Additive Tariffs in the Electricity Sector

I. Apolinário, N. Felizardo, A. Leite Garcia, P. Oliveira, A. Trindade, P. Verdelho

Abstract--**This paper presents and discusses a methodology for the calculation and application of tariffs in the electricity sector based on the principle of tariff additivity. This principle imposes that the prices of the several regulated tariffs, for instance the access tariffs paid by all customers for the use of the networks, are obtained by the summation of the several regulated activity tariffs related with the components or services used by each customer along the value chain of the electricity sector. It is shown how such tariffs can reflect costs and assure the absence of cross subsidies between clients. The methodology presented was adopted in the Portuguese Tariff Code for electricity by the Portuguese Energy Regulator (ERSE), being applied since 2002. The work presented in this article reflects the experience acquired by ERSE during the preparation, discussion and implementation of this additive tariff system.**

***Index Terms*— power system economics, electricity pricing, electricity tariffs, grid access tariffs.**

I. Introduction

The creation of a retail market for electricity imposes two basic premises: (i) the right to purchase electricity from the supplier of the customer's choice; (ii) the right of access, by all economic agents including consumers, suppliers and generators of electricity, to the public networks and associated services, that are natural monopolies and subject to economic regulation.

In the process of gradual market opening different situations can coexist. Some customers are eligible and made the decision of leaving the incumbent supplier paying the regulated tariffs to access the public networks and negotiate freely the price of energy they purchase. Others, although being eligible, opt not to leave the incumbent supplier and pay a regulated tariff designed to account for all the costs of energy supply, including generation, networks, system services and retailing. This tariff is established by the regulatory authorities, being a regulated tariff applicable to the incumbent supplier customers also called integral tariff.

In the primary stages of liberalization, some clients stay ineligible to choose their supplier and remain bind to the incumbent, paying the integral tariff. These customers are typically the smaller ones that are connected to the lower voltage levels.

In such framework is of fundamental importance that the integral tariffs, paid by the incumbent supplier customers, reflect clearly the costs of the several regulated activities along the value chain of the electricity sector, imputable to each consumer. This means that the prices of the integral tariffs and the tariff's pricing variables should be determined in order to allow for the transmission of such signals. At the same time they should be compatible with the tariffs published for each regulated activity, namely the transmission and distribution use tariffs.

The principle of calculating every price, of each integral tariff, based directly on the prices of the regulated activity tariffs along the value chain of the electricity sector, from generation to retail, is also designated by tariff additivity.

II. Brief characterisation of the Portuguese Tariff System

In order to understand the methodology for tariff calculation is useful to take a brief look at the Portuguese regulatory framework [3].

Since its creation, ERSE has the responsibility of determining and publishing the following tariffs: (i) Grid Access Tariffs applied by the transmission and distribution system operators to grid users; (ii) End-User Tariffs applied by the regulated supplier to customers using the Public Service Electricity System (SEP).

The methodology used for calculating these tariffs is previously determined and published on the Tariff Code—a regulatory instrument approved by ERSE according to the law. In addition to the detailed tariff calculation methodology aimed to recover the revenues associated with each regulated activity, these Codes establish the procedure for determining the allowed revenues to each regulated activity and for defining eligible costs, as well as the respective models of regulation and the information that must be provided by the regulated entities. These Codes also establish the procedures and timetable for determining electricity tariffs and prices on annual basis.

Public hearings must be held before the approval of Tariff Code, as well as any review of their rules.

In the framework of the yearly process of establishing tariffs, the regulated companies must send to ERSE every year, up to May 1, the physical and accounting data of the previous year and, up to June 15, estimates regarding the current year and forecasts for the next. Based on this information, and possible additional clarifications, ERSE drafts a Tariff proposal that is duly explained to the Tariffs Council up to October 15. The Tariffs Council, a body composed of representatives from the various stakeholders in the sector—including consumers and companies, makes an

The authors are with ERSE Entidade Reguladora dos Serviços Energéticos (Portuguese Energy Regulator); Direcção de Tarifas e Preços (Prices and tariffs department), Rua Dom Cristóvão da Gama, n.º 1, 3º, 1400-113 Lisboa, Portugal (www.erse.pt; erse@erse.pt)

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appraisal of ERSE's proposal and gives advice up to November 15. Based on such advice, up to December 15 ERSE publishes the tariffs that will apply during the coming year, as from January 1.

The existing Portuguese tariff system anticipates the existence of customers that can either choose a supplier in the Non-Binding Electricity System's (SENV) market, or prefer to be supplied by a regulated supplier linked to the Public Service Electricity System (SEP). Although legally speaking all customers have the right to freely exercise their right to choose suppliers since August 2004, in practice—essentially due to technical reasons—only low voltage customers with contracted power higher than 41,4 kW (SpLV) and those supplied in Medium Voltage (MV) or higher voltages can choose suppliers other than the regulated supplier. It is expected that during 2006 the required information systems are implemented, so as to enable all electricity customers to exercise their right to choose supplier.

A. Tariffs and regulated activities

The unbundling of the several regulated activities was imposed. Income from regulated activities is recovered by way of specific tariffs—each with its own structure, characterized by a given number of billing variables.

Tariff prices in each activity are determined in a way that enables: (i) its structure to match the structure of marginal or incremental costs, and (ii) the allowed revenues to be recovered for every activity.

Tariff application and billing are based on the principle of non-discrimination on the final energy use, all tariff options being available to all consumers.

