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Simulation of consumers and markets towards real time demand response

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Price-based and Incentive-based Framework of Demand Response in Portugal

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Abstract

Demand Response is a flexibility tool that can provide several benefits to the electric power system's operation, namely by providing ancillary services. Although several countries have similar active consumer approaches, the truth is that these methodologies are not always clear or transparent to outsiders, and even sometimes to locals (difficult interpretation of legislation). In this way, the present paper explains Portuguese price-based and incentive-based demand response strategies, and proceed with an analysis and evaluation of the current stage of their implementation. Although the programs exist and are available, their actual use are still very limited.

Keywords: demand response, energy markets, energy policies, smart grid

1. Introduction

In Portugal, Demand Response (DR) strategies are more focused in price-based programs than in incentive-based programs. The price-based ones include market stimulations that motivate the consumer to reduce consumption voluntarily and based on its personal interests, according to the electricity price. In this way, these programs often reflect a decrease of energy costs, or the gain of benefits when in comparison with other consumers. Incentive-based programs reflect the interest of third-party entities in the consumption reduction (e.g. ancillary services performed by a transmission system operator), and implies monetary remuneration [*1*]. When considering ancillary services, one realizes the huge potential of demand response for energy systems and their usefulness for the system operator, since the capability of modifying load can be determinant in emergency and security activities [*1*]. Other European countries have developed DR programs, and are today important success references regarding the benefits of DR implementation [*2*].

In the next section, the characteristics of price-based and incentive-based programs implemented in Portugal are presented. The next section is therefore divided in two subchapters: price-based and incentive-based programs.

2. Price-based DR Programs

Currently, in Portugal, electricity prices are divided into two seasonal periods for all consumers. Time differentiation goes even further when the consumer can choose to consider to have its days be equal (daily cycle – only for consumers connected to low voltage) or different (weekly cycle), in what concerns the tariffs and hours applied. Hours can be included from one to four periods. Fig. 1 presents the tariffs decomposition for the Portuguese scenario. In this way, one can see the general composition defined by the regulator (Entidade Reguladora dos Serviços Energéticos – ERSE) concerning the implementation of price-based active consumer's programs.

As one can see by Fig. 1, the consumer has several options to contract supply and can reduce its energy costs by choosing the program which grants him lower tariffs in the times of his highest consumption, or reduce load in times where the price is higher. The single tariff option is the most used by consumers, since the same price is applied across all periods and days. The double tariff scheme considers two tariffs, that are applied to on-peak (peak plus mid-peak periods) and off-peak periods (valley and super valley periods). In this way, there are several successive hours, especially at night, where the energy price is considerably lower. In the triple tariff scheme, a tariff is applied in the peak, mid-peak, and off-peak periods [*3*], [*4*].

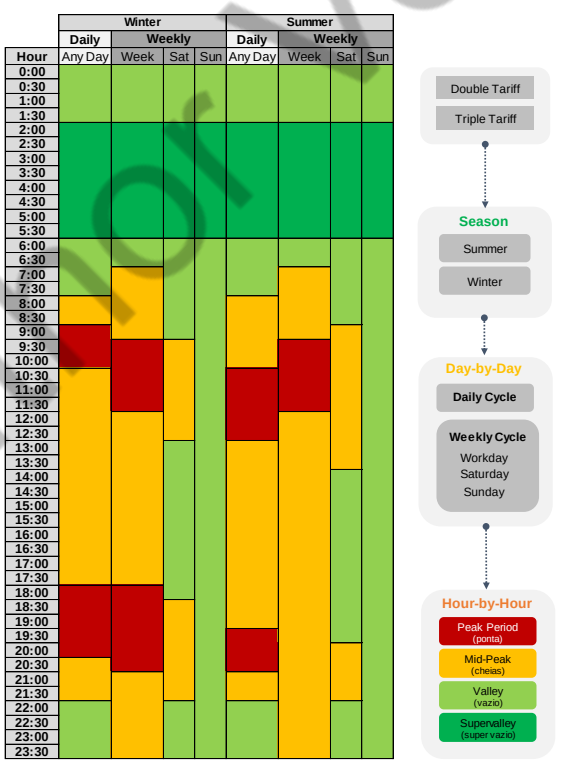

Fig. 1: Tariff decomposition considering winter and summer schedule, daily and weekly, in Portugal.

