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Energy Recovery in Pressurized Hydraulic Networks

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Abstract: This paper aims to evaluate the possibility of using non-utilized hydraulic energy in urban water distribution systems. For this purpose, the viability and possible alternatives of installing conventional turbines or pumps working as turbines

(PATs=Pumps as Turbines) at the head of pressure hydraulic networks in two towns in the province of Huelva have been studied: Cañaveral de León and Aracena (Andalucía, southwest Spain). Sensitivity analyses are carried out for: (a) To study the feasibility and efficiency of installing turbines or PATs in the hydraulic networks; (b) To determine the required hydraulic capacity of the turbines or PATs; (c) To analyse the installation points in the pipeline network; and (d) To evaluate the possible generation of electrical energy. The evaluation of the recoverable amount of hydraulic energy in both water distribution systems requires the application of the energy conservation equation, taking into account the calculation of load losses, the Darcy-Weisbach equation. A diagram energy height-flow rate with different working ranges of commercial turbines/PATs was used for the selection of the appropriate hydraulic machine. The results obtained of the Aracena hydraulic network show that the best solution would be the installation of a 2 kW BANKI that could generate an approximate annual energy of 17,52 MWh/year. In the Cañaveral de León water supply system a 0,75 kW BANKI turbine with an approximate annual energy generation of 6,57 MWh/year is proposed as the best solution.

Keywords: Reversible hydraulic machine; PAT; turbine; water distribution system; energy efficiency; economic viability

1. Introduction

The recovery of non-used hydraulic energy in pressurized water distribution systems is an alternative to microgeneration of electricity. This could be included in the plans and policies of action that facilitate the development of a sustainable economy compatible with social welfare and environmental requirements (European Comission, 2017). The energy cost is a key aspect for the management of water distribution systems.

Although the efficiency of these systems is increasingly better, the water supply cost linked to energy has risen significantly in the last decades (Lima et al., 2019). In specialised literature, the use of microturbines in pressurized hydraulic networks as an alternative to generate electricity from non-used hydraulic energy has been assessed (Mc Nabola et al., 2014; Kim et al., 2015; Samora et al., 2016a; Rodríguez-Pérez et al., 2017; Rodríguez-Pérez and Pulido-Calvo, 2019).

Actually, a term that is increasingly used is that of 'smart cities', which is closely related to the promotion of environmental sustainability in urban districts that seek self-sufficiency in certain productive and service sectors. One approach is the development and implementation of technology and novel methods for the regulation, control and monitoring of water distribution systems (Keeling and Sullivan, 2012; Dini and Asadi, 2020; Ramos et al., 2020). An alternative to this approach is to consider the use of hydraulic machines, turbines or pumps working as turbines (Pumps as Turbines = PATs) in order to recover most of the energy dissipated in the regulating valves of the urban water distribution systems (Fecarotta et al., 2015; Fontana et al., 2019). One of the key aspects in this type of proposal is the evaluation of the optimal location of these hydraulic machines and the hydraulic capacity required to install them in the pipes systems. The nodes where greater energy is dissipated are analysed, in order to carry out a feasibility study (Power et al., 2016; Samora et al., 2016b; Fernandez-García and Mc Nabola, 2020). Another aspect to consider is the number of turbines to insert in pipe systems (Rodríguez-Pérez et al., 2017). For example, Samora et al. (2016a) studied the parallel installation of microturbines that are activated depending on the existing water demand.

Another alternative is the recovery of hydraulic energy not used in pressure irrigation systems, in which energy consumption can be considered approximately 40% of the total cost of water (Crespo-Chacón et al., 2019). This microgeneration could support in the future the energy supply security in irrigation districts of many regions with potential water scarcity combined with growth in the water demands (Kyle et al., 2021). The studies carried out on the placement of pumps working as turbines (PATs) in water distribution systems for urban and irrigation districts, and which show the viability of this alternative should be noted (Carravetta et al., 2014; Pérez-Sánchez et al., 2017; García-Morillo et al., 2018; Romero-Marrero et al., 2018). This energy recovery system is justified by having, in general, a lower initial investment for certain usable energy heights (Pérez-Sánchez et al., 2020).

The main purpose of this study is to evaluate the possibility and viability of making use of the hydraulic energy dissipated in the regulation valves currently installed at the head of the water distribution systems of the towns of Aracena and Cañaveral de León in the Huelva province (Andalucía, southwest Spain). The management of the potable water supply in these towns is currently carried out by the public company 'Gestión Integral del Agua Costa de Huelva S.A (Giahsa)'. The possibility of installing conventional turbines in both hydraulic networks as well as pumps working as turbines (PATs = Pumps as Turbines) is compared. Both alternatives are compared in order to determine viable and profitable solutions. With regard to the study of economic viability, the analysis was carried out by calculating the payback period (PP).

