TIME-OF-USE ELECTRICITY TARIFFS WITH SMART METERS

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Abstract

This paper proposes a method for scheduling tariff time periods for electricity consumers. Europe will see a broader use of modern smart meters for electricity at residential consumers which must be used for enabling demand response.

A heuristic-based method for tariff time period scheduling and pricing is proposed which considers different consumer groups with parameters studied a priori, taking advantage of demand response potential for each group and the fairness of electricity pricing for all consumers.

This tool was applied to the case of Portugal, considering the actual network and generation costs, specific consumption profiles and overall electricity low voltage demand diagram.

The proposed method achieves valid results. Its use will provide justification for the setting of tariff time periods by energy regulators, network operators and suppliers. It is also useful to estimate the consumer and electric sector benefits from changes in tariff time periods.

Key Words: Dynamic Electricity Tariffs; Demand Response; Non-Linear Optimization; Heuristics.

Introduction

This paper is based on the research carried out in the framework of a MSc project (Oliveira, 2013). The internal energy market implements the three strategic vectors of the European energy policy (European Commission, 2010): the continuous availability of energy products and services at reasonable costs (through a competitive market and innovation in energy services); the promotion of security of supply on a European scale (through diversification of energy routes in supplying Europe and promotion of endogenous resources); and, the promotion of social and environmental sustainability. Moving towards 2030, the energy policy objectives build on the previous ones and go deeper into realizing the full potential of renewable generation and energy efficiency (European Commission, 2014).

The 3rd Energy Package of European Directives includes the participation of demand in the electricity market and the adoption of smart meters. Directive 2009/72/CE (European Parliament and Council, 2009) establishes that Member-States must evaluate the rollout of smart energy measurement systems. These smart meters offer a technological leap in the relationship between consumers, networks and the electricity market, allowing for detailed (timely discriminated) and updated (in real time) knowledge concerning consumption. This data can be used by the consumer to manage his/her consumption; by grid operators to improve grid management and to involve consumers in the supply of network services; and by suppliers to develop cost adherent prices that promote rational options by consumers (Vasconcelos, 2008). European policy regards the smart meter as a tool to promote energy demand response which, in turn, will contribute to a competitive and efficient market, to the reduction of CO_2 emissions and to economic growth (European Commission, 2011).

In the Portuguese electricity market, smart meters are already being deployed by network operators in certain pilot projects. The trend is for them to become a standard solution for metering in the future. Network tariffs are approved by the energy regulator while energy generation costs derive from the Iberian wholesale market.

Electricity tariffs

Electricity tariffs paid by end-users reflect costs through the supply chain, some originated from regulated activities (transmission and distribution networks, costs related to energy policy decisions) and others from competitive market activities (generation costs and retail supply costs).

Apolinário et al. (2006) presented the Portuguese additive tariff model. Tariffs for using the networks (also called third-party access tariffs) result from adding sub-tariffs of each activity included in the service. In this additive model, end-user tariff results from adding the network tariff to generation and retail costs.

Houthakker (1951) and Boiteux (1960) presented two fundamental papers about applying marginal cost pricing to electricity. According to the authors, tariffs based on marginal costs produce a better distribution of resources (economic efficiency) and induce demand reduction at peak periods, with subsequent benefits in overall costs of the electricity sector. These costs include either variable generation costs, generation capacity costs or network infrastructure costs.

For consumers, marginal pricing may mean a reduction in the bill, if they can adapt their consumption to prices (Bartusch et al., 2011) and adopt efficient technologies (Kim and Shcherbakova, 2011).

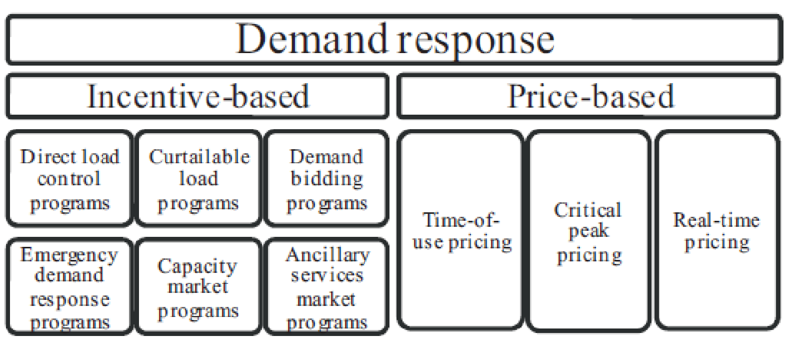
For grid operators, system management costs are reduced (services supplied by generators in standby mode), network losses and maintenance costs are brought down, enabling them to postpone new investments and reduce risks of supply interruptions.

