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Reducing costs of electric power generation through the integration of desalinated water production into insular weak electric systems

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ABSTRACT

An assessment of both electric generation and desalinated water production in the islands of Lanzarote and Fuerteventura has been carried out. The electric system is made up of small groups consisting of two different technologies. The cost of generation has a steep profile, existing a difference between on-peak and off-peak electricity prices, being the difference between the first and the latter of double its value. Water production is performed through reverse osmosis-based technologies. Annual costs for water production in both insular systems are higher than €27 M, an estimated 10% of the total electricity generated. The process of water production can be adjusted to time slots at the lowest cost of production, since water can be stored and there are generators available at the installations. Several simulations are proposed for water and electricity production, achieving a reduction of more than 11% in desalination costs.

Keywords: Optimization; Desalination; Economic dispatch; Integrated water–electricity

1. Introduction

Generation through renewable energy sources has evolved considerably during the last decades. The design of complex industrial installations, which minimize operation costs, has given way to an optimal generation where different technologies are combined [1–3]. The development of information technologies has allowed the real time motorization and control of generation, transport and distribution of electrical power, water and gas systems mainly [4,5]. However, due to the high complexity of these systems and the independence of these sectors from one another, systems for monitoring and optimizing generation and distribution remain normally separated.

The presence of renewable energy sources in isolated electric systems has given way to small-scale pilot experiences aiming to the design and optimization of grids or micro-grids, where there is an interconnection between power generation and distribution and water production exists [6–8].

Many of the insular electric networks are of an in-between case. These systems are not very complex, since the number of power generation plants and transport lines are small. However, a growing population and the scarcity of hydric resources force the generation of water for human consumption, all of which have a significant impact on the insular electric

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system, due to the high demand of energy. In these cases, integrated water–electricity is a major need to guarantee the supply and provides flexibility while minimizing costs [9–11].

The strong demographic and economic growth in the islands of Lanzarote and Fuerteventura as a result of the development of both tourism and building industries have produced an increase in the demand of power and water supplies. Providing the system with new electric generation groups has made possible the increasing demand to be absorbed.

Surface and underground hydric resources, on the other hand, have diminished gradually and are not sufficient to cover the demands of the society. Industrial water production has become part of the current basic needs, which demands seawater desalination and regenerated water reuse.

This work is carried out taking data from power generation and water production through the electric system of the islands of Lanzarote and Fuerteventura. These two islands—currently interconnected by a submarine cable—have in common a weak electric generation system and a high level of water production, based on reverse osmosis (RO) technology. This new energy consumption has meant a significant increase in the insular energy demand and therefore greater oil dependence. Furthermore, with the rising cost of energy, it is also desired to find operating methods to reduce the energy consumption of RO desalination processes in the presence of feed wáter variability. This task requires the development and implementation of effective feedback control strategies [12,13]; hence, the importance of integrating power generation and RO water production in order to minimize costs and satisfy supply demands.

First of all, an overview on current systems available for the optimization of power production is presented and used afterward to be applied to RO plants in variable production regime. Data from power generation and desalinated water production in the two islands are addressed right after. Finally, different alternatives for water–electricity integration are proposed.

2. Power generation optimization. Economic dispatch

The "economic dispatch" difficulty consists of determining the power needed for each generator unit in service to supply a determined power $P_{D,}$ in order to secure the supply and minimize total generation costs. For this purpose, it is necessary to consider variables such as fuel variable costs, units' heat rates (HR) of performance, and the transmission network. The economic dispatch of electric generation in big installations was overcome in the second half of the twentieth century [14,15]. Technological developments in generation machines together with current control systems based on artificial intelligent have allowed in this century multimodal economic dispatch covering big interconnected surfaces [16].

2.1. Economic dispatch of a single power station

The description of a thermal generation unit begins with the specification of the quantity of heat input necessary to produce an amount of electric energy output. The input–output characteristic of the generation unit has a quadratic convex form, as shown in Fig. 1. Heat input (H) expressed in Gcal/h is on the ordinate axis and output power (P) given in kW on the abscissa. The function for the quantity of heat (H) equals the following expression:

$$H = a_0 + a_1 \cdot P + a_2 \cdot P^2 \qquad \text{Gcal/h} \tag{1}$$

Multiplying the quantity of heat (H) by fuel costs, the function fuel costs (F) expressed in €/h is then obtained. Total production costs include fuel, own consumption, operation, and maintenance costs. It is assumed that these costs are a fixed value or percentage of fuel costs, and are generally included in the fuel costs curve.