The scheme presented in Fig.1 shows the relations between the several regulated activities, its allowed revenues and correspondent tariffs.

The Global Use of System tariff makes it possible to recover the income from the System's Global Management activity, which includes system's operation, costs related to economic regulation, the overcost associated with generation from renewable energy sources and other energy policy costs.

The Transmission Use of System tariff makes it possible to recover the income from the Electricity Transmission activity—which includes setting up, operating and maintaining transmission systems.

These two activities are realized by the Transmission System Operator (TSO).

High-Voltage (HV) and Medium-Voltage (MV) Distribution Grid Use of System tariffs make it possible to recover the income from the regulated activity of Electricity Distribution in HV and MV—which include planning, setting up, operating and maintaining distribution systems, so as to convey electricity from its reception points to the final customers. Likewise the LV Distribution Use of System tariff makes it possible to recover income from the regulated activity of LV Electricity Distribution.

The Network Commercial Management tariff makes it possible to recover income from the network commercial management activity—which includes, among others, the metering, billing and settlement of services associated with grid use and other regulated services.

These activities of electricity distribution and network commercial management are realized by the Distribution System Operator (DSO).

The above mentioned activities are conducted on monopoly basis, being associated with infrastructure use and global system's management.

The referred to activity tariffs are paid by all the consumers for the use of the networks. The grid access tariffs paid by all electricity users include the tariffs charged for Global Use of System, Transmission Use of System, Distribution Use of System and Network Commercial Management. Non-binding customers who selected their supplier operating in the market pay their regulated grid access tariffs and freely bargain their energy prices with their supplier.

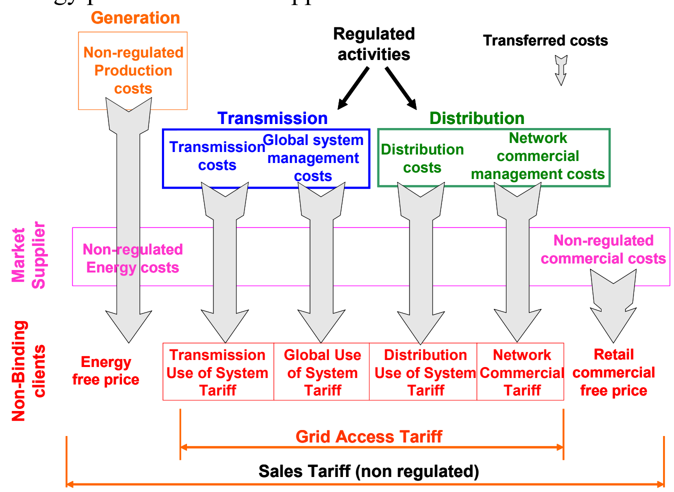


Fig. 1. Regulated activities and tariffs in the Portuguese electrical sector.

The Portuguese electrical sector legislation establishes the existence of a regulated supplier. This regulated supplier is the incumbent one that has several public service obligations and also universal service obligations being the last resource provider. Two regulated activities are performed by this regulated supplier: (i) the Electricity Acquisition activity; and (ii) the Commercial Management activity within SEP.

The Energy & Capacity tariff (TEP) makes it possible to recover the allowed income from the regulated activity of Electricity Acquisition—which includes energy acquisition costs incurred for supplying the SEP customers.

The SEP Supply tariff makes it possible to recover the allowed income from the regulated activity of Commercial Management within SEP—which includes the commercial structures of electricity sale to the binding customers (namely billing).

Calculation of End-User tariffs of SEP Binding Customers, applied by the regulated supplier, is based on the activity tariffs included in the grids' access, plus the regulated Energy & Capacity and Supply tariffs in the SEP. The End-User tariffs of the regulated supplier are also known as Integral tariffs

Other suppliers in the market are free to conduct these two activities, which in their case are not subject to regulation.

Despite the approval in 2003 of the European Directive on the internal market in electricity, a strong integration is observed yet in several electrical sectors, that a few years ago were totally vertical and horizontal integrated. It is important to refer that the ownership unbundling was already applied to the TSO activities. However the DSO remains in the same company of the incumbent supplier. Due to that the unbundling of accounts between distribution activities and electricity acquisition and retail activities was imposed.

It is also important to note that a strong concentration is observed in the generation sector in Portugal. This strong concentration is also observed in the Iberian market. Additionally it cannot be ignored that the electricity market opening is very recent. Consumers, namely the low voltage ones do not have any experience in choosing there supplier. Also wide asymmetries of knowledge and information are observed due to lack of information.

B. Application of tariff additivity

Prices of access tariffs for each billing variable are determined by adding the corresponding prices of tariffs per activity applicable to that supply. This methodology for calculating access tariffs is presented in a simplified manner in Fig. 2, under the name Tariff Additivity.

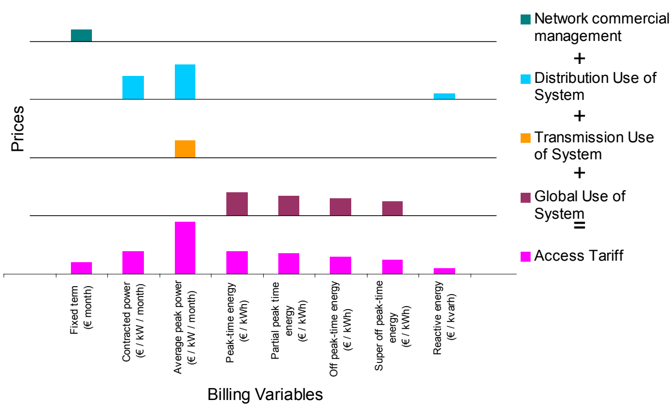


Fig. 2 Tariff additivity methodology for calculating access tariffs.