For suppliers, these tariffs set a more competitive market environment, with more information. Bartusch et al. (2011) also mention the reduction of financial risks of the supply activity since the supplier signs a contract with the customer for a given period, with fixed prices.

For society in general, marginal cost pricing can increase electricity market efficiency, thus reducing the potential for market power abuses, and reduce environmental impacts related to electricity generation and transmission (Bartusch et al., 2011).

There are several examples of prices depending on the time the service is used. Faruqui (2010) mentions prices for car parking, tolls for bridges with traffic congestions, flights and hotels, or prices for cultural events and sports or even pricing in the telecommunications business.

Dynamic demand involvement has been promoted with the goal of offering services to the power system or reducing overall sector costs. Dupont et al. (2011) present a classification of different types of demand response programmes (Figure 1).



Source: (Dupont et al., 2011)

Figure 1 – Types of demand response programmes

Time-of-use (TOU) tariff is a demand response mechanism common in the residential customer segment. TOU tariffs have prices variable with time, fixed within time blocks known in advance. Although TOU tariffs are usually available, they still are not generally applied (Wang and Li, 2011).

This study on TOU electricity tariffs with smart meters aims to contribute to the process of changing the Portuguese electricity market, by looking at new technologies in energy measurement.

Time-of-use tariffs considering demand response

Thanks to smart meters, retail offers can be differentiated in terms of price and service, as today, but also in terms of price differentiation through time. Faruqui (2010) maintains that each consumer should be able to choose his/her own pricing structure, to which he/she can best adapt, among alternative price offers.

This work considers consumer groups with specific demand profiles and parameters for price elasticity of demand, as target groups to the definition of alternative TOU tariffs. A tool is proposed to determine the time location of prices and their respective values, with the purpose of achieving the demand response potential of each consumer group and maintaining fair pricing among all consumers. This tool was applied to the case of Portugal, considering the actual network and generation costs, specific consumption profiles and overall electricity low voltage demand diagram.

Modelling demand response dynamics

The Electric Power Research Institute (2008) states that most consumers show price responsiveness and that the response level differs from one individual or group to another.

Price elasticity of demand is related to the utility function of electricity consumption. In the assumption of a rational use of energy, the consumer will only use energy while its cost is below the marginal utility derived from this energy use. Schweppe et al. (1988) refer to this assumption in the following way: the rational consumer chooses the demand level that maximizes his/her net gain (utility minus cost).

Demand response to price variations includes readjusting the consumption level, changing overall consumption or transferring it between time periods with different prices. TOU tariffs aim mainly to transfer consumption, while structural modification of demand is promoted through other means, such as incorporating environmental externalities (like the European carbon emission trading scheme) in supply costs or promoting consumer information about energy efficiency[1].

In the short term, consumers use technology and behaviour modifications at their disposal, in order to adapt demand to price changes. This short-term response is limited. When price changes persist, consumers adjust demand through additional tools, like investing in more efficient energy using devices (new production technologies, appliances or insulation measures in buildings), searching for information and training or changing the energy sources used in processes. As a result, price elasticity of demand is higher in the long term than in the short term (Electric Power Research Institute, 2008).

Setting TOU tariffs

A method is proposed and applied to identify peak time and off-peak time periods and its prices, using the hourly marginal costs of electricity supply, load profiles of demand of significant consumer groups and parameters for price elasticity of their demand. The half-hourly profile of marginal cost of supply (Figure 2) is estimated from marginal generation cost at wholesale market and incremental costs of using the transmission and distribution networks. Brandstatt and Friedrichsen (2012) have also referred the importance of using not only generation cost data but also network costs in the optimization process.