This information is obtained from the tests performed to the generation group at various levels of output power (100, 75, and 50%). The HR is defined as the relation between heat input, expressed in Gcal/h divided by the output power, given in kW.

$$\frac{H}{P} = \frac{a_0}{P} + a_1 + a_2 \cdot P \qquad \text{Gcal/kWh} \tag{2}$$

HR is the reciprocal of efficiency or performance. Fig. 2 shows that the maximum efficiency of the unit

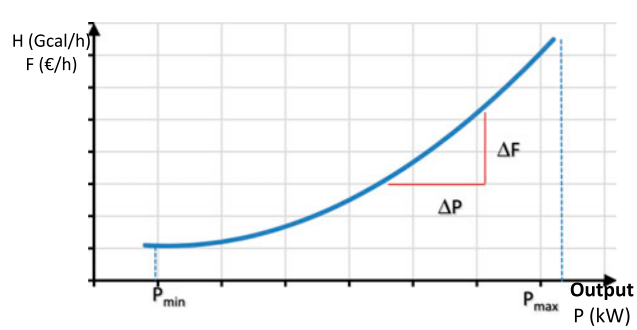

Fig. 1. Input–output characteristic.

is obtained in the minimum of the function (HR), which is given for the values close to the maximum power.

Fuel incremental cost is equal to the derivative of the function cost (F) in relation to power (P) and is given by:

$$\mathrm{IC} = \frac{\mathrm{d}F}{\mathrm{d}P} = a_1 + 2 \cdot a_2 \cdot P \qquad \epsilon/\mathrm{kWh} \tag{3}$$

Generation costs can vary depending on the form and method used to produce electric energy as well as on the characteristic variable costs of each model. The distribution of the load between the different generators requires the simultaneous operation of both old and new generators, maximum and minimum power restrictions in each unit, admissible voltage levels, reactive power, frequency stability, etc.

This theoretical–practical case consists of a configuration of a single station made up of N generation units connected to a bar with an electric demand P_D, as shown in Fig. 3. The known data for each generation unit are the specific costs F_i of each unit to produce the electric energy. Thus, the addition of individual costs is equal to the system total costs, being the basic restriction in this analysis that the addition of the powers injected to the system by all of the generation units must be equal to the power demanded.

Through the mathematical formula to this problem, we obtain a target function to be minimized, which is the result of adding production costs of each generation unit F_i, subjected to the restriction, equalling the addition of the power of each unit to the total power of the demand:

$$\begin{aligned} F_T &= F_1 + F_2 + \ldots. + F_N = \textstyle\sum_{i=1}^{N} F_i \\ P_D &= P_1 + P_2 + \ldots. + P_N = \textstyle\sum_{i=1}^{N} P_i \end{aligned} \tag{4}$$

The optimization problem is solved using Lagrange operators, which consists of defining a new function

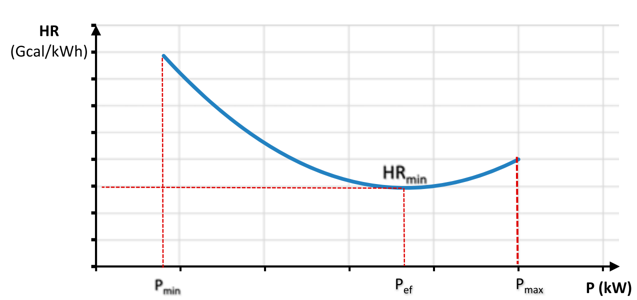

Fig. 2. HR.

