plays a key role in the electricity market because it has many advantages such as a rapid and efficient response to the variations of the demand and consequently an adjustment in production, in the price of electricity produced is constant and has a high reliability of service, enabling a supply of constant energy, among other advantages [3].

As mentioned previously, the main objective of this article is to focus on the impact of drought on hydroelectric production in Portugal in 2017, in an extremely dry year and to verify the impact of drought on energy production in general, to verify that was offset the lack of water production and lastly to analyze the variation of the electric energy price. The same analyzes were carried out for the years 2016 and 2015 in order to have a possible comparison. In section II we speech about factors that influence the production of hydroelectric energy, in section III we explain the study methodology, in section IV we present the case study's in section V we do a conclusion of this paper.

2. Factors that Influence the Production of Hydroelectric Energy

The Hydroelectricity production has a great advantage when compared to the production of wind power, that is highly irregular and unpredictable. One of the major factors that influencing hydroelectricity are the periods of drought, due to lack of precipitation and inability to store water in dams that have reservoirs. In the year of 2017, Portugal recorded a fall in the production of hydroelectric energy, around 55%, due to the drought that the country was experiencing [4]. There are many factors that together have led to this dry period, such as high temperature, little rainfall and not enough water in the rivers to be able to produce energy and consequently the pumping barrages could not perform this process to not destroy the flora rivers and to protect all living things in rivers.

This set of factors led to an extreme drop in water production that Portugal tried to compensate with wind energy, but like this irregular and unpredictable was not enough and had to compensate the lack of hydropower through fossil fuel power stations such as coal and natural gas. In sum, in Portugal water production fell by 55% to 7,200 GWh in 2017 while natural gas production increased by 53% (8,029 GWh) and coal production increased by 27% (16,847 GWh).

3. Study Methodology

The method used in the cases studies is represented in Block Diagram in Fig. 1. The (1) will be the starting point, (2) will be the definition of the month that is the variable "M", and the variable "X" will take the values less than or equal to 6 before the variable "M ", and the (3) will make a relation between the precipitation occurred for that same month to verify if the month can be considered dry, in case the precipitation is less than 40% of the value said normal for that same month is considered dry and the program proceeds, otherwise a matrix with the data of the months analyzed with the indicators of energy produced by monthly energy and monthly energy price is printed in the step (5).

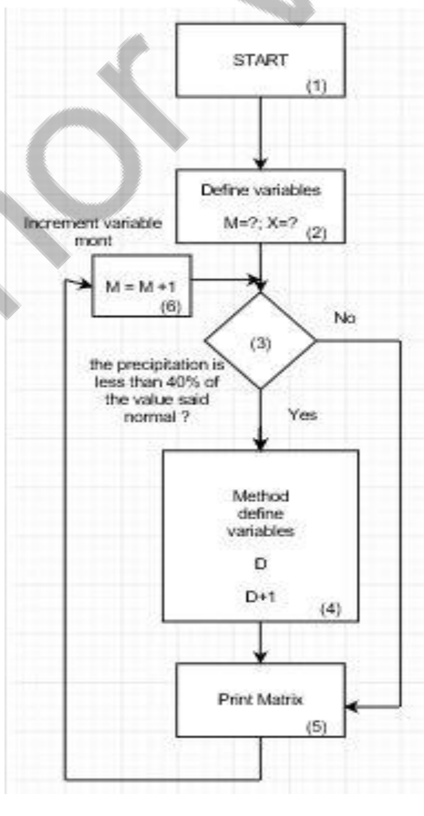

Fig. 37: Base of the applied method.

In the case of a valid relation, it follows the step (4) where the analysis of the driest month is performed, thus defining the variable "D" and the following month, thus defining the variable "D+1", analyzing the precipitation indicators monthly and will perform step (5) by extracting the matrix with the indicators data, monthly precipitation, energy production per monthly technology and monthly energy price and indicating the driest month and the following month, the method will proceed to the step (6) by incrementing the "M = M+1" function to analyze the months following the month defined in step (1) for the variable "M". Will proceed to step (3) and create a loop until to stop the method. It is recommended that variable "*X*" take value less than or equal to 6 to be correlated with month "*M*", because if month "*M*" is December 2000 and "*X*" take values greater than 6, in the month January 2000 may it has rained a lot and in the following months and only in August was it has become a dry height, this will influence the December analysis in relation to energy production data and market price. The analysis of the data of the months closest to the variable "M" will make the analysis more precise and concrete.