Likewise, the prices of End-User tariffs practiced by the regulated supplier are determined, for each billing variable, by adding the corresponding prices of access tariffs, applicable to that supply, to the prices of the SEP Energy & Capacity tariff and of the SEP Supply tariff. This methodology for calculating the End-User tariffs is presented in a simplified version on Fig. 3. With the objective of limiting the impacts on the invoices of each SEP customer, a transitional mechanism has been established that makes it possible to gradually apply tariff additivity for calculating End-User tariffs.

If tariffs that compose the addition are based on marginal costs, it is possible to avoid inter-customer cross-subsidization. The closer those tariff prices are to marginal costs, the closer we will get to an efficient resource allocation that promotes wellbeing maximization.

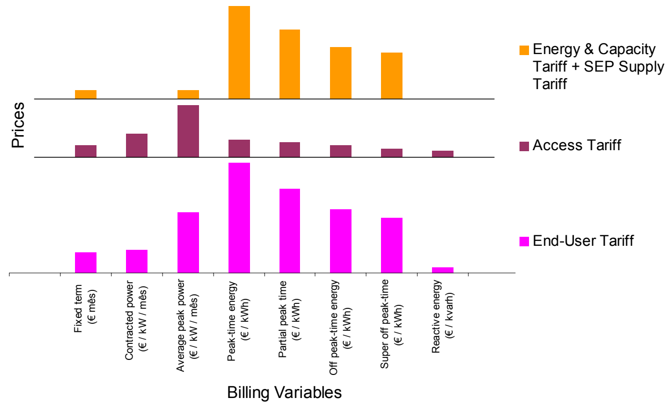


Fig. 3 Tariff additivity applied by the regulated supplier to calculate Sale-to-Final-Customer tariffs.

Likewise by applying the principle of tariff additivity to the End-User tariff of the regulated supplier, we assure that there is no cross-subsidization between the binding customers and the non-binding customers. We thus ensure that there is no discrimination in the access to electricity grids by all customers, irrespective of their supplier.

This tariff calculation methodology makes it possible to have a detailed knowledge of all tariff components by activity or service. Thus customers may know exactly how much they pay, for example, for using the MV distribution system and how is that value considered in terms of billing. Upon request, customers may receive a breakdown of their electricity bill by each applicable regulated tariff component, by average price and by tariff term. This possibility is laid down in the electricity sector codes currently in force.

It should be noted that tariffs are charged by delivery point. Their prices, if necessary, are converted into different voltage levels – by applying loss adjustment factors. When the metering equipment does not make it possible to directly apply the billing variables of activity-specific tariffs, then prices to be applied to the metered variables are calculated, based on typical consumption profiles of each tariff option.

Implementing a system of this kind results in transparent tariff definition, which is particularly important for customers who have not the ability to choose their supplier—especially those with less information. In the context of a non-regulated monopoly, these customers with less demand/price flexibility are the most vulnerable target of discrimination and become a means to subsidize other customers that are more informed and have the ability to choose suppliers.

III. Tariff Variables

Tariffs have several price variables that differ from tariff to tariff. The choice and definition of those variables is extremely important in order to successfully implement an efficient tariff structure. The tariff variables should be selected to reflect appropriately the costs of each regulated activity.

The tariff variables used in the Portuguese tariff system are:

(i) A Fix Term that is applied by costumer, per month, which is used in the commercialization and supply tariffs and also in the integral tariffs and is related with the costs of metering, billing and contracting.

(ii) The Contracted Power disposable to the clients in contractual terms. For very high voltage (VHV), high voltage (HV), medium voltage (MV) and low voltage with contracted power higher than 41,4 kW (Special Low Voltage - SpLV) is the maximum average active power in kW, in any uninterrupted period of 15 minutes. For low voltage with contracted power lower than 41,4 kVA (Standard Low Voltage - StLV) is the apparent power in kVA.

(iii) The Average Peak Power that is the ratio between peak hour active energy and the number of peak hours.

(iv) The Peak Hours Active Energy that is the energy consumed in the peak hours time period.

(v) The Partial Peak Hours Active Energy that is the energy consumed in the partial peak hours time period.

(vi) The Off-Peak Hours Active Energy that is the energy consumed in the normal off-peak hours time period.

(vii) The Super Off-Peak Hours Active Energy that is the energy consumed in the super off-peak hours time period.

(viii) The Reactive Energy Supplied that is the reactive energy supplied which exceeds 40% of the active energy, in peak and partial peak hours.

(ix) The Reactive Energy Received that is the reactive energy received in off-peak hours.

Every existent tariff (activity tariffs, access tariffs and integral tariffs) can be applied using some or all of these variables.

For every activity tariff the variables are defined to reflect the marginal or incremental costs effectively caused by the consumer and measured by the variable in question. The price structure of every tariff is based on marginal costs and then scaled so that the level of allowed revenues in each activity is obtained. The allowed revenues for each activity are determined independently of this process, and differ by activity (price cap, revenue cap, rate of return, standard costs among other forms of allowed revenue regulation used). In every activity the relation between marginal costs and revenues, in each activity, is given by the scale factor.