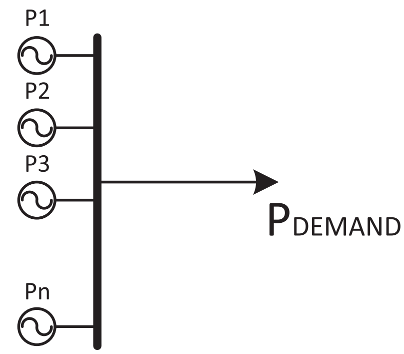

Fig. 3. Unimodal economic dispatch.

including generation costs and the mentioned restrictions in Eq. (4) being:

$$\text{To minimize} = L = F_T + \lambda \cdot \left(P_D - \sum_{i=1}^{N} P_i\right) \tag{5}$$

Operative limits of generation units must also be added to the optimization. That is, the output power of each unit must be greater or equal to the minimum allowed power (e.g. technic limit) and smaller or equal to the maximum power allowed in the generation unit. Formulating the economic dispatch optimization problem is as follows:

$$P_{i,min} < P_i < P_{i,max} \tag{6}$$

Kuhn–Tucker conditions complement Lagrangian conditions, in order to include inequality restrictions as additional terms. The conditions necessary for the economic dispatch of a unimodal station are:

$$\begin{aligned} &\frac{\mathrm{d}F_i}{\mathrm{d}P_i} = \lambda && P_{i,min} < P_i < P_{i,max} \\ &\frac{\mathrm{d}F_i}{\mathrm{d}P_i} \leq \lambda && P_i = P_{i,max} \\ &\frac{\mathrm{d}F_i}{\mathrm{d}P_i} \geq \lambda && P_i = P_i = P_{i,min} \end{aligned} \tag{7}$$

Adding minimum power $P_{i,min}$ and maximum power $P_{i,max}$, as well as the restrictions of each generation unit, increases the complexity in the function (5), resulting in:

$$\text{To minimize}: L = F_T + \lambda \cdot \left(P_D - \sum_{i=1}^{N} P_i\right) + \sum_{i=1}^{N} \mu_i \cdot (P_i - P_{i,max}) + \sum_{i=1}^{N} \beta_i (P_i - P_{i,min}) \tag{8}$$

This allows aggregating more terms to the Lagrange equation, to the extent that more restrictions are taking into account, until the number of equality or inequality restrictions is sufficient to achieve the optimization problem showing, as accurately and precisely as possible, all the conditions found in the economic dispatch conformed to reality.

2.2. Economic dispatch of an electric network

This section describes the general lines for the performance of an economic dispatch in regard to the electric energy generation, when conformed by several electric stations with their own generation units and various transport lines powering the electric consumptions.

Besides the above-considered terms, several factors must be included in the equation to be minimized in (8). It must be taken into account the complexity of the resolution in real time to minimize the total costs of electric production [17–20]. The most significant factors to be included are, among others, the following:

- Energy transport losses.
- Voltage limits in every node of the electric network.
- Time, start-up and stop costs for every generation unit.
- Programmed maintenance for every generator or transport line.

3. Power generation and water production in the islands of Lanzarote and Fuerteventura

This section describes the power generation and water production systems in the islands of Lanzarote and Fuerteventura. Next, electric energy demand data are shown in order to assess the importance of water production within power production.

3.1. Power generation in the islands of Lanzarote and Fuerteventura

The single-line diagram of the electric systems in the islands of Lanzarote and Fuerteventura is shown in Fig. 4. The network is made up of two power stations, one in each island, three substations in the island of Fuerteventura, two substations in the island of Lanzarote, and a submarine cable that connects both electric systems.

Table 1 shows the power generation technologies in both islands. As it can be observed, diesel engines and gas turbines are the only technologies used. The first of these two technologies generates an inferior consumption and is used as base generator. Gas turbines, on the other hand, are used to generate the power at demand peaks, since this technology despite having a higher specific consumption has also a higher speed response.

Some of these electric generation groups are older than 30 years. This obsolete technology is currently being replaced. Electric generation data in each of the two islands, first separately, and then as a whole, are presented in Table 2.

Table 2 shows the annual generation data from 2006 until 2012. Energy consumption has followed an increasing trend until 2008. However, it can be observed that after the maximum value in 2008, energy consumption has experimented fluctuations.

3.2. Water production in the islands of Lanzarote and Fuerteventura

Public water desalination plants in the island of Lanzarote are managed by INALSA—a public company, operating with investments from local and municipal governments. In Fuerteventura, on the other hand, water production is managed by the Insular Water Council. However, there are also private plants in some municipalities. Table 3 shows water production in both islands, first separately, and then as a whole.

