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Intelligent load management in local and wholesale demand response markets

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Demand Response Cost vs Cost of Energy Purchased in the Wholesaler Market

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Abstract

With the increase of the production of electricity through renewable sources and the with the growing penetration of distributed production (decentralized production) as well as the implementation of the concept of Demand Response (DR), it is progressively possible to operate distribution networks autonomously. The aim of the DR concept it is to reduce consumption in exchange of an incentive or remuneration, when requested. This article studies the implementation of DR in a distribution network in order to verify what type of remuneration (tariff) suits best, from the point of view of the network operator.

Keywords: demand response, tariff, energy

1. Introduction

The growing technological evolution, the constant rise of the consumption of electric energy, the increase of the renewable power production and the alteration of the paradigm of the electric sector, all led to the creation of measures, which aim to rationalize consumption. Hence, a new concept called Demand Response (DR) emerged. It aims to reduce electricity consumption in certain periods (excessive consumption, possibility of not starting a generator, etc.) in exchange for remuneration [1], [2].

This concept is only possible due to the current technological evolution and allows that the customer, who usually has a passive role in the network to become an active customer, able to reduce consumption when requested. In this paper, we intend to study the profitability of the use of DR in a small electric network managed by an operator in an island concept.

In this paper, we will approach the case study, the methodology, followed by a brief explanation of the DR concept in point 4, and the analysis of the results, listing the conclusions drawn from this study.

2. Use Case (Analysis of the Tariff Adequate for DR)

In this use case, we propose an analysis according to the perspective of the network operator, about the best type of compensation to customers with DR contracts. Therefore, two different types of tariffs were defined for the remuneration of the network operator, whenever there is an underballast of loads.

After the definition of the tariffs, several scenarios were created. In each one, the request for DR was verified through the linking of aspects such as the quantity of energy discharged, the number of periods in which the request occurred and the remuneration paid to each type of customer. In this study, we chose the

operator / Aggregator to be as self-sufficient as possible, thus we will also need to analyze the amount of energy not purchased as well as its cost.

2.1. Concept

To create this study, we will propose an analysis of an intelligent net, with distributed production (DP). An operator manages the whole network and, therefore, we will call it the aggregator. As presented in figure 1, this network consists of residential, commercial and industrial customers. Some of these clients have energy production in units, which enabled some of these customers to enter into energy sales contracts with the aggregator. The aggregator also has a wind farm and a solar park giving it a significant energy production capacity.

Where:

- 1) Command Aggregator Center
- 2) Wind Farm
- 3) Solar Park
- 4) Industry
- 5) Trade
- 6) Customer with Production
- 7) Customer with DR
- 8) Customer without production and DR

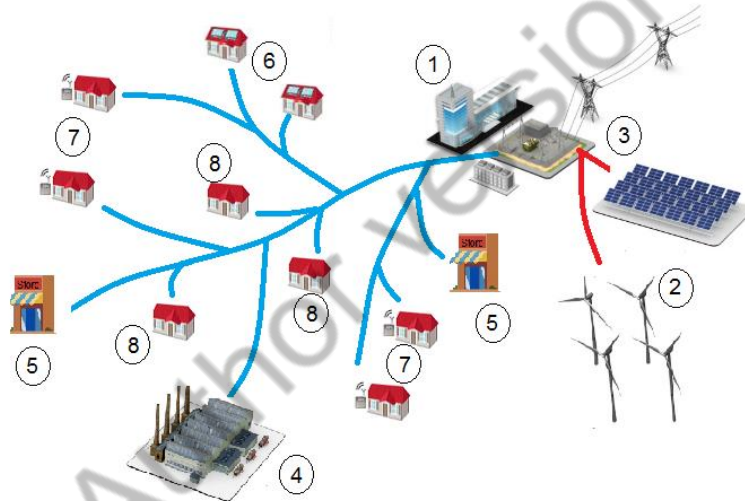


Fig. 1: Aggregator Smart Grid.

Due to the high productive capacity, the aggregator wants to become as self-sufficient as possible. Thus, it intends to incorporate a system of Demand Response (DR) so that in periods when production approaches consumption (but it is not enough to satisfy all demand) through DR, loads are underballasted, reducing consumption to levels equal to those produced.

When demand is higher than production, the aggregator will have to buy the necessary energy in the wholesale market through the Iberian market (MIBEL).

2.2. Methodology

In order to accomplish this study, it was necessary to acquire several consumption profiles (with and without production) [3] acquire production history through wind power plants and Photovoltaic [4] and acquire the historical energy prices in MIBEL [5]. The number of DR profiles, the number of groups per type and the amount of remuneration for each profile were also defined.