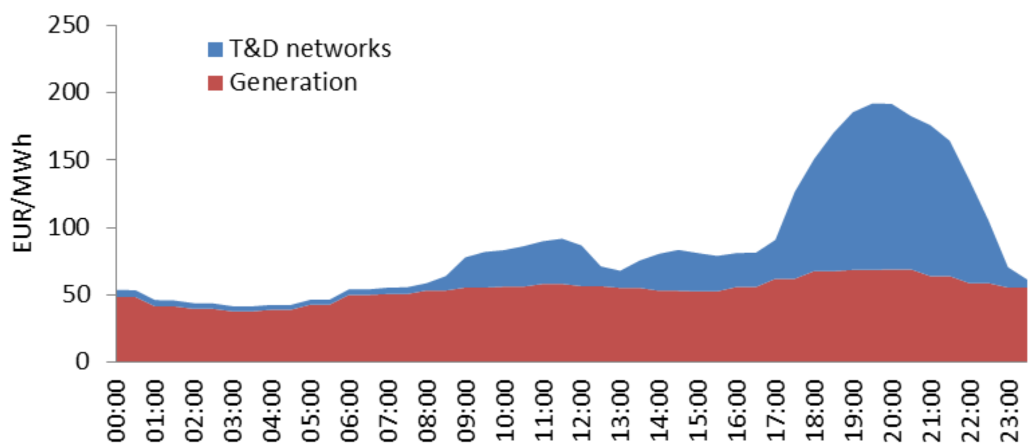


Figure 2 – Hourly profile of marginal cost of supply (example for a typical winter day)

[1] This is the case of energy labels for appliances and buildings or information campaigns targeted to end-users.

For generation costs this research considered data on hourly wholesale market day-ahead prices (publicly available data at the website of the Iberian Electricity Market Operator, OMIE), without technical restrictions or ancillary services costs, in the Portuguese price area, during 2011. Prices at market referential were adjusted to low voltage consumer level through the application of power loss factors published by ERSE for 2011.

For transmission and distribution incremental costs there is no market reference to be used. Instead the authors developed a method to estimate half-hourly incremental costs based on the regulator's approved average incremental costs of each tariff period (peak, half peak, off-peak and super off-peak) in 2012 and on the characterization of the probability of each half hour period belonging to a given tariff period. Demand used to calculate the mentioned probability was from a 2005 internal study by the regulator on the demand profile at each voltage level. The method here described is detailed by Oliveira (2013).

Three load profiles are used to represent residential consumers and small companies in Portugal (A, B, C). The regulatory consumer segments defined for load profiling by the regulator and determined by ERSE (2011) were used. Group A corresponds to contracted power above 13.8 kVA (medium tertiary companies), Group B to contracted power up to 13.8 kVA and annual consumption above 7140 kWh (large residential consumers) and Group C to other consumers with contracted power up to 13.8 kVA (general small residential consumers). Group A accounts for 27% of consumption by consumers with contracted power under 41.4 kVA, Group B accounts for 3% and Group C makes the other 70%, according to the regulator's 2012 data. These consumers to which demand profiles apply represent 40% of total electricity demand.

Assumptions made by the authors on price elasticity of demand were based on price-demand elasticity parameters from a review of several papers presenting empirical studies. Fan and Hyndman (2011) indicate values between -0.4 and -0.2 for own elasticity, while Electric Power Research Institute (2008) mentions -0.6 to -0.2 (and 0.04 to 0.11 for crossed elasticity). In a study on Spanish consumers, Labandeira, Labeaga and López-Otero (2012) pointed to -0.25 to own elasticity and 0.05 for crossed elasticity.

Method for determining TOU tariff periods

The purpose of the method developed is to set tariff time periods, e.g. the classification of each hour in the day into tariff price levels, and the determination of the price levels which optimize a given objective function.

The method for determining TOU tariff periods is based on a non-linear optimization model with real and binary variables (optimization model). A heuristic is used to determine valid (feasible) solutions to the optimization problem. The heuristic has two components that act sequentially: a greedy selection algorithm (which sets values for the binary variables) and a procedure to solve a system of non-linear equations. Other authors presented alternative methods for determining TOU tariffs such as Li et al. (2014) that used clustering of time periods without considering the dynamics of demand response. Holtschneider and Erlich (2013) used neural networks and an optimization heuristic for TOU determination close to real time. For regulators and other public bodies, the transparency of the optimization model proposed in the current study, including its constraints, can be considered an advantage because it enables stakeholder consultations and involvement.

As a result from the application of this methodology, TOU tariffs are set for each consumer group.