This paper is an extension and improvement of the work Rodríguez-Pérez and Pulido-Calvo (2019), by means of a more concise and detailed analysis. This was done, considering other water distribution networks, modelling different turbines/PATs locations, and comparing the results in terms of efficiency and viability for both studied systems.

2. Study area

In this paper, we are going to study the water distribution systems of the towns of Cañaveral de León and Aracena (Huelva, southwest Spain) in order to know the possible installation of hydraulic machines (turbines and/or PATs), which can recover the non-used hydraulic energy. The pipe section in which the optimal location of the turbine and/or PAT is analysed includes the conduction between the supply tank and the regulation valve to the intakes of both towns (Fig. 1 and 2).

In the case of Cañaveral de León, the supply reservoir is at a height of 604 m. From there, the water is distributed through a 160 mm diameter polyethylene pipe to the regulation valve at a height of 551 m. From this point, potable water is supplied to the urban nucleus. The flow at the inlet of the regulation valve is 5 l/s. Points in the conduction every 50 m (points 1, 2, ... , 10; Fig. 1) are analysed as locations of turbine and/or PAT installation. The valve, which regulates the inlet flow to the urban nucleus of Cañaveral de León, is a pressure-reducing valve. The pipe is made of 160 mm diameter polyethylene and is 8 years old.

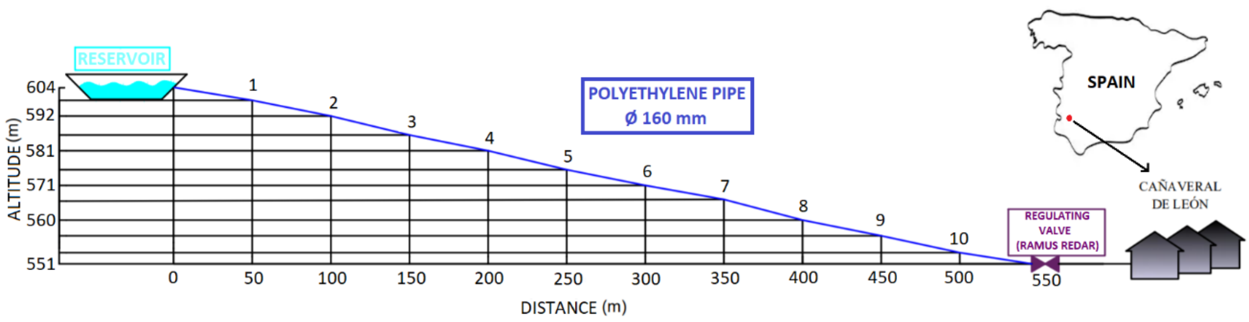

Fig. 1. Scheme of the head of the water supply system in Cañaveral de León (Huelva, Spain).

The water supply system of Aracena has a supply reservoir at an altitude of 715 m. From this the water is distributed through a 250 mm diameter cast iron pipe to the regulation valve, located at a height of 664 m, the purpose of which is to regulate the drinking water flow requirements of this town. The flow at the inlet of the regulation valve is 15 l/s. Points in the conduction every 50 m (points 1, 2, ... , 6; Fig. 2) are analysed as locations of turbine installation and/or PAT. The Aracena regulation valve is a pressure-reducing valve with an external pilot. The pipe is made of 250 mm cast iron and is 10 years old.

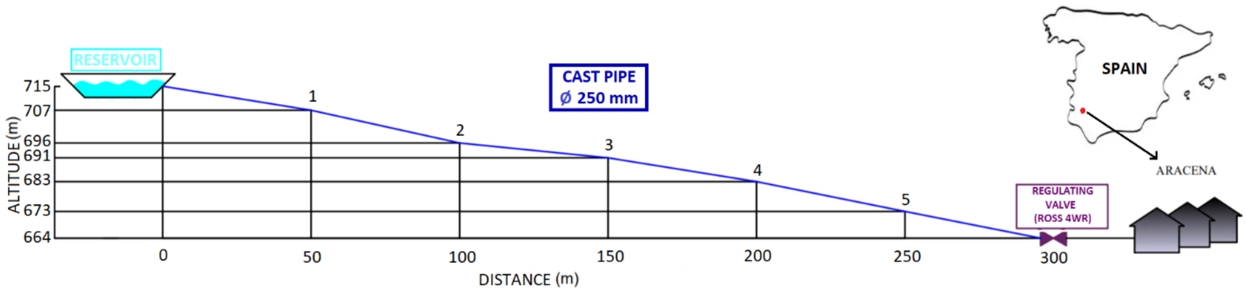

Fig. 2. Scheme of the head of the water supply system in Aracena (Huelva, Spain).