4. Case Study

Based on the method presented previously in Fig. 1, in the case studies we performed an analysis of monthly rainfall data, energy production per monthly technology and energy price to verify the impact that the dry periods have on the Portuguese market and how this behaves with little or no availability of hydroelectric production. Therefore, three case studies were performed:

- The first will be between December 2017 and October 2017, the latter being considered the driest month of the last six months, consequently the month of November 2017 will be considered the following month. Finally, a comparison will be made between these months and the month of March 2018, which is considered a rainy month.
- The second case study will be between the month of December 2016 and July 2016, the latter considered the driest month on the last nine months, consequently the month of August 2016 that is the following month. Finally, a comparison will be made between these months and the month of February 2017 that is considered a rainy month.
- The third case study will be between the month of December 2015 and July 2015, the latter considered the driest month on the last twelve months, consequently will be analyzed the month of August 2015 considered the following month. Finally, a comparison between these months and the month of January 2016 that is considered a rainy month.

The Table 1 shows the values assigned to the variables according to the basis of the applied method.

Table 1: Values assigned to variables.

Variables	Case A	Case B	Case C
M	December 2017	December 2016	December 2015
X	6 months	9 months	12 months
D	October 2017	July 2016	July 2015
D+1	November 2017	August 2016	August 2015

A. Dec 2017

- **Precipitation data:**

According to Table 1, our chosen month "*M*" is the month of December 2017. When we begin to execute our method, the month of October is the variable "*D*" since it is the month where the current amount of precipitation is the lowest as we shown in the Table above. Consequently, the variable "*D+1*" will be represented by the month of November 2017. Like we see in above in the Table 2, the month of October assumes the variable "*D*" (being less than 40% of the normal value for that month), according to the method implemented. On the other hand, and with the course of the method, and knowing that we increase the function "*M = M+1*" to analyze the months following the month defined by the variable "*M*", we verify that the month of March can also assume the variable "*D*", but in this case to take over as the month very rainy.

Table 2: Precipitation values of case A (Built with data from [5]).

Year 2017			
October	24,4	92,5	Lower
November	43,2	118	Lower
December	116,2	129,8	Near
October	24,4	92,5	Lower
Year 2018			
January	63,4	126,8	Lower
February	74,9	112,2	Lower
March	259,2	93,5	Higher
January	63,4	126,8	Lower

Looking at IPMA data, we observed that the month of October was the hottest of the last 87 years for October, when 2 heat waves ran occurred from 1 to 16 and from 23 to 30 October, which covered a large part of the territory continent, and the total rainfall in October was about 30% below of normal, being considered the driest of the last 20 years with an average value of precipitation of 26.9 mm, which correlates with the implementation of our method [6]. Consulting also the same data, but this time for the month of March 2018, in Continental Portugal was considered an extremely rainy and very cold month. The average value of the amount of precipitation in March was about 4 times the monthly average value and it was considered the second rainier month of March since 1931 which correlates with our method [7].

- **Production Mix Statistics:**

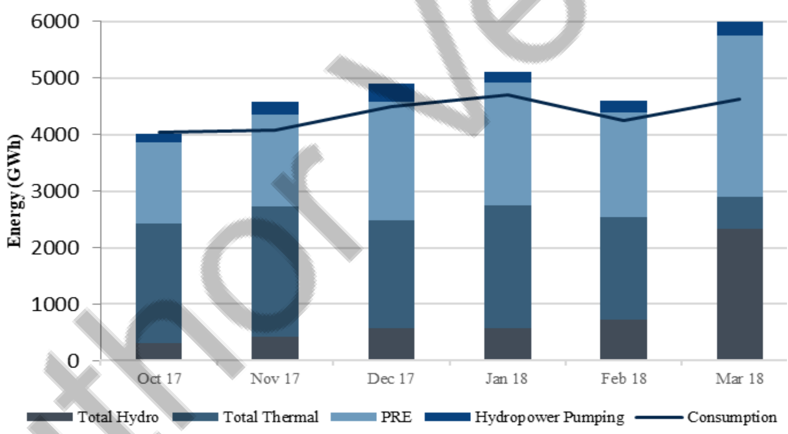

Fig. 38: Monthly Production Mix Statistics of Case Study A (Built with data from [10]).