Non-linear optimization model

A new integer non-linear programming model was developed, for two tariff price levels: peak (p_1) and off-peak (p_2). Considering that the time horizon H (1 day) is divided in sub periods h (30 minute periods), the model's variables are the price levels p_1 and p_2, the vector $[y_h]$ which associates to each period h a price level p_1 or p_2 and the demand in each period h represented by q_h.

$$\min f_1(p_1, p_2, [y_\mathrm{h}]) = \sum_h q_h \cdot c_h - C_{ref} \qquad \text{(a)}$$

$$s.a \begin{cases} \sum_h (1 - y_h)(q_h \cdot c_h - q_h \cdot p_1) = 0 & \text{(b)} \\ \sum_h y_h (q_h \cdot c_h - q_h \cdot p_2) = 0 & \text{(c)} \\ q_h = q_h^0 + \sum_j q_j^0 \cdot \left\{ \varepsilon_{hj} \frac{[(1-y_j)\cdot p_1 + y_j \cdot p_2] - p^0}{p^0} \right\}, with\ h \in H & \text{(d)} \\ p_1 \in [p^0, p_{\max}] & \text{(e)} \\ p_2 \in [p_{\min}, p^0] & \text{(f)} \\ y_\mathrm{h} \in \{0,1\}, with\ h \in H & \text{(g)} \\ q_h \geq 0, with\ h \in H & (h) \end{cases}$$

where the variables are:

y_h	decision variable on the applicable price for period h (0 for p_1 or 1 for p_2)
p_1, p_2	price variables (two time period tariff)
q_h	demand during time period h

and the parameters are:

p^0	single starting price

q_h^0 demand during time period h with starting price

c_h unit cost of supply during time period h

C_{ref} reference cost for starting conditions of demand and price (starting bill)

$\varepsilon_{hh}, \varepsilon_{hj}$ own price-demand elasticity in period h (ε_{hh}), crossed between h and j (ε_{hj})

Constraints for price adequacy to cost

Model constraints (b) and (c) ensure that prices, p_1 and p_2 , are set such that resulting revenue is equal to the cost of supply. In the present case, the constraints were used so that the social optimum is pursued. However, they can be formulated as inequality conditions, namely ensuring that the tariff revenue is at least equal to cost, which could be the goal of a single market competitor when setting its prices.

These constraints, along with (d), impose the non-linearity to the model. Revenue is a square function of price, once demand depends linearly on price.

Demand response to price functionality constraint

Constraint (d) relates demand in each 30 minute time period with the starting demand, as a function of own and crossed price-demand elasticities. Own elasticities are negative hence demand in period h decreases when price in the same period increases. Crossed elasticities are positive, and consequently demand in period h increases when prices in time periods next to h increase, since consumers transfer consumption from one period to the next. For the parameters ε_{hj} in the elasticity matrix the following values were used:

- Own elasticity: base value $\varepsilon_{hh} = -0.2$, with a sensitivity analysis in the interval [-0.4, -0.1].
- Crossed elasticity: base value $\varepsilon_{hj} = 0.05$, with a sensitivity analysis in the interval [0, 0.1]. It was considered in the central scenario that demand in a given period is only influenced by price in the previous and next 2 hours. The parameter value set for crossed elasticity corresponds to the sum of all contributions from time periods close to h.

The sensitivity analysis for elasticity values was used to investigate the response of the model to different consumer segments with specific consumption patterns. Special tariffs can be designed for each consumer group. Another scenario was also used to simulate a more complex consumption type, with price-demand elasticity varying throughout the day, representing the greater or lesser will to modulate consumption according to prices in different times of the day. This scenario was called “optimized elasticity”.

Price structure constraints

Constraints (e) and (f) define the price structure, namely that p_1 is higher or equal to starting price p^0 (uniform price during the day) and that p_2 is lower or equal to p^0. It also confines prices within the max and min interval corresponding to the limits of the marginal cost function. Limits are also used in order to avoid extreme results coming from the linear demand function (Faria and Vale, 2011).

Time period classification constraint

Constraint (g) assigns each time period either to price p_1 or p_2.

Demand variable constraint

Demand constraint (h) limits demand to a non-negative real number.

Objective function

The objective function (a) minimizes cost for the supplier and for the customer. If market prices reflect marginal costs then the reduction of costs to the end user means also reduction of total system costs, as well as environmental impacts.

A sensitivity analysis was performed on the marginal cost function using two alternative sets of marginal costs.