3. Localization and selection of hydraulic machines

The current distribution of monthly flows in each of the water supply systems under study is shown in Figure 3. This figure has been made with the monthly data provided by the company that manages the network. The maximum monthly flows are from April to October in Aracena and from June to September in Cañaveral de León. In the simulations carried out in this work, the maximum flow rates were considered when selecting the hydraulic machines. This facilitates the performance of the turbine by receiving a constant flow. This approach implies a maximum flow operation scheme due to the fact that the water is driven by gravity from the supply tanks (Fig. 1 and 2). This would be possible thanks to the fact that the company has storage tanks in the town to store the excess flow that we could have. In our case, it would be 5 l/s in Cañaveral de León and 15 l/s in Aracena.

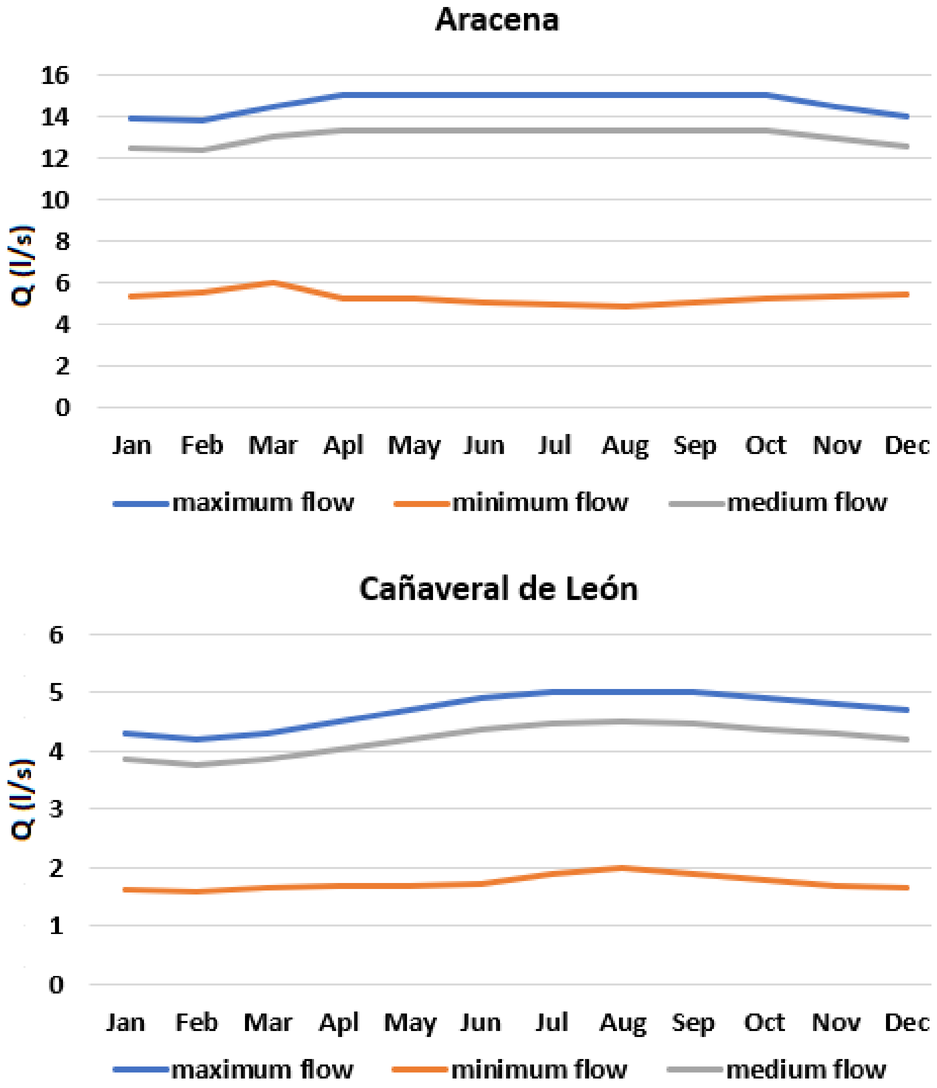

Fig. 3. Temporal series of monthly flows in the water supply systems of Aracena and Cañaveral de León (Huelva, southwest Spain).

A diagram of energy height (H)-flow rate (Q) is shown in Figure 4, representing the ranges in which different types of commercial turbines operate. It was built collecting data from different manufacturers and suppliers of commercial turbines and PATs. Among the types of turbines included in this diagram are BANKI, FRANCIS, KAPLAN, PELTON and TURGO and pumps working as turbines PAT. This H-Q relation has been implemented in a computer program, designed with a user-friendly framework, to support decisions making in the installation of these hydraulic machines in water distribution systems (Rodríguez-Pérez et al., 2021).

