Ciências ULisboa

Use of water to run-of-river

Introduction

Hydropower production is seen as one of the most efficient and less pollutant once it takes advantage of renewable energy. For different water paths, there are different ways of using that water to generate electricity being weir constructed depending on the characteristics of that water utilization. In the case of study, weirs with this kind of utilization, usually are on water paths with small slopes and its low capacity of water storage launches affluent almost instantaneously downstream.

Hydroelectric power plants have the goal of producing electricity through the potential of running water in river. This kind of powerhouse works with big water storages upstream in our water shed, to ensure generation of electricity throughout the year.

These plants are responsible for various impacts. Those can be nature impact, social impact or economic impact. As environmental impacts, we have deforestation for construction of hydric powerhouse, that will trigger a raise in emission of green house effects and consequently will cause increase in global warming. There can also be a block of flood cycles, the stopping of reproductive cycles of fishes, modification of large scale of ecosystems, or even affect negatively near peoples that depend on fishing.

Regarding the construction of this kind of central we have some negative impacts like deforestation and degradation of upstream areas, reduction of biodiversity, decay of environmental services, disturbs to animal habitats and habits because of roads and accesses to infrastructure.

Economically speaking, this powerhouse usually come at a very high price and is not that profitable as we would expect because studies almost every time underestimate the costs of central.

This being said, there are, of course, some good impacts like: Irrigation, generation of electricity, allows to control floods, fresh water supply and usually generates opportunities for farming.

Results Analysis

In this part of our report, we want to estimate the various parameters that will be related with precipitation. Precipitation consists in all the water that come from atmosphere and reaches surface of Earth, being measured here and there in isolated points with specials devices called udometers.

In our case, there were available an hourly series for 2008 with values of precipitation from each hour of each that from that year. We also have relevant data for our calculations as the percentage of that precipitation that would be available for us in a specific form, like 20% for direct flow during a period of 24 or 40% as indirect flow being its period of 1 month.

Precipitation for each day of the year:

$$P_{daily} = \sum P_{daily,hour} \left[\frac{mm}{day}\right] \quad [1]$$

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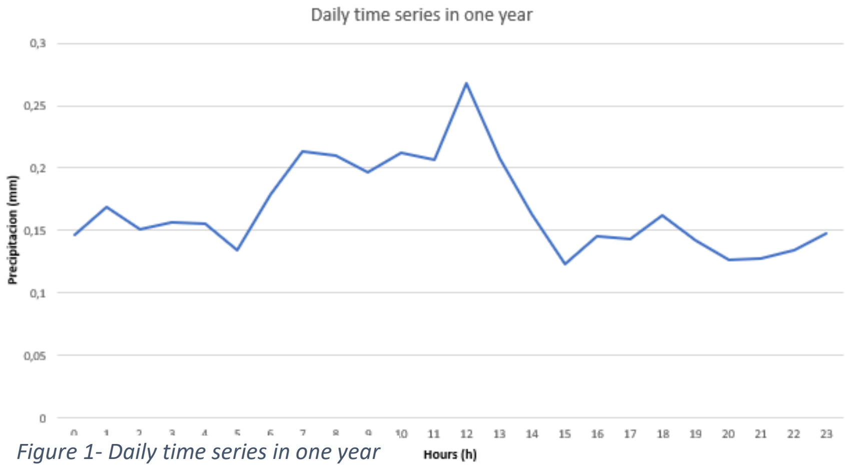

Figure 1- Daily time series in one year

A flow consists of a part of precipitation that goes to a water course through surface or by soil infiltration. This being said a flow in any section of river, in some given time period, the referent the amount of water that crosses that section. As we know 20% of precipitation comes as direct flow:

$$P_{Direct,daily} = P_{daily} \times 0.20 \quad \left[\frac{mm}{day}\right] \quad [2]$$

Knowing that 40% comes as indirect flow we can estimate the amount of water that will be realized throughout time:

$$P_{Indirect,daily} = P_{daily} \times 0.40 \quad \left[\frac{mm}{day}\right] \quad [3]$$

Our 40% indirect flow can't be introduced to our system directly, so we need to calculate its behavior in the period of time that he will be in our system, with this we need to use an exponential for month before of we are analyzing so we can get accumulated indirect flow:

$$P_{Indirect,accumulated} = \sum P_{Indirect[30-n]} \times C.normalization[1+n] \quad \left[\frac{mm}{day}\right] \quad [4]$$

The total amount of water that will run on our riven depends on direct flow and on accumulated indirect flow, this way:

$$P_{Direct\ and\ indirect\ accum} = P_{Direct,daily} + P_{Indirect\ accum} \left[\frac{mm}{day}\right] \quad [5]$$

Counting existing losses and knowing that its value is 20%, we will calculate the flow value that reaches river resulting from sumatory of direct flow and accumulated indirect flow:

$$P_{w/losses} = P_{Direct\ and\ indirect\ accum} * 0.8 \left[\frac{mm}{day}\right] \quad [6]$$