As can be seen in Figure 2 the analysis had two aspects. In the first there is no forecast of consumption or production and whenever there is possibility is done DR. The second aspect is considering the existence of forecasts in terms of quality of consumption, production and energy price in MIBEL (as it would be expected in a user operator in the energy market).

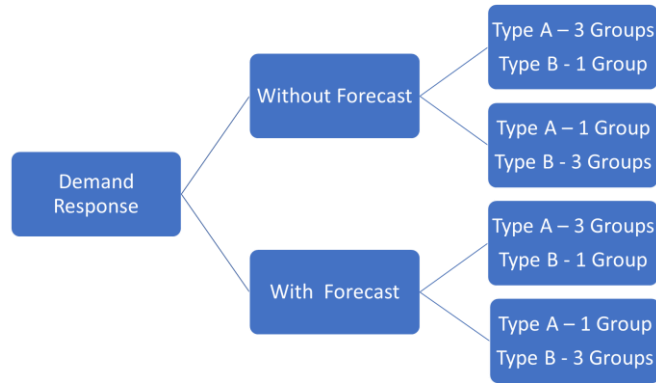


Fig. 2: Proposed scenarios.

Due to the number of clients, it was possible to create 4 client groups with DR contracts. Each group has the ability to blast up to 15 kWh for each 15-minute period.

The difference between the groups is the level of remuneration for the application of DR:

- Remuneration A
 - Have a fixe remuneration and for each request the remuneration adds 5%
 - If the underballast need does not reach 15 MWh in one period the DR can continue in the following period without any type of aggravation
 - Maximum of 5 requests per week
- Remuneration B
 - Have variable remuneration depending on the daily period
 - Drainage capacity is 15 MWh per period
 - Impossibility of being requested DR in two consecutive periods
 - Maximum of 5 requests per week

The remuneration value per kWh is presented in the following table because it is the magnitude that makes the most sense for the final consumer.

Table 1. DR Tariff.

DR Tariff						
Hour	Remuneration Type A with penalty					Remuneration Type B
	Normal	5%	10%	15%	20%	
00:00 - 01:00	0,045 €	0,047 €	0,050 €	0,052 €	0,054 €	0,035 €
02:00 - 06:00	0,045 €	0,047 €	0,050 €	0,052 €	0,054 €	0,030 €
07:00	0,045 €	0,047 €	0,050 €	0,052 €	0,054 €	0,035 €
08:00 - 10:00	0,045 €	0,047 €	0,050 €	0,052 €	0,054 €	0,045 €
11:00 - 13:00	0,045 €	0,047 €	0,050 €	0,052 €	0,054 €	0,055 €
14:00 - 18:00	0,045 €	0,047 €	0,050 €	0,052 €	0,054 €	0,045 €
19:00	0,045 €	0,047 €	0,050 €	0,052 €	0,054 €	0,055 €
20:00 - 21:00	0,045 €	0,047 €	0,050 €	0,052 €	0,054 €	0,060 €
22:00	0,045 €	0,047 €	0,050 €	0,052 €	0,054 €	0,055 €
23:00	0,045 €	0,047 €	0,050 €	0,052 €	0,054 €	0,045 €

For the analysis of the problem and in order to select a period of time that allowed the application of DR in load periods and emptiness periods, where the energy price in the MIBEL was lowest and higher, some monthly graphs were created with the consumption and production of energy and the price in the market. The week was then selected from 8 to 14 May 2017. Figure 3 shows the periods that were studied in this paper.

In a quick analysis of figure 3 we can see consumption is relatively constant and shows a slight decrease in the last 2 days (weekend). The production is very unstable due to the production through wind energy that in this system is considerable. Regarding the price of energy, there are some variations in equal periods of different days due to the variation of renewable production.