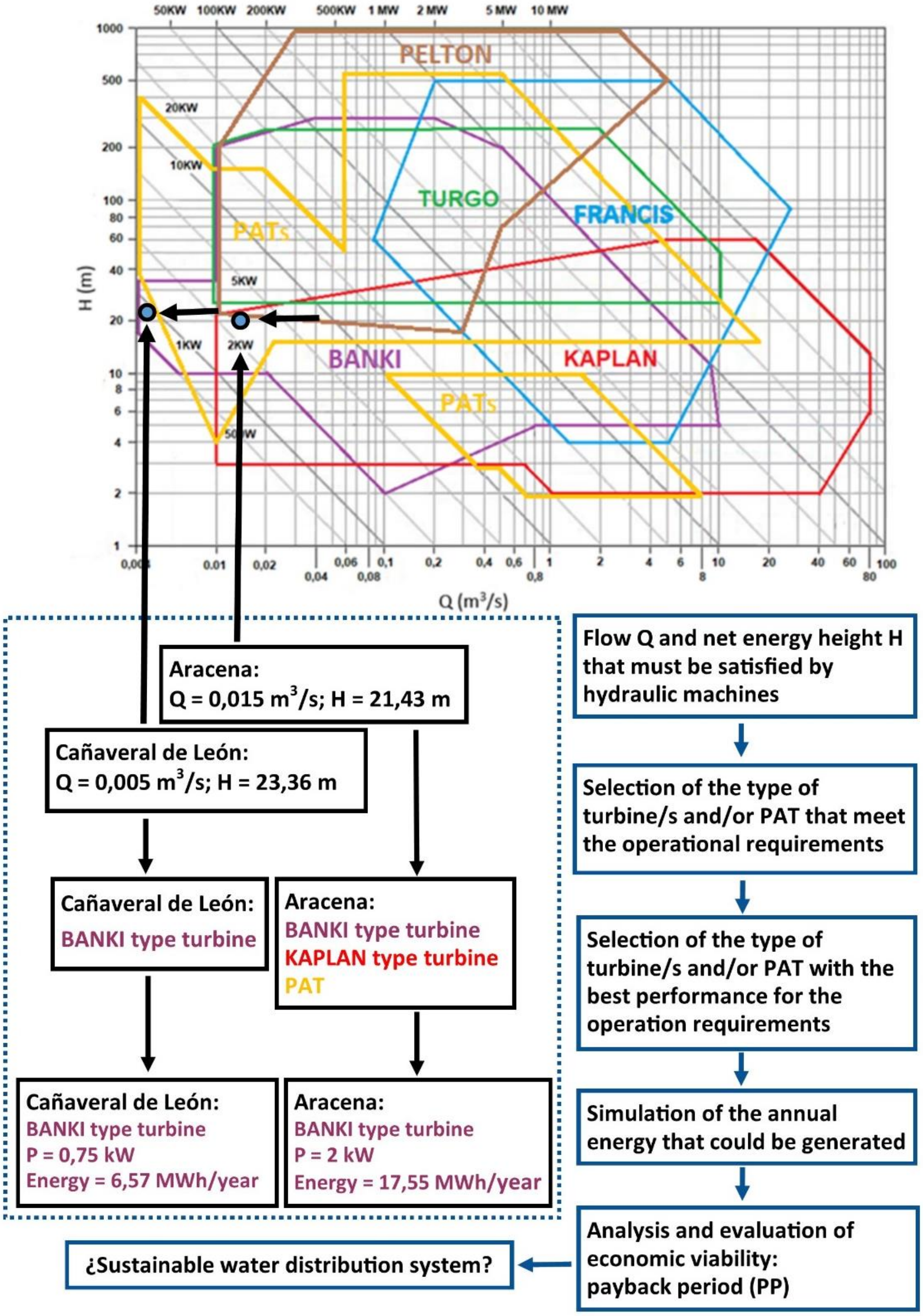

Fig. 4. Operation requirements in diagram energy height (H)-flow rate (Q) for the selection of turbines and/or PATs (pumps working as turbines) in the water supply systems of Aracena and Cañaveral de León (Huelva, southwest Spain) (Rodríguez-Pérez

et al., 2021). Flowchart with the description of the methodology followed to the selection of hydraulic machines.

To determine the optimal location of the turbine installation in the water supply systems of this study, the following parameters are considered: (a) the elevation at the point of installation; (b) the distance at which the aforementioned chosen point is from the supply reservoir; (c) the height of energy required by the fluid at the inlet of the regulation valve; and (d) the non-used energy height of the fluid.