Fig. 1 also presents the different types of schedule available for consumers, namely considering, season, day, and hour. As one can see, peak periods are the minority amongst other periods as it would be expected, followed by mid-peak periods that are more often, not only on week days but also on Saturdays. Finally, off-peak periods (valley and supervalley) complement the majority of a week schedule with occupancy on the nights of the week, Saturdays, and fully on Sundays. Having the schedule presented in Fig. 2, one can easily apply the tariffs from a supplier and perform a cost/benefit analysis according to a particular consumer situation.

3. Incentive-based DR programs

In Portugal, incentive-based programs are defined through government legislation with a common link with the Spanish regulation. Since Portugal belongs to the Iberian market, MIBEL, the Portuguese and Spanish legislation are harmonized between each other in order to facilitate the energy connections and communication amongst the two countries. In this way, Fig. 2 presents the timeline of incentive-based programs legislation publication, in Portugal [*5*]–[*13*].

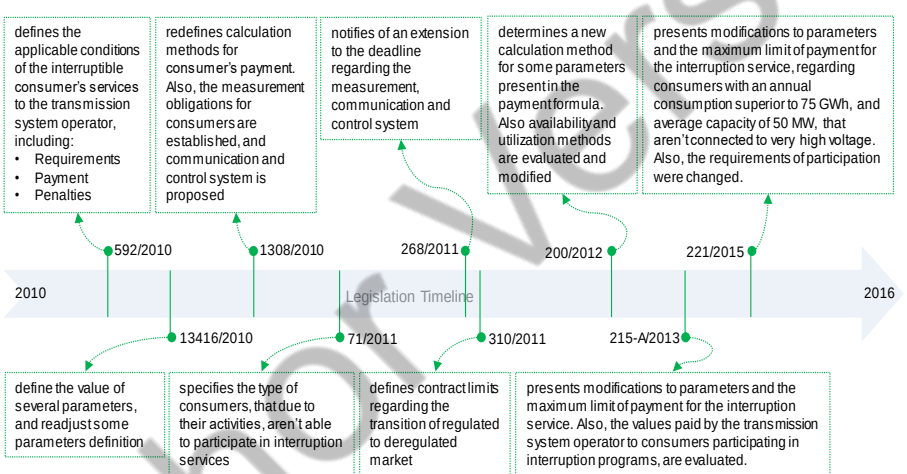

Fig. 2: Portugal's DR legislation timeline and respective features.

In Portugal, DR programs are defined by their type, notice time, maximum duration, number of periods allowed, and maximum duration per period. In this way, the following Table 1 presents the characteristics of Portuguese programs.

Table 1 shows that, per example for the first type of consumer, the transmission system operator can perform only one request per day, to a maximum of 5 per week. In each order the operator can have a maximum of 3 periods of time, each with a limit of 4 hours. This means each request will have a maximum duration of 12 hours. The transmission system operator has a limit of 120 hours of use for each consumer, per year. Finally, the operator needs to notify the consumer at least 2 hours before the actual interruption period [*5*]. Each reduction order sent by the operator must contain the following [*5*]:

- Type of reduction (1, ...,5);
- Number of periods for request at hand;
- For each period include:

- The beginning and finish time;
- Maximum load consumed value by the service provider (consumer).

Table 1: Portuguese DR programs characteristics.

Type	Notice time (min)	Max. requests per week	Max. requests per day	# of Periods per request	Period duration (h)	Max. request duration (h)	Max. use (h/year)
1	120	5	1	3	4	12	120
2	120			2	4	8	
3	60			1	3	3	
4	5				2	2	
5	0				1	1	

Considering the type of reduction chosen, two options are presented where only reduction type 3 can have one or the other: model A (types 3, 4, and 5), or model A+B (types 1, 2, and 3). Table 2 presents the definitions that are to be considered in order to better understand the formulation [*5*]–[*13*].

Table 2: Portuguese DR programs definitions.