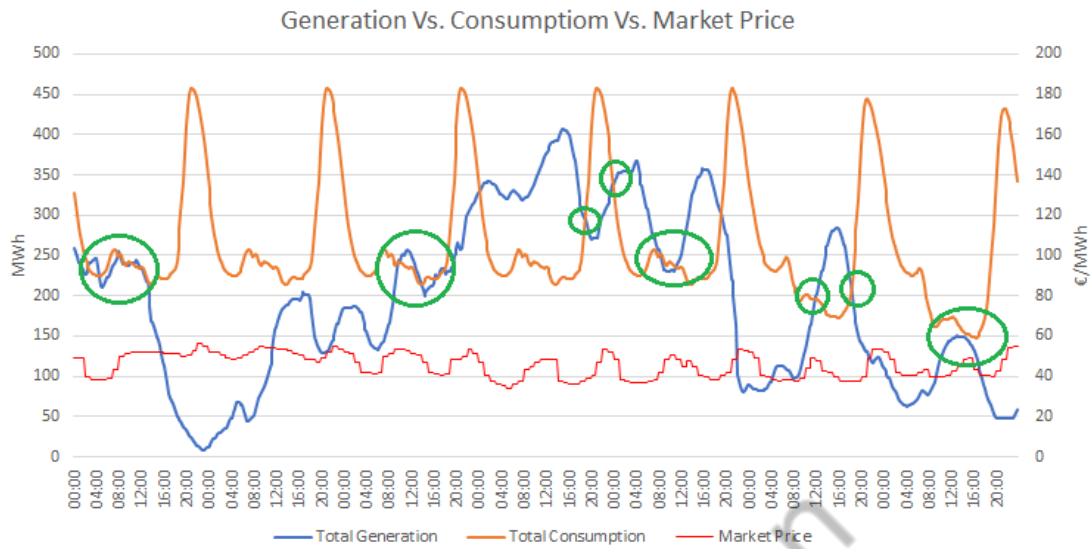


Fig. 3: Proposed scenarios.

Also in figure 3 it is possible to verify the possibility of applying DR in periods when the energy price in the market is low and high.

3. Demand Response

In an electrical system, in order for it to remain stable at all times, the production must match consumption. As energy storage is difficult and expensive, it is necessary to constantly adjust energy production to consumption.

With the evolution of the paradigm of the energy sector, new consumption rationalization technologies have emerged between them, the consumption management denominated Demand Response (DR).

The DR concept intends to manage demand for certain periods, during periods of peak consumption in order to not overload the networks and increase the production for a short period of time (the start-up of a generator set has high costs) calls for a reduction in consumption to consumers in return for monetary remuneration [6].

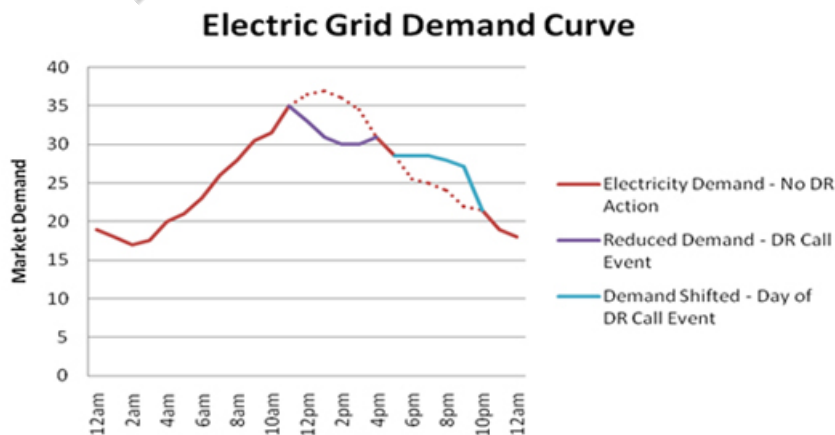


Fig. 4: Consumption profile with and without DR.

Figure 4 illustrates the profile of consumption of a consumer without DR and how would be the consumption with the application of DR.

The DR is defined / implemented through programs that may be price-based or incentive-based. There are several types of DR programs within [1] [8]:

- Programs based in prices
 - Time-of-Use (TOU)
 - Real Time Price (RTP)
 - Critical Peak Pricing (CPP)
- Programs based in incentives
 - Direct Load Control – DLC
 - Interruptible/Curtaible Service (IC)
 - Demand-Side Bidding (DSB)
 - Emergency Demand Response Programs (EDRP)

4. Results

The present section shows the results obtained in terms of scheduling of the appliances defined by the dependency vector and the energy bought from the network. In Fig.4 it is shown the total scheduling of the consumer's consumption, presenting the energy bought from the supplier, the initial demand before flexibility arrangement, and the final demand after flexibility implementation. Demand is divided into two categories, namely, fixed and dynamic, where the first represents the appliances that cannot be shifted, and the latter to the appliances that can be shifted to other periods. In this way there is a fixed cost for the consumer because of the fixed appliances, however, with dynamic appliances the energy management system adjusts their implementation to reduce the cost of it.

For this study was used 3 programs of DR:

- Time-of-Use (TOU) - with the implementation of a tri-hour tariff (empty periods, full and tips) promotes the reduction of peak consumption because it is the most expensive period.
- Direct Load Control - allows remote control of some devices (heater, AC, Fridge, etc.) in order to turn them off for short periods of time <15 minutes.
- Interruptible / Curtaible Service - consumer commitment to reduce the load, usually used in commercial and industrial environments.