Using a heuristic-based method to solve the problem

An optimization solver was applied to the model described - *Risk Solver Platform v11.5*, from Frontline Systems, Inc. (Frontline Systems, 2011), running with Microsoft Excel 2010. However, due to the model's structure and dimension of the instances tested, the solver did not determine optimal solutions. In fact, it was possible to manually find better solutions than the ones found by the solver, hence a heuristic was designed and applied to the problem. The heuristic uses a greedy constructive algorithm to fix the integer variables and has two major steps:

- Procedure to solve the non-linear equation system, constraints (b)-(c), through a numeric approximation method to determine p_1 and p_2 and the value of the objective function.
- Greedy algorithm to search for a vector $[y_h]$ that improves the value of the objective function, by changing one component of the vector in each iteration, constraint (g).

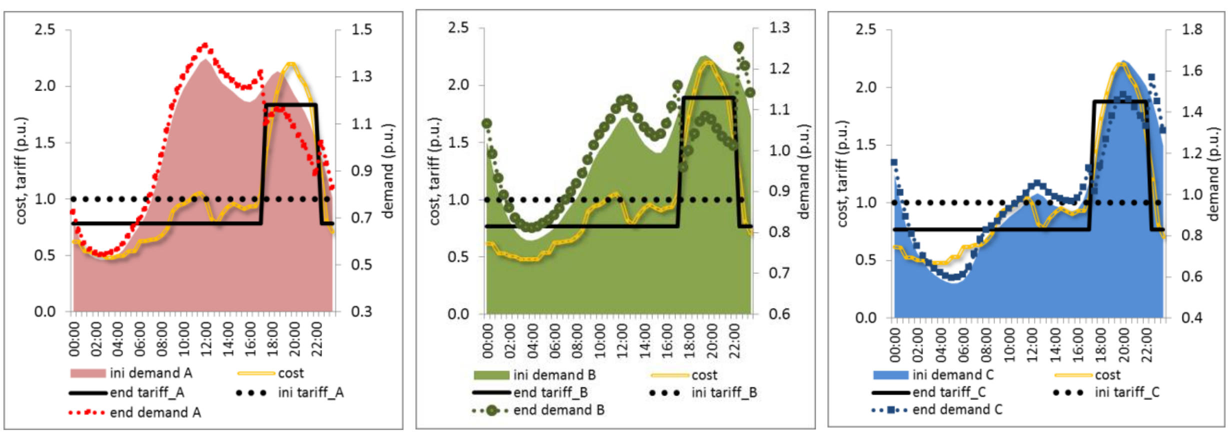
The heuristic-based method to solve the non-linear optimization problem makes it easy to further impose other constraints on the solution. These constraints can be useful, for instance, if one wants to interfere in the time duration of each price block, the number of discontinuous price blocks throughout the day or other type of requirements. In fact, including these constraints in the model could be quite challenging and complex. Hence, the proposed heuristic-based approach gives much flexibility to the user of the optimization model.

Results obtained for TOU electricity pricing in Portugal

As mentioned above, three load profiles were considered (A, B and C), corresponding to the three groups used in the Portuguese regulatory regime concerning load profiles for tariff setting (ERSE, 2011). The proposed method was applied to setting a two price TOU tariff (2 TOU tariff) for all the days in the winter period, as an example. The winter period generally includes the yearly peak demand and, correspondingly, the greater marginal price differentiation.

Demand profile changes with TOU tariff

Applying TOU tariffs with two prices (peak and off-peak) results in changes of the hourly profile of demand, due to the price elasticity of demand (Figure 3). The transfer of consumption is notorious when the peak price is considerably superior to off-peak price. In the cases studied, total daily demand was practically invariant.



Note: ini demand – initial demand profile; end demand – demand profile when TOU tariff is applied; "p.u." – per unit

Figure 3 – Impact of TOU tariffs in load profile of demand for load profiles A, B and C

Analysis of results expected with TOU tariffs application

The methodology proposed in this study was applied through simulations performed for the different consumer groups, considering the base scenario of demand-price elasticity.

The results all suggested the same time period location for prices at peak (p_1) and off-peak (p_2) (Table I). The current 2 TOU tariff has a peak time period between 8:00 and

22:00, every day of the year. The time periods that resulted from the application of the methodology proposed in this study differ from those currently in place in Portugal. The proposed peak price time period is shorter and ends half an hour later (Table I).