When applied to consumers every price reflects specific costs. The prices of energy for peak hour and partial peak hour reflect the marginal costs of energy generation and a part of the generation capacity costs that is attributed to active energy. These marginal costs are determined using the program VALORAGUA, through a simulation of the response of the several generation plants to satisfy a foreseeable value of demand. The program includes non-linear programming to optimize hydro-electric plants considering different weather scenarios and it returns energy marginal costs for time-of-the-day periods. In terms of energy and power costs only peak and partial peak values are scaled to meet allowed revenues, all off-peak prices are unscaled and therefore equal to marginal costs [4].

The use of Average Peak Power as a tariff variable allows for payments to be sensible to the costs with the more central branches of the networks. Central branches are used by a large number of consumers and, due to the weak synchronism shown by 15 minutes peak of every individual consumer, one can admit that the behavior of an individual consumer only affects the more central branches of the network in the proportion of the average power during peak hours and not in proportion of the maximum peak of the month (or year) during 15 minutes. Therefore it is more adequate to use average peak power than maximum 15 minutes peak power of the year to signal consumers regarding the costs of central branches of the distribution networks. The prices should be aligned with the incremental costs caused in the network by one additional unit of average peak power, by voltage level. This variable, and for the same reasons, is also used in the Transmission Network Use of System tariff and in the capacity parcel of the Energy and Power tariff.

Branches in the network periphery are shared by a smaller number of consumers. Hence the individual peak of each consumer has an impact on the costs of these parts of the network. To capture such effect it is more appropriate to use the maximum demand of each consumer, in a 15 minutes period, as price variable. The price is calculated considering incremental costs for the different type of networks and voltage level. Each consumer only pays for maximum 15 minutes peak power to the network he is connected, and according to the voltage level.

Prices of reactive energy are determined to give incentive to local reactive power compensation. Because it is a local phenomenon, specific to that grid, reactive energy is only billed to the consumer regarding the network and voltage level of connection. It is more rational to compensate for reactive energy locally, in the consumer facilities, than in a centralized manner in the transmission or distribution substations.

Commercialization and supply costs, that include metering, reading, billing and related functions, only vary with the type of consumer. Therefore the variable used to transmit these costs to the market is a fixed charge per costumer, per month, in accordance with the voltage level of connection and other similar contractual characteristics of the costumer.

IV. Activity Tariff Calculation and Conversion to the Various Voltage Levels

For each regulated activity the allowed revenues are defined. Several regulation methods can be applied.

In Portugal, for the TSO activities the revenues are established by a rate of return regulation method. The operational costs are accepted on annual basis and the capital is remunerated by rate of return.

The electricity distribution activities are regulated by a price-cap method. The revenues for each year of a regulatory period are obtained by a fixed component plus a variable component dependent of supplied energy. The fixed and variable components are established for a regulatory period, taking into account the evolution of the activity costs and the potential increase in economic efficiency.

For the commercial management activities a revenue cap regulation is applied in annual basis. Thus the revenues are contracted for each year.

A. *Activity tariff calculation*

Knowing the allowed revenues for a defined activity the prices of the tariff are calculated so that there products by the predicted quantities for that year equal the allowed revenues. As already mentioned the tariff variables should be selected to reflect appropriately the costs of each regulated activity. The predicted quantities for each tariff variable have to be defined at the output of the activity. This means that the quantities that are measured in the clients delivery points have to be estimated in the activity output frontier, and so have to be estimated in upper voltage levels. This is done applying to the physical quantities, measured in the consumers facilities, loss adjustment factors for each network, voltage level and time period published by ERSE. This methodology is presented in (1) for the case of the Global Use of System tariff. The price variables of this tariff are measured energy by time period. The output frontier of this tariff coincides with the transmission network output at 60kV.

$$\tilde{R}_{GUS,\mathrm{t}} = \sum_{h} Wh_{VHV,t} \times \left(1+\gamma^{h}_{\mathrm{VHV/HV}}\right)^{-1} \times TWh_{t}^{GUS} + \\ + \sum_{n}\sum_{i}\sum_{h} Wh_{i_{n},t} \times \prod_{j}\left(1+\gamma_{j}^{h}\right) \times TWh_{t}^{GUS} \quad (1)$$

With, n - voltage level (n=HV, MV and LV); j - voltage level (j≤n); i - Tariff options in a defined voltage level; h - time periods (Peak Hours, Partial Peak Hours, Normal Off-peak Hours, Super Off-peak Hours)

Where $\tilde{R}_{GUS,\mathrm{t}}$ represent the revenues of the Global Use of System activity for year t; $Wh_{VHV,t}$ - energy supplied to VHV clients in time period h; $Wh_{i_{n,t}}$ energy supplied to voltage n clients in time period h; TWh_t^{GUS} - energy price of the Global Use of System tariff for the time period h; $\gamma^h_{VHV/HV}$ - loss adjustment factor between VHV and HV transformation; γ^h_j - loss adjustment factor in voltage level j for the time period h.

In order to promote economic efficiency the tariff prices should be equal to the respective marginal or incremental associated cost. However with prices equal to the respective marginal costs the allowed revenues may not be recovered.

Due to that the marginal or incremental costs have to be scaled. If the scaling factors are small then a multiplicative scaling should be applied so that the marginal cost structure is preserved equation (2).

$$TX_t = Kx \times PmgX \quad (2)$$

Where TX_t is the price of variable *X*, Kx is the multiplicative scaling factor of variable *X* and $PmgX$ is the marginal cost of variable *X*.