Water available to turbinate is the result from the amount calculated after the previous:

$$P_{avail\ for\ turbination} = P_{w/losses} * 0.80 \left[\frac{mm}{day}\right] \quad [7]$$

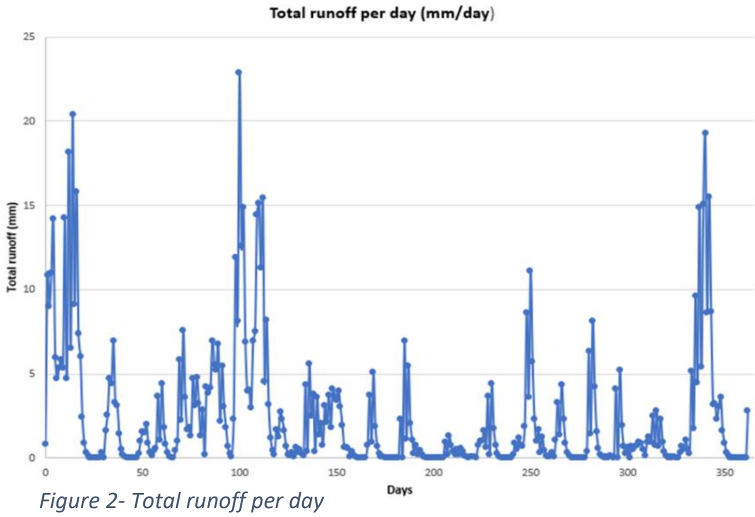

Figure 2- Total runoff per day

Assuming the average flow of river it's the result of the previous steps we calculated constricted in the area of watershed then:

$$Q_{average,daily} = (P_{w/losses} * 10^{-3} * 0.80 * water\ shed\ area * 10^{6})/(3600 * 24) \left[\frac{m^3}{s}\right] \quad [8]$$

Ecological flow describes the amount, quality and timing from flows of water necessary to keep fresh water and ecosystems from estuaries, as well well-being from people that depend on that ecosystem. Main goal its to maintain river ecology, refill aquifers and keep riven channel, can be calculated the following way:

$$Q_{eco} = (Q_{aver,daily} - P_{avail\ for\ turbination} * 10^{-3} * water\ shed\ area * 10^{6})/(3600 * 24) \left[\frac{m^3}{s}\right] [9]$$

Available flow:

$$Q_{avail} = Q_{average,daily} - Q_{eco} \left[\frac{m^3}{s}\right] [10]$$

Average flow from island:

$$Q_{average\ island} = \frac{\sum Q_{avail}}{363\ days} [11]$$

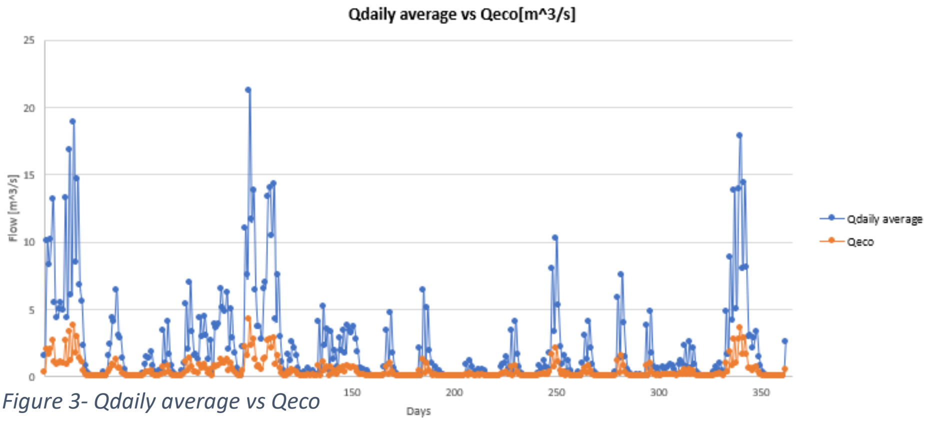

Figure 3- Qdaily average vs Qeco

Power installed in hydroelectric power plants is given by the following formula through some parameters established on protocol of report and with $Q^{island}_{maximum}$ previously calculated:

$$P_{installed} = Q^{island}_{maximum}\ \left[{}^{m^3}/_{s}\right] \times \rho\ \left[{}^{kg}/_{m^3}\right] \times g\ \left[{}^{m}/_{s^2}\right] \times \eta \times h_{fall}\ [m]\ \text{[W] [12]}$$

Average power of hydroelectric power plants:

$$P_{average} = Q^{island}_{average}\ \left[{}^{m^3}/_{s}\right] \times \rho\ \left[{}^{kg}/_{m^3}\right] \times g\ \left[{}^{m}/_{s^2}\right] \times \eta \times h_{fall}\ [m]\ \text{[W] [13]}$$