Load profile (cons. group)	Bill variation [€/year]	p_1/p_2	Peak TOU
Profile A	-16.54	2.35	17:30 - 22:30
Profile B	-18.69	2.47	17:30 - 22:30
Profile C	-20.01	2.45	17:30 - 22:30
Current 2 TOU tariff			8:00 - 22:00

Notes: p_1/p_2 - ratio between prices

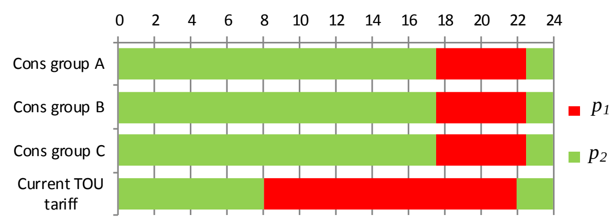


Table I – TOU tariff time periods for load profiles A, B and C, with base scenario of elasticity

After the simulations using the base scenario of elasticity, a sensitivity analysis was performed for different values for price elasticity of demand. Different values for own (ε_{ii}) and crossed (ε_{ij}) demand-price elasticity were considered: higher (high scenario) and lower (low scenario) than the base case, as well as an optimized elasticity scenario where elasticity values vary along the hours of the day, as described in the section where the method is presented. The results showed that price period time location is quite insensitive to different scenarios of elasticity (in Table II the sensitivity results are presented for the profile C, the most significant consumer group).

Load profile (cons. group)	Elasticity scenario	Bill variation [€/year]	ε_{ii}	ε_{ij}	p_1/p_2	Peak TOU
Profile C	Base	-20.01	-0.2	0.05	2.45	17:30 - 22:30
Profile C	High	-45.25	-0.4	0.10	2.44	17:30 - 22:30
Profile C	Low	-12.07	-0.1	0.00	2.45	17:30 - 22:30
Profile C	Optimized	-24.08	*	**	2.34	18:30 - 23:00

Legend: p_1/p_2 - TOU price ratio

* -0,4 (6-9h and 21-24h); -0,1 (0-6h and 9-21h)   ** 0,1 (6-9h and 21-24h); 0,025 (0-6h and 9-21h)

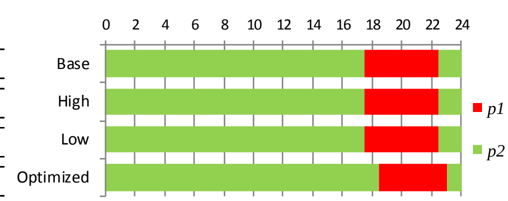


Table II – Sensitivity analysis to price elasticity in TOU tariff for load profiles C

The proposed methodology calculates an optimal 2 TOU tariff which, in turn, leads consumers to change their consumption patterns (demand profile). This demand response has consequences either for each responsive consumer or for the electric system as a whole.

The consequences of the application of the TOU tariffs derived from the methodology presented can be estimated in terms of variation of consumer bills and maximum demand values (the latter is reflected on investment costs in the networks). Three demand-price elasticity scenarios described above were considered (high, base, low).

Table III presents the main results respecting each consumer group. The table shows own (ε_{ii}) and crossed (ε_{ij}) elasticity values used in each scenario and indicators on anticipated results: the ratio between peak (p_1) and off-peak (p_2) prices; annual bill variation; and the variation of the maximum demand value between 18:00 and 23:00. This critical period contains the maximum aggregated demand in low voltage networks with 92% of probability, according to an analysis of the aggregated demand in the low voltage distribution network. With the data used and the options taken, described in this paper, the time location of price periods was very stable across different scenarios. The period from 17:30 to 22:30 was chosen as the peak price time period.

Load profile Consumer group	Demand elasticity to price Scenario	ε_{ii}	ε_{ij}	p_1/p_2	Annual bill variation [EUR/year]	[%]	Max demand 18-23h variation [%]
Group A	Base	-0.2	0.05	2.35	-16.54	-3.1%	-12.5%
	High	-0.4	0.10	2.35	-36.73	-7.0%	-18.7%
	Low	-0.1	0.00	2.35	-10.06	-1.9%	-7.5%
Group B	Base	-0.2	0.05	2.47	-18.69	-3.5%	1.6%
	High	-0.4	0.10	2.46	-41.32	-7.8%	8.0%
	Low	-0.1	0.00	2.47	-11.43	-2.2%	-2.2%
Group C	Base	-0.2	0.05	2.45	-20.01	-3.5%	-5.2%
	High	-0.4	0.10	2.44	-45.25	-8.0%	1.1%
	Low	-0.1	0.00	2.45	-12.07	-2.1%	-6.8%