According to Fig. 2, October presented a large deficit of hydroelectric energy used (about -58.5% in relation to the previous year), which correlates the data obtained for precipitation shown in Table 1, which we classified the month as extremely dry. Thus, thermal energy was needed to be used more than normal (10.5%) in order to compensate for the lack of hydroelectric production that would be expected for October. Regarding the energy of the Special Regime Production, there is not a large difference in relation to the previous year, but there is an increase in hydroelectric pumping (6.9%), which may be justified by the need to recover the average flow rates of rivers. In the case of the month of March, there is a substantial increase in water production (155%), which is justified by the fact that is a month where a above precipitation occurred that was expected (as shown in the first Table), with energy hydro together with the energy coming from the Special Regime were practically able to meet demand / supply demanded by the energetic market, so that thermal energy was not so necessary for this month, noting a variation of (-67.5%) compared to the previous year. For the energy sources of the Special Regimes, wind energy production contributed the most by (52.1%).

Energy price (€/MWh):

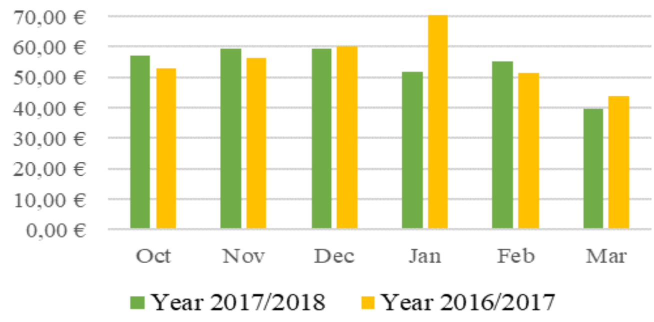

Fig. 39: Average monthly price (€ / MWh) of case study A (Built with data from[11]).

Regarding the average monthly prices of energy Fig. 3, our cases of studies, and comparing with the data obtained so far, we found that the month of March was the lowest month in the average monthly price (€/MWh), which could be explained by the fact that in these month the hydroelectric power has been the most used since there was enough abundance of this sector, as well as the production of these kind of energy are considered the cheaper in the production of electric energy. In turn, the months of October, November and December were the most expensive months in which justification will be since there was no available hydraulic energy and it was necessary to resort to thermal energy, which energy is more expensive to produce energy in order to meet the needs of the electricity market.

B. Dec 2016

- **Precipitation data:**

According to Table 3, our chosen "M" month will also be the month of December for the year 2016. When we start executing our method, the month of July will most likely become the "D" variable due to the fact of being the month in which the current amount of precipitation is the lowest as shown in Table 3. Therefore, the variable "D+1" will be represented by the month of August.

Table 3: Precipitation values of case B (Built with data [5]).

Year 2016			
Month	**Actual rainfall (mm)**	**Average precipitation (mm)**	**Relationship**
July	2,8	10,3	Lower
August	3,7	11,6	Lower
September	18,2	41,8	Lower
October	64,4	92,5	Lower
November	98,7	118	Lower
December	51,3	129,8	Lower
Year 2017			
January	47,8	126,8	Lower
February	87,9	112,2	Lower

It is shown that the month of July assumes the variable “D“ (being less than 40% of the normal value for that time of the month), going according to the implemented method. On the other hand, and with the course of the method, and knowing that we increased the "M = M+1" function (as we did for the first case) to analyze the months following the month defined by the variable "M" the month of February may also assume the variable “D”, but in this case to assume as a very rainy month. The month of July 2016, in mainland Portugal, was extremely hot and very dry. It should be noted that according to the IPMA data, in many regions of the North and Central coast and the Alentejo and Algarve there was no precipitation this July. [8] As for February 2017, it was classified as a normal month for the season of the year for precipitation and temperature[9].

- **Production Mix Statistics:**

In relation to energy production Fig. 4, we can see that in December 2016, it was verified that a great part of the energy was produced through the thermal, about 36.8%, as a result of the little precipitation that occurred in this month, even when compared to December 2015 there was an increase in water production, the same goes for the month of July 2016.