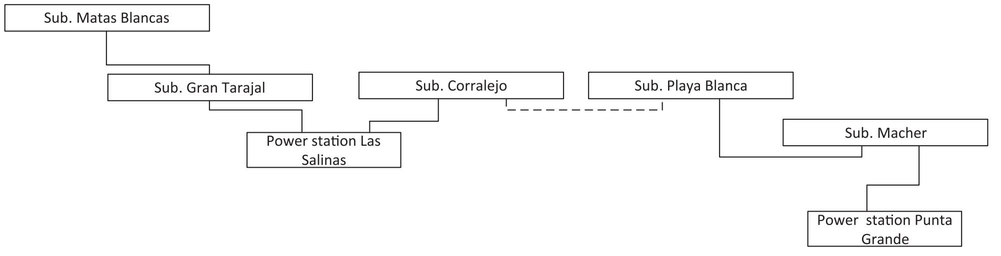

Fig. 4. Single-line diagram of the electric system in the islands of Lanzarote and Fuerteventura.

Table 1
Technologies and power generation in Lanzarote and Fuerteventura power stations

Island	Station	Technology	Group	Effective net power (MW)
Lanzarote	Punta Grande	Diesel oil	Diesel 1	6.49
			Diesel 2	6.49
			Diesel 3	6.49
			Diesel 4	12.85
			Diesel 5	12.85
			Diesel 6	20.51
			Diesel 7	17.20
			Diesel 8	17.20
			Diesel 9	17.60
			Diesel 10	17.60
		G.T. (Gas oil)	Gas 1	19.60
			Gas 2	32.34
			Total Lanzarote	187.22
Fuerteventura	Las Salinas	Diesel oil	Diesel 1	3.82
			Diesel 2	3.82
			Diesel 3	4.11
			Diesel 4	6.21
			Diesel 5	6.21
			Diesel 6	20.51
			Diesel 7	17.20
			Diesel 8	17.20
			Diesel 9	17.20
		T.G. (Gas oil)	Gas 1	21.85
			Gas 2	29.40
			Gas movile 1	11.74
			Total Fuerteventura	159.27

It can be appreciated from data in Table 4 that water monthly produced in water-treatment plants in the islands of Lanzarote and Fuerteventura remains constant, with no periods of higher production, since there is no seasonal consumption.

Water production in both islands is performed in RO plants located in different urban areas. The total of operating plants in both islands is shown in Table 4.

Installation and maintenance basic costs for RO technology are presented in Table 5 [21]:

3.3. Power generation and water production systems

This section studies the most important characteristics in both power generation and water production systems. Each system works with a separated organization, existing only one operator in the electric system. Data of energy profiles and costs for years 2011 and 2012 have been extracted from the operator. Power generation production costs are presented in Fig. 5, along with annual hours. The maximum values correspond to the use of both diesel and gas turbine technologies. Compared to year 2011, there are few fluctuations in 2012, which is not significant. Fig. 5(b) shows the values of accumulated hours.

The energy demand profile has been obtained for year 2012. Fig. 6(a) shows the hourly evolution with three curves corresponding to the profiles of the minimum, medium and maximum costs, respectively. In the same way, Fig. 6(b) describes the annual costs, showing the minimum, medium, and maximum energy day by day.

The extremely high costs during peak hours must be highlighted, since these costs double exceed those during off-peak hours. There is also a variability in costs according to the day of the week, as Fig. 6(b) shows. These fluctuations in energy consumption are of key importance and will be used in the design of different alternatives for water production with RO technology.

Water producing companies in both islands have the potential to produce a volume higher than the actual produced, considering the fact that there are reservoirs for maintenance, programmed stops, non-predicted contingencies, etc. A normal operation entails a steady water production during the year.

Table 2
Annual electric energy production in the islands of Lanzarote and Fuerteventura, first separately, and then as a whole

Year	Lanzarote (MWh)	Fuerteventura (MWh)	Lanzarote–Fuerteventura (MWh)
2006	840,862	651,195	1,492,057
2007	891,132	696,460	1,587,592
2008	899,134	700,718	1,599,852
2009	865,663	662,356	1,528,019
2010	874,717	649,013	1,523,730
2011	850,558	662,891	1,513,449
2012	856,475	659,409	1,515,884

Table 3
Annual desalinated water production in the islands of Lanzarote and Fuerteventura, separately and as a whole

Year	Lanzarote (m^3)	Fuerteventura (m^3)	Lanzarote–Fuerteventura (m^3)
2006	20,620,045	14,678,146	35,298,191
2007	21,582,838	15,219,407	36,802,245
2008	22,215,534	15,415,836	37,631,370
2009	22,648,675	14,020,019	36,668,694
2010	23,017,465	12,664,627	35,682,092
2011	23,734,678	12,825,253	36,559,931
2012	24,171,890	12,645,603	36,817,493