After determining the best location for the hydraulic machine, the velocity at which the fluid water reaches the turbine/PAT, the energy conservation equation is applied, considering and comparing, for the calculation of energy losses due to friction, the Darcy-Weisbach equation. With the flow and speed with which the water reaches the point of optimal location of the turbines/PATs, the selection of those which meet the hydraulic requirements is made considering: (a) the type of turbine (Pelton, Francis ...), (b) the hydraulic capacity of the pumps working as turbines (PATs) (Rodríguez-Pérez et al., 2017). Subsequently, the energy is obtained in MWh which could be generated with the selected hydraulic machine.

Two alternatives for the location of the turbines/PATs are also analysed: in series and in parallel to the regulating valve (Samora et al., 2016a; Rodríguez-Pérez et al., 2017; Rodríguez-Pérez and Pulido-Calvo, 2019). With the option in series to the regulating valve (Fig. 5B), we find the problem that in order to maintain it, the line would have to be stopped. With the second alternative, the turbine would be placed parallel to the regulating valve (by-pass installation) (Fig. 5A). This option is considered the ideal because the maintenance of the turbine/PATs or the regulating valve can be carried out without having to stop the line at any time, thanks to the motorized valve that regulates the flow that circulates through each one of the lines. On the other hand, this motorized valve is also responsible for regulating the maximum flow that must pass through the turbine/PATs, since an excess flow could be a problem for it.

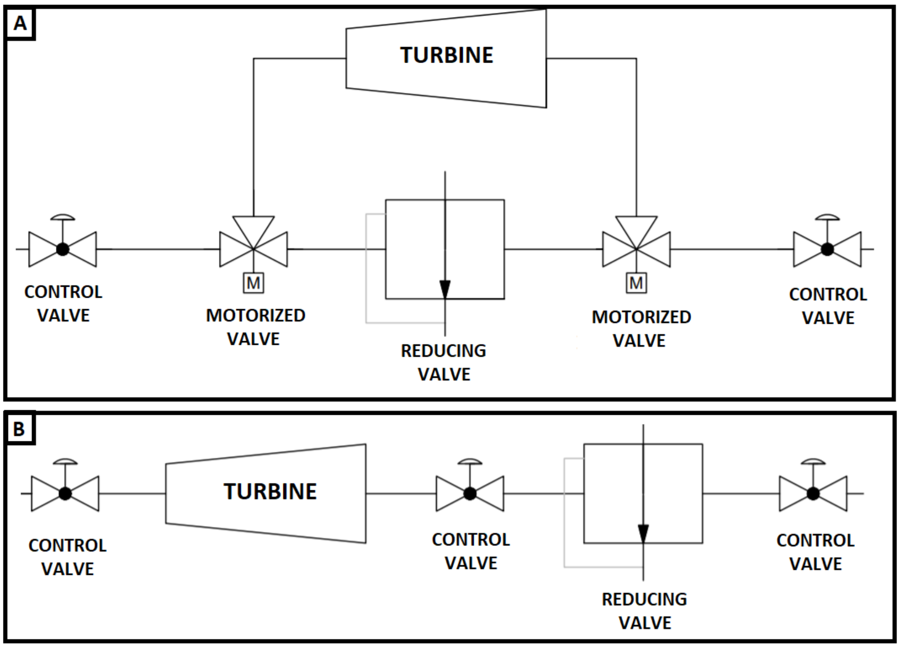

Fig. 5. Alternatives for installing the turbine in the hydraulic network: (A) Turbine in parallel to the regulation valve (by-pass); and (B) Turbine in series to the regulation valve (Rodríguez-Pérez et al., 2019)

The economic evaluation of this study is carried out from the analysis of the payback period (PP) (Fig. 4). It should be noted that the same analysis will be developed in both water supply systems. In order to carry it out, the scenario of this investment project must be established in order to calculate the total cost which the initial investment will entail. An estimation of the energy cost savings involved in turbine installations in the hydraulic networks of the study is also made. To achieve it, some simulations of the fluctuation of the price of electrical energy in future years are evaluated, considering two scenarios. In the first scenario, an annual increase of 3% in the price of energy is evaluated for 10 years. The second scenario foresees a decrease in the price of energy of 3% per year due to the promotion and increase of renewable energies.

3.1 Efficiency and usable annual energy in the water distribution systems in study.

In order to analyse and evaluate the usable energy height (Δh final) in each of the selected locations of Cañaveral de León and Aracena water supply systems (Fig. 1 and 2), in the application of the conservation equation, friction energy losses H_{loss} are calculated using the Darcy-Weisbach and Colebrook-White equations (Equations 1 and 2). For the 8-year polyethylene pipe of the Cañaveral de León headwater system an absolute roughness value of k = 0,0015 mm are considered (Giles, 1962). For the 10-year ductile iron pipe of the Aracena header system an absolute roughness value of k = 1 mm (Giles, 1962).