Parameter	Definition	Description	Unit
$P_{max\ a}$	Max. load after interruption	Maximum value of consumption that the consumer must have at the time of requested interruption	MW
$P_{max\ b}$			
$P_{50\%}$		$P_{50\%} = P_{max\ b} + 0.5 \times (P_{cb} - P_{max\ b})$	
P_{ca}	Consumption power	Maximum value of annual average power consumption, in the last three years of interruptible services, on peak periods	MW
P_{cb}			
$P_{\text{int } a}$	Maximum interruptible power	Obtained from the formula $P_{\text{int } a} = P_{ca} - P_{max\ a}$	MW
$P_{\text{int } b}$		Obtained from the formula $P_{\text{int } b} = P_{cb} - P_{max\ b}$	
Δ_a	Average monthly power difference quotient	Quotient of the difference between the monthly average power of the last year interruptible services in peak periods, the maximum load after interruption, and the maximum interruptible power	-
Δ_b			
$FWpc$	Energy Quotient	Quotient between the total annual energy consumed and the annual energy consumed in peak and mid-peak periods	-
FWh		Quotient between the total annual energy consumed and the annual contracted power	
μ	Factor	Monthly calculated according to the consumption made, and equal to: FWpc ≥ 2.223, μ=1.9 2,223 >FWpc≥ 2.095, μ=1.75 2,095>FWpc ≥ 1.971, μ=1.55 1.971>FWpc ≥1.852, μ=1.30 FWpc<1.852, μ=1	-
φ		Monthly calculated according to the consumption made, and equal to: FWh ≥ 5500, φ=1.4 5500>FWh ≥ 4500, φ=1.3 4500>FWh ≥ 3500, φ=1.2 FWh<3500, φ=1	

Parameter	Definition	Description	Unit
pm	Average daily market price	Daily market price average for the hours where interruption was requested to the consumer	€/MWh
T_a	Sum of interruption hours per month	Sum of requested interruption hours in the month, for each reduction type	hours
T_b			

* The (a) and (b) indexes are related to reduction types 3, 4, 5, and 1, 2, respectively

After this parameter definition, one can now evaluate the consumer's payment formulation. In this way, model A is defined as follows:

$$rb_a = 2371.9 \times P_{\text{int } a} \times \Delta_a \times \mu \times \varphi \quad (1)$$

$$ra_a = 1.2 \times P_{\text{int } a} \times pm \times T_a \quad (2)$$

Where (1) represents the calculation of availability by the consumer over the course of the month (currently set at 18€/MWh maximum), i.e. actual use of DR (consumption reduction) isn't a part of this calculation, and (2), the actual reduction made by the consumer that is calculated and added to the previous payment – the operator is obligated to annually perform test reduction requests with a minimum duration of one hour, for 10% of the total interruption amount for that year. The model A+B is defined as follows:

$$rb_{ab} = rb_a + \left(1016.5 \times P_{\text{int } a} \times \Delta_b \times \mu \times \varphi\right) \quad (3)$$

$$ra_{ab} = ra_a + \left(1.1 \times P_{\text{int } a} \times pm \times T_b\right) \quad (4)$$

Where (3) represents the calculation of availability by the consumer over the course of the month, and (4) the actual reduction made by the consumer that is calculated and added to the previous payment. The requirements needed to participate in Portuguese DR programs, consider several features of the consumers and is mostly directed to the load consumption and capacity of the consumer. The following describe these features [*5*]:

- Connection to medium, high, or very high voltage;
- Minimum load reduction of 4 MW;
- Install a frequency relay that operates within a frequency interval determined by the transmission system operator – Type 5 reduction;
- Install the required measurement, registry, and control equipment;
- If the operator wishes to establish a contract, and if in the last three years of interruptible load service, the consumer hasn't failed to deliver twice or more times;
- The activity of the consumer isn't one of the activities considered essential, i.e. the operator can't contract with [*7*]:
    - Water, electricity, or natural gas suppliers;
    - Post office or telecommunication companies;
    - Medical associations (hospitals, clinics);
    - Security or national defence organizations (fireman, police);
    - Public transportation sector (including transport security);
    - Public service organizations related to solid or water waste.

The penalties for failure to comply with the amount requested, implies the following:

- If the first time in the last 12 months, the penalty results in a monetary fine equal to 4 months of availability remuneration;
- If the second time in the last 12 months, the penalty results in a monetary fine equal to 12 months of availability remuneration;
- If two or more failures have occurred in the last 12 months, the penalty results in a monetary fine equal to 12 months of availability remuneration, and the cancellation of the contract with the consumer.