Table 4
RO plants in Lanzarote and Fuerteventura

Island	Public and private management	
	Location	Capacity (m^3/d)
Fuerteventura	Puerto del Rosario	23,000
	Corralejo	4,000
	Gran Tarajal	4,000
	La Oliva	13,690
	La Antigua	12,540
	Pájara	19,870
Island total		77,100
Lanzarote	Arrecife Lanzarote III	42,000
	Arrecife Lanzarote IV	42,000
	Planta Sur Janubio	7,500
Island total		91,500
Total		168,600

Table 5
RO basic costs

Unit cost of exploitation	0.37 €/m^3
Investment amortization	0.23 €/m^3
Rejection percentage	55–60%
Energy consumption	4.5 kWh/m^3

There might be occasional fluctuations in the production, due to climate circumstances, or failures in the reservoirs or in the distribution pipelines. In any case, for the purpose of this study, a steady production will be considered, being discarded any unpredictable behavior. From data in Table 4, which show the percentage of usage of each installation, we conclude that although both installations have the potential of production, both count with reservoirs to solve problems in the production. The reservoir in the island of Lanzarote is currently inferior in comparison with the reservoir in Fuerteventura; the total capacity of both is of 28%, being the average percentage usage of each installation of 72.3%. Table 6 provides the data on the water production in each of the installations in 2011 and 2012.

Data on Table 7 show the global power demanded by RO plants in Lanzarote and Fuerteventura together. The percentage employed to produce desalted water has been calculated treating data on global power generation, water production, and energy costs of a cubic meter produced through RO.

The last column in Table 7 shows the percentage of the energy produced, which is then used in seawater desalination. Though conservative considering the actual installations, a value of 4.5 kWh/m^3 has been fixed as average cost. As a result, we conclude that the percentage of energy consumed in water production is around 10–11% of the total energy generated.

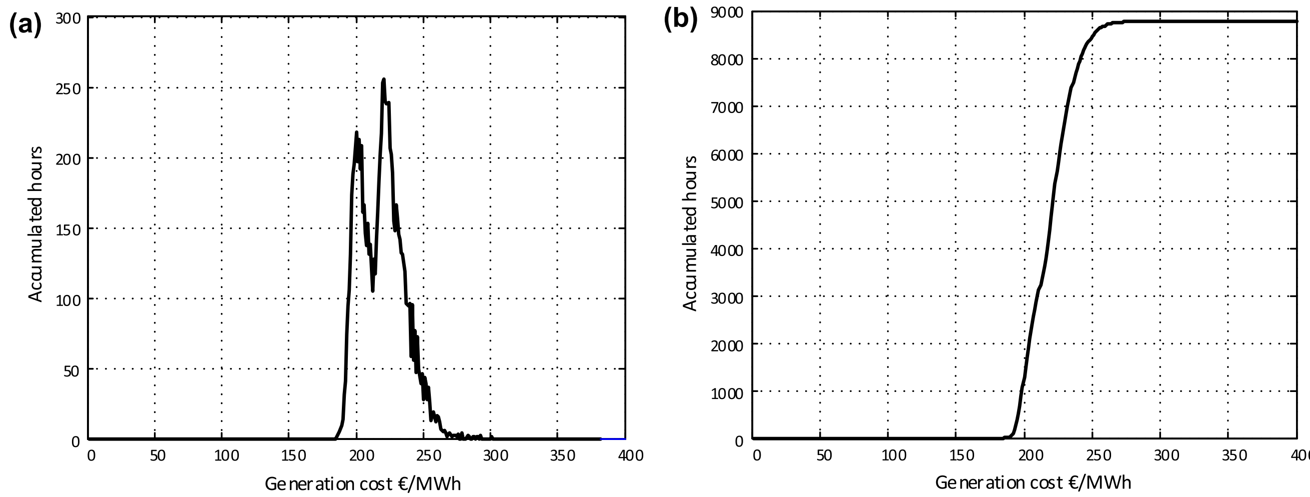

Fig. 5. (a) Profile of energy costs and (b) Number of accumulated hours, 2012.