Darcy Weisbach equation:

$$\mathrm{H}_{\mathrm{loss}} = \frac{8\lambda\,\mathrm{L}Q^2}{g\pi^2 D^5} \quad (1)$$

Colebrook-White equation:

$$\frac{1}{\sqrt{\lambda}} = -2log_{10}\left(\frac{k/D}{3,7} + \frac{2,51}{Re\sqrt{\lambda}}\right) \quad (2)$$

The Reynolds number for a full pipe that the flow circulates inside is given by:

$$Re = \frac{uD}{v} \quad (3)$$

where λ is Darcy`s friction coefficient; k/D is the relative roughness (absolute roughness/pipe diameter); u is the velocity of the fluid; and *v* the kinematic viscosity of the fluid. For the calculation of Reynolds number, a value of 1,0023e-6 m^2/s for the kinematic viscosity of water was taken.

Table 1 shows the hydraulic characteristics of the pipe in the head of the water supply systems of Cañaveral de León and Aracena (Figures 1 and 2). Tables 2 and 3 show all the results of usable energy height for all localizations studied in both water distribution systems. To calculate the length of the pipe in each section, the inclination in each of them (angle) has been taken into account, obtaining a total length of 552,78 m in Cañaveral de León and 304,51 in Aracena (Tables 2 and 3).

Table 1. Hydraulic characteristics for the water supply systems of Cañaveral de León and Aracena

	Q (m^3/s)	D (m)	k (m)	Ɛ =k/D	Re	λ	u (m/s)
Cañaveral de León	0,005	0,16	1,5 e-6	9,375e-6	39697,43	0,0220	0,25
Aracena	0,015	0,25	0,001	0,004	76219,07	0,0298	0,31

Table 2. Simulations of the usable energy height (Δh final) in the Cañaveral de León water supply system (Huelva, Spain), considering different locations of the turbine/PAT (Fig. 1) (Rodríguez-Pérez et al., 2019).

	x abscissa (m)	Δz (m)	α (degree)	Length of the pipe branch L (m)	Head losses by Darcy-Weisbach (m)	ΔH final (m)
1	50	7	7,97	50,49	0,02	6,98
2	100	12	5,71	100,74	0,04	11,96
3	150	18	6,84	151,10	0,07	17,93
4	200	23	5,71	201,35	0,09	22,91
5	250	28	5,71	251,59	0,11	27,89
6	300	33	5,71	301,84	0,13	32,87
7	350	38	5,71	352,09	0,15	37,85
8	400	44	6,84	402,45	0,17	43,83
9	450	49	5,71	452,70	0,20	48,80
10	500	51	2,29	502,74	0,22	50,78
Regulation valve	550	53	2,29	552,78	0,24	52,76

Table 3. Simulation of the usable energy height (Δh final) in the Aracena water supply system (Huelva, Spain), considering different locations of the turbine/PAT (Fig. 2) (Rodríguez-Pérez et al., 2019).

	x abscissa (m)	Δz (m)	α (degree)	Length of the pipe branch L (m)	Head losses by Darcy-Weisbach (m)	Δh final (m)
1	50	8	9,09	50,64	0,03	7,97
2	100	19	12,41	101,83	0,06	18,94
3	150	24	5,71	152,08	0,09	23,91
4	200	32	9,09	202,72	0,12	31,88
5	250	42	11,31	253,71	0,14	41,86
Regulation valve	300	51	10,20	304,51	0,17	50,83

The power P generated by the turbine/PAT in the studied localizations are calculated as:

$$P = \gamma\ ŋ\ Q\ H \quad (4)$$

where Q is the flow driven by the hydraulic machine, H is the usable net energy height, ŋ is the yield of the hydraulic machine (an average value of 85% is considered) and γ is the specific weight of the water (9810 N/m^3). Considering that the turbine/PAT will be in operation 24 hours/day throughout the year (8760 h), the maximum usable energy would be calculated as:

$$\text{Usable energy} = \text{annual hours x P} \quad (5)$$

For the selection of the best locations for the installation of turbines/PATs, the following criteria are followed:

1) The energy available in Cañaveral de León is taken into account, which is 23,36 m. For this reason, locations 1, 2, 3 and 4, in which the available energy has not yet been reached, would be discarded (Table 2). The minimum energy required in

Aracena, is 21,43 m. For this reason, locations 1, 2 and 3 would be discarded in which the available energy has not yet been reached (Table 3).

2) Among the remaining locations, the one with the lowest installation cost is taken into account. As mentioned in the paper, it is intended to parallel the regulating valve with a bypass system. This implies that to obtain a lower installation cost, it should be placed at the shortest possible distance from the regulating valve. It must be taken into account that in this location there is already a pit in which the regulating valve is located and the work that would have to be done would be less significant.