Table III – Results expected from applying TOU tariffs

The results in Table III show a price ratio $^{p_1}/_{p_2}$ between 2.35 and 2.47. This compares with a lower ratio in current 2 TOU tariff in Portugal for the year 2012 (ratio of 1.9). A higher price ratio corresponds to a greater price differentiation between peak time period and off-peak time period. Hence, the time periods for TOU tariff proposed in this paper are more effective in carrying price signals to consumers. Li et al. (2014) proposed a technique for TOU tariff determination using clustering algorithms which looks for reducing within-group dissimilarity in each time block with the same price, corresponding to a greater price differentiation between price block.

Demand response to different prices during the day results in annual bill reductions for consumers. Results expected (Table III) account for 1.9% to 8.0% reductions in the annual bill (assumed bill includes only the marginal costs of supply used in this paper, excluding taxes and fixed tariff prices). The major differences come from the responsiveness of the consumer to the different elasticity scenarios rather than the different consumer groups. The effects on the bill simulated for the three different consumer groups are quite invariant for each elasticity scenario: from -1.9% (Group A) to -2.2% (Group B) with low elasticity and from -7.0% (Group A) to -8.0% (Group C) with high elasticity.

Finally, in order to measure changes to the hourly load profile of demand resulting from TOU tariffs, the expected variation in the maximum value of demand inside the 18:00-23:00 time window was estimated. In the simulated cases, the reduction of maximum demand in the critical period reached 18.7% (Table III). However, the results for the three consumer groups are quite distinct. For example, while Group A can reduce maximum demand in the time window 18:00-23:00 for 18.7% (with high elasticity), Group B increases the demand in the same period about 8% (and Group C demand increases 1.1%).

Considering the base scenario of elasticity values, the proposed TOU tariff results in an estimated variation in peak demand between +1.6% and -12.5%. These figures are in accordance with results of other studies, such as those of Faruqui and Sergici (2010), which mention an average 4% decrease in peak demand by consumers in several TOU tariff pilot projects.

Conclusion

This study proposes a method to set electricity TOU tariff time periods for small size low voltage consumers (residential and companies). The adoption of smart meters, thus enabling consumption registration and consumer interaction far beyond current standards, will permit the promotion of demand response through electricity pricing.

Electricity supply costs vary in time and are bound by aggregated demand. Tariffs set by regulators or by market suppliers should reflect these costs, allocating them to the consumers that cause them, and should convey price signals that promote a correct response from demand.

The method proposed is based on information about the hourly marginal cost of supply, the load profile of demand of certain consumer groups and their respective parameters for demand-price elasticity.

From the scenarios studied, the application of TOU tariffs with two prices resulted in a reduction in the annual bill of consumers between 2% and 8% (mostly due to different price-demand elasticities), besides a reduction in the maximum demand in the critical period of up to 18.7% (for one consumer group). All consumer groups simulated showed a similar potential for reducing bills when applying such a TOU tariff. In other dimensions, such as changing the maximum demand in the 18:00-23:00 time window, the three consumer groups presented very different results (from an 18.7% decrease in maximum demand in Group A to an 8% increase in Group B). This can mean that for certain objectives to be achieved, network operators or public bodies should target specific consumer groups for applying TOU tariffs. This is also true for the geographical dimension of the problem.

These figures show that both consumers and network operators stand to gain with added efficiency brought about by this type of tariff. It also points to the relevance of enabling demand responsiveness. Different forms of promoting consumer responsiveness levels can coexist and can be delivered in the energy services market. Together with a cost reflective TOU differentiated electricity tariff this can deliver value to consumers and to the power sector alike.

TOU pricing should be accompanied by complimentary measures facilitating demand response. Electronic devices such as in-house displays are examples of tools for marketing price and consumption information to consumers. TOU tariffs can play an important role in the electricity system in order to cope with electric vehicles charging, which can follow TOU tariff price incentives to minimize network reinforcement costs (Brandstatt and Friedrichsen, 2012).

The method and the results obtained in this study could support the setting of time location of TOU prices by market players (regulators, suppliers, network operators). The method is also useful to assess the estimated benefits obtained by consumers and by the electricity sector as a whole, as a result of different pricing options, since the dynamics of price responsiveness of demand are considered.

Disclaimer

The analysis, opinions and conclusions in this paper reflect only the authors' views.

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