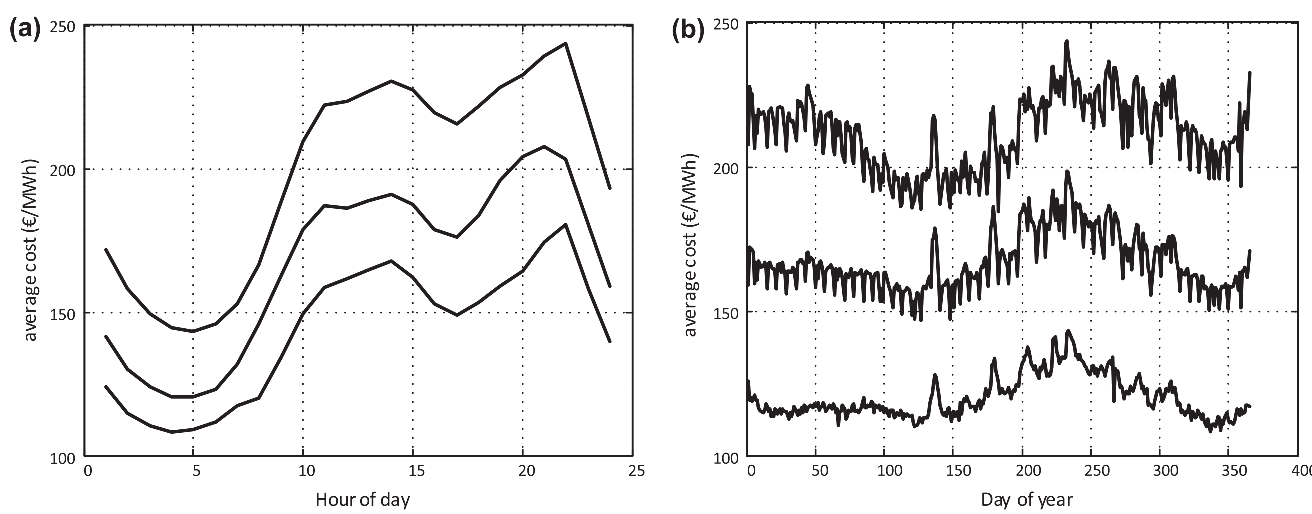

Fig. 6. (a) Profile of average hourly consumption and (b) Profile of 2012 annual costs on a daily basis.

Table 8 shows data of costs related to water desalination in 2011 and 2012, amounting to more than €27 M a year.

4. Flexible integration of desalination plants with the insular electric systems

There are different alternatives available for the integration of desalination plants with electric systems. Generally, electric systems have their own optimization management. However, generation optimization does not necessarily manage a global production, power generation, and water production in an optimal way. Also, this section presents alternatives for an optimal integration. The following are the alternatives available from a technical point of view:

- Discontinuous connection of a water desalination plant
- Variable connection of a water desalination plant
- Discontinuous connection of a water desalination plant operating with variable power.

4.1. Discontinuous connection of a water desalination plant

Costs of water desalination plants connected discontinuously or intermittently to the electric system have already been assessed in some investigations

Table 6
Water production in the installations. Percentage of usage

Island	Location	Public exploitation			Private exploitation			Percentage of usage (%)
		Capacity (m^3/d)	Production (m^3) 2011	Production (m^3) 2012	Capacity (m^3/d)	Production (m^3) 2011	Production (m^3) 2012	
Fuer.	Puerto del Rosario	23,000	6,200,255	6,100,975				72.6
	Corralejo	4,000	824,535	898,630				61.5
	Gran Tarajal	4,000	586,190	714,670				50.0
	La Oliva				13,690	1,303,568	1,282,146	25.6
	La Antigua				12,540	1,564,282	1,479,398	32.3
	Pájara				19,870	2,346,423	2,169,784	30
Total		31,000	7,610,980	7,714,275	46,100	5,214,273	4,931,328	45
Lanz.	Lanzarote III	42,000						73.3
	Lanzarote IV	42,000						73.3
	Planta Sur Janubio O.I.	7,500						60
Total		91,500	23,734,678	24,171,890				72.3

Table 7
Power generation and water production in the islands of Lanzarote and Fuerteventura