3) Finally, the maintenance that must be performed on the turbines/PATS and the regulating valve is taken into account. If both are in the same pit, it facilitates such maintenance. As the two are in parallel, the maintenance of both elements can be carried out without the need to cut the line, thanks to the motorized valve that regulates the flow that passes through the turbine and the regulating valve.

Cañaveral de León water distribution system:

$$H = 52{,}76\ (m) - 29{,}40\ (m) = 23{,}36\ m \quad (6)$$

$$P_{regulation\ valve} = 0{,}85 \cdot 9810\ (N/m^3) \cdot 0{,}005\ (m^3/s) \cdot 23{,}36\ (m) = 973{,}94\ W \quad (7)$$

Aracena water distribution system:

$$H = 50{,}83\ (m) - 29{,}40\ (m) = 21{,}43\ m \quad (8)$$

$$P_{regulation\ valve} = 0{,}85 \cdot 9810\ (N/m^3) \cdot 0{,}015\ (m^3/s) \cdot 21{,}43\ (m) = 2.680{,}41W \quad (9)$$

With these data, the most appropriate turbine/PAT is chosen for the selected localizations in each of the water distribution systems under study. Figure 4 shows a diagram which represents the ranges in which the types of commercial turbines most used work (Pelton, Francis, Kaplan, Banki and Turgo), as well as pumps working as turbines (PATs). With the requirements for flow (Q) and usable energy height (H), and using this diagram, the type of turbine and/or PAT recommended for the cases under study is determined.

For the Cañaveral de León water distribution system, as can be seen in Figure 4, the only turbine that could be valid for this area is the BANKI type turbine. With regard to a PAT, for this flow and net energy height, it would not be possible. The BANKI turbine which would be placed would have a generated power of 0,75 kW (this power is used since it is the one that can be found in commercial turbines). Therefore, the maximum usable annual energy would be:

$$\text{Annual energy} = 8760\ (\text{h/year}) \cdot 750\ (\text{W}) = 6{,}57\ \text{MWh/year} \quad (10)$$

For the Aracena water distribution system, as can be seen in Figure 4, a BANKI type turbine could be used. On the other hand, it would also be within the range of Kaplan turbines, but in this case, said turbine would be discarded because it is at one end of the section, considerably reducing its performance. Taking into account the characteristics of the selected location, a higher performance would be obtained with the choice of a BANKI turbine (85% depending on the manufacturer). PATs underperform. Therefore, in this case a BANKI turbine is selected, in the same way as we selected in Cañaveral de León. The hydraulic capacity of this BANKI implies a generated power of 2 kW. The maximum usable annual energy would be:

$$\text{Annual energy} = 8760\ (\text{h/ year}) \cdot 2000\ (\text{W}) = 17{,}52\ \text{MWh/year} \quad (11)$$

With regard to the localization of the turbine in the pipes network, both in Cañaveral de León and Aracena, it would be placed parallel to the pressure-reducing valve. This is because by placing it in a parallel position, maintenance can be carried out without the need to cut the hydraulic network that supplies the population. However, if it were placed in a series, the hydraulic network would have to be cut if there were any type of failure in the turbine.

3.2. Economic viability of the proposed alternatives

The investment elements to consider in this investment for the recovery of unusable hydraulic energy in both water supply systems are the following: (a) In the case of the Cañaveral de León hydraulic network, a 0,75 kW commercial BANKI turbine which includes a speed control system and electrical protections; (b) For the Aracena hydraulic network, a 2 kW commercial BANKI turbine with a speed control system and electrical protections. The installation of these turbines requires in both hydraulic networks: (a) a membrane valve; (b) construction materials (cement, bricks, etc.); and (c) the transportation of all these supplies from the factory to the place of delivery and reception. In addition, the cost of installation and initial operation in both municipalities must be taken into account.

The calculation of the cost of these elements has been carried out using real data provided by companies of the sector that estimate the cost of the materials and labours required to install them. Thus, the initial investment values have been established, including the installation costs, which are reflected in Table 4.

Table 4. Budgets for the initial investment of the proposals for the installation of turbines for the use of energy in the water supply systems of the municipalities of Cañaveral de León and Aracena in the province of Huelva (southwest Spain)

	Initial investment budget (€)	
	CAÑAVERAL DE LEÓN	ARACENA
Turbine	6.500,00	7.300,00
Diaphragm valve	300,00	300,00
Construction materials	1.500,00	1.500,00
Equipment transport	250,00	250,00
Initial operation	2.000,00	2.000,00
Budget	10.550,00	11.350,00
21% VAT	2.215,50	2.383,50
Budget with taxes included	12.765,50	13.733,50

It must also be considered that, once the investment has been made, there are some minimal costs related to maintain the investment. These expenses consist on operating costs, eventual repairs and so on. In order to quantify the cost of this maintenance, an approximate cost of 200 €/year has been considered. This amount could be consumed annually or accumulated for the following year, as this type of facility may or may not require this maintenance for several years. Furthermore, it can be considered that the useful life of this investment in both municipalities, with its maintenance, is 25 years.