As already mentioned in the methodology, it was created 4 different scenarios. The main differences between them are the existence of a forecasting system and the capacity (quantity of energy) discharged for each type of tariff as well as the remuneration of the tariff.

In this analysis, we discuss topics such as the number of requested dives, the amount of energy discharged, the cost of using DR and the cost of purchasing the energy in MIBEL. These results are mentioned in Table 2 and will be discussed below.

Table 2. DR Tariff.

Scenario	DR Application		Unused Energy (MWh)	DR Cost	Cos of energy in the MIBEL
	Type A	Type B			
1.1	15	5	198,14	9.006 €	8.343 €
1.2	5	15	198,14	8.037 €	8.815 €
2.1	12	5	201,35	9.296 €	9.453 €
2.2	4	15	203,64	8.137 €	9.436 €

Aggregator without forecast

In this part, it is assumed that the aggregator does not have any type of forecasting system so the DR is used as much as possible.

3 groups with tariff A and 1 group with tariff B

According to Table 2, DR requests were settled in all groups, in a total of 198 MWh of energy underballasted. With the application of DR the total cost amount was 9.000 € and was around 663 € more expensive if the aggregator bought the energy in the market. This event is justified either by the significant

application of DR in periods of emptiness where the market price was below 40 € / MWh, or by the penalty for the request of the groups inserted in tariff A, causing the cost of the DR application to around 45.45 € / MWh.

We can also verify that DR was only applied during the first 3 days because the maximum number of requests was quickly reached.

1 group with tariff A and 3 groups with tariff B

In this scenario, the number of groups associated to tariffs was changed: only 1 group had the type A tariff and 3 groups had the type B tariff.

Similar to the previous scenario, we will have the maximum number of requests for all groups, the same amount of energy underballasted and the same cost of energy purchase in the market. These values are justified by the DR request occurring in the same periods of the previous scenario. The difference is in the remuneration since there are 3 groups with variable rates. In addition, the requests occur during periods of emptiness, allowing the application of DR to have a cost of 8.037 €, about 11% lower than the remuneration of the previous case. In this case there is a cost for the application of DR on average 40.45 € / MWh.

Aggregator with forecast

In this section, we will assume the aggregator has a forecast system with a high degree of certainty to predict the value of demand and production of energy as well as the market price. This system allows the aggregator to assertively manage the periods in which the DR application might be requested.

3 groups with tariff A and 1 group with tariff B

Analyzing first the request number of DR we can verify the type A requests did not reach the maximum, for each type A group only 4 DR episodes were verified, because due to the penalty the price of the fifth request for each group would be higher than the market price of energy in the same period.

Comparing point 2.1 with point 1.1 of Table 2 we can attest a smaller number of requests, however, the amount of energy lost is slightly higher, proving the use of forecasting makes the use of DR more profitable.

In this type of scenario we also verified the use of DR would have a lower cost of 157 € if purchased the same amount of energy in the MIBEL. In this case the average cost is 46.91 € / MWh with the application of DR to 47.71 € / MWh for purchase of energy in MIBEL.

This improvement is validated by the choice of the best periods to apply DR, which is only possible with the help of Forecast techniques.

If the remaining 3 utilizations of the tariff A were applied the savings no longer would exist and the average value of DR € / MWh would be equal to the cost of energy in the market.

1 groups with tariff A and 3 group with tariff B

After analyzing point 2.2 of Table 2, we verified that tariff A has not been fully utilized.

There is a reduction of 1.300 € in the use DR instead of the purchase of energy which translates to savings of around 14%. The average value of the DR application is 41.07 € / MWh and is significantly lower than 47.62 € / MWh in the case of the energy price in the MIBEL.

As a result, this scenario is the most appropriate because it gives the Aggregator the most savings.

5. Conclusions

Throughout the creation of this study, it was possible to acquire knowledge about DR and your applications.

We acknowledged that the DR application was a good solution for some network problems, not only for island networks but also for Operators that manage small networks, containing several types of clients and Production Park as the case of this study.

It has also been proven that the use of forecasting techniques in conjunction with the Demand Response application significantly increases the System's profitability.

Regarding the tariffs, we confirmed that the choice of the tariff and the number of customers affected by this tariff is of great importance, mainly because, as demonstrated in section 1.1, the use of DR was more expensive than buying the energy needed in MIBEL. It is important also to note that, while defining tariffs, the aggregator should take into account the periods in which it may be necessary to apply DR together with a historical market price of energy. In this case of use, tariff A was found to be inadequate, possibly due to the amount of the incentive or the amount of customers associated with this tariff.

In this case, we verified that the tariff B with a variable rate according to the period of the day is quite profitable, but the use of a fixed tariff should not be neglected for the periods in which the tip (more expensive).

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