Year	Power generation Lanzarote–Fuerteventura (MWh)	Desalted water produced Lanzarote–Fuerteventura (m^3)	Energy costs for water production (4.5 kWh/m^3)	Percentage of energy generated employed in RO (%)
2006	1,492,057	35,298,191	158,841	10.64
2007	1,587,592	36,802,245	165,610	10.43
2008	1,599,852	37,631,370	169,341	10.58
2009	1,528,019	36,668,694	165,009	10.79
2010	1,523,730	35,682,092	160,569	10.53
2011	1,513,449	36,559,931	164,519	10.87
2012	1,515,884	36,817,493	165,678	10.92

Table 8
Power generation and water production costs in Lanzarote and Fuerteventura

Year	Power generation Lanzarote–Fuerteventura (MWh)	Unit cost (€/MWh)	Power generation annual costs (M€)	Desalted water produced Lanzarote–Fuerteventura (m^3)	Percentage of energy generated employed in RO	Electric annual cost for water production (M€)
2011	1,513,449	1,686,572	255.25	36,559,931	10.87	27.74
2012	1,515,884	1,670,169	253.17	36,817,493	10.92	27.64

[22]. Those are water production installations connected to the electric systems only when electricity production costs are reduced (when diesel engines are operating; the case of the studied islands), preventing water to be produced during peak hours when costs are extremely high. This way, water is produced during off-peak hours, which generally coincide when electric generation is working with diesel engines. The major inconvenience of this model is the demand of higher capacity in production referring to desalination plants, since they will be operating for a decreased number of hours. The amortization of these installations would be higher than this from desalination plants with a continuous connection, but the difference in real production costs justifies the model. A simulation would be of use in order to define the

amount of equivalent hours for water production in this type of systems. Two simulations have been performed on the basis of the following hypotheses:

(1) Hypothesis 1: plant with no reservoir
(2) Hypothesis 2: reservoir of 10% full the plant.

Both hypotheses can give an estimated result of the reduction in water production costs for both islands. Since the Fuerteventura's reservoir is greater than Lanzarote's—being 55% the first, and 27.7% the latter, greater results are obtained for the island of Fuerteventura. These two hypotheses will allow calculating the number of operation hours needed to produce the necessary volume in each island and determining the more appropriate hours in the production costs curve for a kWh. With the data obtained, total costs of water production for each island can be assessed.

Simulation results are shown in Table 9. In the island of Lanzarote, 6.400 operation hours are necessary to produce the volume of water to cover the demand. Likewise, producing the sufficient volume of water in the island of Fuerteventura requires 4.000 operation hours. It can be observed that electric energy costs diminished from 167.01 to 153.7 €/MWh in Lanzarote and to 138.1 €/MWh in Fuerteventura. In the second simulation, which entails a higher number of operation hours for water production, generation costs increase. Coordinating power generation costs with water production costs could result in a maximum reduction of approximately 10% of the total.

4.2. Desalination plant with a variable connection

Previous works have demonstrated the capacity of desalination plants operating in a variable connection regime. Moreover, one of the main conclusions of these studies carried out in this line [21] indicates that RO plants have a similar behavior to the previously defined in generation groups, as shown in Fig. 7.

Each production module must be studied locally in each RO plant, in the same way as previously done in the case of electric energy generation systems, until getting their correspondent consumption and production curves. The aim in this case will consist in obtaining cubic meters for the production and kWh for the input power demanded.

If we define variable W as the total volume produced by a single module we obtain Eq. (9) for the RO plant, being:

$$P = b_0 = b_1 \cdot W + b_2 \cdot W^2 \qquad \mathrm{KW/m^3/h} \tag{9}$$

The cost function, using the Lagrange operator and incorporating the capacity of each module in the water production plant, is of the following form:

$$\text{Tominimize}: L = P_T + \lambda \cdot (W_D - \sum_{i=1}^{M} W_i) + \sum_{i=1}^{M} \mu_i \cdot (W_i - W_{i,max}) + \sum_{i=1}^{M} \beta_i \cdot (W_i - W_{i,min}) \tag{10}$$

Each variable maintains the same analogy as expressed in Fig. 8. The function must minimize the total energy consumption in the plant. The first restriction is the quantity of water that must be produced, being W_D the value for the desired demand. This value will have to include the advantage of water, allowing the storage and making flexible the economic dispatch of water production. The last two restrictions will limit the production capacity of each module. This way the water producing company will minimize production costs, since water demand is adjusted in each operating module to an optimal operating point. The available information on water production and power generation is used to calculate the production per cubic meter, in order to define the optimal operation mode of the installation. This curve must be