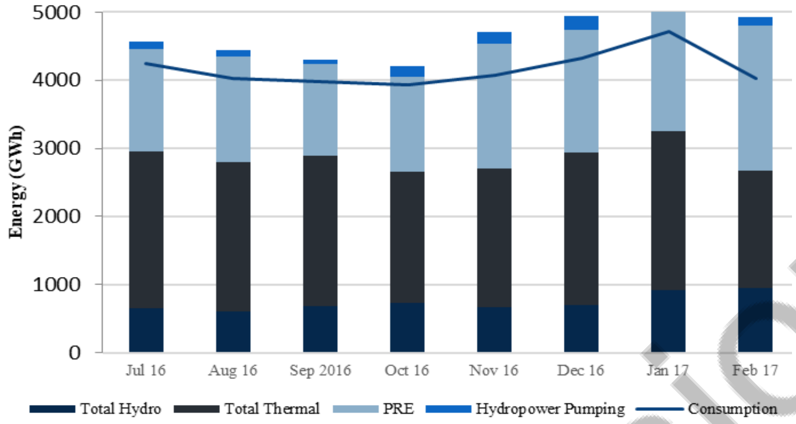

Fig. 40: Monthly Production Mix Statistics of Case Study B (Built with data [10]).

As for February 2017, it was verified that there was a 56.3% fall in the production of hydroelectric energy, given that in February 2016 it was the 2nd rainiest month of the year, and in counterpart to compensate these values there was an increase in more than 100 % in thermal power production in February 2017 compared to 2016, and a 29% increase in hydroelectric pumping.

- **Energy price (€/MWh):**

According to the data of average monthly prices for the years 2016/2017 and 2015/2016 Fig. 5, we can verify the highest price for the energy occurred in January 2017, approximately 71,52 €, where much of the energy produced was through the Thermal energy. In contrast, in January 2016 a large part of the energy produced was through hydropower.

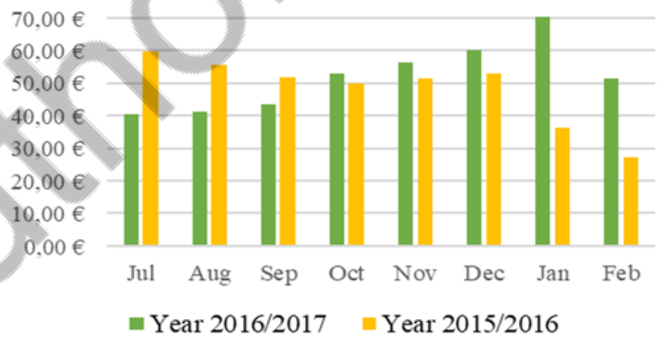

Fig. 41: Average monthly price (€ / MWh) of case study B (Built with data from [11]).

We can also verify that in the months of July, August and September 2015 the energy value is higher compared to the same months of 2016, since a great part of the energy production in the months of 2015 comes from thermal energy, whereas in the months 2016 already come from water production. We can then verify that the price of energy varies with the type of production, thermal or water, and when this same production comes from the water, that is when there is more water in the reservoirs also the energy price decreases.

C. Dec 2016

- **Precipitation data:**

In this case study our chosen month, "*M*", was the month of December 2015. During this month the average value of precipitation was about half of the normal value, as we can see in Table 4. It was verified that during the year of 2015, in only two months of the year, the volume of precipitation was higher than the monthly average, making this year, a year dry, and in about 6 months of this year the precipitation volume was lower by about 50% of the average value [12].

Table 4: Precipitation values of case C (Built with data from [5]).

Year 2015			
Month	**Actual rainfall (mm)**	**Average precipitation (mm)**	**Relationship**
July	4,1	10,3	Lower
August	7,1	11,6	Lower
September	45,4	41,8	Near
October	118,7	92,5	Higher
November	46,5	118	Lower
December	61,1	129,8	Lower
Year 2016			
January	166,9	126,8	Higher

When we performed the method considering the month "M" December, our month "D" is July, since it was the month with the least precipitation, at the amount of precipitation in July 2015 this value was 4.1 mm, lower than the average value of 10.3 mm, and month "D+1", August. January 2016 was characterized as a very rainy month with enough wind. As for precipitation, the values in January 2016 were 166.9 mm, higher than the average value, being the highest value of the last 15 years. In some days of January, there were high values of precipitation in certain regions, mainly north, and strong wind [13].