If the elasticity's of the several price variables are known then it is preferable to apply different scaling factors for each price variable. The scaling factors for each price variable should be proportional to the inverse of the elasticity leading to efficient resource allocation that promotes wellbeing maximization.

For higher scaling factors other solutions should be adopted namely the application of additive scaling. In this case the price differences coincide with the marginal costs differences.

$$TX_t = A + PmgX \quad (3)$$

Where *A* is the additive scaling factor.

B. *Activity tariff conversion to the various voltage levels*

To allow for the application of tariff additivity every activity tariff must be converted to the referential of the consumer who is paying it. The prices must be calculated considering again the physical quantities measured in the consumers facilities, so that the application of such prices to the quantities in question, for all the variables, results in the allowed revenues previously established. The conversion is needed in particular for energy and power quantities in different voltage levels and it is done using again the loss adjustment factors for each network, voltage level and time period published by ERSE.

When a price is calculated for a variable in a superior voltage level it can be converted to a lower voltage level by application of the correspondent loss factor. Also by applying an adequate loss factor to energy measured in the consumer meter in a lower voltage level it should be possible to obtain the quantity in the original referential at a higher voltage level. The price and quantities conversions are done in a way that the same revenues are obtained whether multiplying prices and quantities at the level of consumption or at the level of generation.

Additionally another type of conversion is necessary. It's the conversion from complex tariffs with several variables to simpler tariffs with just some few tariff variables for application to smaller clients. These conversions are made using load profiles for each tariff category and the conversion occurs in a way that the amount of revenue recovered by variable is not affected.

Table 1 illustrates the conversion of the Global Use of System tariff to the several voltage levels VHV, HV, MV and low voltage level tariff options of three, two or one time period. This tariff presents a unique energy price at the VHV level of the transmission network. As it can be seen this price increases for lower voltage levels. This increase is also higher for peak time periods than off-peak time periods due to the values of loss factors.

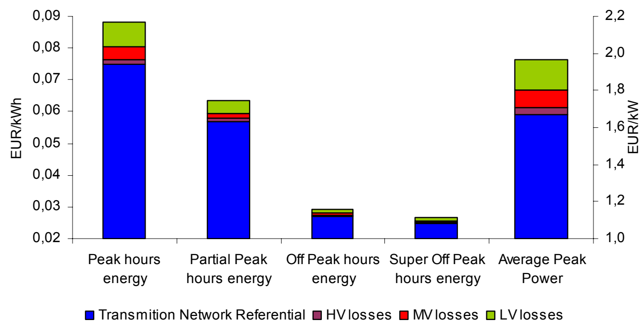
Fig. 4 illustrates a more complex case related to the conversion of the Energy & Capacity tariff to be applied to binding consumers in LV. This tariff presents four different energy prices for each time period and also an average peak power price. Fig. 4a presents the conversion of the tariff to a low voltage level tariff with also four different energy prices for each time period and also an average peak power price. The tariff prices are converted from the VHV level of the transmission network to the voltage levels of the consumers in three steps, first to the HV level, second to the MV level and then to the LV level, by applying the loss adjustment factors.

Again as it can be seen in Fig. 4a, the lower the voltage level the higher are the prices. Also it can be seen that for higher demand time periods higher prices increases are applied.

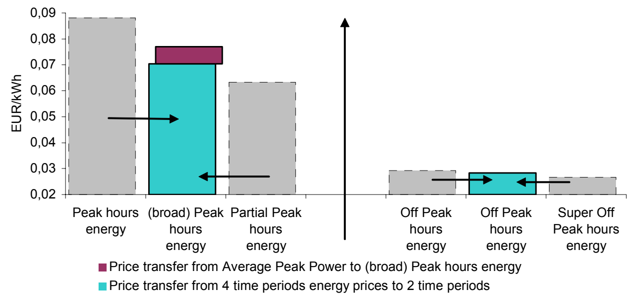
TABLE I

ACTIVITY TARIFF CONVERSION TO THE VARIOUS VOLTAGE LEVELS

Global Use of System tariff	Nº of time periods	Active energy (EUR/kWh)			
		Peak-time	Partial peak-time	Off peak-time	Super off peak-time
VHV	4	0,0080	0,0080	0,0080	0,0080
HV	4	0,0082	0,0081	0,0081	0,0081
MV	4	0,0086	0,0083	0,0082	0,0082
SpLV	3	0,0094	0,0089	0,0086	
STLV 3-time periods	3	0,0094	0,0089	0,0086	
STLV 2-time periods	2	0,0090		0,0086	
STLV 1-time period	1	0,0089			



(a) Energy & Capacity tariff conversion to a 4 time periods LV tariff



(b) Energy & Capacity tariff conversion to a 2 time period LV tariff

Fig. 4 Energy & Capacity tariff conversion to a 2 time periods LV tariff

Fig. 4b shows the conversion of the low voltage Energy & Capacity tariff with five prices presented in Fig. 4a to a simplified two time period LV tariff applicable to small LV consumers. This two time period LV tariff presents only two prices of energy (on broad peak hours and off-peak hours) and a price of contracted power. Thus the energy prices on peak hours and partial peak hours and the average peak power price are all converted to a broad peak hours energy price. Also the energy prices on off-peak and super off-peak hours are both converted to a larger off-peak hours energy price.