As one can see, the requirements imposed by the Portuguese legislation regarding the participation of consumers in interruptible services, is mostly targeted for large consumers of electricity (e.g. voltage level, minimum interruptible amount). In this way, the program isn't embracing other classes of consumers that are more common than the ones considered for the DR program, namely, households, apartments, office buildings, small commerce facilities, amongst others. By limiting the DR program to a relatively small class of consumers, reduces the amount of interruptible load amount available for the transmission system operator.

4. Analysis of Incentive-based DR in Portugal

In the present chapter, one performs the analysis of the current status of DR implementation in Portugal, regarding incentive-based programs. Table 3 represents the progress of incentive-based DR in Portugal, since 2013 [*14*]–[*16*].

Table 3: Incentive-based DR evolution.

Year	Model	# of Consumers	Interruptible Power (MW)	# of Reduction Orders	Payment for Availability (M€)	Payment for Use (M€)
2013	A	2	671	0	87.3	0
	A+B	47	653.3			
2014	A	2	705.2	0	101.9	0
	A+B	49	687.5			
2015	A	50	714.2	0	109.9	0
	A+B	2	696.4			

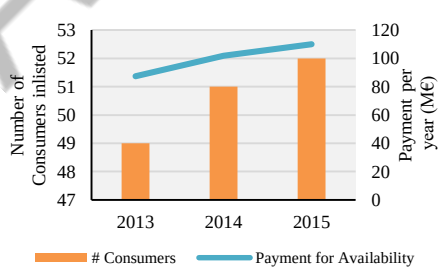

Fig. 3: Incentive DR: #consumers vs payment.

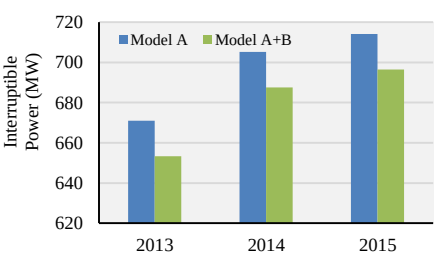

Fig. 4: Incentive DR: models A vs A+B

Focusing on the past year, according to [*16*] by the end of 2015, the transmission system operator (Redes Energéticas Nacionais – REN) had interruptible services agreement with 52 consumers. Of these consumer's interruptible capacity, 714.2 MW are from model A (reduction types 3, 4, and 5), while 696.4 MW are from model A+B (reduction types 1 and 2), thus obtaining a total available amount of 1.41 GW.

As one can see by the previous figures (Fig. 3 and Fig. 4) and Table 3, the progress of incentive-based DR is very lacking without a single request in 3 years. This shows that the costs to the transmission system operator, REN, are reflected only on the consumer's availability, spending millions of euros each year. In this way, these costs seem as unnecessary since the consumers aren't used at all, and thus an evaluation of the need of flexibility in Portugal should be considered in order to clarify if there's in fact a necessity for flexibility resources. Additionally, one can see that the transmission system operator hasn't fulfilled the legislation currently applied, since not even a test reduction request was made across the years or else not declared in the annual reports, which is obligated by law, as referred in [*6*].

5. Conclusions

The present work details the Portuguese legislation in what concerns the use of demand response measures, namely, the incentive-based and price-based programs available for consumers. Currently, price-based programs are made available by several entities (suppliers, retailers, amongst others) and therefore they are more common than incentive-based programs. Moreover, consumers connected to higher voltage levels (medium, high, and very high voltage) are metered with time differentiation, thus the tariffs used by these consumers have to be also time differentiated, namely, four time blocks (peak, mid-peak, valley, and supervalley).

Regarding incentive-based programs, they are only available for consumers connected to medium, high, and very high voltage networks. The results about incentive-based programs show that these aren't very used by the transmission system operator, in fact, not at all. The consumers with an established agreement are only paid for being available, since their activation throughout the years has never been made. This shows a huge loss in terms of DR potential and monetary funds that could have been used for other important network-related activities. In this way, Portuguese legislation needs to be improved and control mechanisms should be implemented, in order to enable a more transparent, attractive, and fair remuneration system for DR integration.

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