Therefore, having calculated the parameters of the total initial investment, useful life and annual maintenance cost, we calculate the payback period (PP). According to the data obtained, Cañaveral de León and Aracena facilities are estimated to generate 6,57 MWh/year and 17,52 MWh/year, respectively. The aim of these investments will be to use this generated energy for self-consumption of the hydraulic installations under study. The approximate consumption in the Cañaveral de León water supply system is 13,85 kW and 0,75 kW could be generated, while in the Aracena water supply system it is 2 kW and 2 kW could be generated. The Cañaveral de León installation consumes so much energy because it is the only installation of these characteristics in the municipality, while the Aracena there are many small substations within the same municipality and the energy consumption is lower. The consumptions that exist in both hydraulic networks correspond to the energy expenditure of the machines and the lighting system that currently exists in each of the two installations. For the calculation of the costs related to self-consumption, it is very probable that, in the near future, the new regulation controlling this will not include the high linked taxes due to many of the European regulations that propose and favour economies that make social welfare compatible with respect for the environment.

To calculate the energy savings of this investment, which is considered to have begun in 2020, it is necessary to estimate the fluctuation of the price of electrical energy in subsequent years. With regard to this, the variation that the price of energy has suffered in the last decade, from January 2010 to December 2019, has been analysed, using the data provided by the Iberian Energy Market Operator (OMIE, www.omie.es), which reflects an average annual increase of 3%-4% over the last 10 years.

Two scenarios are taken into consideration in order to calculate the future evolution of the price of energy. Both scenarios have been calculated taking as a starting point the price of electrical energy 2019 (47,7460 €/MWh). Therefore, in the first scenario (scenario a), it is estimated that the price will increase in a similar way as in the last 10 years an average annual increase of 3% is considered. For the second scenario (scenario b), an average annual decrease of 3% is estimated, a situation which could arise in the face of policies to promote and encourage investments in renewable energy, following the recommendations and European regulations (Table 5).

Table 5. Simulation scenarios considered for estimating the evolution of the monthly average price of electrical energy (€/MWh): (a) Considering an average annual increase of 3%; and (b) Considering an average annual decrease of 3%

Year	Scenario (a) Average monthly price of electrical energy (€/MWh)	Scenario (b) Average monthly price of electrical energy (€/MWh)
2020	49,17	46,31
2021	50,65	44,92
2022	52,17	43,57
2023	53,73	42,26
2024	55,35	41,00
2025	57,01	39,77
2026	58,72	38,57
2027	60,48	37,42
2028	62,29	36,29
2029	64,16	35,20
2030	66,09	34,15

The payback period (PP) of the installation of the selected hydraulic machines in Cañaveral de León and Aracena water supply systems is calculated as:

$$PP = a + \frac{I_0 - b}{F_t} \quad (12)$$

with a the immediately previous year in which the investment is recovered, I_0 the initial investment of the project, b the sum of the flows up to the immediately previous year in which the investment is recovered and F_t the cash flow of the year in which it is recovered the investment (Váquiro, 2010).

The investment value (a) including the cost of the installing was given in the table 4. Regarding to calculation of the flows to calculate b and F_t, the flows reflect the inflow and outflow of cash during the useful life of the investment. Therefore, in order to calculate it, we consider the incomes derived from the generated energy by its price, depending of each scenario. We also discount the annual maintenance costs in each location per year.

After calculated these flows, we obtain that for the first scenario the payback of Cañaveral de León is 80 years and the payback of Aracena would be 17 years. However, for the second scenario it was obtained that the payback of Cañaveral de León and Aracena would be higher than its useful life.

4. Conclusions

This study examines the possibility of recovering non-used hydraulic energy at the head of two water distribution systems in two urban areas. A graph of the energy height-flow rate requirements is used to select the commercial turbines/PATs to install in a project of these characteristics and, therefore, it facilitates the estimation of the possible generation of electrical energy. It is recommended that the hydraulic machines be installed in a parallel position with the valve that regulates the distribution of the water flow to each of the intakes of the urban areas.

Although the payback period does not support the decision to promote this type of microgeneration of electrical energy, it would be advisable to add in future studies indexes which characterize the socio-environmental benefits that can be obtained with this type of alternatives.

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