The use of load profiles to obtain simplified tariffs might create some distortions between consumers in the same tariff. Nevertheless it is believed that such small inefficiency is accepted when compared with the costs of implementing more sophisticated metering to smaller consumers, which maybe hardly economically justifiable. The converted tariffs to the different levels of application are published by ERSE in a justified way. Therefore every consumer might know in advance what is included in every price variable he pays. This is valid both for Grid Access tariffs and SEP Binding End-User tariffs.

V. EXAMPLES OF APPLICATION OF TARIFF ADDITIVITY

A. Additive Access tariffs

The Grid Access tariff is paid by all consumers for the use of the networks. This tariff varies by voltage level and is determined by addition of the relevant activity tariffs.

Table 2 present prices to be paid for grid access in HV, SpLV and StLV voltage levels. The HV grid access tariff presents a four time period energy differentiation. The SpLV grid access tariff presents a three time period energy differentiation. The StLV grid access tariff chosen is applied for customers with a contracted power lower than 20,7kVA, and presents two active-energy prices differentiated by day/night period (two-rate time-of-day tariff). Prices have been unbundled by tariff of each activity (Global Use of System, Transmission Use of System, Distribution Use of System and Network Commercial Management) and billing variable (Fixed term, Contracted Power, Average Peak Power, Active Energy and Reactive Energy).

TABLE II

HIGH VOLTAGE (HV) GRID ACCESS TARIFF

WITH FOUR TIME PERIODS

Grid Access Tariff High Voltage with four time periods	Fix term (EUR/mês)	Power (EUR/kW.mês)		Active energy (EUR/kWh)				Reactive energy	
		Contracted	Peak	Peak Hours	Partial Peak	Off-Peak	Super Off-Peak	Supplied	Received
Global Use of System	-	-	-	0,0082	0,0081	0,0081	0,0081	-	-
Transmission Use of System	-	-	1,877	-	-	-	-	-	-
HV Distribution Use of System	-	0,175	0,262	-	-	-		0,0120	0,0090
HV Network Commercial	101,22	-	-	-	-	-	-	-	-
HV Grid Access Tariff	101,22	0,175	2,139	0,0082	0,0081	0,0081	0,0081	0,0120	0,0090

SPECIAL LOW VOLTAGE (SPLV) GRID ACCESS TARIFF

WITH THREE TIME PERIODS

Grid Access Tariff Special Low Voltage with three time periods	Fix term (EUR/mês)	Power (EUR/kW.mês)		Active energy (EUR/kWh)			Reactive energy (EUR/kvarh)	
		Contracted	Peak	Peak Hours	Partial Peak	Off-Peak	Supplied	Received
Global Use of System	-	-	-	0,0094	0,0089	0,0086	-	-
Transmission Use of System	-	-	2,162	-	-	-	-	-
HV Distribution Use of System	-	-	0,503	-	-	-	-	-
MV Distribution Use of System	-	-	3,799	-	-	-	-	-
LV Distribution Use of System	-	0,642	5,780	-	-	-	0,0151	0,0115
SpLV Network Commercial	26,26	-	-	-	-	-	-	-
SpLV Grid Access Tariff	26,26	0,642	12,244	0,0094	0,0089	0,0086	0,0151	0,0115

STANDARD LOW VOLTAGE (STLV) GRID ACCESS TARIFF

WITH TWO TIME PERIODS

Grid Access Tariff Standard Low Voltage with two time periods	Fix term (EUR/mês)	Contracted Power (EUR/kW.mês	Active Energy (EUR/kWh)	
			Broad Peak Hours	Off-Peak Hours
Global Use of System	-	-	0,0090	0,0086
Transmission Use of System	-	-	0,0075	-
HV Distribution Use of System	-	-	0,0017	-
MV Distribution Use of System	-	-	0,0132	-
LV Distribution Use of System	-	0,642	0,0200	-
StLV Network Commercial	1,42	-	-	-
StLV Grid Access Tariff	1,42	0,642	0,0514	0,0086

Prices of grid access tariffs in each voltage level are determined by adding up, for each billing variable, the tariff prices by activity converted into the voltage level of energy delivery. For example, the peak power price of the grid access tariff in SpLV is determined by adding up the peak power prices of the following tariffs, i.e. HV Transmission Use of System, HV Distribution Use of System, MV Distribution Use of System and LV Distribution Use of System.

The grid access tariffs presented in the above tables are applied to three types of consumers Dc, Ib and Ig with the consumption profiles established in table V. The Ig consumer is a industrial consumer connected to the high voltage distribution network, Ib is a small industrial consumer connected to the low voltage network (SpLV) and Dc is a household consumer (StLV).

TABLE V
CHARACTERIZATION OF DC, IB AND IG TYPE CONSUMERS

Consumer-types	Contracted power (kW)	Annual consumption (kWh)	Annual off-peak consumption (kWh)	Use of contracted power (hours)
Dc (StLV)	4,6	3 500	1 300	761
Ib (SpLV)	50	50 000	0	1 000
Ig (HV)	4 000	24 000 000	11 040 000	6 000

The average prices paid by Dc, Ib and Ig type consumers for grid access are presented in Fig. 5. The values indicated herein do not include the Value Added Tax (VAT), at the legal rate of 5 percent currently in force.