- **Production Mix Statistics:**

About Production Fig. 6, we can verify that the values of water energy production in both July and December 2015 are low and in comparison to previous years, namely 2014, there was a reduction of this production in about 56% in December and 17% in the month of July, as we have seen, these months have been hot and dry due to the little precipitation we had. On the other hand, thermal energy increased in these months, probably to compensate for this reduction in water, and compared to 2014 there was an increase of about 40% in July and near 31% in December, as well as pumping, namely in December (48.4%).

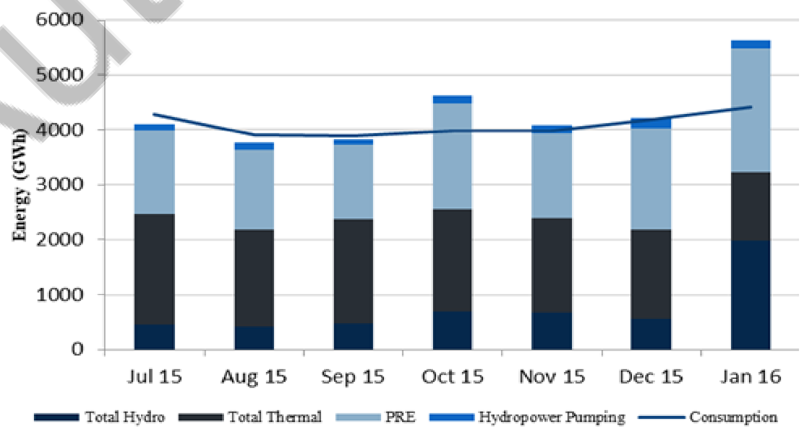

Fig. 42: Monthly Production Mix Statistics of Case Study C (Built with data from [10]).

As for January 2016, the opposite occurs: once it was a very rainy month there was an increase in water compared to 2015 by 98.5% and a reduction in thermal energy production by about 15%. This month there was also a 23% increase in hydroelectric pumping. Also, in January there was an increase in energy production under a special regime, mainly 33.5% in wind energy production, given that it was considered a month with strong wind. [10]

- **Energy price (€/MWh):**

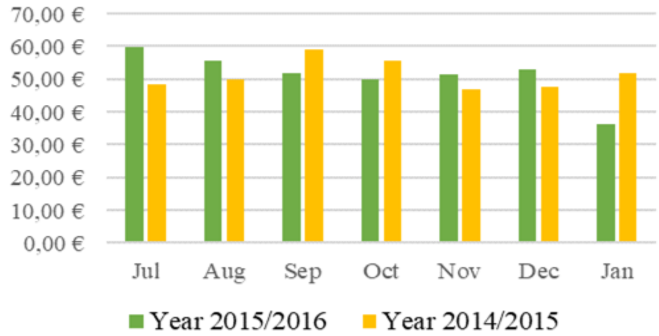

Fig. 43: Average monthly price (€ / MWh) of case study C (Built with data from [11]).

According to Fig. 7, we can verify what we have already considered, in which the price of energy will vary depending on its type of production, thermal or water, reaching higher prices when thermal energy production is higher, as in the case of July 2015, or reaching lower prices as production increases through hydropower, as we can verify in January 2016.

5. Conclusions

It is verified that in Portugal the hydro production has a very significant weight in the energy production, it is concluded through the cases of study that the lack of hydro energy production led to the necessity of the use of thermal production plants to compensate the lack of production as a consequence there was a high increase in energy prices in the months of the years studied. This variation in hydroelectric production is due to periods of drought. The implemented method of study became useful for the analysis of the case studies because through the inputs of the assigned variables there was a quick sampling of all the data necessary for analysis of the cases, either the precipitation data, the production data by monthly energy and monthly market prices. It is noteworthy that this method can be applied to any month of any year. Since most of the major rivers that exist in Portugal have their source in Spain, whenever droughts occur the water becomes scarce in order to produce enough hydro energy to maintain normal energy prices and not need to resort to energy production through fossil fuel power plants. A solution to this type of situation would be to use the smaller rivers that have their source in Portugal and which flow into these large rivers, is where it would be possible to use a reservoirs using the retention of water in these tributaries, taking into account the, so that during these periods of drought we can use this retained water in the tributary rivers to increase the main riverbed where the dams are installed for the production of hydroelectric energy.

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