Energy produced by the station is calculated doing:

$$E_{produced} = P_{average}\ [MW] * 24\ h \times 365\ days\ [MWh] \quad [14]$$

Available energy follows the same thinking:

$$E_{available} = P_{installed}\ [MW] * 24\ h \times 365\ days\ [MWh] \quad [15]$$

We can now calculate number of hours equivalent to nominal power capacity factor:

$$NEP's = \frac{E_{produced}}{P_{installed}} \left[\frac{hours}{year}\right] \quad [16]$$

$$FC\ (\%) = \frac{E_{produced}}{P_{installed} \times 24\ h \times 365\ days} \times 100\ [17]$$

Energy produced for each person in a year, knowing the Island has 50000 people is calculated by:

$$E_{per\ capita} = \frac{E_{produced}}{island\ inhabitants} \left[\frac{MWh/person}{year}\right] [18]$$

Energy density is calculated by:

$$Energy\ density = \frac{E_{produced}}{island\ area} \left[\frac{MWh/m^2}{year}\right] [19]$$

The results are able in the next table:

Installed power [MW]	7.06
Average power [MW]	0.75
FC	10.59
NEPS [h]	928.07
E per capita [MWh/person/year]	0.13
Energy density [MWh/m^2/year]	$1.31*10^{-5}$
Available energy [MWh]	61867.39
Energy produced annually [MWh]	6554.47

Table 1-Results obtained for the above equations

Turbine

To choose which turbine fits better our data and calculations for hydroelectric power plant we used the figure 4. As we can observe, to choose which kind of turbine we will use in this scenario, we need to know three parameters, Maximum flow [m^3/s], power [MW] Height [m]. Once formulas for each of the parameters were enunciated before, by replacement we obtained:

Maximum Flow[m^3/s]	16.96
Power [MW]	7.1
Height [m]	50

Table 2- Necessary results for choosing the turbine

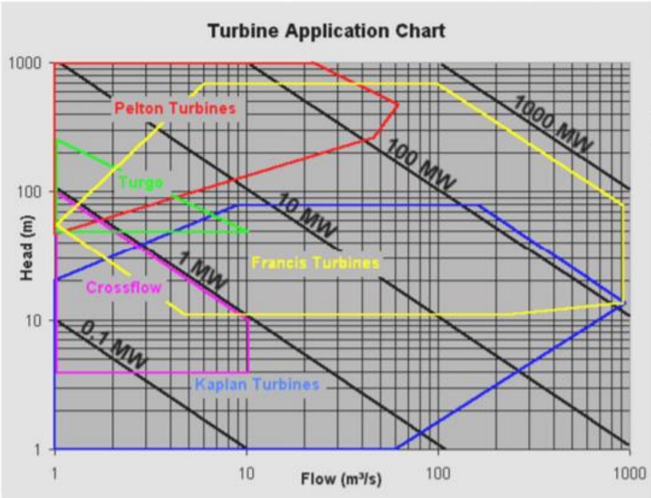

Figure 4- Representation of existing turbine types according to the previous parameters

Through this table, we can deduce that the best turbine to be used will be a Francis turbine, with a factor Kp of 4.500.000 that will use later to know costs.

Costs

So that we can estimate the cost of energy from the island [€/kWh], its crucial calculate how much is the total cost for the hydric powerhouse. Usually there are numerous costs associated to construction of an hydroelectrical station, that can go from study, to supervision of constructions, connection to electric grid and roads, as well as salaries that will not be considered in this report for insufficient information. This way total costs associated to this station, will be considered 75% from different equipment of station and turbines or generators, 25% will be associated to costs of civil construction and infrastructures.

So we resort to this calculation to find out the total cost of station:

$$Total\ cost\ of\ the\ hydroeletric\ power\ = K_p \times P^{0.7}[MW] \times H_{power}{}^{-0.35}[m]\ [20]$$

Where K_p is 4.500.000 for Francis turbine; P is installed power and H_{power} is height of water fall. As we said before:

$$Construction\ equipment\ cost\ = Total\ cost\ of\ the\ hydroeletric\ power\ * 0.75\ \ [21]$$

$$Construction\ cost\ = Total\ cost\ of\ the\ hydroeletric\ power * 0.25\ \ [22]$$

Maintenance cost is influenced by lifetime of our station, that for this project is 40 years and by the actualization rate that we were given, representing a value of 5%, this way:

$$Mantenance\ cost\ = Total\ cost\ of\ the\ hydroeletric\ power * lifetime * discount\ rate$$
[23]

Replacing:

Total cost PowerStation	$4.496*10^6$ €
Equipment costs	$3.372*10^6$€
Construction costs	$1.124*10^6$€
Maintenance	$8.992*10^6$ €

Table 2-Costs

So now we have all the necessary data to get the energy cost [€/kWh] from our station:

$$Energy\ cost = \frac{Total\ cost\ of\ the\ hydroeletric\ power}{E_{produced} * lifetime} = 0.017\ [€/kWh]\ [24]$$