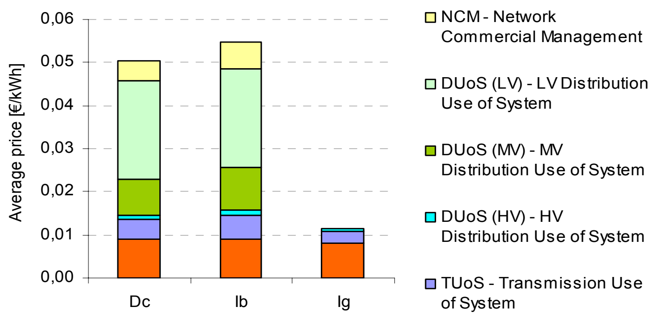


Fig. 5 Average prices paid by Dc, Ib and Ig type consumers for the Grid Access tariffs.

Fig. 5 shows that each consumer pays only the infrastructures or services really used. Also it can be noted that Ib type consumers, although using a contracted demand power that is higher than Dc type consumers, pay a higher average price than the latter for their grid access. This situation is due to the fact that Ib type consumers, contrary to Dc type consumers, do not use electricity in off peak hours. The average price of the former is thus higher namely due to the payments of the distribution use of system tariffs.

B. Additive integral tariffs

The integral tariffs, applicable to binding consumers by the regulated supplier, are also obtained by addition of the relevant activity tariffs, following the same procedure described for the grid access tariffs.

Table 3 presents the SEP integral tariffs for HV, SpLV and StLV, applicable to the three types of consumers referred Dc, Ib and Ig. The SEP integral tariffs present the same differentiation as the correspondent grid access tariffs shown in table 2. Prices have been unbundled by Grid Access tariff and the activity tariffs of the regulated supplier: (i) SEP Energy and Capacity tariff and (ii) SEP Supply tariff. Prices of SEP integral tariffs in each voltage level are also determined by adding up, for each billing variable, the tariff prices by activity converted into the voltage level of energy delivery.

Fig. 6 shows the average prices paid by Dc, Ib and Ig type consumers for the regulated supplier End-User tariffs. These average prices are determined by applying the tariffs shown in table 6 to the consumption profiles established for the Dc, Ib and Ig type consumers shown in Table 5. In this figure, the average price of each customer is broken down into the following parcels: (i) Grid Access tariff presented in Fig. 5, (ii) SEP Energy and Capacity tariff and (iii) SEP Supply tariff.

TABLE III
HIGH VOLTAGE (HV) END-USER TARIFF
OF THE REGULATED SUPPLIER WITH FOUR TIME PERIODS

SEP End-User Tariff High Voltage with four time periods	Fix term (EUR/mês)	Power (EUR/kW.mês)		Active energy (EUR/kWh)				Reactive energy	
		Contracted	Peak	Peak Hours	Partial Peak	Off-Peak	Super Off-Peak	Supplied	Received
SEP HV retail supply	54,88	-	-	-	-	-	-	-	-
SEP Energy & Capacity	-	-	1,917	0,0825	0,0624	0,0281	0,0259	-	-
HV Grid Access Tariff	101,22	0,175	2,139	0,0082	0,0081	0,0081	0,0081	0,0120	0,0090
SEP Integral Tariff (HV)	156,10	0,175	4,056	0,0907	0,0705	0,0362	0,0340	0,0120	0,0090

SPECIAL LOW VOLTAGE (SPLV) END-USER TARIFF
OF THE REGULATED SUPPLIER WITH THREE TIME PERIODS

SEP End-User Tariff Special Low Voltage with three time periods	Fix term (EUR/mês)	Power (EUR/kW.mês)		Active energy (EUR/kWh)			Reactive energy (EUR/kvarh)	
		Contracted	Peak	Peak Hours	Partial Peak	Off-Peak	Supplied	Received
SEP SpLV retail supply	13,70	-	-	-	-	-	-	-
SEP Energy & Capacity	-	-	2,209	0,0932	0,0670	0,0295	-	-
SpLV Grid Access Tariff	26,26	0,642	12,244	0,0094	0,0089	0,009	0,0151	0,0115
SEP Integral Tariff (SpLV)	39,96	0,642	14,453	0,1026	0,0759	0,0381	0,0151	0,0115

STANDARD LOW VOLTAGE (STLV) END-USER TARIFF
OF THE REGULATED SUPPLIER WITH TWO TIME PERIODS

SEP End-User Tariff Standard Low Voltage with two time periods	Fix term (EUR/mês)	Contracted Power (EUR/kW.mês)	Active Energy (EUR/kWh)	
			Broad Peak Hours	Off-Peak Hours
SEP StLV retail supply	0,96	-	-	-
SEP Energy & Capacity	-	-	0,0821	0,0296
StLV Grid Access Tariff	1,42	0,642	0,0514	0,0086
SEP Integral Tariff (StLV)	2,38	0,642	0,1335	0,0382

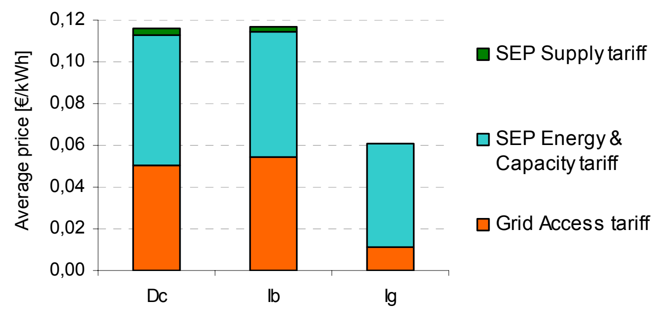


Fig. 6 Average prices paid by Dc, Ib and Ig type consumers for the regulated supplier End-User tariffs.