Table 9
Power generation and water production costs in 2012. Simulation of hypothesis 1 and hypothesis 2

	Actual			Hypothesis 1. Reservoir (0%)			Hypothesis 2. Reservoir (10%)		
	Annual hours	Cost MWh	Water production costs 2012 M€	Annual hours	Cost MWh	Water production costs 2012 M€	Annual hours	Cost MWh	Water production costs 2012 M€
Lanzarote	8,760	167.01	18.17	6,400	153.7	16.71	7,100	157.39	17.12
Fuerteventura	8,760	167.01	9.97	4,000	138.1	7.86	4,400	141.05	8.02
Total M€ (reduction %)	27.74			24.58 (−11.4%)			25.15 (−9.3%)		

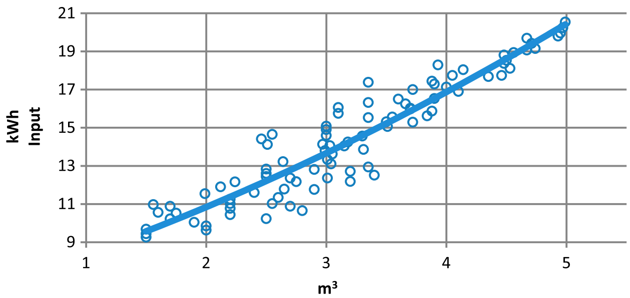

Fig. 7. Power input vs. water production in a conventional tube with six membranes.

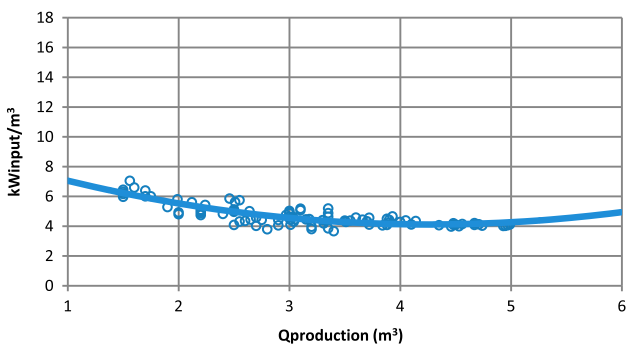

Fig. 8. Power input per cubic meter produced vs. water production in a conventional tube with six membranes.

calculated for each production unit to find their optimal point. Fig. 8 corresponds to the experimental installation made up of a tube with six membranes—as described in previous works [22], shows the optimal position for the production of desalted water in the installation.

As it can be observed in Fig. 8, for a single tube, it is possible to get a fluctuation in performance when production is between 3 and 6 m^3. This variation, though little, must be considered for the total number of existing tubes. In the experimental installation, a variation of around 1% can be obtained. This value must then be multiplied by the number of tubes in the installation, from what the lowest energy consumption can be obtained.

4.3. Discontinuous connection of a water desalination plant operating with variable power

This section describes the operation of an electric system in coordination with a desalted water production system and the optimization at the desalination processes. This alternative includes the previous two and the same advantages and disadvantages already described.

In this situation, the electric power operator will have to command start-ups and stops of each module and indicate the operation points of each water production unit. This way, the system operator can modify the electric demand variable, obtaining further costs reduction in the water–electricity system. The design of a smart network allowing the operation of RO plants being commanded from the central dispatch of electric energy production will lead to the inclusion of the performance improvements indicated in Sections 4.1 and 4.2 simultaneously, getting the already mentioned improved results.

5. Conclusions

(1) Power generation costs in weak insular electric systems are excessively high depending on the hour of the day, being the average cost 167.01 €/MWh.
(2) Increasing the energy demanded when power generation performance is not optimal can reduce considerably the costs.
(3) Water production through artificial methods such RO is one of the most energy consuming elements in these two islands, where hydric resources are scarce.
(4) The flexibility in water production, due to the possibility of storage allows managing the economic dispatch in conventional power generation plants, increasing or lowering water production when generators are in an optimal operation point, but power costs are high.
(5) With the management of water energy systems, energy production costs can be lowered in more than 11%, and even 17% in some occasions.
(6) Optimization of specific consumptions at RO can further improve the energy costs for water production.

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