The described methodology allows for everyone to know in detail the components of every price in terms of the activity services they correspond. For example every consumer can see exactly how much he is paying for the use of the MV distribution network. Furthermore, it is possible to identify in what price variable that amount is being billed. The Tariff Code allows for consumers who express this wish to request a detailed invoice from the retailer. Such feature can be very useful when comparing the integral tariff, from the incumbent, with other tariffs proposed in the market. The consumer can easily identify what part of his bill is for the payment of regulated tariffs (access) that have to be paid whatever the supplier and the remaining of the bill that contains the activities that are open to competition, energy generation and retailing. Another advantage of the methodology is to identify, determine and explain the differences between energy prices in the various time-of-the-day periods. Namely, by depicting how the consumption of energy in different time periods can cause different costs to the system, thus orienting consumers' decisions and economic rationality.

The mere publication of these values is an incentive to eliminate cross subsidies between consumers. An informed costumer, or group of costumers, would not accept to pay more for a certain service if the costs he cause in the system, given by the respective activity tariff, do not justify it.

Transparency in the formulation of end users tariffs, that is a consequence of this type of system, is of particular importance for the consumers that do not have the opportunity to choose their supplier, and especially for those who have less access to information. In a context of non regulated monopoly, or when strong market power exists, these consumers that typically exhibit a lower price elasticity of demand are preferential target for discrimination and a source of cross subsidization to other costumers, better informed and/or with the possibility to freely choose supplier.

VI. Conclusion

In this paper we present the tariff calculation methodology established in the Portuguese Tariff Code for electricity and of ERSE's responsibility.

Allowed revenues are determined separately for every regulated activity, assuring that there are no cross subsidies between activities. Additionally, the application of the tariff additivity principle assures the inexistence of cross subsidies between consumers. Regulated tariffs applicable to end users of electricity are determined by summation, variable by variable, of the different activity tariffs in accordance with the services the costumer uses and in the proportion of that use.

The corollary is that if the different activity tariffs are cost reflective and promote efficiency in resource allocation, the tariffs applicable to consumers (access tariffs or integral tariffs) will also reflect costs in the same manner. Therefore, besides economic efficiency, equity between non binding system consumers and binding system consumers is promoted.

The examples presented in the article intend to show how additive tariffs reflect costs giving adequate economic price signals for the rational use of the networks and electric energy consumption.

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VIII. Biographies

Isabel Apolinário was born in Lisbon, Portugal, on October 29, 1973. She graduated in Economics, in 1996, and received her MSc Degree in Energy and Environment Economics in 2005, both from the Technical University of Lisbon - Instituto Superior de Economia e Gestão. She his with ERSE since1998 and her professional background includes the Portuguese Electricity Operator (EDP) and the Portuguese National Institute of Statistics, producing the Quarterly National Accounts. Her current interests are electricity and gas tariffs, economic regulation, efficiency and productivity, energy efficiency and market liberalization.

Nuno Felizardo was born in Beja, Portugal, on November 4, 1971. He graduated in electrical engineering, in 1997, and he got the MSc. degree in Strategy and Industrial Management in 2004, both from the Technical University of Lisbon (IST and ISEG), Lisbon, Portugal. He is with ERSE since 1997 and his professional background includes the Portuguese Distribution System Operator, EDP. His current interests are energy supply tariffs, energy efficiency, market liberalization and renewable energy systems.

António Leite Garcia was born in Porto, Portugal, on June 27, 1933. He graduated from University of Porto - Engineering Faculty, in Electrical Engineering (1956) and studied Nuclear Engineering, in Institut de Sciences et Techniques Nucléaires de Saclay, in Paris (1958). He is adviser of the Portuguese Electricity Regulatory Authority, since 1998. His employment experience includes auditing (1985-98) and tariff and strategic plan activities (1976-85), at central directorate level, in the Portuguese electricity company, EDP.

Paulo Oliveira was born in Lisbon, Portugal, on December 19, 1976. He graduated from the Technical University of Lisbon - Instituto Superior Técnico, Lisbon, in power engineering (1999). He is with ERSE since 2001 and his professional background includes the Portuguese Transmission System Operator, REN. His current interests are energy supply tariffs, energy efficiency, market liberalization and information systems.

Artur Trindade was born in Nampula, Mozambique, on May 13, 1971. He graduated from the Catholic University of Lisbon, in Economics (1994). He Received the M.A in Development Economics from the University of Kent at Canterbury (1995).
He is with ERSE since 2000 and his professional background includes the Portuguese Energy Agency (ADENE), the Portuguese Secretary of State for Industry and Energy and lecturing undergraduate economics. His current research interests include economic regulation, energy efficiency, renewable energy and energy markets reform.

Pedro Verdelho was born in Porto, Portugal, on December 26, 1963. He received the Dipl. Ing., the M.S. and Ph.D. degrees from the Technical University of Lisbon-Instituto Superior Técnico, Lisbon, Portugal in 1987, 1990 and 1995, respectively, all in electrical engineering. He joined Instituto Superior Técnico in 1985 and till 2002 he has been an Assistant Professor. In 1999 he joined the Portuguese Energy Regulatory Authority, being the head of the Tariff and Prices Division. His main interests include electricity and gas tariffs, energy efficiency, economic regulation, power quality, power electronics, active power filters, reactive power compensation systems, variable speed drive and generator systems. He received the Meritorious Paper Award in 1996 from the IEEE Industrial Electronics Society.